EVALUATION OF THE NRC 1996 WINTER FEED REQUIREMENTS FOR BEEF COWS IN WESTERN CANADA

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By

Jodi Lynn Bourne

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ABSTRACT

A trial was conducted to evaluate the accuracy of the 1996 NCR beef model to predict DMI and ADG of pregnant cows under western Canadian conditions. Over two consecutive years, 90 Angus (587±147 kg) cows assigned to 15 pens (N=6) were fed typical diets *ad libitum*, formulated to stage of pregnancy. Data collection included pen DMI and ADG (corrected for pregnancy), calving date, calf weight, body condition scores and ultrasound fat measurements, weekly feed samples and daily ambient temperature. DMI and ADG for each pen of cows in each trimester was predicted using the computer program “Cowbytes” based on the 1996 NRC beef model. The results indicate that in the 2nd and 3rd trimester of both years the model under predicted ($P \leq 0.05$) ADG based on observed DMI. *Ad libitum* intake was over predicted ($P \leq 0.05$) during the 2nd trimester, and under predicted ($P \leq 0.05$) during the 3rd trimester of pregnancy. A second evaluation was carried out assuming thermal neutral (TN) conditions. In this case, it was found that during the 2nd and 3rd trimesters there was an over prediction ($P \leq 0.05$) of ADG relative to observed. Under these same TN conditions, the *ad libitum* intake of these cows was under predicted ($P \leq 0.05$) for both the 2nd and 3rd trimesters. These results suggest current energy equations for modelling environmental stress, over predict maintenance requirements for wintering beef cows in western Canada. The results also suggest that the cows experienced some degree of cold stress, but not as severe as modelled by the NRC (1996) equations. Further research is required to more accurately model cold stress felt by mature cattle, and their ability to acclimatise to western Canadian winter conditions.

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1.0 INTRODUCTION

Beef producers are continually looking for ways to improve the profitability of their herds. Since the majority of production costs are tied up in winter-feed, one goal would be to reduce these costs. The winter-feed cost of beef cows accounts for 60-65% of total production costs (Kaliel and Kotowich 2002). Ferrell and Jenkins (1985) suggest that 70-75% of the total annual energy requirements for beef production is required for maintenance. This data shows there is potential in improving beef production efficiency by reducing the cost of winter-feeding beef cows.

There are several objectives to winter-feeding. The feed supplied must be enough to maintain the cow and support fetal growth. Maternal nutrition during pregnancy should not be underestimated regarding its influence on overall efficiency of livestock production and animal health. Influences of malnutrition can be seen through effects on return to breeding status, conception rates, prenatal growth and development and the ability of the calf to survive. The ultimate result of poor nutrition of the beef herd is a reduction in the number of offspring produced.

Prolonged postpartum anestrus is a factor limiting reproductive efficiency in cattle, because it prevents achievement of a 12-month calving interval. Under-nutrition contributes to prolonged postpartum anestrus, particularly among cows dependent upon forages to meet their feed requirements. DeRouen et al. (1994) found that cows with body condition score (BCS) of 3.5 (5 point scale) at calving had a 74 day post-partum to pregnancy interval. In the same study, thin cows (BCS of 2.5) at calving had a 96 day post-partum to pregnancy interval. Lower body condition scores at calving can also reduce pregnancy rates. Spitzer et al. (1995) showed that cows with a BCS of 2.5 have a conception rate of 56% whereas cows with a BCS of 3.5 have a conception rate of 96% at 60 days of the breeding season. Inadequate nutrient intake results in loss of weight and BCS and finally cessation of estrous activity (Monteil and Ahuja, 2005).

Severe maternal under-nutrition at all stages of pregnancy, particularly during late gestation reduces fetal growth by varying degrees, even though nutrient partitioning favours the conceptus at the expense of the dam (Redmer et al. 2004). The effects of nutrient restriction during pregnancy is inconsistent, and may depend on the level and (or) length of restriction as well as the stage of pregnancy evaluated. Redmer et al. (2004) reviewed several studies which showed reduced fetal growth as an effect of maternal-under nutrition during both early to mid gestation and mid to late gestation. Optimum management of energy reserves is critical to economic success with cows. Cows that are too fat or too thin are at risk from metabolic problems and diseases including decreased milk yield, low conception rates, ketosis and difficult calving (Monteil and Ahuja 2005, Redmer et al. 2004, Spitzer et al. 1995).

The objective of winter feeding cows is to ensure optimal reproductive performance at minimal cost. This requires knowing exactly how much feed the animals will need for the level of production desired. Mathematical models can be used to predict nutrient intake of beef animals at all life stages and production rates. The National Research Council (NRC) published the seventh revised edition of the *Nutrient Requirements of Beef Cattle* in 1996, which includes a computer simulation program that uses mathematical equations in an attempt to predict the performance of beef animals based on energy requirements and intake. In order for these predictions to be most useful to the producer, they must be accurate. Failure to accurately model growth and reproduction in beef cattle can cost producers time and money.

The objectives of this review are to:

1. Examine factors that influence the estimation and prediction of beef cattle energy requirements;
2. Examine factors that influence the estimation and prediction of beef cattle feed intake;
3. Review the NRC (1996) beef cattle model in terms of how it predicts cold stress in cattle exposed to western Canadian winter conditions.

2.0 LITERATURE REVEIW

2.1 Predicting Energy Requirements

Energy of the feed minus the energy lost in faeces is termed digestible energy (DE). Digestible energy has some value for feed evaluation because it reflects diet digestibility and can be measured with relative ease. However, DE fails to consider several major losses of energy associated with digestion and metabolism (NRC, 1996). Metabolizable energy (ME) is defined as gross energy minus faecal, urinary and gaseous energy losses. Metabolizable energy is an estimate of the energy available to the animal and represents an accounting progression to assess feed energy values and animal requirements (NRC, 1996). Gaseous losses accounted for in ME are primarily methane created through microbial fermentation, which also results in heat production. This heat is useful in helping to maintain body temperature in cold-stressed animals, but is otherwise an energy loss not accounted for by ME. The definition of ME indicates that ME can appear only as heat production (HE) or retained energy (RE). Therefore ME = RE + HE. When RE = 0, then ME = HE, and is defined as maintenance requirement of the animal (NRC, 1996).

2.1.1 Factors Effecting and Prediction of Net Energy for Maintenance.

The maintenance energy requirement has been defined as the amount of feed energy intake that will result in no net loss or gain of energy from the tissues of the animal body (NRC, 1996). This energy is required for essential metabolic processes, body temperature regulation, and physical activity (Fox and Tylutki, 1998). The requirement for maintenance varies with level of feeding, previous plane of nutrition and breed. It is an estimate of the amount of energy necessary to achieve a weight equilibrium state including the cost of any muscular activity associated with supplying this energy. To predict the amount of feed intake required for these purposes in each situation, the metabolic requirement, physical activity, and energy that must be partitioned to maintain body temperature at 39°C must be determined. The NRC (1996) model uses the following equation to predict net energy required for maintenance.

Equation 2.1:

$$\mathbf{NE_m = [0.077+0.0007(20-T_p)]\ SBW^{0.75}*\{0.8+[(CS-1)\ 0.05)]\}*BE*L*SEX}$$

Where NE_m is net energy for maintenance, Mcal d^{-1}; T_p is previous average monthly temperature (°C), SBW is shrunk body weight, CS is condition score (9 point scale), BE is breed effect on NE_m requirement, L is lactation effect on NE_m requirement (1 if dry), and SEX is gender effect on NE_m (1 for cows). Therefore the maintenance energy requirement for beef cows in the second and third trimester of pregnancy is based on body weight, metabolic heat production, body composition, and environmental demands.

2.1.1.1 Fasting Metabolic Rate

The heat production at zero feed intake is equivalent to the animal's net energy (NE) requirement for maintenance (NRC, 1996). Fasting heat production of the animal equates to the NE required for maintenance. Fasting heat production should be measured during the post-absorptive state with the prior feed intake as close to maintenance level as possible (Blaxter, 1989). The animal must be in a stress free atmosphere both before and during the measurement. The animal needs to be in a post-absorptive state in order to ensure the effects of previous meals and metabolism are negligible (Blaxter, 1989).

Measurements for fasting heat production are carried out through the use of direct or indirect calorimetry. Direct calorimetry is the measurement of heat loss by radiation, convection, conduction and as latent heat arising from the vaporisation of water. Indirect calorimetry is a method of estimating heat production and is based on determination of gaseous exchange of oxygen for carbon dioxide (Blaxter, 1989).

Genotype influences fasting heat production and therefore maintenance energy requirements. The 1996 version of the NRC recognises large and significant differences in the energy costs of maintenance of cows of different genotypes. It suggests that Holstein, Jersey and Simmental cattle have a 20% higher requirement for maintenance than 16 other beef breeds, and that *Bos indicus* cattle require less energy for maintenance. Reid et al. (1991) found that in a dry temperate climate, Red Poll cows had the highest average ME requirement (0.81 MJ ME_m kg $^{-0.75}$ day^{-1}) while the Brahman x Hereford and Brahman x Angus cows had the lowest requirements (0.67 MJ ME_m kg $^{-0.75}$ day^{-1}). They stated that due to their comparatively low maintenance requirements, *Bos taurus* crosses that have a medium body size and milk yield potential have relatively high biological efficiency in beef production systems in a dry temperate climate. Ferrell and Jenkins (1998) found that crossbred cattle sired by *Bos indicus* breeds had similar efficiency of ME use for maintenance as *Bos taurus* breeds. Therefore they concluded *Bos indicus* and *Bos taurus* breeds require similar levels of energy consumption in order to maintain themselves. The results of Ferrell and Jenkins (1998) do not support the hypothesis that tropically adapted *Bos indicus* breeds have lower maintenance energy requirements than

Bos taurus cattle. However, the experiment was conducted during the interval from January to June. Thus the *Bos indicus* breeds may have been more adversely affected by environmental conditions during the winter, resulting in a higher maintenance requirement in those breeds.

Factors inherent to the individual animal will also affect fasting heat production that in turn affects maintenance. DiCostanzo et al. (1990) used a herd of cows that were closed to outside maternal lines for over 30 years to estimate within-herd variation of energy use. Animals with high-energy efficiencies are able to utilise lower amounts of energy yet have production levels equal to or greater than animals with lower energy efficiencies consuming the same amount of energy. This herd had an efficiency of use of ME for gain or loss of body energy of 76%, with a standard deviation of 30%. These data demonstrate that cows with markedly different energetic efficiencies may be found within a herd.

Selection for lower maintenance requirements is difficult and measures of feed efficiency such as feed to gain ratio are related to measures of body size, growth rate, composition of gain and appetite (Arthur et al. 2001). Alternatively, residual feed intake or net feed intake was first identified by Koch et al. (1963) as a feed efficiency trait that was independent of body weight and weight gain. Koch et al. (1963) suggested that feed intake could be partitioned into two components: 1) the feed intake expected for production and maintenance, and 2) a residual portion, which is the difference between actual feed intake and expected feed intake for production and maintenance. The residual portion could be used as a measure to identify efficient animals (negative residual feed intake) or inefficient animals (positive residual feed intake). The trait is moderately heritable ($h^2 = 0.29$-0.46), implying that improvements could be made in feed efficiency without affecting body size or growth rate. (Arthur et al. 2001).

Residual metabolizable feed intake (RFI) is the difference between the metabolizable energy intake and the predicted metabolizable energy required for maintenance and gain (based on body weight and growth) and is therefore independent of growth and maturity patterns (Okine et al. 2001). This uses the concept of net feed efficiency to identify efficient animals. When metabolizable energy intake equals metabolizable energy required for maintenance and gain, RFI equals 0 and the energy requirements of the animal are completely met. A positive RFI means metabolizable energy intake is greater than metabolizable energy required for maintenance and gain, therefore the animal's energy intake exceeds its requirement for maintenance and growth. A negative RFI means metabolizable energy intake is less than predicted metabolizable energy required for maintenance and gain and that the animal either requires less energy than what is estimated or is eating less to produce the same weight gain (Okine et al. 2001). The predicted metabolizable energy is calculated by NRC (1996) beef model equations (Okine et al. 2001) and therefore it is very important the prediction calculations are correct. Incorrect metabolizable energy equations will result in incorrect calculation of residual feed intake of the animals being tested. Basarab et al. (2003) found that adjusting RFI for live animal indicators of body composition (gain in ultrasound backfat thickness and marbling) showed animals with negative RFI values consumed less feed, had lower heat production and retained less energy than animals with average or positive

RFI values. This is consistent with NRC (1996) which reported that the efficiency of ME use for retained energy is not constant, but decreases as MEI increases. Improvements in RFI will lead to improvements in feed efficiency without the confounding effects of ADG (Basarab et al. 2003)

2.1.1.2 Body Weight and Composition

The NRC (1996) suggests that fasting heat production is proportional to cow metabolic weight and body condition. Birnie et al. (2000) agrees with this as their experiment found a large degree of error occurred with the calculation of maintenance requirements if only the metabolic weight and not the condition score of the cow, was taken into account. The researchers found fasting heat production to be significantly higher for cows with low body condition compared with cows displaying high body condition when metabolic body weight was considered. They found no significant difference in fasting heat production when weight was removed from the equation. This may explain why Klosterman et al. (1968) concluded that cows with a high degree of finish tended to gain weight while those in thin condition lost weight when the amount of feed energy allotted was based on the animal's metabolic size. Thompson et al. (1983) indicates that in the winter it is more costly for cows to maintain protein than to maintain fat, suggesting that the maintenance requirement of cows may not be proportional to their metabolic weight if they are in differing body condition scores. From these data it is possible to suggest that a thin cow with a higher lean to fat ratio will need more energy to maintain herself than a fatter cow of the same metabolic weight. This is due to the higher amount of energy needed for protein turnover than for fat accretion. It can therefore be concluded that body condition must be considered along with metabolic weight to determine energy requirement, as the value of maintaining lean tissue is more costly than maintaining fat tissue, and that there are inherent differences in the energetic efficiency of fat and thin cows.

2.1.1.3 Environment

The thermal neutral zone is defined as the range of ambient temperatures within which an animal's metabolic heat production is over the short term, independent of ambient temperature (Forbes, 1995). When the environmental temperature rises above this thermal neutral zone, the animal will attempt to decrease metabolic rate through a decrease in feed intake, and by increasing heat dissipation. The reduction in feed intake is of great concern for producers in hot climates, as the productivity of the animal will decrease. If the temperature becomes too hot there is the risk of the animal refusing to eat. The lower end of the thermal neutral zone is called the lower critical temperature (LCT). The LCT is defined as the point at which normal heat of fermentation and metabolism can no longer maintain body temperature and dietary energy must be used for this purpose (Fox et al. 2004). Below this temperature an animal must increase its metabolic rate in order to equalize the rate of heat production and the rate of heat loss from the body. This arbitrary temperature depends on individual insulation factors, such as hide thickness, hair depth and fat cover, as well as available shelter and bedding (NRC, 1996).

The NRC (1996) accounts for the animal's natural insulation by determining the internal tissue insulation (TI) value through an equation including age of the animal and body condition score. Added to this, is an equation to determine external insulation (EI), which takes into account the amount of mud and moisture on the hide of the animal, thickness of the hide and the effective hair depth, as well as the wind speed the animal is exposed to. Internal and external insulation values are expressed as °C $Mcal^{-1}$ m^2 day^{-1}, and together add up to the total insulation value (IN) of the animal (IN = TI+EI). With this insulation value, it is possible to determine the animal's LCT from the following equations (NRC 1996):

Equation 2.2: $\mathbf{SA = 0.09\ BW^{0.67}}$

Equation 2.3: $\mathbf{HE = [MEI-(RE+YE_n+NE_{preg})]/SA}$

Equation 2.4: $\mathbf{EI = (7.36 - 0.296*WIND+2.55*HAIR)*MUD2*HIDE}$

Equation 2.5: $\mathbf{IN = TI+EI}$

Equation 2.6: $\mathbf{LCT = 39- (IN * HE * 0.85)}$

Where SA is surface area, m^2; BW is weight of animal, kg; HE is the heat production of the animal, Mcal day^{-1}; MEI is metabolizable energy intake, Mcal day^{-1}; RE is net energy available for production, Mcal day^{-1}; YE_n is net energy milk Mcal kg^{-1}; NE_{preg} is net energy retained as gravid uterus, Mcal kg^{-1}; EI is external insulation value, °C $Mcal^{-1}$ m^2 day^{-1}; WIND is wind speed, kph; Hair is effective hair depth, cm; MUD2 is mud adjustment factor for external insulation, 1 = dry and clean; HIDE is adjustment factor for external insulation, 2 = average; IN is insulation value, °C $Mcal^{-1}$ m^2 day^{-1}; TI is tissue (internal) insulation adjustment facto based on age and condition score, °C $Mcal^{-1}$ m^2 day^{-1}; and LCT is animal's lower critical temperature, °C.

The lower critical temperature is a dynamic target as the animal is able to acclimatize due to prolonged exposure to cold by increasing either metabolic rate or insulation. Acclimatization to chronic cold involves increases in metabolic fasting rate, feed intake and thermal insulation (Degen and Young, 2002). Animals are able to compensate within limits for changes in environmental ambient temperature by altering metabolism, heat dissipation and feed intake, and as such influence the partition of dietary energy for maintenance and production functions. Below the lower critical temperature, the animal has to increase its rate of heat production in order to maintain its deep body temperature within the range compatible with normal function. Chemical energy used for work performed within the body at a cellular level is converted into heat. Energy used for the mastication of feed and its propulsion and digestion through the alimentary tract is also released as heat. Only when the animal is in a particularly cold environment is this heat of any use (Christopherson et al. 1993). By increasing the amount of chemical energy that is released as heat, the animal is able to lower its lower critical temperature. Heat of rumen fermentation is also beneficial at low environmental temperatures. Once the LCT is exceeded an increase in energy requirements would be expected to result in an increased feed intake and this has been observed (Christopherson et al. 1993). The net result is an altered energetic efficiency, as more of the dietary energy is used for heat production rather than growth or other productive functions. During cold stress, maintenance requirements can increase by 28 to 38% (Stanton, 1995). Below the lower critical temperature, energy requirements increase and feed intake normally increases in parallel (Degen and Young, 2002). The increase in energy needs at low temperature is to augment heat production in order to maintain a state of thermal equilibrium.

2.1.1.4 Composition of Gain

Animals that have been acclimatised to western Canadian winter conditions have been found to accumulate less fat and similar amounts of muscle in their carcasses compared to those raised indoors when fed at equal intakes and slaughtered at the same body weight. For example, Degen and Young (2002) found that sheep housed at 20°C had a final body mass higher in fat (68.7%) and lower in protein (13.7%) than sheep housed at 0°C, when feeding levels were held constant. Degen and Young (2002) also found that mean energy requirements in sheep were lower when housed at 20°C (0.47 MJ kg^{-1}) than those housed at 0°C (0.82 MJ kg^{-1}). Similar results were shown by Delfino and Mathison (1991) who found the proportion of total energy retained as fat in indoor steers (86%) was greater than that in outdoor steers (78%). They also found that steers housed indoors grew 49% faster and had 51% better feed conversion efficiencies than outdoor steers, even though feed intakes were the same (Delfino and Mathison 1991). These results suggest maintenance requirements were increased and estimated values of dietary net energy for available gain were substantially reduced in ruminants fed in cold compared to warm environments.

Metabolizable energy is retained in fat with a higher efficiency than in protein. Williams and Jenkins (2003b) found that the efficiency of metabolizable energy utilisation for fat and protein deposition was 0.75 and 0.20, respectively. This explains the "expensive", high rate of turnover in protein tissue, compared to fat which constitutes a reserve of energy with slow turnover rate.

2.1.1.5 Digestibility

Christopherson and Kennedy (1983) summarised numerous studies to determine the nature of the relationship between temperature and digestion. They determined there is a decrease in digestibility that is consistent in long, chopped and ground –pelleted forms of hay in animals that are cold stressed. They also noted that heavier cattle show smaller changes in digestibility with temperature than lighter cattle. These authors concluded that the decrease in digestibility induced by cold environments is related to the thermal demand imposed on the animal. In a later study, Miaron and Christopherson (1992) found dry matter digestibility was 11% higher in steers housed at 28°C than those housed at –10°C. The major cause of the relationship between animal rectal temperature and digestibility is the change in the rate of passage of feed through the rumen**.** Increased rumen motility could account for the increased rate of passage of particulate matter, which would decrease the digestibility of the feed. An increase in gut motility under cold exposure leads to an increase in the rate of passage, which could be responsible for increases in feed intake, if physical constraints are not limiting (Christopherson and Kennedy, 1983). Mairon and Christopherson (1992) found that during rumination, the frequency of the reticular contractions was shorter in steers housed at -10°C than those housed at 28°C (1.26 vs. 1.35 min^{-1}, respectively). Similarly the duration and amplitude of the reticular contractions were elevated in the steers housed at -10°C compared to those housed at 28ºC (5.76 vs. 4.55 min and 4.98 and 2.57 mm Hg, respectively). These same authors found that particulate passage rate showed a quadratic response to temperature and was inversely related to digestibility (Mairon and Christopherson, 1992). This research shows that associated changes in digestive function and increased rate of digesta passage through the rumen, reduces the constraints imposed by rumen fill. These changes in the digestive function causes a reduction in digestibility, but this may be counteracted by an increase in feed intake, and in the rate of nutrient absorption (Russell et al. 1992).

2.1.1.6 Regulation of Fasting Metabolic Rate

Christopherson (1976) reported that in steers exposed to cold, resting metabolic rates is increased and diet digestibility decreased. It is recognised that metabolic rate increases when animals are subjected to chronic cold exposure, and that the magnitude of the increase is related to the extent of cold stress (NRC, 1984). A study by Han et al. (2003) found that the fasting heat production was 10.5 to 12.5% higher in *Bos taurus* cattle exposed to temperatures of -15 to 0°C than those exposed to 5 to 26°C temperatures. When environmental temperature decreases below the thermal neutral zone, an increase in metabolic rate is necessary to maintain body temperature. During immediate periods of cold stress, metabolic heat production increases to compensate for the faster rate of heat loss to the environment and the animal is usually able to adapt by increasing feed intake to meet the increased metabolic demand. An early study by Young (1975) demonstrated that fasting metabolism increased by 37% as a result of physiological acclimatisation to several weeks of cold exposure. With acclimatisation to cold, resting metabolism and metabolic demand for energy increase.

NRC (1996) adjusts for the increase in energy requirement of the animal due to acclimatisation (adjustment for previous temperature) of ambient temperatures above or below 20°C through use of the equation;

Equation 2.7: $\mathbf{a_2 = 0.0007 * (20 - T_p)}$

Where a_2 is maintenance adjustment for previous ambient temperature, Mcal kg^{-1} d^{-1} $SBW^{-0.75}$ and T_p is previous average monthly temperature, °C. Therefore, NRC (1996) suggests that maintenance energy requirement of the animal increases by 0.91% per 1°C when previous ambient temperature was below 20°C (Degen and Young, 2002; NRC, 1996).

2.1.2 Factors Effecting and Prediction of Fetal Growth

The efficiency of energy utilisation for conceptus growth is defined as energy recovered in conceptus tissues divided by ME available or used for growth of those tissues (Garrett and Johnson, 1983). Ferrell et al. (1976) found that the efficiency of utilisation of ME for pregnancy ranged from 9.4 to 20.4 % with a mean of 14.7%. The large range is due to low metabolizable energy requirements for gestation during the early stages of gestation (1.23 MJ day^{-1}, on day 100). However, this increases rapidly during later stages (40.01 MJ day^{-1} on day 280) of pregnancy (Ferrell et al. 1976). The maintenance requirement of the gravid uterus is the major energy cost of gestation (Robbins, 1993), and as the gestation period extends, the maintenance requirement increases (**Figure 2.1**). For this reason, NRC (1996) computes pregnancy requirements and body weight gain from growth of the gravid uterus based on day of gestation and expected calf birth weight. The fetus and associated fetal tissue is deposited throughout gestation and energy is required to maintain the deposited tissue. Therefore, final calf weight is a factor in the cost of maintenance energy for that tissue. Some variation exists in energy requirements for gestation and lactation among types of beef cows, but

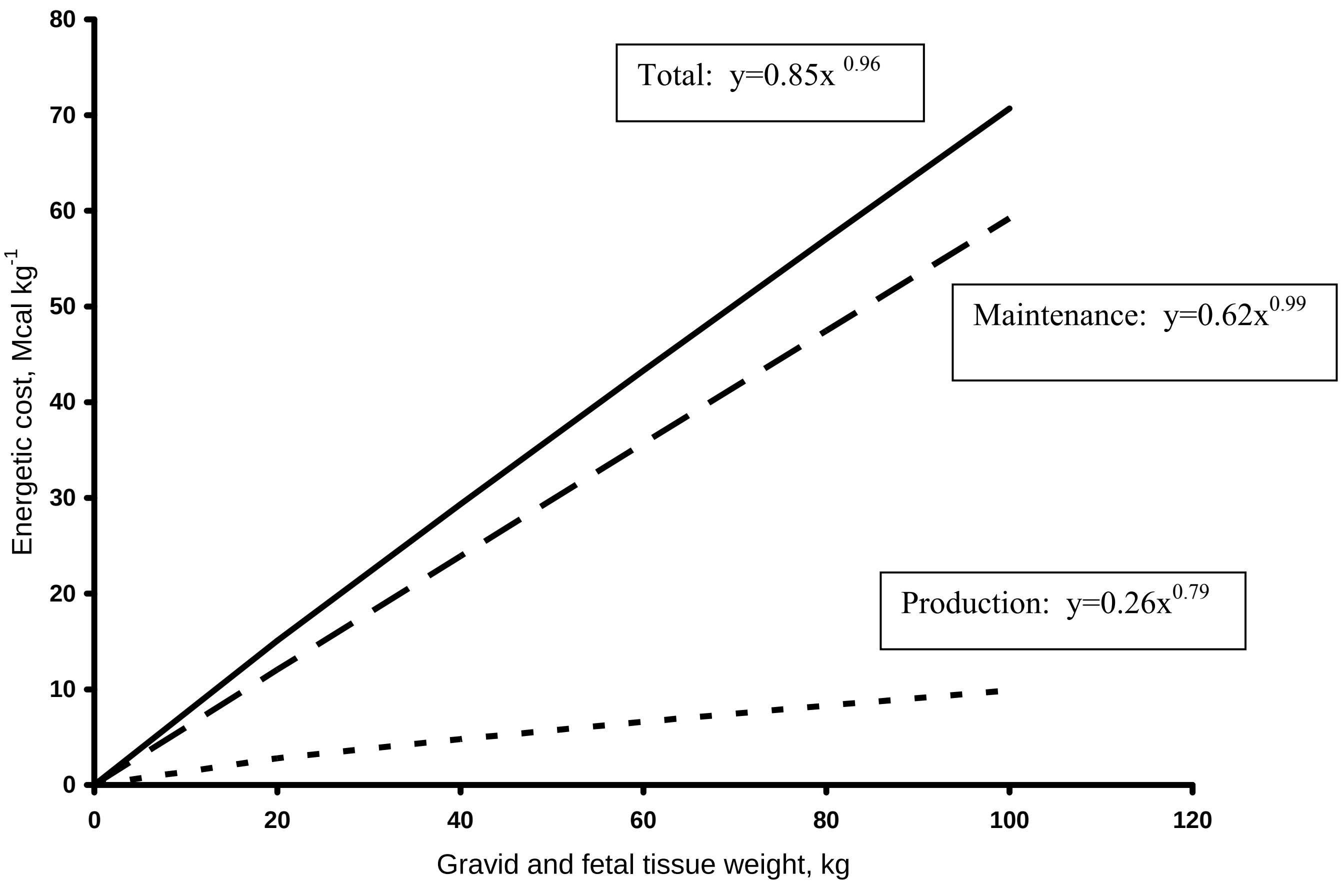

Figure 2.1: Total energy cost of the developing gravid uterus and fetal tissue (adapted from Robins, 1993)

variation in energy requirements for these functions appears to be small relative to variation in energy requirements for maintenance (Ferrell and Jenkins, 1985). NRC (1996) uses the following equation to predict fetal tissue weight at any given day of gestation:

Equation 2.8: $$\text{Conceptus weight (kg)} = (CBW*0.01828)*e^{[(0.02*t)-(1.43e-005*t*t)]}$$

Where CBW = calf weight at birth and t = days of pregnancy. This equation can be used to determine pregnancy adjusted live weight for the cow at any stage of pregnancy.

2.1.3 Factors Effecting and Prediction of Body Weight Gain

Growth is routinely measured as the change in live weight or mass. The growth of beef cattle follows a sigmoidal curve, with growth accelerating until puberty when growth continues but at a decreasing rate (Berg and Butterfield, 1976). The point at which protein accretion ceases can be used as an estimate of mature body weight (Owens et al. 1995). Fat becomes an increasing proportion of body composition as an animal matures. This shift in composition must be accounted for when determining energy used for gain since more energy is needed to synthesis fat than the other components of thebody. The mature size and sex of the animal is a large factor in determining the weight at which this shift in composition occurs. By the same token, there is an assumption that cattle have a similar body composition at the same degree of maturity (NRC, 1996). Therefore, in order to predict energy requirements for growing cattle, the body weights of cattle of varying body sizes and sexes must be adjusted to a standard reference base (NRC, 1996). The NRC (1996) beef model uses a medium-frame steer equation:

Equation 2.9: $I_m = NE_{mr} / (NE_{ma} * ADTV)$

Equation 2.10: $RE = (DMI - NE_m) * NE_g$

Equation 2.11: $SWG = 13.91 * RE^{0.9116} * EQSBW^{-06837}$

Where I_m is intake for maintenance, kg DM d^{-1}; NE_{mr} is the net energy required for maintenance; NE_{ma} is the net energy value of diet for maintenance, Mcal kg^{-1}; ADTV is 1.0 for diets not containing ionophores; NE_m is then net energy for maintenance of the animal: SBG is shrunk body weight gain, kg; RE is retained energy, Mcal day^{-1}; NE_g is net energy value of diet for gain, Mcal kg^{-1}; SBW is shrunk body weight, kg; and EQSBW is equivalent shrunk body weight, kg.

Energy requirements of a mature, non-lactating pregnant cow are based on maintenance and fetal growth. Any remaining energy that has been consumed will be used for tissue gain. When energy intake does not limit growth, the empty body contains an increasingly smaller percentage of protein and an increasingly larger percentage of fat and reaches chemical maturity when additional weight contains little additional protein (NRC, 1996). Therefore, any gain or loss of empty body weight in a mature cow is due largely to utilisation or deposition of fat. In order to calculate average daily gain, NRC (1996) predicts days to change a body condition score based on energy surplus or deficiency in the diet, weight change required for a change in body condition score, and 27.98 MJ NE_m per kg SBW gain or loss. It must be remembered that the energy released during weight loss is only used with 80% efficiency (NRC, 1996).

2.2 Prediction of Feed Intake

The consumption of feed is fundamental to nutrition as it determines the level of nutrients ingested and therefore the animal's function and production level. The supply of nutrients to the body is what the animal attempts to maintain through feeding. Prediction of feed intake in ruminants is often difficult because of the interaction between animals and diet and is particularly difficult under conditions where few reliable data are available on which to base the predictions (i.e. grazing). Despite these difficulties, there have been numerous attempts at prediction of the voluntary intake of sheep and cattle (Blaxter et al. 1961; Balch and Campling; 1962, Thompson et al. 1983; Baile and Mclaughlin, 1987; Fox et al. 1992).

Feed intake level can be imposed on an animal by such means as restricted intake which is a controlled means of feeding, or zero intake such as when the animal is fasting. *Ad libitum* intake means that there is food available at all times, and implies that the animal is able to maximise consumption to meet maintenance and pregnancy requirements without over consuming (Forbes, 1995).

Required intake is the amount of feed required to meet all of the animal's nutrient requirements, which may be higher than voluntary intake due to the physical or chemical constraints within the animal or environmental limitations (Forbes, 1995). It is necessary to be able to predict the level of voluntary intake in order to decide the optimum formulation of a ration to meet the animal's requirement under conditions of *ad libitum* feeding as well as to optimise the utilisation of the diet.

2.2.1 Voluntary Intake

The aim of voluntary intake is to match feed consumption with the required level of production. It is defined as the weight of feed dry matter consumed by an animal or group of animals during a given period of time during which they have free access to feed (Forbes, 1995). Physical characteristics of the feed and physiology and metabolism of the animal are factors regulating intake of feed. The quantity of indigestible residues which push the ingesta through the digestive tract and the rate of absorption of the metabolizable nutrients entering the animal's system determine voluntary intake. Therefore, voluntary feed intake is dependent to an extent on the physical and chemical characteristics of the feed consumed (Forbes, 1995).

The NRC (1996) has an equation to determine voluntary or *ad libitum* dry matter intake of pregnant beef cows. This equation is based on SBW and energy density of the diet:

Equation 2.12:

$$\mathbf{DMI = \{[SBW^{0.75}*(0.04997*NE_m{}^2+0.03840)/NE_m]*(Temp1)*(Mud1)+0.2*Yn\}}$$

Where SBW is shrunk body weight, kg;, NE_m is the net energy value of diet for maintenance, Mcal kg^{-1}; Temp1 is the temperature adjustment factor for DMI; Mud1 is the mud adjustment factor for DMI and YN is milk production, kg d^{-1}.

2.2.2 Intake Control

If it is possible to understand what causes an animal to start and stop eating then it is possible to understand the control of feed intake. Ruminants control feed intake to meet nutrient requirements under a wide range of circumstances. The general scheme suggests that physical factors (reticulo-rumen distension) are primary regulators of feed intake up to some "critical level" of metabolizable energy density in the diet. As diet energy density increases above this critical level, feed intake decreases but metabolizable energy intake remains reasonably constant according to physiological demand for substrates (Balch and Campling, 1962). Therefore, the critical levels of dry matter consumption at which physical factors regulate feed intake is not constant but is adjusted after a time to higher or lower levels in response to an animal's changing requirements for energy.

Early research established a relationship between dietary energy concentration and dry matter intake by beef cattle (Balch and Campling, 1962). This is based on the concept that consumption of less digestible, high fibre, low-energy diets is controlled by physical factors such as ruminal fill and digesta passage while consumption of more digestible, low-fibre, high energy diets is controlled by the animal's energy demands (NRC 1996). Tolkamp and Ketelaars (1992) in an alternative theory hypothesised that ruminants do not eat to rumen capacity. Rather they will optimise the cost and benefits of oxygen consumption and consume the amount of feed that will meet this objective. In other words the *ad libitum* intake of a ration is the amount of feed in which net energy (NE) intake per unit of oxygen consumption is maximised.

2.2.2.1 Physical Factors Determining Voluntary Intake

The physical capacity of the fore-stomach in ruminant animals provides for long periods of storage for microbial fermentation. This long period of time required for fermentation becomes a potentially limiting factor to intake and gives rates of digestion, breakdown and onward passage of particles of food considerable importance. There is a limit of rumen distension that the animal will not voluntarily exceed by eating more feed

(Blaxter et al. 1961). Intake of poor or moderate quality hay is limited mainly by distension, due to slow digestive rates and slow rate of passage. When better quality roughage is fed, chemical factors become important as signals of satiety.

2.2.2.2 Chemical Factors Determining Voluntary Intake

The dietary metabolizable energy content is probably the most important factor affecting voluntary intake in cattle (Forbes, 1995). With high-energy diets that are digested quickly, physical capacity of the digestive tract is not reached and the animal controls its intake to meet its energy requirements. This is because high-energy diets contain a high proportion of fast degrading, non-structural carbohydrates and protein (Sniffen et al. 1992). The metabolizable energy requirements of the animal can be met by these feeds before the rumen has reached capacity. Intake is depressed by infusions of volatile fatty acids such as acetate and propionate, the major products of rumen fermentation suggesting intake control depends on acid receptors (Simkins et al. 1965). Energy requirements of the animal will vary depending on such factors as size, breed, production level, and housing available.

2.3 Evaluation of the 1996 NRC Beef Submodel

The National Research Council published the seventh revised edition of the *Nutrient Requirements of Beef Cattle* in 1996. This edition is focused on defining the impact of biological, production, and environmental factors on nutrient utilisation and animal requirements. This includes breed effects on nutrient requirements that are accounted for by reference to animal mass and other factors relating to body condition and the subsequent impact on the ability of the animal to undertake compensatory growth. Environmental stress can also have an effect on nutrient requirements, most notably on feed intake. The ability to predict and understand relationships between nutrient inputs and animal requirements has benefited by the development of mathematical equations to model the factors discussed above.

2.3.1 Cornell Net Carbohydrate and Protein System

It is important to understand the Cornell Net Carbohydrate and Protein System (CNCPS) (Russel et al. 1992; Sniffen et al. 1992; Fox et a., 1992) as the seventh revised edition of the NRC (1996) uses many of the same equations found in this system. One example is the equation used for adjustment for environmental stress. The CNCPS is a mathematical model that uses information on the animal, environment and feed to predicted cattle requirements and performance in diverse production situations (Fox et al. 2004). Carbohydrate and protein degradation and passage rates of the feed are used to predict such factors as ruminal fermentation, microbial protein production, post-ruminal absorption, and total supply of metabolizable energy and protein to the animal. In order to achieve these, sub-models that simulate rumen fermentation, carbohydrate, protein and amino acid availability and cattle requirements are used. By considering the animal's nutrient requirements and determining the level of these nutrients available in the feed it is possible to place more emphasis on predicting the nutrient supply to the animal. The primary purpose of the CNCPS model is to improve feeding practice, thus improving the management of nutrients in the animal (Fox et al. 2004).

2.3.2 NRC Evaluation

To formulate diets and predict performance of cattle on any given feeding program, it is necessary to predict intake. Accurate estimates of feed intake are vital to predicting rate of gain and to the application of equations for predicting nutrient requirements of beef cattle (NRC, 1996). As shown in an earlier section, equations given in NRC (1996) relate feed intake to dietary energy concentration (NE_m). Based on such equations, energy concentration accounts in part, for effects on feed intake attributed to gastrointestinal fill, energy demands, and potential effects of absorbed nutrients. Yet it is also clear that intake is influenced by live weight, energy demand and feed quality (Forbes 1995).

2.3.2.1 Computer Simulation Model of Feed Intake and Cattle Production

Computer models of biological systems use mathematical relationships to represent biological processes that are responsible for the conversion of inputs to outputs (Williams and Jenkins, 2005b). Dynamic simulation models have the advantage of accommodating a wider range of management options and transition states that may be difficult to handle with static systems. These dynamic models are input driven and are ideal for studying animal response (i.e. feed intake, growth, etc.) to changes in nutritional management (Williams and Jenkins, 2003c). Models such as NRC (1996) that predict heat production attributable to maintenance and growth were developed on the basis of three concepts (Williams and Jenkins, 2003a). The first is that animals fed fixed amounts of the same diet achieve weight equilibrium over an extended feeding period, and the metabolizable energy consumed at weight equilibrium is the maintenance requirement. The second is that a part of the heat production resulting from metabolizable energy consumed above the maintenance requirement is associated with the increase in digestion, absorption and assimilation and this heat production can be modelled as a function of the level of feeding. The third is that the previous level of nutrition affects current estimates of heat production and that this impact can be modelled as a delayed response in heat production associated with the support of metabolism (Williams and Jenkins, 2003a).

The use of computer models to predict feed intake and daily gain of cattle is beneficial to the producer. This allows the producer to feed only what is required to meet the various production stages of the animal with minimum wastage. It also enables the producer to reasonably predict efficiency and feed conversion and to thereby adjust for optimum production and economic returns. The NRC (1996) includes a computer simulation program that attempts to predict the performance of beef animals.

The computer simulation model has two levels of analysis. The first level relies on tabular energy and protein values, which is revised from the NRC (1984) version. This level is used when the knowledge of feed composition is incomplete and equations are used to determine the partitioning of the energy in the feed that is available to the animal. The second level uses the rumen simulation sub-model of CNCPS, which places more emphasis on predicting nutrient supply, both in the feed and availability to the animal. Hopefully this enables the program to predict performance with greater accuracy. In order to conduct a diagnostic evaluation using this level it is important that nutrient availability of the feed is known (NRC, 1996).

Alberta Agriculture developed a user-friendly computer program, “Cowbytes”, based on equations for predicting beef cattle performance found in NRC (1996). The program is a ration formulation and balancing program that contains nutrient analysis of many different popular cattle feeds in order to develop balanced rations. With a complete description of a ration used, along with the ability to allow the program user to describe the animal and management conditions, this program is able to predict the average daily gain and dry matter intake of the animal portrayed. In order to predict the ADG of a mature beef cow, "Cowbytes" uses Equation 2.9 to Equation 2.11. This differs from the NRC (1996) in which ADG calculation is based on days to change a body condition score using energy surplus or deficiency in the diet, weight change required for a change in body condition score, and 27.98 MJ NEm per kg SBW gain or loss. Dry Matter intake is based on SBW and energy density of the diet as shown in Equation 2.12. "Cowbytes" uses the same equations to predict voluntary DMI in pregnant beef cows as NRC (1996). Similarly, "Cowbytes" adjusts maintenance energy requirements for changes in temperature by using the following equation suggested by NRC (1996);

Equation 2.13: $\mathbf{0.0007*(20\text{-}T_p)\ Mcal\ d^{-1}*SBW^{\ 0.75.}}$

Where T_p is the previous average monthly temperature, °C and SBW is shrunk body weight, kg.. The program is able to accomplish this as it is possible for the user to include the current and previous month temperature in the information entered.

2.3.2.2 Energy Evaluation

Okine et al. (2003) looked at 26 cereal forages grown in Alberta to determine the accuracy of predicted energy content of the feed over a range of ADF levels. They found that DE decreases as ADF increases however, the variability in DE for a given level of ADF is considerable. They also found the relationship between the actual energy content and the NRC predicted energy using the Weiss et al. (1992) equation was twice as accurate as that from ADF predicted energy. These authors conclude that the NRC recommended method of using summative models such as Weiss et al. (1992) for predicting energy in cereal forages might prove to be the best alternative available (Okine et al. 2003). The necessity of accurate feed energy values for correct prediction of performance was shown by the work of Okine et al. (2003). These workers conducted four feedlot trials in Alberta to evaluate whether the NRC (1996) is able to accurately estimate DMI of finishing steers as predicted by *in vivo* digestibility and laboratory analysis of feed (Okine et al. 2003). It was found that using NRC (1996) to predict DMI using the *in vivo* or the laboratory analysis methods to determine DE were positively related to actual dry matter intake. In this experiment there were no differences in predicted DMI by either the *in vivo* digestibility or the laboratory analysis method to determine DE. Both methods under-estimated DMI actually consumed by the cattle by 6.8% and 4.9% using the DE of the diet from the *in vivo* digestibility and laboratory analysis, respectively (Okine et al. 2003). Using these results the researchers then used regression analysis to indicate whether there was a relationship between actual and predicted values. It was found that there was a positive relationship between the actual intake and predicted DMI, regardless of whether the *in vivo* digestibility or laboratory analysis was used. It was also found that 85% of the variation of actual DMI could be explained by the in vivo and laboratory method, indicating that about 15% of the variation in actual DMI could not be explained by these methods.

Patterson et al. (2000) used data from 54 diets in seven previous beef cattle growing studies to evaluate the 1996 NRC model for the accuracy of intake and gain predictions. They found the model over-predicted calf intake on low quality diets and under-predicated intake on high quality diets. The model also over-predicted gains on high quality diets and under-predicted gains on low quality diets. Therefore the NRC (1996) beef model did not accurately predict performance of cattle on either low or high quality diets.

Block et al. (2001a) also found that the NRC (1996) model inaccurately predicted the gain of cattle fed diets varying in ingredients and energy density. They were able to improve the NRC (1996) gain prediction accuracy by developing NE adjusters based upon the equations derived to relate the required NE adjuster to ADG, TDN intake and TDN concentration. These results generate questions as to the reliability of the current NRC (1996) equations used to define the energetic needs of beef cattle.

2.3.2.2.1 Western Canadian Winter Effects on Energy Requirements.

Milligan and Christison (1974) found that a decrease of 10^{o}C in the mean monthly temperature resulted in a decrease of 0.14 kg d^{-1} ADG in finishing steers. This agrees with the NRC (1996) suggestion that the animals require more feed, and produce less gain in low temperatures, like those found in western Canada during the winter. In contrast, many studies have shown that in western Canada the lower critical temperature is quite low if the animals are acclimatised. Webster (1970) found that the lower critical temperature of cows in western Canada ranges from –11 to –23^{o}C when there is no wind and the pens are dry. When it is wet, with a 1.61 km hour^{-1} wind, and there is no available shelter, the lower critical temperature increases to -9^{o}C. Degen and Young (1993) showed no significant difference in the rate of metabolic heat production of steers in 15°C versus 0°C air temperatures. However, there was an increase in the rate of metabolic heat production (39 to 56%) of steers that stood in 50 cm of water and were showered relative to control steers (Degen and Young, 1993). Forbes (1995) found that from 8^{o}C to –16^{o}C there is no heat or cold stress in cattle, therefore they can tolerate these temperatures with no changes in intake. In Degen and Young's (2002) study they found that intermittent daily cold exposure of sheep to moderate (-10°C) and cold (-20°C) environments increased fasting heat production by 5 and 8% respectively when compared to the control treatment. This difference was found to be not significant.

The 1996 NRC Beef model is based largely on data from the United States (Block, 1999). Management practices and environmental differences in western Canada create a need for separate evaluation of the 1996 NRC Beef Model. This is largely due to the lower temperatures experienced during Canadian winters. When an animal is in its thermal neutral zone there is no evidence of heat (panting) or cold stress (shivering). The NRC (1996) believes this to be between 15 and 20ºC. When environmental temperature drops below the animal's lower critical temperature (LCT), shivering will start, which increases the energy released as heat, thereby altering the partitioning of dietary energy by the animal. The NRC (1996) Beef model has been shown to be flawed when predicting the change in energy repartitioning as a result of cold stress. This has resulted in over feeding of the animals (Koberstein et al. unpublished). As feed wastage is a big expense to beef producers it is important to evaluate the NRC model's method of predicting DMI and ADG of beef cows when used under western Canadian winter conditions.

Block et al. (2001b) evaluated the NRC (1996) beef model in order to predict DMI and ADG on finishing feedlot steers wintered in Saskatchewan. These workers found that the computer model was able to predict DMI of finishing beef steers accurately, but the precision was very poor (r^2=0.31, P=0.0001). The ADG was predicted to be only 91-95% of the animal's actual ADG. It was then found that when the model was forced to assume thermal neutrality, (15-20^{o}C) the ADG and DMI were predicted correctly. These results were confirmed in a 2001/02 follow up study of eight feedlots in western Canada (Schenher and McKinnon, 2002). Koberstein et al. (2001) found that use of temperature-correction equations in the NRC system appears to result in an over-estimation of energy requirements for wintering cows, which maintained their condition over the winter.

2.4 Summary of Literature Review.

The objective of winter-feeding beef cows is to ensure optimal reproductive performance at minimal cost. This entails knowing exactly how much feed the animals will need for the level of production desired. In order to predict intake of the animals, energy requirements and factors affecting these requirements must be recognised. Maintenance energy requirements have been defined as the amount of feed energy intake that will result in no net loss or gain of energy from the tissues of the animal's body (NRC, 1996), and is affected by metabolic energy requirement, physical activity, and the energy that must be partitioned to maintain body temperature. Genotype, body weight and composition, and the energetic efficiency of the animal affect metabolic energy requirement. Animals are able to compensate within limits for changes in environmental ambient temperatures by altering metabolism, heat dissipation and feed intake, and as such, influence the partitioning of dietary energy for maintenance and production functions. Maintenance requirements are increased when animals are subjected to chronic cold exposure; the magnitude of this increase is related to the extent of cold stress. NRC (1996) adjusts for the acclimatisation to previous ambient temperatures by increasing energy requirements of the animal by approximately 1% for each 1ºC below 20ºC. When this occurs the estimated values of dietary net energy for available gain and fetal growth in pregnant cows are substantially reduced.

Growth is measured as the change in live weight or mass. When energy intake does not limit growth, the empty body contains an increasingly smaller percentage of protein and an increasingly larger percentage of fat and reaches chemical maturity when additional weight contains little additional protein (NRC, 1996). Energy requirements of a mature, non-lactating pregnant cow are based on maintenance and fetal growth. Any remaining energy consumed is used for tissue gain. The consumption of feed is fundamental to nutrition as it determines the level of nutrients ingested and therefore the animal's function and production level. Voluntary or *ad libitum* intake means there is food available at all times (Forbes, 1995), the aim of which is to maximise consumption to meet maintenance and pregnancy requirements without over consuming. *Ad libitum* intake is dependent on the physical and chemical characteristics of the feed consumed.

The ability to predict and understand relationships between nutrient inputs and animal requirements has benefited by the development of mathematical equations, such as those found in the NRC (1996) beef model. When adapted into a computer program such as "Cowbytes", developed by Alberta Agriculture, it is beneficial to the producer as it is then possible to feed only what is required to meet the various production stages of the animals with minimum wastage. As well, it is possible to predict efficiency and feed conversion, thereby targeting optimum production and economic returns. It is extremely important to have accurate data on the energy density of the feed, as this is one of the main components in predicting cattle intake and gain.

Management practices and environmental differences in western Canada create a need for separate evaluation of the 1996 NRC beef model. This model has been shown to be flawed when predicting the change in energy repartitioning of growing cattle as a result of cold stress such as that experienced during Canadian winter conditions.

The hypotheses for the research presented in this thesis was that due to inaccurate partition of dietary energy to maintenance functions the NRC (1996) is unable to accurately predict cow performance under Western Canadian winter conditions.

3.0 EVALUATION OF THE NRC (1996) BEEF MODEL FOR PREDICITON OF FEED REQUIRMENTS FOR BEEF COWS IN WESTERN CANADA

3.1 Introduction

In today's economy cattle feeders must ensure economical methods of feeding wintering beef cows in order to achieve optimal reproductive performance at minimal costs. This can only be achieved by using reliable tools that are able to predict the feed required to meet an economical level of production. Cattle feeders require predictions of both dry matter intake, as well as the average daily gain that can be achieved by specific intakes. Mathematical models, such as the NRC (1996) beef model, have the potential to meet the aforementioned requirements. The computer simulation program based on equations presented in the NRC (1996) considers most factors that will affect productivity, including environmental temperatures. These equations attempt to predict the performance of beef animals based on energy requirements and energy availability in the feed. Thus it is extremely important for the evaluation of energy in the feed to be correct. In addition, the performance predictions must be accurate in order to be useful for cattle producers. Failure to accurately model beef cattle can cost producers time and money.

For a model to be accepted and used with confidence, it should be capable of representing the actual performance of cattle under a wide range of environmental conditions with a reasonable degree of accuracy. Accuracy and repeatability can only be gained through an extensive evaluation of the model, and this is critical to its credibility in industry (Williams and Jenkins, 2003c).

This study was conducted to evaluate the ability of the 1996 NRC model as adapted by Alberta Agriculture “Cowbytes” program to predict the actual feed intake and performance of beef cows under western Canadian winter conditions. This involved comparing actual versus predicted feed intake, body weight gain and condition of cows of similar age during the second and third trimester of pregnancy when fed under Saskatchewan winter conditions. To accomplish this actual dry matter intake and weight gain of wintering beef cows were compared to that predicted by the NRC (1996) beef cattle model as adapted by Alberta Agriculture “Cowbytes” program.

3.2 Materials and Methods

3.2.1 Feeding Trial

Two feeding trials were conducted at the Western Beef Development Centre’s (WBDC) Research Farm in Lanigan located in the east central area of Saskatchewan, Canada, on the Saskatchewan Plain. This area consists of Chernozemic Black Oxbow soils which are a grassland soil developed in a dry prairie environment, where there is slight to moderate heat and moisture deficiency (Saskatchewan Soil Survey, 1992). The soil is moderate in organic matter, neutral to mildly alkaline in reaction, low in available phosphorus and high in available potassium (Acton and Ellis, 1978).

3.2.1.1 Experimental Animals

The cows used in this study were obtained from the main herd of the WBDC research farm. In the first year, 90 commercial Angus cows with a weight of 580± 8.8 kg, BCS of 3.2 ± 0.2 (five point system) and age of 39 ± 1.5 months were used. In year two, 90 commercial Angus cows (primarily the same cows) with a weight of 587 ± 4.9 kg, BCS of 2.8 ± 0.2 (five point system) and age of 52 ± 1.9 months were used. For more detail on the cows used in this trial see Appendix A. Each year, they were pregnancy checked prior to the start of the feeding trail in order to separate them into early, mid and late-calving groups. This was done in order to more precisely deliver the required nutrients for conceptus growth. A vitamin ADE injection was administered two weeks prior to the start of the trial. Within each group in each year, the animals were randomly assigned to five pens, with six animals per pen. In each year, the trial lasted from the first Tuesday of November until two weeks prior to estimated calving date for each respective group. There were booster shots of Vitamin ADE (Bimeda-MTC, Cambridge ON) and Scourguard (Novartis Animal Health, Missiauga ON.) administered approximately six weeks prior to calving.

3.2.1.2 Housing

The cows were housed in 15 outdoor pens (6 animals per pen), 7.4m by 24.5m, separated by metal rail fences. The feed bunk ran the length of the pens along the south edge, while a wood slated fence ran 2.43 m past the entire north end of the pens creating a 20% porosity windbreak. The pens were bedded with wood chips twice per week. Straw was used for animal comfort such as when temperatures approached -30°C, based on the judgement of the herdsperson.

3.2.1.3 Feeding

The cows were fed a total mixed ration, which was formulated to meet nutrient requirements including support for gravid uterine growth in accordance with requirements as given by the National Research Council (NRC, 1996). The goal was to have the cows maintain body condition and have no weight gain above that of fetal tissues. The ingredients used were typical of a western Canadian wintering cow ration. This ration was distributed once daily by a means of a mixer wagon. The cows were fed *ad libitum* with a 5 to 10 % carry over. Bunks were cleaned weekly to obtain the weight of orts as well as to minimise feed build-up.

In each year the feeding period was separated into two periods. Period one encompassed the second trimester of pregnancy. In year one, period one ration consisted of 55.9% processed barley green feed and 44.1% oat straw (DM basis) and was formulated to contain 11.83 MJ kg^{-1} digestible energy (DE) and 8.5% crude protein (CP) (Table 3.1). In the second year, period one ration consisted of 55.1% processed barley green feed and 44.9% oat straw (DM basis) and contained 10.42 MJ kg^{-1} DE and 7.1% CP. These rations were formulated to meet NRC (1996) requirements for cows in the second trimester of pregnancy with weight gain only due to conceptus growth. The second period encompassed the third trimester of pregnancy. In year one, the diet for period two consisted of 63.1% alfalfa hay, 24.2% oat straw and 12.7% barley grain (DM basis) and contained 12.72 MJ kg^{-1} DE and 11.9% CP. In the second year, the period two ration consisted of 61.5% alfalfa hay, 25.2% oat straw and 13.4 % barley grain (DM basis) and was formulated to contain 12.10 MJ kg^{-1} DE and 12.2% CP. In both years,

Table 3.1: Ingredient make-up of diets fed to wintering cows in Year 1 and Year 2.

Item	% in diet	
	As fed	**DM**
Mid Gestation Ration		
Year 1		
Barley Greenfeed	54.6	55.9
Oat Straw	45.4	44.1
Year 2		
Barley Greenfeed	54.6	55.1
Oat Straw	45.4	44.9
Late Gestation Ration		
Year 1		
Alfalfa Hay	63.0	63.1
Oat Straw	26.0	24.2
Barley Grain	11.0	12.7
Year 2		
Alfalfa Hay	62.0	61.5
Oat Straw	26.0	25.2
Barley Grain	12.0	13.4

during both periods, the ration was augmented with a commercial 1:1 mineral (Feed-Rite Hi C-N-Z (1:1) (with selenium), Feed Rite Ltd. Humboldt, SK) and cobalt iodized salt (Feed-Rite Cobalt iodized salt, Feed Rite Ltd. Humboldt, SK) which was available free choice (Table 3.2).

3.2.1.1 Data Collection

3.2.1.1.1 Weight

Each animal was weighed on two consecutive days at the start and end of each trial in order to minimise variation due to rumen fill. Throughout the trial, each animal was weighed individually every three weeks with weights taken in the morning before feeding. This was in order to gather information on body weight gain or loss throughout the trial. The actual calving dates and birth weight were also recorded in order to correctly determine the beginning of the third trimester of pregnancy as well as to account for the affect of fetal and associated uterine tissue growth. The animal's actual body weight corrected for stage of gestation, assuming a gestation period of 283 days, was determined using Equation 2.8 (NRC, 1996). For each period, the adjusted weight gain was divided by the appropriate days on feed to determine ADG.

3.2.1.1.2 Body Condition Scoring and Ultra-sounding

In year one, the cows were individually body condition scored by an independent technician at the start and end of test. This also occurred in the second year with an additional body condition scoring at the estimated beginning of third trimester. Measurements were according to Houghton et al. (1990). At the start and end of test, as

Table 3.2: Composition of Cobalt Iodized salt and 1:1 Mineral used in cattle rations.

1:1 Mineral		Cobalt Iodized Salt	
Ingredient	**Analysis**	**Ingredient**	**Analysis**
Calcium	16.0%	Salt (Min)	99.0%
Phosphorus	16.0%	Sodium	39.0%
Iron	450 mg/kg	Iodine	150 mg/kg
Iodine	125 mg/kg	Cobalt	100 mg/kg
Manganese	5300 mg/kg		
Copper	4000 mg/kg		
Cobalt	40 mg/kg		
Zinc	10 000 mg/kg		
Fluorine (max)	2000 mg/kg		
Vitamin A (min)	200 000 IU/kg		
Vitamin D (min)	45 000 IU/kg		
Vitamin E (min)	40 IU/kg		

well as every third week, an independent technician individually measured the cows for ultrasound fat thickness. This was done using an Echo Camera SSD-500 diagnostic real time ultra-sound (RTUS) unit (Overseas Monitor Corporation Ltd., Richmond BC) equipped with a UST 5044 - 17 cm 3.5 MHz linear array transducer. The first RTUS fat measurement was take over the third quarter of the *longissimus dorsi* (rib eye) muscle between the 12th and 13th rib. The second measurement was on the rump area, which is located midway between the hooks and pins about 4 cm above the greater trochanter of the femur (Domecq et al. 1995). The third RTUS fat measurement was near the tail head, 4 to 5 cm off the midline, midway between the hooks and pins and parallel to the sacral vertebrae. All measurements were made on the left side of the animal.

3.2.1.1.3 Feed Samples

Bunk samples were collected three times per week and compiled weekly. Weekly composites were placed in a forced air oven at 55ºC to obtain DM content, then ground to pass a 1-mm screen using a Christie-Norris mill (AOAC, 1990). These samples were used for laboratory analysis. Pen intakes (as fed) were recorded daily and used with weekly dry matter measurements to calculate dry matter intake (DMI) for each pen.

3.2.1.2 Temperature

A Taylor Min/Max thermometer (Taylor USA, Oak Brooks, Illinois), was used to record daily minimum and maximum temperatures. These were then averaged in order to obtain average daily temperature. Daily temperatures were averaged for the duration of each feeding period to determine current temperature for input into the NRC (1996) model, as suggested by Fox and Tylutki (1998). To determine the previous month's average temperature, daily temperatures were averaged from four weeks prior to the beginning of each trimester to four weeks prior to the end of each trimester.

3.2.2 Digestibility Trial

A total tract *in vivo* digestibility trial was conducted in order to determine voluntary intake, nutrient digestibility and DE content of the rations fed to the cows in each period for each year.

In the first year, nine Angus steers with a weight of 377 ± 27.5 kg were used. In the second year, seven Angus cross steers with a weight of 343 ± 19.5 kg were used. Each year the steers were given 14 days of *ad libitum* feeding to adapt to the barn and the diet. For both the early and late gestation rations the diets consisted of the same ingredients, in the same proportions, as the wintering cow diets in each year of the study (Table 3.1). In year one, the animals fed the early gestation ration were administered a controlled release rumen marker capsule (Captec® Cattle chrome MCM, active constituent: Chromium sesquoxide). In the late gestation ration for both years, and the early gestation ration of the second year, 400g (as fed) of chromic oxide pellets were added to the diet as an indigestible marker. A 10-day adaptation period was given to allow for distribution of chromium through the digestive tract. After seven days of the animal's receiving the indigestible marker, the animals began a 3-day restricted feed period in which they received 90% of their *ad libitum* intake. Following this, the collection period consisted of five days during which feed, orts and fecal samples were collected. Feed and ort samples were collected daily and composited. Sub-samples of faeces from each animal were collected at 0800, 1200 and 1600 each day. These samples were composited on a daily basis. All samples were immediately placed into a forced air oven (55ºC) for 72 h. The fecal samples were then composited to give one sample per steer.

3.2.3 Laboratory Analysis

In both years, the samples collected from the feed bunks were analysed in duplicate for moisture (Association of Official Analytical Chemists (AOAC, 1990), method 930.15), ether extract (EE) (AOAC, method 920.39), acid detergent fibre (ADF) (AOAC, method 973.18) and acid detergent lignin (ADL) (AOAC, method 973.18) (AOAC 1990). Neutral detergent fibre (NDF) was analysed according to the procedure of Van Soest et al. (1991). Heat stable α- amylase (A3306, Sigma Chemical Co., St. Louis, MO) was included in the NDF procedure at 0.17 ml per 0.5 g sample. Crude protein (CP) was analysed by Kjeldahl nitrogen (AOAC method 976.05) using a Kjeltec 1030 auto analyser, which was also used to analyse acid (ADFIP) and neutral detergent fibre insoluble protein (NDFIP) (AOAC, method 984.18) with residues recovered on Whatman No. 54 paper (AOAC 1990).

The feed and faecal samples from each year of the digestibility trials were analysed to determine, CP, NDF, ADF, and moisture using the methods stated above. Gross energy (GE) (Parr Instrument Company, 1970) and ash (AOAC, method 942.05) was also analysed (AOAC, 1990). The faecal and ort samples were analysed for chromic oxide using a LKB-Ultorspec III Spectometer (Pye-Unicam Ltd., Markham, ON) (Fenton and Fenton, 1979). Due to the low amount of chromic oxide released from the controlled release faecal marker capsule in the early gestation ration trial of the first year the chromic oxide was analysed for chromium using a 4000 Atomic Absorption Sectrophotometer (Perkin-Elmer Ltd., Boston, MA) (Zasoske and Burau, 1977).

3.2.3.1 Dietary Energy Predictions

Three methods were used to determine dietary energy of the rations fed during each period. First the total digestible nutrient (TDN) content was calculated from composited feed analysis data according to the forage equation of Weiss et al. (1992).

Equation 3.1:

$$\{0.98*(1000-\{(NDF*10)-(CP*NDFIP/10)+[0.7*(CP*ADFIP/10)]\}- (CP*10)-(ash*10)+[0.7*(CP*ADFIP/10)]-(EE*10))+[-0.0012*(CP*ADFIP/10)]^2*(CP*10)+2.25*[(EE*10)-10]+0.75*(\{(ADL*10)-(CP*NDFIP/10)+[0.7*(CP*ADFIP/10)]\}-(ADL*NDF/10))*[1-((ADL*NDF/10)/\{(NDF*10)-(CP*NDFIP/10)+[0.7*(CP*ADFIP/10)]\})\hat{}(0.667)]-70\}/10$$

where NDF, CP, EE, ash and ADF were expressed as %DM, NDFIP and ADFIP were expressed as %CP, and ADL was expressed as %NDF

Secondly, the results from the digestibility trials were used to determine the apparent digestible energy (DE) content of the diet using the equation by Schnieder and Flatt (1975).

Equation 3.2: $100-\{100*-[(Cr_{feed}*GE_{faeces})/(Cr_{faeces}*GE_{feed})]\}$

where Cr_{feed} is % chromium in feed consumed by the animal, GE_{feces} is % gross energy in feces – orts, Cr_{faeces} is % chromium in faeces and GE_{feed} is % gross energy in feed – orts, (all on a dry matter basis). This was then converted to apparent digestible energy (DE) by multiplying the result of the above equation by the gross energy in the feed. DE was converted to TDN by the following equation:

Equation 3.3: 21.16 MJ DE = 1 kg TDN (NRC, 1996).

The final method used to determine % TDN was based on the Pennsylvania State equation that uses ADF as a measure of indigestible fibre in mixed forages and grasses (Adams, 1995).

Equation 3.4: $4.898+\{89.796*[1.0876-(0.0127*ADF)]\}$

where ADF is expressed on a DM basis.

3.2.4 Evaluation of the 1996 NRC Beef Model

For each pen, computer modelling was undertaken to predict pregnancy adjusted daily gain (kg day^{-1}) and DM intake (kg) for each trimester in each year. Prediction of pregnancy adjusted daily gain and DM intake involved using equations from the 1996 beef model as adapted by the Alberta Agriculture program CowBytes® (Alberta Agriculture, Food and Rural Development, Edmonton, AB, 1999). Actual environment data collected during the winter feeding trials were entered as well as detailed feed analysis and feed amounts. Pregnancy adjusted ADG and actual DMI values that were inputted into the model for prediction purposes were the actual values observed in the given period. The "CowBytes" model predicted pregnancy adjusted ADG is based on actual DMI and uses the NRC (1996) prediction equation shown in Equation 2.9 to Equation 2.11. This same model gives a "Recommended DMI", which is predicted *ad libitum* feed intake and is based on shrunk body weight and energy density of the diet using Equation 2.12: found in NRC (1996).

For each scenario, the model was run two times using energy values generated from the Weiss et al. (1992) equation and the digestibility trial. This was carried out in order to show the importance of using the correct energy values.

3.2.4.1 Thermal Neutral Data Set

In addition to collecting prediction data for the actual environment conditions, the "Cowbytes" model was re-run using thermal neutral conditions for both the current and previous temperatures (20°C with no wind). Thermal neutral conditions were used to predict dry matter intake (kg) and daily gain (kg day^{-1}) for each trimester in each year for each individual pen used in the wintering cow trial. This second data set was run so that any part of the prediction equation used in the model which partitions energy towards maintaining body temperature in cold weather was removed. By comparing the predictions obtained through the NRC (1996) model using thermal neutral conditions with the predictions observed using actual environmental conditions it is possible to evaluate the impact of the thermal submodel.

3.2.5 Statistical Analysis

The early, mid and late calving groups were analysed to determine if there was any influence of calving date on the accuracy or inaccuracy of the model prediction. As there were no differences detected, calving group was eliminated from further analysis.

Individual pens constituted experimental units allowing 15 observations each year. Comparisons were made between: 1) actual pregnancy adjusted ADG vs. predicted ADG based on actual DMI, and 2) actual DMI vs. predicted *ad libitum* intake. Comparisons were made using the regression procedure of SAS (SAS Institute Inc., Cary, NC) according to the methods of Mayer and Butler (1993) and by means comparisons. Details on evaluation of model accuracy included:

1) Regression procedures were first used to evaluate the relationship between predicted (x) and observed (y) values for DMI and ADG. If a relationship existed ($P \leq 0.05$), the resulting linear regression equation was compared to a theoretical equation with intercept = 0 and slope = 1, which would denote accurate prediction. Fitted regression equations that differ ($P \leq 0.05$) from this theoretical equation indicate an inaccurate model. Equations that do not differ are accepted as accurate.
2) If there was no relationship ($P > 0.05$) between predicted (x) and observed (y) values for DMI and ADG then regression was run on residuals (predicted minus actual) versus predicted DMI or ADG. If there is a relationship (i.e. a pattern) between residuals and predicted DMI or ADG ($P \leq 0.05$) then the model is deemed inaccurate.
3) If there is no relationship ($P > 0.05$) between residuals and predicted values, then the mixed model procedure of SAS Institute Inc. (1989) was used for means comparison. The model was deemed accurate if this comparison was found to be not significant.

Evaluations were conducted with energy values from the theoretical equation of Weiss et al. (1992) using composited feed analysis data or results from the steer digestibility trial. Data from each year was evaluated in two time blocks: the 2nd trimester data set, and the 3rd trimester data set. Data from each year were analysed separately. If the data sets of the second trimester, from the first year and the second year, were both deemed accurate, or both deemed inaccurate, they were combined. If one year was found accurate, but the other was inaccurate, the data sets were not combined. Combining the two years of data allows for a more powerful evaluation of model accuracy, but is only appropriate if the level of accuracy/inaccuracy is similar across both years. This procedure was also used for the third trimester data sets.

3.3 Results and Discussion

3.3.1 Animal performance

Each year of the trial was separated into the second and third trimester of pregnancy. The second trimester ran from the start of test (1st week in November) to twelve weeks prior to the average calving date for each pen of cows. The third trimester was deemed to start twelve weeks prior to the average calving date for each pen of cows. This part of the trial continued until 2 weeks before estimated average calving date for each group of cows, or until calving, which ever occurred first.

Results from the 2nd and 3rd trimester of each year were compiled and analysed separately for ADG and *ad libitum* intake. When the predictions for ADG and DMI were compared to actual values over the two years of the study the direction of under or over prediction was similar. For example in the 2nd trimester of each year DMI was over predicted relative to actual intake while in the 3rd trimester of each year the DMI was under predicted. For this reason, the results of the two years were combined and analysed together.

In the first year of the trial, one cow was removed due to early abortion of the fetus. Body weight, body condition score and ultrasound fat of the cows throughout the trial are given in Table 3.3. The nutrient management strategy during the second trimester was to maintain weight and allow for fetal growth requirements according to the 1996 NRC beef model. During the 3rd trimester the nutrient quality of the ration was increased to support increased pregnancy requirements yet maintain basic body weight.

Table 3.3: Performance summary for wintering beef cows in each of two years.

Item	YEAR 2002-2003 Mean	2002-2003 SD	2003-2004 Mean	2003-2004 SD
Start of Test				
Live weight without fetus, kg	580	8.84	587	4.95
Body Condition Score [z]	3.18	0.19	2.78	0.17
Ultra-sound				
12/13th rib fat, mm	5.6	1.03	3.8	1.01
Rump fat, mm	7.4	1.26	4.2	1.33
Tailhead, mm	8.6	1.34	5.1	1.36
End of 2nd Trimester				
Live weight without fetus, kg	589	10.59	593	9.97
Body Condition Score [z]	3.25	0.09	2.87	0.16
Ultra-sound				
12/13th rib fat, mm	5.2	0.70	3.2	1.12
Rump fat, mm	6.7	1.24	3.6	1.12
Tailhead, mm	7.9	1.01	3.4	1.42
End of 3rd Trimester				
Live weight without fetus, kg	590	11.27	606	9.17
Body Condition Score [z]	3.19	0.21	3.21	0.19
Ultra-sound				
12/13th rib fat, mm	5.1	0.33	4.4	0.89
Rump fat, mm	6.6	1.80	6.6	1.53
Tailhead, mm	7.6	1.47	7.7	1.53

[z] Body Condition Score based on 1 to 5 point scale.

3.3.2 Chemical Analysis and Determination of Dietary Energy Content

Nutrient composition of rations fed to wintering cows is shown in Table 3.4. The early gestation ration was found to be 7.7% CP and 51.7% TDN (DM basis) in year one, and 6.6% CP and 49.8 % TDN (DM basis) in year two. In the first year, the late gestation ration was found to be 9.6% CP and 55.3% TDN, where as in year two this ration consisted of 7.6% CP and 56.4% TDN (DM basis). The NRC (1996) prediction model requires accurate estimates of diet energy in order to predict DMI and ADG in cattle (McKinnon et al. 2002). In order to reduce the prediction errors associated with inaccurate dietary energy values entered into the NRC/ ”Cowbytes” program, dietary energy content was determined using three different methods. The digestibility trials evaluated the feeds used for the wintering cow rations to determine DE content in the early and late rations of both years (Table 3.5). In addition, the Weiss et al. (1992) and the Pennsylvania State (Adams, 1995) equations were used to determine the TDN content in each of the four rations presented to the cows over the course of the two years.

3.3.2.1 Digestibility Trial

In the first year, two steers were removed from the early gestation ration digestibility trial due to undetectable chromic oxide release from the bolus. One steer was removed from the early gestation ration digestibility trial in the second year due to non-consumption of the chromic oxide pellets. The dry matter digestibility (DMD) of the early gestation ration during the first and second year was 51.8 ± 5.9%, and 53.0 ± 4.4%, respectively (Table 3.5). The DMD of the late gestation ration during the first and second year was 56.2 ± 3.4% and 58.1 ± 3.3%, respectively. The total tract digestiblity

Table 3.4: Chemical composition and nutrient analysis of rations fed to wintering cows for both years.										
Item	**DM(%)**	**CP(%)**	**ADF(%)**	**NDF(%)**	**Ash(%)**	**TDN[z]**	**NDIN**	**ADIN**	**ADL**	**EE**
Year 1										
Early gestation ration	67.1	7.7	45.4	69.3	8.0	51.7	3.3	2.4	7.0	1.4
Late gestation ration	75.9	9.6	42.8	60.2	8.2	55.3	4.7	2.7	8.3	1.8
Year 2										
Early gestation ration	73.7	6.6	45.9	69.2	7.6	49.8	3.0	1.7	7.7	1.6
Late gestation ration	78.5	7.6	44.0	68.8	6.9	56.4	4.7	2.2	7.5	1.7

[z] Energy calculated using the Weiss et al. (1992) forage based equation

Table 3.5: Dry matter digestibility and digestible energy (as a percent of Gross energy) in the digestibility trial for both years.

	%DMD		%DGE		DE MJ kg^{-1}		%TDN[z]
Item	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Year 1							
Early Ration	51.79	5.89	50.09	5.86	10.46	1.33	49.6
Late Ration	56.19	3.38	54.19	3.66	11.52	0.44	54.6
Year 2							
Early Ration	52.95	4.35	50.60	4.51	10.32	0.94	48.9
Late Ration	58.10	3.30	58.13	3.29	11.62	0.85	55.0

[z] Calculated from DE (DE/21.16) (NRC 1996)

trial determined tat the digestibility of the gross energy of the diet was found to be 50.1 ±5.9% for the early ration and 54.2 ± 3.7% for the late ration of year one. DE (MJ kg^{-1} day), TDN values (%) were calculated (Table 3.5) based on the GE content and its digestibility

Digestibility trials are an important tool for describing the nutritive value of feeds, as it is not chemical composition alone that determines the value of feed, but rather nutritive value which depends upon the composition, digestibility and factors such as species utilising the feed. These types of trials are a means of defining energy values of livestock feeds that require few animals and the facilities are less expensive to purchase and operate than those necessary for determining other energy values such as net energy (Schnieder and Flatt, 1975). Potential negative factors of a digestibility trial include a high possibility of error while conducting the trial (Schnieder and Flatt, 1975) as shown by the high variability in the dry matter digestibility of the energy values in this trial (Table 3.5).

In this study, there very large variation in dry matter digestibility, most notably in the first year using the early trimester ration (coefficient of variation = 0.0884). One possible reason for this was due to variation (1.7 g ± 10%) in the daily release of chromium sesquoxide controlled release rumen marker capsule (Captec® Cattle chrome MCM, active constituent: chromium sesquoxide). The small amount of chromium released is very difficult to measure precisely. This, in addition to the variability in release rate of the chromium sesquoxide can cause a highly variable result. When these results were used to calculate DE and TDN, the variation was perpetuated.

Chromic oxide pellets were used in the digestibility trials for the late gestation ration of the first year, and the early and late gestation ration of the second year. Use of these pellets offers a more precise calculation of the amount of chromium in the pellets, and therefore the exact amount of chromium presented to each individual steer. In this trial, the steers did not always eat all pellets presented to them. Although analysis of the amount of chromium found in the orts could rectify some of this, it is not possible to ascertain the amount of chromium lost due to feed spillage. Therefore, when chromic oxide was used as a marker there was a variation of 8% in the dry matter digestibility in the late gestation ration in the first year, and 6 and 3% in the early and late gestation rations, respectively, of the second year.

3.3.2.2 Pennsylvania State Equation (Adams, 1995)

Acid detergent fibre (ADF) content as determined in the laboratory is the only component of the feed that influences the Pennsylvania State equation (Adams, 1995). The use of ADF rather than crude fibre content has improved prediction of various estimates of energy or TDN. It also provides a means of estimating unavailable or "heat-damaged" protein through the determination of Acid Detergent Fibre Insoluble Nitrogen (ADFIN) content (Adams, 1995). The use of ADF to predict TDN values of feeds has been criticised because ADF is not a uniform nutritional fraction, is environmentally unstable, and its digestibility is not constant among or within feeds (Van Soest et al. 1991).

The early gestation ration had 50.8% TDN in the first year and 50.2% in the second year using the Pennsylvania State equation (Adams, 1995). The late gestation ration consisted of 51.7% TDN and 52.4% TDN (Table 3.6).

Table 3.6: Comparison of energy values on predicted by three different methods.

Item	**DE (MJ kg^{-1})**	**TDN (%)**
Year 1		
Early Ration		
Weiss Equation[z]	10.94	51.74
Digestibility Trial[y]	10.46	49.55
Pen State Equation[x]	10.51	50.79
Late Ration		
Weiss Equation	11.66	55.28
Digestibility Trial	11.52	54.55
Pen State Equation	10.85	51.71
Year 2		
Early Ration		
Weiss Equation	10.51	49.75
Digestibility Trial	10.32	48.86
Pen State Equation	9.89	50.17
Late Ration		
Weiss Equation	11.90	56.38
Digestibility Trial	11.62	55.00
Pen State Equation	11.62	52.38

[z] TDN calculated via Weiss equation (Weiss et al. 1992)
[y] DE calculated via digestibility trial
[x] TDN calculated via Pennsylvania State equation (ADF content of the feeding trial diets)
(Adams, 1995)

3.3.2.3 Weiss et al. (1992) Equation

In comparison to the Pennsylvania State equation (Adams, 1995) and the digestibility trials, the Weiss et al. (1992) equation uses many different factors to determine the energy content of the feed. This includes neutral detergent fibre, crude protein, neutral detergent fibre insoluble protein, ADFIP, ash, ether extract and lignin.

Using the Weiss equation (Weiss et al. 1992) the early gestation ration consisted of 51.7% TDN in the first year and 49.8% TDN in the second year (Table 3.6). The late gestation ration in the first year was found to consist of 55.3 % TDN, where as the second year consisted of 56.4% TDN.

Several factors were considered in deciding which energy values to use in evaluating the model. First the high variability in the digestibility trial data was assumed to be unacceptable and thus the energy values calculated using this approach were not used. Second, when comparing the Pennsylvania State Equation to Weiss et al. (1992) it is clear that the latter method uses a more comprehensive approach based on nutrient content to determine ration energy values. The NRC (1996) beef model uses the rumen simulation model to predict fermentation along with a similar approach of Weiss et al. (1992) to calculate the energy content of the feed. In the trials of Block et al. (2001b) and McKinnon et al. (2002) the energy values of the rations were also estimated using the Weiss et al. (1992) equation. Thus in this study the energy values determined using the forage equation published by Weiss et al. (1992) were used.

3.3.3 Accuracy of 1996 NRC Beef Model for Predicting Performance of Wintering Beef Cows

In both years each pen contained animals which had similar average start of test weights, BCS, and expected day of gestation at the beginning of the trial (Table 3.3). During the second trimester, for the first and second year, average live weight (±SD) of the cows was 599 ± 9.6 and 603 ± 6.9 kg, respectively when fetal and associated uterine tissue weights were included (Table 3.7). When the fetal and associated uterine tissue weight was not included the cows weighed 584 ± 9.8 and 590 ± 6.3 kg, respectively. The pregnancy adjusted ADG for the second trimester in the first and second year was 0.13 ± 0.20 and 0.07± 0.12 kg day^{-1}, where as the average DMI was 10.9 ± 0.44 and 11.7 ± 0.71 kg day^{-1}. During this trimester, the average BCS was 3.21 ± 0.12 in year one and 2.83 ±0.15 in year two.

During the third trimester of the first and second year the average live weight of the cows was 632 ± 11.03 and 643 ± 9.59 kg including fetal and associated uterine tissue weight (Table 3.7). When the fetal and associated uterine tissue weights were not included, the average weight of the cows was 590 ± 10.21 and 600 ± 7.32 kg. The ADG for this period was 0.00 ± 0.31 kg day^{-1} in the first year and 0.12 ± 0.15 kg day^{-1} in the second year. The DMI for this same period was 12.7 ± 0.90 kg day^{-1} and 13.6 ± 0.53 kg day^{-1} in year one and two, respectively. The average body condition score during this period for year one and two was 3.22 ± 0.10 and 3.04 ± 0.15, respectively. The average calf birth weight in the year one was 45.1 ±1.72 kg and 44.3 ± 2.20 kg in year two.

Table 3.7: Summary of input data for 2nd and 3rd trimester for wintering beef cows (2002-2003 and 2003-2004)

	2002-2003				**2003-2004**			
Item	**2^{nd} trimester**		**3^{rd} trimester**		**2^{nd} trimester**		**3^{rd} trimester**	
	Mean^{z}	**SD**	**Mean^{z}**	**SD**	**Mean^{z}**	**SD**	**Mean^{z}**	**SD**
Cow weight, kg	599	9.59	632	11.03	603	6.86	643	9.59
Cow weight adj. for conceptus, kg	584	9.18	590	10.21	590	6.31	600	7.32
Gestation month	5.1	0.18	7.6	0.16	5.28	0.26	7.82	0.12
ADG, kg d^{-1}	0.13	0.20	0.00	0.31	0.07	0.12	0.15	0.14
DMI, kg d^{-1}	10.9	0.44	12.7	0.90	11.7	0.71	13.6	0.53
Temperature, ^{o}C								
Current	-9.6	1.37	-10.1	2.61	-11.6	1.32	-8.2	1.05
Previous	-7.2	0.32	-13.8	2.24	-10.9	0.13	-10.2	1.51
BCS	3.21	0.12	3.22	0.10	2.83	0.15	3.04	0.15
Ultrasound, mm								
12/13th rib fat	5.4	0.99	5.1	0.93	3.48	1.01	3.78	0.97
Rump fat	7.1	1.21	6.6	1.42	3.89	1.21	5.08	1.35
Tailhead Fat	8.3	1.11	7.7	1.09	4.56	1.29	5.84	1.38
Calf weight at birth, kg	45.1	1.72	45.1	1.72	44.3	2.20	44.3	2.20

Average during the specified trimester

Actual and predicted values for ADG and DMI for both the second and third trimester are presented in Table 3.8. As previously mentioned, "Cowbytes uses the net energy of maintenance and gain equations for growing and finishing cattle (see Equation 2.9 to Equation 2.11) using observed DMI to predict ADG, while predicted DMI was based on shrunk body weight and energy density of the diet, corrected for factors such as maintenance, pregnancy and acclimation to environment (NRC 1996).

3.3.3.1 Prediction of ADG under actual environmental conditions

As discussed in the literature review, there are two approaches to calculating body weigh gain of mature beef cows. One method is to look at the gain or loss of body condition and the amount of NE_m required or provided at each condition score change. The NRC (1996) model uses this approach and assumes that each kg of shrunk body weight change contains 27.99 MJ of NE_m with the efficiency of use of 80% for NE_m during weight loss. The "Cowbytes" model takes a different approach and calculates ADG of mature beef cows. This model uses the net energy of maintenance and gain equations for prediction of gain in growing and finishing cattle (see Equation 2.9 to Equation 2.11;E. Okine, personal communication).

During the second trimester the cows consumed 11.3 kg DM d–1. When this DMI was used to predict the ADG using NRC (1996) equations as employed by "Cowbytes" the ADG was under predicted ($P \leq 0.01$, r2=0.6421, b1=0.129) when compared to actual ADG (–0.18 vs. 0.10 kg DM d–1; Table 3.8, Table 3.9, Figure 3.1)). In the third trimester, the cows consumed 13.2 kg DM d–1. When ADG was predicted using this amount of dry matter amount of dry matter consumed the ADG was under

Table 3.8: Mean and standard deviation of observed and "Cowbytes"® predicted DMI and ADG of wintering beef cows in the 2nd and 3rd trimester of pregnancy under actual and thermal neutral conditions (averaged over both years).

	Dry Matter Intake, kg day^{-1}				Average Daily Gain, kg day^{-1}			
	Actual		Predicted *Ad libitum*[z]		Actual		Predicted based on DMI[y]	
Item	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
2nd Trimester								
Actual Conditions	11.3	0.65	11.8	0.12	0.10	0.11	-0.18	0.17
Thermal Neutral Conditions	11.3	0.65	11.0	0.12	0.10	0.11	0.16	0.06
3rd Trimester								
Actual Conditions	13.2	0.87	12.1	0.17	0.08	0.15	-0.10	0.25
Thermal Neutral Conditions	13.2	0.87	11.3	0.21	0.08	0.15	0.23	0.12

[z] *Ad libitum* intake based on SBW and energy density of the diet (NRC, 1996)

[y] Average daily gain predicted from actual dry matter intake.

Table 3.9: Regression analysis of observed and residuals on predicted ADG (based on actual DMI)[z] in the 2nd and 3rd trimester of wintering beef cows under actual and thermal neutral environmental conditions.

Item	Slope		Intercept		$S_{y.x}$	R^2	P-value regression	*P*-value of Isopleth
	Estimate	SE	Estimate	SE				
Actual Conditions								
2nd Trimester								
Regression Observed	0.18	0.12	0.13	0.03	0.11	0.08	0.14	
Regression Residual[y]	0.82	0.12	-0.13	0.03	0.11	0.64	<0.01	
3rd Trimester								
Regression Observed	0.36	0.09	0.11	0.02	0.12	0.37	<0.01	<0. 01
Thermal Neutral Conditions								
2nd Trimester								
Regression Observed	0.26	0.35	0.06	0.06	0.11	0.02	0.47	
Regression Residual[y]	0.74	0.35	-0.06	0.06	0.11	0.14	0.04	
3rd Trimester								
Regression Observed	0.36	0.12	8.93	1.48	0.78	0.23	<0.01	<0.01

[z] ADG predicted by NRC 1996 to be achieved by actual DMI
[y] Predicted – observed = Residual

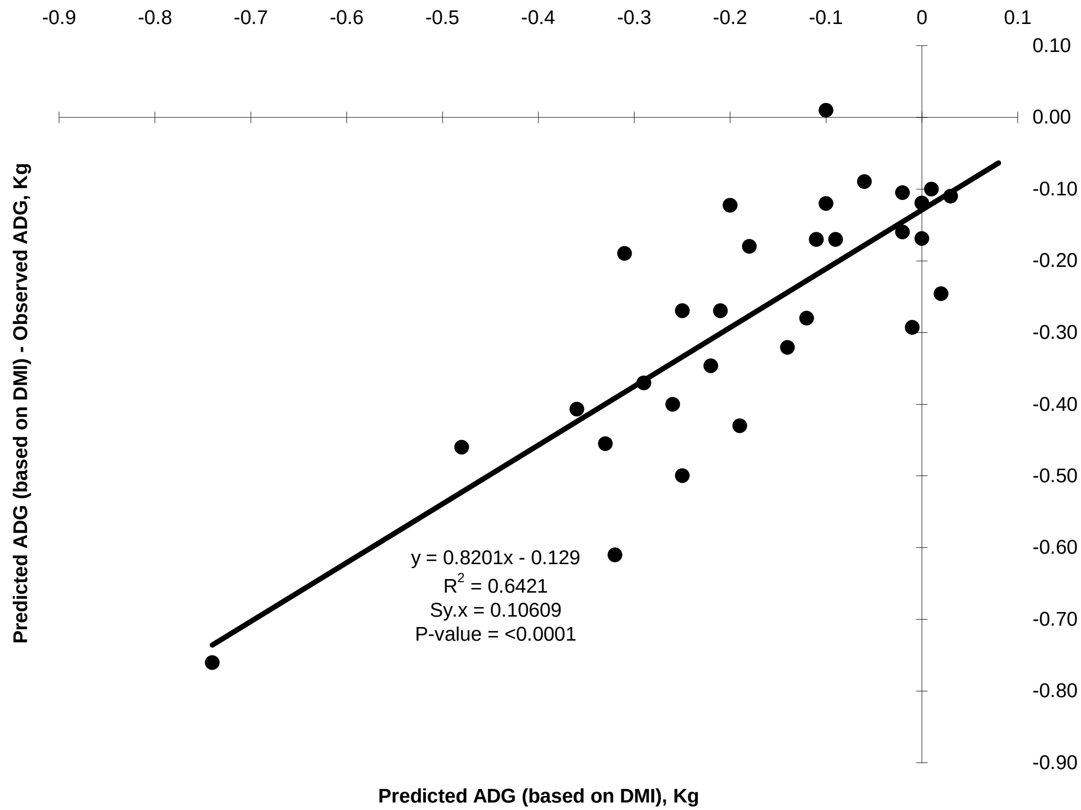

Figure 3.1: Regression analysis of predicted ADG (based on DMI and "Cowbytes") and residuals of predicted ADG – actual ADG for the 2nd trimester using actual environmental temperatures and the Weiss equation to determine energy values over both years.

predicted ($P \leq 0.01$, $r2=0.3696$, $b1=0.1116$) when compared to actual ADG (–0.10 vs. 0.08 kg d–1) (Table 3.8 and Table 3.9, Figure 3.2)). This suggests that under actual environmental conditions, the cows during the 2nd and 3rd trimesters partitioned more energy to gain and less to maintenance functions than predicted by the "Cowbytes" model. As previously discussed the "Cowbytes" program uses the net energy of maintenance and gain equations of growing and finishing cattle (see Equation 2.9 to Equation 2.11) to predict the ADG of mature beef cows (E Okine, personal communication).

This under prediction of ADG is similar to that seen in the study of Block et al. (2001b) where there was an under prediction by the NRC (1996) beef model of ADG in backgrounding and finishing steers. Schenher and McKinnon (unpublished) also found an under-prediction of ADG in calves, but observed no difference ($P \leq 0.01$) between actual and model predicted values for yearling steers. Kloberstein et al. (unpublished) also reported the mean actual gains of their wintering beef cows were greater than the NRC (1996) beef model predicted. In contrast, Okine et al. (2003) found actual ADG of feeder cattle was over-predicted when energy was calculated using DE estimated from ADF as well as when values were determined *in vivo*. One reason for Okine et al. (2003) finding contrary results was the calculated DE (Mcal kg^{-1} DM) was adjusted using the reported decrease in DM digestibility of 0.18 percentage units per degree drop in temperature from 0ºC (Westra and Christopherson 1976). This was in order to account for the effects of cold environmental temperatures on digestibility. These researchers suggested the rational for the lower ADG could be an even lower digestibility of the diet than the

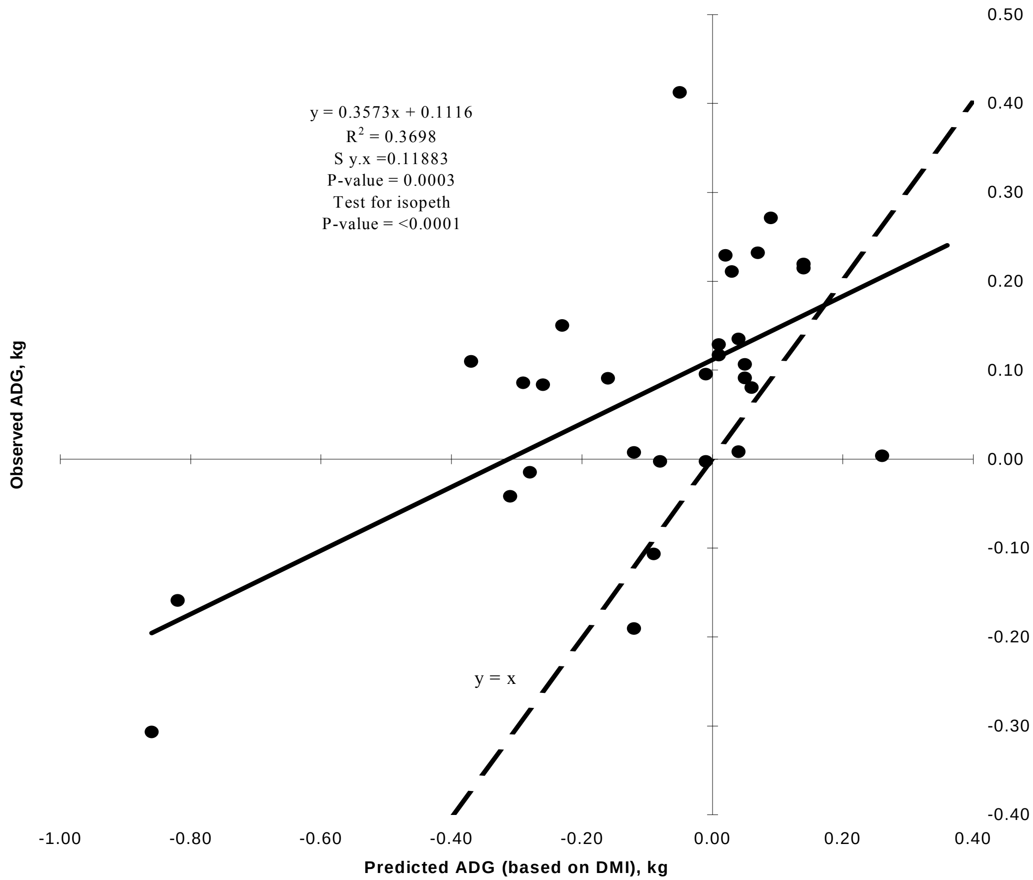

Figure 3.2: Regression analysis of predicted ADG (based on DMI and "Cowbytes) and actual ADG for the 3rd trimester using actual environmental temperatures and the Weiss equation to determine energy values over both years.

correction of DE suggested by Westra and Christopherson (1976). They also suggest there was a slight increase in NE_m requirements even at –9ºC thus potentially explaining the lower observed gains (Okine et al. 2003). A second possible reason for the difference in model prediction between studies is that Okine et al. (2003) used temperature adjusting equations that were tested on sheep rather than steers.

It is evident from the results of the current work where the cattle were observed to gain weight, yet the "Cowbytes" model predicted weight loss, that there was an over estimation of NE_m requirements by the model. For example, the cows in the 2nd trimester consumed 11.8 kg DM of a diet that averaged 4.75 MJ NE_m kg^{-1} DM (i.e. 53.71 MJ NE_m d^{-1}). However, when one models the NE_m requirements of the cows using the approach of NRC (1996) the requirement is 57.26 MJ NE_m d^{-1}. The model is indicating that they require more NE_m than consumed yet the cows actually gained weight (Table 3.8). A similar example can be cited for the cows in the last trimester (65.19 MJ NE_m consumed vs. 71.42 MJ NE_m required). It should be noted that these results point to a problem with the calculation of the maintenance energy requirements of the cows and is independent of how daily gain is calculated.

Energy requirements of a mature non-lactating pregnant cow are based on maintenance and fetal growth with any remaining energy that has been consumed used for tissue gain. With less energy used for maintenance of the animal, which includes maintaining the animal within the thermal neutral zone, more energy is available for growth of conceptus and body tissues. The value of 0.37 MJ $kg^{-0.75}$ suggested in the NRC (1996) is appropriate for determining NE_m requirements when using empty body weight (EBW), with normal effects of activity and environment included into the equation (NRC 1996). However, the 1996 NRC beef model uses shrunk body weight (SBW = 1.12 EBW) and increases maintenance requirements for elevated activity and temperature effects (NRC 1996). This study questions the value of 0.37 MJ kg $SBW^{-0.75}$, as it appears to be an overestimation of the energy needed for net energy of maintenance for cows exposed to western Canadian winters.

Webster (1970) reported that pregnant cows exposed to an air temperature of –27ºC did not increase their rate of heat production above those recorded in a thermoneutral environment. This suggests that as average temperatures in the current trials (-11°C) were above this temperature and the cows were given sufficient opportunity to adapt to the environment, they would have been in their thermal neutral zone. The cows could be expected to maintain the same rate of heat production as they would in a thermoneutral environment of 20ºC. Therefore the approximate 31% average increase in maintenance requirement during this trial as modelled by the 1996 NRC Beef Program (i.e. 1% increase for each 1ºC below 20ºC) would have contributed to the under prediction of ADG. This helps explain why in this trial more energy went to tissue gain than maintenance, opposite to what the model predicted.

3.3.3.2 Prediction of ADG under Thermal Neutral conditions

As indicated earlier, one reason why the NRC (1996) model under predicts ADG is inaccurate assignment of the NE_m requirement of the animal. This rational has also been suggested by Block et al. (2001b) and Schenher and McKinnon, (unpublished). According to the model, the animal would have to increase DMI in order to receive adequate energy to meet requirements for maintenance and the weight gain observed. On the same note, if the model allocates more energy consumed towards maintenance than is required, then there is less energy available to be deposited as growth. Therefore, predicted ADG based on observed DMI will be less than what the animal's actually gained. If the above hypothesis is correct, the model would have partitioned more energy toward maintenance in order to compensate for the lower temperatures endured under western Canadian winter conditions. Koberstien et al. (2001) found that use of temperature-correction equations in the NRC system appears to result in an overestimation of energy requirements for wintering cows which maintained their condition over the winter. The NRC (1996) adjusts maintenance energy requirements by increasing the thermal neutral maintenance requirement by 1% per degree Celsius for temperatures below 20°C by using Equation 2.13.

In order to test the theory that the 1996 NRC beef model over-estimates the NE_m requirements of wintering beef cows in western Canada, the data for the second and third trimester were analysed using thermal neutral conditions where actual environmental conditions were replaced with 20°C and no wind.

When thermal neutral conditions were used with the second trimester data set, the result was a general over-prediction ($P \leq 0.05$, $r^2=0.1411$, $b_1=0.0572$) of the ADG (0.10 vs. 0.16 kg d^{-1} for actual vs. predicted, respectively) (Table 3.8, Figure 3.3). This is in contrast to the under-prediction ($P \leq 0.01$, $r^2=0.1411$, $b_1=0.0572$) of ADG (0.10 vs. -0.18 kg d^{-1} for actual vs. predicted, respectively) resulting from the NRC (1996) beef model equations using actual environmental conditions. A similar over-prediction was found under thermal neutral conditions for third trimester ADG ($P \leq 0.05$, $r^2=0.3018$, $b_1 0.086$) (0.15 vs. 0.23 kg d^{-1}; Table 3.8 and Table 3.9, Figure 3.4). This is again in contrast to actual environmental conditions where in the third trimester ADG was under-predicted

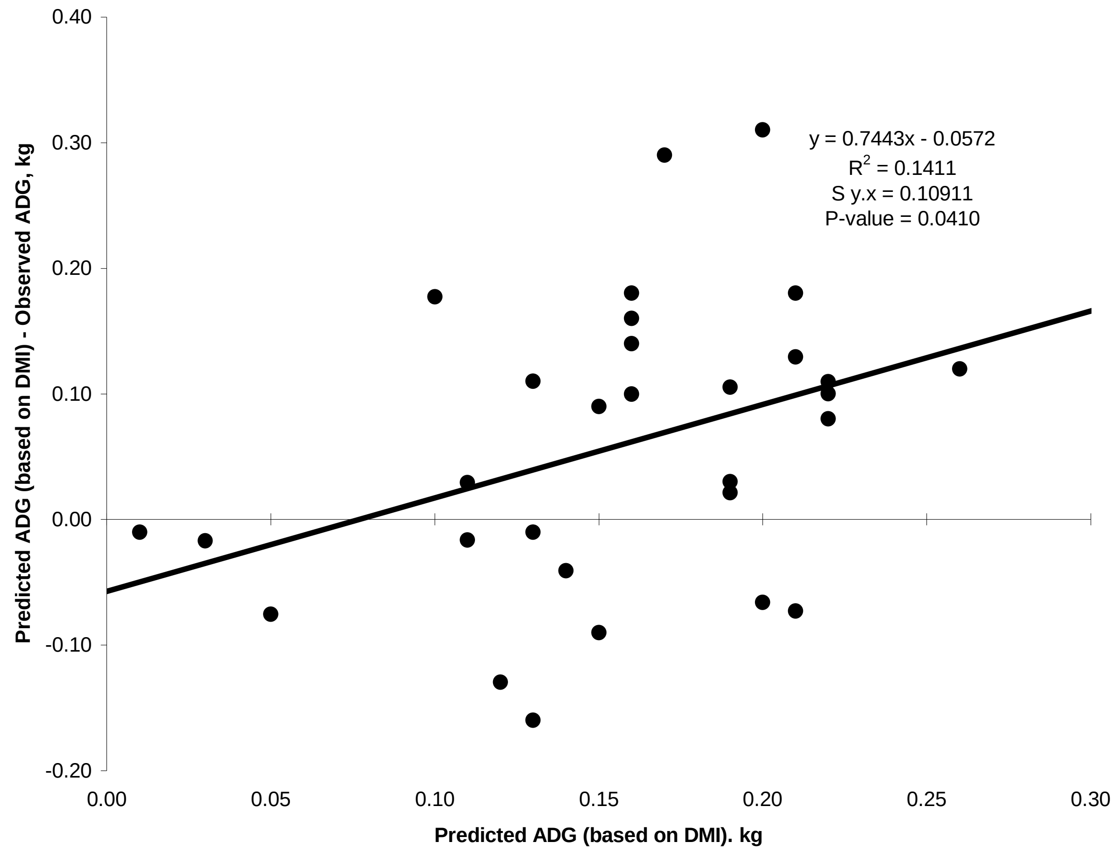

Figure 3.3: Regression analysis of predicted ADG (based on DMI) and residuals of predicted ADG – actual ADG for the 2nd trimester using thermal neutral conditions and the Weiss equation to determine energy values over both years

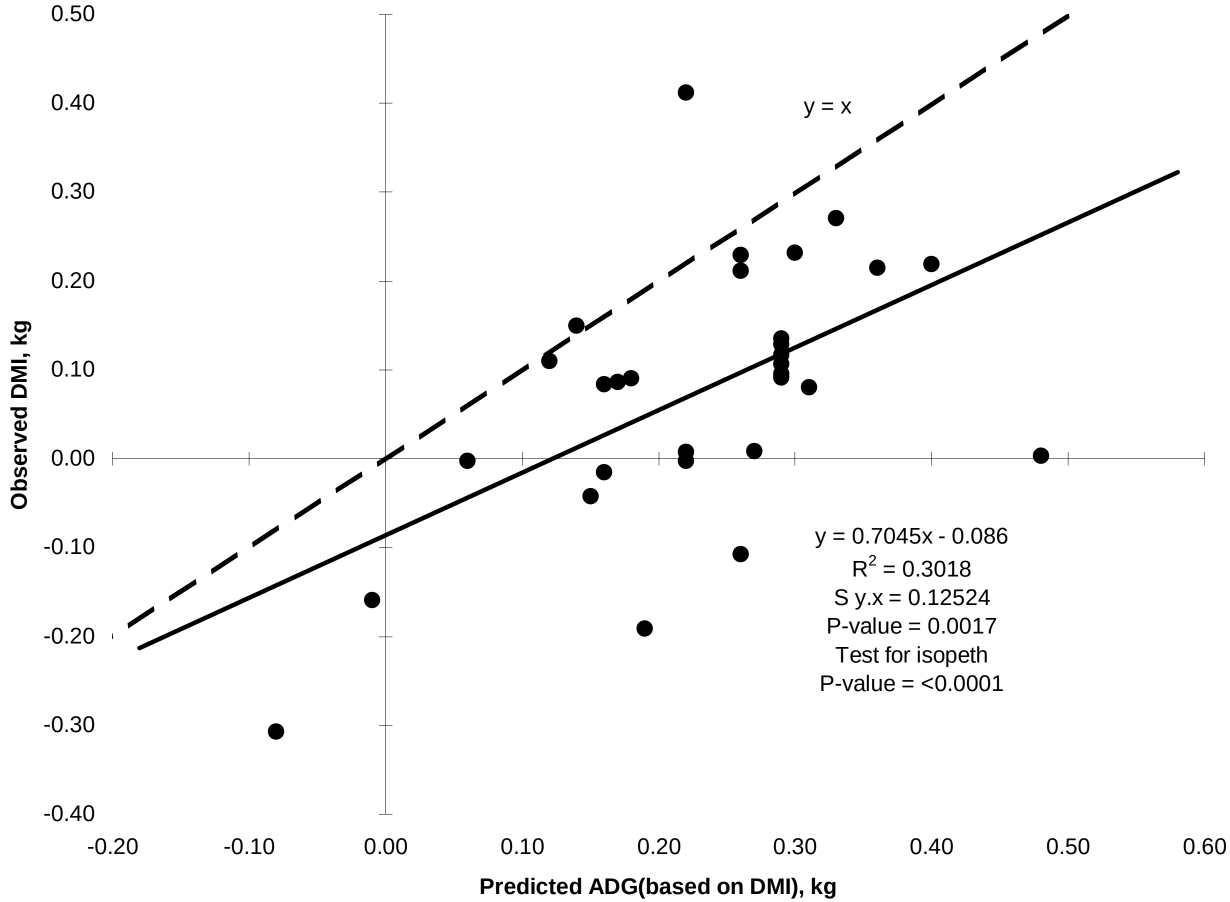

Figure 3.4: Regression analysis of predicted ADG (based on actual DMI) and actual ADG for the 3rd trimester using thermal neutral environmental conditions and the Weiss equation to determine energy values over both years

(0.15 vs. -0.10 kg d^{-1} for actual vs. predicted, respectively) ($P \leq 0.01$, $r^2 = 0.3018$, $b_1 0.086$). These results suggest that the cows in this study experienced some degree of cold stress as evidenced that actual gains were less than predicted gains using thermal neutral conditions. However, the degree of cold stress was not as severe as that modelled by NRC (1996) using Equation 2.13. Further research could focus on how to more accurately model the degree of cold stress actually felt by cattle and their ability to acclimatise to extended periods of moderate cold weather.

Kloberstein et al. (2001) in their study of wintering beef cows found when energy requirements were not adjusted for temperature effects predicted gains were much closer to actual gains. These researchers concluded that although some adjustment of maintenance requirements and hence predicted gains due to low environmental temperature was warranted in their experiments, the NRC (1996) adjustments for temperature appear to be excessive. Block et al. (2001b) suggests that the use of thermal neutral conditions for all predictions would maximise the prediction of ADG and contribute to inaccurate prediction any time that the environmental conditions were severe enough to depress ADG. Therefore, over prediction of ADG can occur with invalid assumption of thermal neutral conditions. Using a compilation of historical data sets, Block et al. (2006) showed that an adjustment to the NE_m equations for more effective modelling of environmental impacts on ADG by growing cattle would bring observed and predicted ADG into closer agreement. In the current study, the over prediction of ADG when using thermal neutral conditions shows the model allocated too much energy to NE_g, thus over predicting ADG. The animals in this study were cold stressed more than what is suggested under thermal neutral conditions, but not as much as the model suggests under actual conditions.

Other factors that could also explain the over prediction of gain under thermal neutral conditions include inaccuracies in the approach used by the "Cowbytes" program in modelling ADG of pregnant beef cows (i.e. use of growing and finishing equations) or in basic assumptions such as calculation of basal metabolic rate included in maintenance energy requirements. It is outside the scope of this study to examine the role such factors play in the accuracy of gain predictions observed under thermal neutral conditions.

3.3.3.3 Prediction of Feed Intake in Actual Environmental Conditions.

The 1996 NRC beef model predicts "*ad libitum*" DM intake based on shrunk body weight and energy density of the diet with the adjusters for lactation, temperature and mud depth. In the "Cowbytes" model this predicted DM intake is referred to as "Recommended" DM intake (E. Okine, personal communication). Under the conditions of this trial, the NRC (1996) model predicted the *ad libitum* intake of pregnant cows to be 11.8 kg DM d^{-1} during the second trimester. This is an over prediction (P <0.05, means comparison) of what was actually consumed "*ad libitum*" (11.3 kg DM d^{-1}) (Table 3.8 and Table 3.10, Figure 3.5).

Table 3.10: Regression analysis of observed and residuals on predicted *ad libitum* intake in the 2nd and 3rd trimester wintering beef cows under actual and thermal neutral environmental conditions.

Item	Slope		Intercept		$S_{y.x}$	R^2	*P*-value Regression	*P*-value of Isopleth
	Estimate	SE	Estimate	SE				
Actual Conditions								
2nd Trimester								
Predicted Ad Libitum								
Regression Observed	0.95	0.98	-0.01	11.58	0.65	0.03	0.34	
Regression Residual[y]	0.06	0.98	0.01	11.58	0.65	0.01	0.96	
3rd Trimester								
Predicted Ad Libitum								
Regression Observed	2.11	0.85	-12.30	10.30	0.80	0.18	0.02	<0.01
Thermal Neutral Conditions								
2nd Trimester								
Predicted Ad Libitum								
Regression Observed	0.75	0.99	3.00	11.02	0.65	0.02	0.46	
Regression Residual[y]	0.25	0.99	-3.00	11.02	0.65	0.02	0.80	
3rd Trimester								
Predicted Ad Libitum								
Regression Observed	1.17	0.74	-0.14	8.35	0.85	0.08	0.12	
Regression Residual[y]	-0.17	0.74	0.14	8.35	0.85	0.00.	0.81	

[z] ADG predicted by NRC 1996 to be achieved by actual DMI

[y] Predicted – observed = Residual

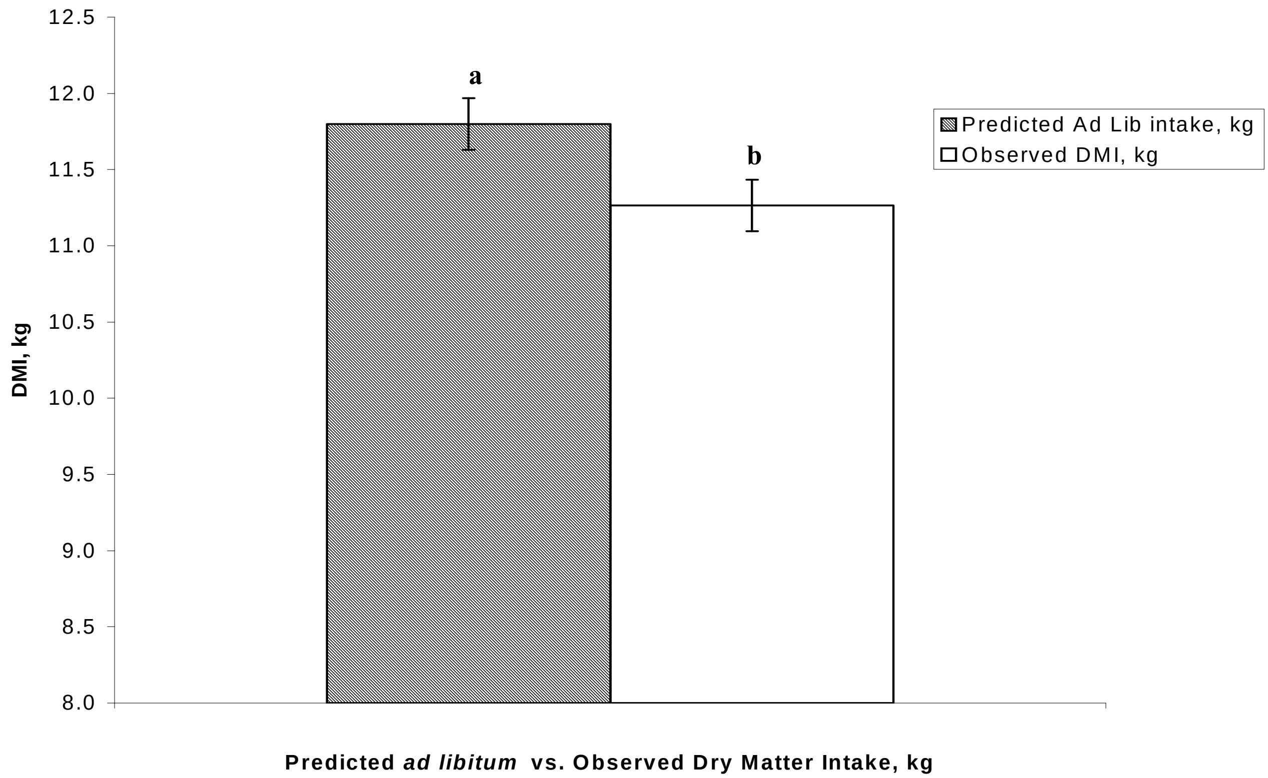

Figure 3.5: Means comparison of predicted ad libitum intake vs. observed DMI ($P \leq 0.05$) for the 2nd trimester using actual environmental conditions and the Weiss equation to determine energy values averaged over both years. Pooled standard error was 0.085. Error bars are standard error of the means. Means with different letters are different ($P \leq 0.05$).

Similarly, “*ad libitum*” intake was evaluated for the third trimester of pregnancy. It was found that the model predicted the cows should consume 12.1 kg DM d^{-1} when actual environmental conditions were considered. The equation under-predicted (P<0.05, r^2=0.1793, b_1=12.299) what was actually consumed (13.2 kg DM d^{-1}) (Table 3.8 , Table 3.10, Figure 3.6).

The adjusters for the effect of temperature on voluntary DMI increase the prediction of intake with decreasing temperature (NRC, 1996). The magnitude of these adjustments under the actual conditions of the trial would be to increase DMI by approximately 16%. Since the temperature was below freezing, no effect of the mud depth adjuster was present.

When we look at the prediction of intake in the second trimester there was an over-prediction. It is possible that the magnitude of the adjuster employed by NRC (1996) was too high resulting in the over-prediction. In contrast, for cows in the last trimester, DMI was under predicted. These cows were in a different physiological state due to stage of pregnancy so it is possible that the adjustment factor was too low for these cows and thus there was an under prediction of DMI.

A second more plausible reason for the inaccuracy of the prediction of DMI is the energy density of the diets used in this study. For prediction of DMI, the NRC (1996) model sets the diet NE_m to 4.56 MJ kg^{-1} DM for all diets with an energy density less then 4.81 MJ NE_m. This modelling reflects the transition from chemostatic regulation of intake (i.e. curvilinear response in feed intake relative to energy density of the diet) to regulation of intake through fill effects (NRC, 1996). The diets used in this study, particularly the 2nd trimester diets, were very close this value. It is possible that due to

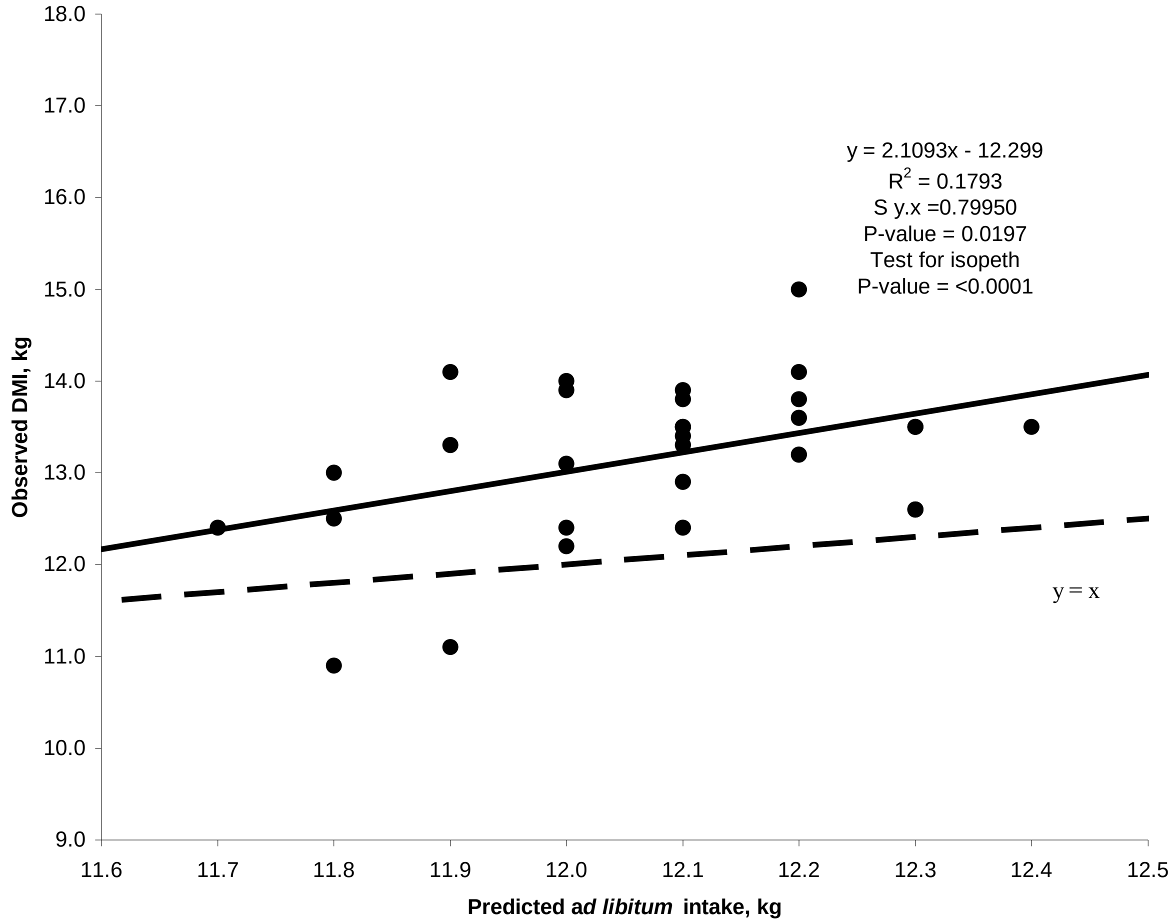

Figure 3.6: Regression analysis of predicted ad libitum intake and actual DMI for the 3rd trimester using actual environmental temperatures and the Weiss equation to determine energy values over both years.

fill effects, the cattle could not consume what the model actually predicted, thus the over-prediction. As diets are increased in energy density in the 3rd trimester there is a transition from regulation of intake based on fill to chemiosmotic regulation. This shift in fill condition (fill effects are reduced) and the emphasis on actual dietary energy concentration could potentially allow the animals to consume more than predicted. These results suggest that a potential for improvement in DMI predictions for mature beef cows would be for NRC (1996) to base its prediction on factors other than energy density of the diet, such as physiological state and/or actual fill effects on intake. If cows in this study were at a point where fill was affecting intake (i.e. 2nd trimester), it does not seem appropriate to predict intake on a constant, arbitrary assigned standard energy concentration of the diet (i.e. 4.57 MJ diet NE_m kg^{-1} DM). More research is required to see if such an approach can improve DMI predictions.

There is a lack of evidence in the area of feeding mature cows in western Canadian winter conditions on an *ad libitum* basis, as most research in this area uses feedlot steers. Therefore it is difficult to find other research evaluating *ad libitum* intake predictions to support or argue against the findings in the predicted *ad libitum* data of this study. It has been found that there was no change in digestibility when mature cows were exposed to 20°C and –11°C (Christopherson, 1976), therefore *ad libitum* intake of mature cows would not be expected to change during these temperatures. This may be due to the large body size and smaller surface to mass ratio of mature cows, as well as better insulation, causing them to be relatively cold tolerant (Christopherson and Kennedy, 1983), and resulting in the NRC (1996) inaccurately predicting *ad libitum* intake in mature cows. Contrarily, these same researchers suggest that the digestibility of forage diets, which tend to be fermented slowly, appears to be more susceptible to influence by temperature-induced changes in motility and the rate of passage of digesta. This statement suggests that the relative effect of change in temperature on intake would be larger in a study such as this, where forage was fed than with a study in which a high grain diet was fed.

3.3.3.4 Prediction of Feed intake in Thermal Neutral Conditions

When thermal neutral conditions were applied to the equations for *ad libitum* DM intake using the second trimester data set, there was a 2.6% under prediction (11.3 vs. 11.0 kg d^{-1}, P<0.05; Table 3.8, Table 3.10, Figure 3.7). This is in contrast to the 4.2% over prediction of *ad libitum* intake under actual environmental conditions (11.8 kg d^{-1}, P<0.05;. Similarly, in the 3rd trimester when DMI was modelled under thermal neutral conditions, the under prediction increased to 14.4% (13.2 vs. 11.3 0 kg d^{-1}, $P \leq 0.01$; Table 3.8, Table 3.10, Figure 3.8). These results are not surprising. By running the model under thermal neutral conditions the temperature adjustment for DMI was effectively set to zero. This reduces the prediction of DMI and in both trimesters results in an under-prediction. If the magnitude of this adjustment factor is the problem, the results for the 2nd trimester would indicate that the adjustment should be somewhere between 0 and 16% (i.e. the cows were experiencing some degree of cold stress but not as much as modelled by NRC, 1996). Similarly with the 3rd trimester data, if the adjustment factor is not corrected for the environment and stage of pregnancy to start with, simply removing the temperature adjuster is going to make the predictions worse as is the case. Again, further research is necessary to improve the DMI predictions of mature wintering beef cows.

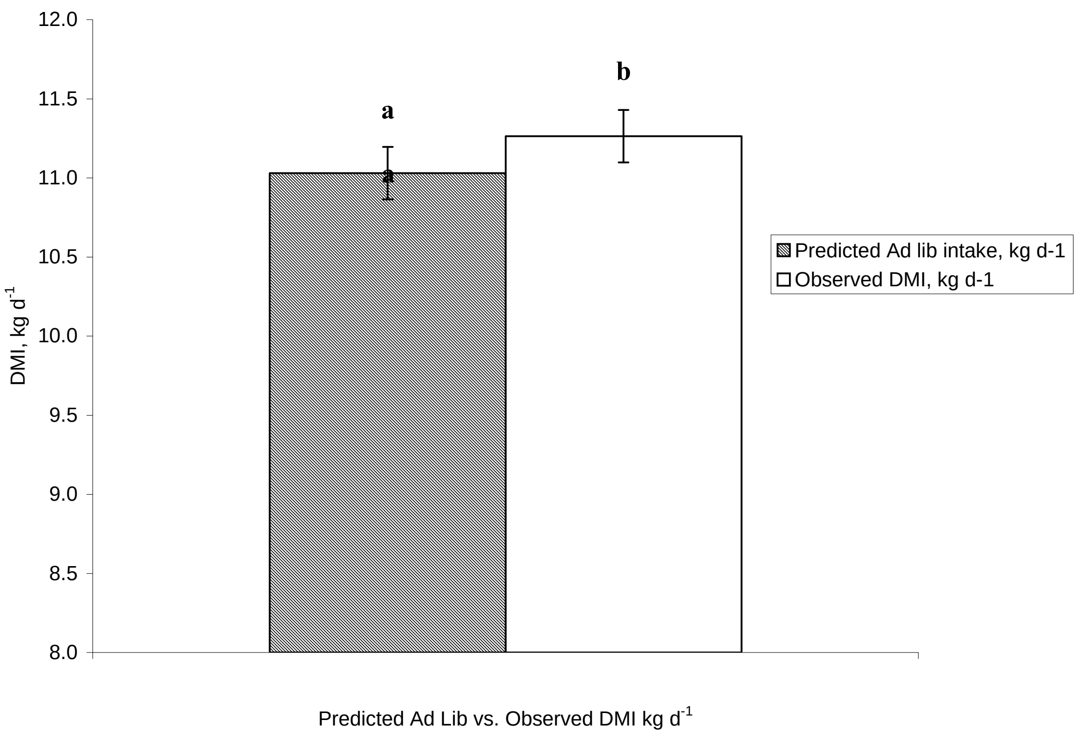

Figure 3.7: Means comparison of predicted ad libitum intake (kg d^{-1}) and actual DMI (kg d^{-1}) for the 2nd trimester using thermal neutral temperatures and the Weiss equation to determine energy values over both years. Pooled standard error was 0.1657. Error bars are standard error of the means. Means with different letters are different (P≤0.05).

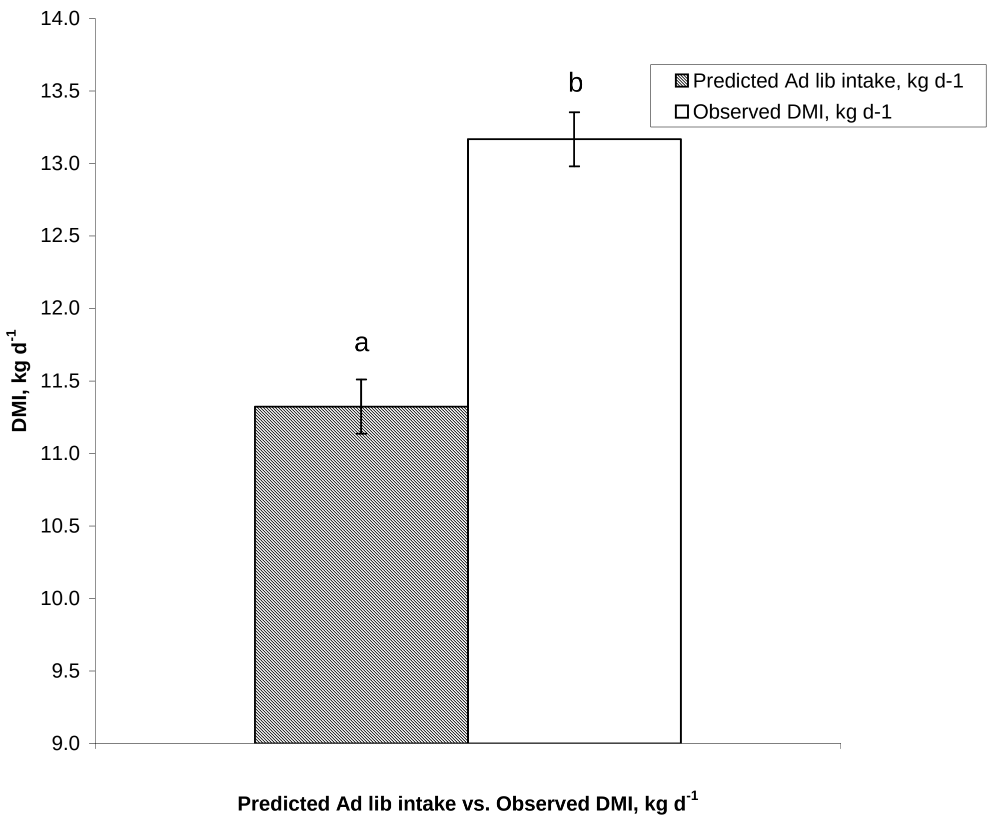

Figure 3.8: Means comparison of predicted *ad libitum* intake (kg d^{-1}) and actual DMI (kg d^{-1}) for the 3rd trimester using thermal neutral temperatures and the Weiss equation to determine energy values over both years. Pooled standard error was 0.1866. Error bars are standard error of the means. Means with different letters are different ($P \leq 0.05$).

3.3.4 Importance of Correct Energy Values Going Into the Model

Paterson et al. (2000) found a greater degree of inaccuracy in ADG prediction by the NRC (1996) beef model when lower energy diets are fed. Block et al. (2006) suggested that if the cause of inaccurate ADG prediction is related to diet energy level, the use of diet energy level in adjusting ADG prediction is the most relevant basis for corrections. The correct energy value of the feedstuffs used in the steer digestibility trial was difficult to determine due to a large standard deviation in the digestibility energy values (Section 3.3.2.1). When these digestibility trial energy values were compared to Weiss et al. (1992) energy values it was found that under actual environmental conditions the predicted ADG was lower than those predicted using the energy values calculated by the Weiss et al. (1992) equation (Table 3.11). This was found for both the second and third trimester whether they were analysed using actual environmental or thermal neutral conditions. This is because the lower energy value of the feed found through the digestibility trial resulted in less total energy consumed by the animal. The result is less energy available for gain, therefore lower ADG for the animal (Balch and Campling, 1962).

Table 3.11: NRC (1996) beef model performance predictions using energy values obtained through Weiss et al (1992) equations versus and Digestibility trials.

	2nd trimester		3rd Trimester	
Item	**Actual conditions**	**Thermal Neutral**	**Actual conditions**	**Thermal Neutral**
Actual ADG	0.10	0.10	0.08	0.08
Predicted ADG[z]				
Weiss[y]	-0.18	0.19	-0.10	0.23
Digestibility	-0.28	0.10	-0.19	0.18
Actual DMI	11.3	11.3	13.2	13.2
Predicted DMI				
Weiss	11.8	11.0	12.1	11.0
Digestibility	11.8	11.3	12.0	11.2

[Z] ADG based on observed DMI

[y] Equations by Weiss et al. (1992)

4.0 CONCLUSIONS

To predict performance of mature beef cattle NRC (1996) uses gain or loss of body condition and the amount of NE_m required or provided at each change, and assumes that each kg of SBW change contains 27.99 MJ of NE_m with 80% efficiency of use for weight loss. Alternatively the Alberta Agriculture "Cowbytes" program uses the net energy of maintenance and gain equations for prediction of gain in growing and finishing cattle (Equation 2.9 to Equation 2.11) found in the NRC (1996) beef model (E.Okine, personal communication). Using the "Cowbytes" program the ADG based on actual DMI of mature wintering beef cattle in western Canada was under estimated when predicted using actual environmental conditions. This shows an over estimation of NE_m requirements, and points to a problem with calculation of maintenance energy requirements of the cows. This is independent of how daily gain is calculated. When thermal neutral conditions (20°C with no wind) were used the "Cowbytes" program over estimated ADG based on DMI for these same cows. This suggests the cows experienced some degree of cold stress, but not as severe as modelled by the equations in NRC (1996). Further research could focus on how to more accurately model the degree of cold stress actually felt by cattle and their ability to acclimatise to extended periods of moderate cold weather. Other factors to explain the discrepancy between predicted and actual ADG include inaccuracies in approach used by "Cowbytes" in modelling pregnant beef cows the same as growing and finishing cattle and the possibility of inaccurate calculations of basal metabolic rate included in maintenance energy requirements.

Further research is required in such areas as how to more accurately model cold stress felt by mature cattle, and their ability to acclimatise to western Canadian winter conditions.

Ad libitum DM intake, as predicted by the NRC (1996) beef model, is based on shrunk body weight and energy density of the diet, with adjusters for lactation, temperature and mud depth. When using these same equations, "Cowbytes" program over predicted the 2nd trimester and under predicted the 3rd trimester DMI of mature beef cows. It is possible that the magnitude of the temperature adjuster, which was 16% in this study, was too extreme for the cows during the 2nd trimester, while this same adjuster was not adequate for the same cows in their 3rd trimester of pregnancy. There is potential for improvement in *ad libitum* DMI predictions for mature beef cows if the NRC (1996) predictions were based on factors other than energy density of the diet. This would include physiological state of the animal as well as actual fill effects on intake. This information could be important for further study as it may disagree with the 0.077 Mcal SBW kg^{-1} used in the NRC (1996) equations. More research is required to see if such an approach can improve DMI predictions.

In thermal neutral conditions *ad libitum* DMI was under predicted in both the 2nd and 3rd trimester trimesters of pregnancy, again showing the need for further research to improve DMI predictions for mature wintering beef cows.

The results of this study often show very small difference between actual and predicted DMI, in some cases only 0.5 kg day^{-1}. In these scenarios the long-term costs must be considered as 0.5 kg day^{-1} cow^{-1} is 90 kg day^{-1} when feeding 180 cows. The typical winter feeding period in western Canada is 120 days, which results in 10,800 kg of excess feed per year. This small inaccuracy of the NRC (1996) beef model can result in a large monetary loss for Canadian beef producers.

The NRC (1996) beef model is a good guideline for estimating beef cattle performance as it considers most managerial and environmental factors effecting productivity. This study shows that cold environmental conditions as common to western Canada, affects maintenance energy requirements less than the model assumes with actual environmental conditions, yet more energy is required than when the animal is in a thermal neutral situation. Therefore, further studies are needed to better define a correct adjustment for effects on cold maintenance energy requirements of wintering beef cows.

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APPENDIX A

Age and physiological status of cows at the start of test by pen in each of the two years.

Table A.1: Age and Physiological status of cows at start of test by pen in year 1

Pen	Weight[z]		Age		BCS (5 point scale)		Day of Pregnancy		Length of test (days)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	570.8	44.6	3.3	6.2	3.04	0.25	65.0	5.48	167	1.67
2	585.8	59.6	3.2	4.9	3.04	0.40	65.0	5.48	167	1.55
3	581.4	38.9	3.3	9.8	3.00	0.00	65.0	5.48	166	2.45
4	569.6	65.9	3.3	9.8	3.04	0.33	65.0	5.48	168	0.82
5	579.2	38.1	3.3	9.8	3.04	0.25	65.0	5.48	167	1.33
6	589.2	41.5	3.2	4.9	3.00	0.16	80.0	5.48	153	0.00
7	594.4	45.9	3.3	6.2	3.00	0.00	80.0	5.48	153	0.00
8	580.0	54.7	3.3	9.8	3.04	0.60	80.0	6.32	153	0.00
9	587.1	52.5	3.3	9.8	3.00	0.00	79.2	5.85	153	0.00
10	604.4	65.0	3.2	4.9	3.00	0.27	80.0	5.48	153	0.41
11	591.8	47.3	3.0	0.0	3.04	0.40	91.7	4.08	139	0.00
12	582.8	40.2	3.0	0.0	3.00	0.16	93.3	5.16	139	0.00
13	589.7	24.8	3.3	9.8	3.04	0.25	91.3	4.08	139	0.00
14	585.0	53.8	3.2	4.9	3.04	0.25	92.5	6.12	139	0.00
15	588.2	44.1	3.2	4.9	3.04	0.33	91.7	4.08	139	0.00

[z] **Mean weight with fetus**

Table A.2: Age and Physiological status of cows at start of test by pen in year 2

Pen	Weight[z]		Age (Months)		BCS (5 point scale)		Day of Pregnancy		Length of test (days)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2	594.9	47.0	52	10.0	2.83	0.38	81	12.0	177	5.93
3	594.8	44.8	53	9.8	2.83	0.45	81	4.9	179	3.83
4	592.6	57.8	54	10.0	2.58	0.27	81	8.0	177	5.73
5	595.5	72.8	56	12.4	3.00	0.61	80	14.1	176	7.63
6	603.6	39.3	54	10.0	2.67	0.66	81	12.0	172	9.74
7	597.9	37.4	50	4.9	2.75	0.52	103	5.2	160	1.03
8	593.4	65.5	52	9.8	2.83	0.82	103	5.2	161	0.00
9	594.1	48.1	52	9.8	3.00	0.52	103	5.2	160	1.60
10	587.4	46.6	52	9.8	2.67	0.41	103	5.2	160	1.03
11	591.7	26.1	52	9.8	2.92	0.26	103	5.2	160	2.51
12	593.1	88.0	50	4.9	2.67	0.80	115	5.5	150	3.71
13	593.6	71.4	50	4.9	3.08	0.41	113	5.2	148	0.00
14	591.1	40.5	50	4.9	2.75	0.52	113	5.2	148	0.00
15	596.3	51.5	52	9.8	2.75	0.61	115	5.5	148	0.00
16	595.6	50.5	50	4.9	2.83	0.58	115	5.5	148	0.00

[z] **Mean weight with fetus**

APPENDIX B

Canadian wintering cow data entered into "Cowbytes" to obtain NRC (1996) beef model predictions for performance of beef cows.

Table B.1:Wintering cow data entered into "Cowbytes" to obtain NRC (1996 beef model prediction for performance of beef cows in the 2nd trimester, 2002-2003

Item	Pens														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mean weight with fetus, kg	583	604	597	584	593	597	609	601	599	619	608	594	605	589	603
Mean weight without fetus, kg	568	594	585	571	577	586	592	585	585	603	589	579	591	575	587
Mean gestation month	5.1	5.0	4.9	4.9	5.1	5.2	4.9	5.0	5.1	5.3	5.5	5.2	5.1	5.2	5.2
ADG, kg	0.08	0.25	0.18	0.17	0.11	0.08	0.05	0.28	0.08	0.13	0.12	0.06	0.27	-0.08	0.13
DM Feed/Head/day, kg	10.1	10.5	11.2	11.0	11.4	11.1	10.3	11.4	11.1	11.1	11.5	10.8	11.3	10.7	10.4
Temperature, ^{o}C															
Current	-10.4	-10.4	-7.4	-10.4	-10.4	-7.4	-10.4	-10.4	-10.4	-10.4	-10.4	-10.4	-7.4	-7.4	-10.4
Previous	-7.4	-7.4	-6.7	-7.4	-7.4	-6.7	-7.4	-7.4	-7.4	-7.4	-7.4	-7.4	-6.7	-6.7	-7.4
BCS	3.04	3.21	3.29	3.06	3.23	3.21	3.41	3.16	3.20	3.35	3.24	2.96	3.19	3.26	3.38
Calf weight at birth, kg	46.7	43.2	46.6	43.0	46.0	43.3	45.1	47.6	43.5	43.7	47.9	44.8	45.9	42.9	45.8
Ultrasound, mm															
12/13th rib fat	5.6	7.4	6.4	4.8	4.6	6.5	5.3	4.8	5.3	6.3	5.3	5.2	3.5	4.3	5.2
Rump fat	7.8	8.9	8.5	5.1	5.8	7.6	8.0	6.2	7.0	7.6	6.2	6.9	4.9	8.2	7.3
Tailhead Fat	8.3	8.4	10.0	6.5	7.1	9.1	9.3	7.6	7.8	9.6	7.8	7.8	6.6	8.3	9.8

Table B.2: Wintering cow data entered into "Cowbytes" to obtain NRC (1996 beef model prediction for performance of beef cows in the 3nd trimester, 2002-2003

	Pen														
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mean weight with fetus, kg	623	644	641	626	630	629	639	636	627	655	631	614	638	614	630
Mean weight without fetus, kg	575	601	595	585	582	592	594	594	588	612	585	577	599	575	591
Mean gestation month	7.9	7.7	7.6	7.6	7.9	7.8	7.4	7.5	7.6	7.8	7.8	7.5	7.4	7.5	7.5
ADG, kg	0.09	0.00	0.10	0.15	0.01	0.08	0.01	-0.11	-0.02	0.11	-0.31	-0.16	0.00	0.09	-0.04
DM Feed/Head/day, kg	12.5	13.6	13.9	13.0	14.1	13.1	12.4	13.4	12.2	12.6	11.1	10.9	12.9	12.4	12.4
Temperature, ^{o}C															
Current	-6.7	-6.7	-9.1	-6.7	-6.7	-11.7	-9.7	-9.7	-9.7	-9.7	-12.3	-12.3	-14.0	-14.0	-12.3
Previous	-10.5	-10.5	-12.4	-10.5	-10.5	-15.8	-14.5	-14.5	-14.5	-14.5	-15.1	-15.1	-16.4	-16.4	-15.1
BCS	3.21	3.29	3.23	3.27	3.35	3.34	3.36	3.24	3.16	3.29	3.16	3.04	3.07	3.07	3.19
Calf weight at birth, kg	46.7	43.2	46.6	43.0	46.0	43.3	45.1	47.6	43.5	43.7	47.9	44.8	45.9	42.9	45.8
Ultrasound, mm															
12/13th rib fat	5.6	6.9	6.6	4.6	4.8	6.0	4.6	4.7	5.0	5.8	5.0	5.5	3.8	3.7	4.7
Rump fat	8.3	9.2	9.2	5.5	5.3	6.8	8.0	6.0	6.3	6.8	4.7	6.5	5.0	6.4	6.0
Tailhead Fat	8.7	8.6	10.0	6.4	7.4	8.3	8.5	8.1	6.3	8.7	6.5	7.2	6.3	7.6	7.7

Table B.3: Wintering cow data entered into "Cowbytes" to obtain NRC (1996 beef model prediction for performance of beef cows in the 2nd trimester, 2003-2004

	Pens														
Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Mean weight with fetus, kg	617	610	597	612	612	605	599	601	601	594	595	602	597	603	606
Mean weight without fetus, kg	603	596	583	598	598	591	588	588	588	581	582	588	585	589	593
Mean gestation month	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
ADG, kg	0.29	0.14	0.14	0.16	-0.02	0.02	0.02	0.03	0.24	-0.11	-0.12	0.06	0.02	0.00	0.14
DM Feed/Head/day, kg	11.5	12.5	13.0	12.1	11.9	11.4	9.9	12.2	11.6	11.9	11.0	11.5	11.6	11.7	11.3
Temperature, ^{o}C															
Current	-13.4	-13.4	-13.4	-13.4	-13.4	-10.7	-10.7	-10.7	-10.7	-10.7	-10.7	-10.7	-10.7	-10.7	-10.7
Previous	-11.1	-11.1	-11.1	-11.1	-11.1	-10.8	-10.8	-10.8	-10.8	-10.8	-10.8	-10.8	-10.8	-10.8	-10.8
BCS	2.63	2.88	2.63	2.92	2.63	2.83	2.88	3.00	2.75	3.00	2.67	3.08	2.83	2.92	2.79
Calf weight at birth, kg	46.4	42.6	46.1	45.6	42.2	47.0	40.2	45.3	45.4	40.4	44.7	44.4	42.8	47.0	44.0
Ultrasound, mm															
12/13th rib fat	4	3	2	3	6	3	4	4	4	2	4	4	4	4	3
Rump fat	5	3	2	4	6	4	5	3	3	3	5	5	4	6	3
Tailhead Fat	6	4	3	4	7	4	5	3	5	4	7	4	4	5	3

Table B.4: Wintering cow data entered into "Cowbytes" to obtain NRC (1996 beef model prediction for performance of beef cows in the 3rd trimester, 2003-2004

	Pens														
Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Mean weight with fetus, kg	655	649	646	657	645	659	633	640	643	629	628	637	635	641	645
Mean weight without fetus, kg	607	603	598	610	599	612	595	595	600	588	587	596	597	599	608
Mean gestation month	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
ADG, kg	-0.19	0.00	0.21	0.11	0.09	0.41	0.12	0.13	0.08	0.22	0.21	0.14	0.27	0.23	0.23
DM Feed/Head/day, kg	12.6	15.0	14.1	13.5	13.2	13.5	13.3	13.5	13.8	14.0	13.3	13.5	13.8	13.9	13.5
Temperature, ^{o}C															
Current	-7.7	-7.7	-7.7	-7.7	-7.7	-9.6	-9.6	-9.6	-9.6	-9.6	-7.2	-7.2	-7.2	-7.2	-7.2
Previous	-8.7	-8.7	-8.7	-8.7	-8.7	-12.2	-12.2	-12.2	-12.2	-12.2	-9.6	-9.6	-9.6	-9.6	-9.6
BCS	3.08	3.08	2.88	3.13	2.75	3.13	3.00	3.08	2.88	3.17	2.79	3.17	3.21	3.17	3.08
Calf weight at birth, kg	46.4	42.6	46.1	45.6	42.2	47.0	40.2	45.3	45.4	40.4	44.7	44.4	42.8	47.0	44.0
Ultrasound, mm															
12/13th rib fat	5	4	2	3	6	3	4	4	4	3	4	4	4	4	3
Rump fat	6	4	4	6	8	5	5	3	4	4	6	6	5	6	3
Tailhead Fat	7	6	5	6	9	5	6	4	6	4	8	6	6	7	4

APPENDIX C

Actual and predicted ADG and DMI for each pen by the NRC (1996) beef model using the Weiss et al (1992) equation to derive energy values for 2002-2003 and 2003-2004.

Table C.1: Predicted and actual DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) using actual environmental conditions in the year 2002-2003 for each pen

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.08	0.25	0.18	0.17	0.11	0.08	0.05	0.28	0.08	0.13	0.12	0.06	0.27	-0.08	0.13
Predicted (based on observed DMI)	-0.29	-0.25	-0.14	0.00	0.01	-0.09	-0.36	-0.01	-0.02	-0.22	0.00	-0.11	0.02	-0.20	-0.33
Dry Matter Intake, kg															
Actual	10.1	10.5	11.2	11.0	11.4	11.1	10.3	11.4	11.1	11.1	11.5	10.8	11.3	10.7	10.4
Predicted *Ad Libitum*	11.5	11.9	11.8	11.6	11.7	11.8	11.9	11.8	11.8	12.1	11.9	11.7	11.9	11.6	11.8

Table C.2: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) using actual environmental conditions in the year 2002-2003 for each pen

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.09	0.00	0.10	0.15	0.01	0.08	0.01	-0.11	-0.02	0.11	-0.31	-0.16	0.00	0.09	-0.04
Predicted (based on observed DMI)	-0.16	-0.08	-0.01	-0.23	0.04	-0.26	-0.12	-0.09	-0.28	-0.37	-0.86	-0.82	-0.01	-0.29	-0.31
Dry Matter Intake, kg															
Actual	12.5	13.6	13.9	13.0	14.1	13.1	12.4	13.4	12.2	12.6	11.1	12.8	12.9	12.4	12.4
Predicted *Ad libitum*	11.8	12.2	12.0	11.8	11.9	12.0	12.1	12.1	12.0	12.3	11.9	11.8	12.1	11.7	12.0

Table C.3: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) in thermal neutral conditions in the year 2002-2003 for each pen

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.08	0.25	0.18	0.17	0.11	0.08	0.05	0.28	0.08	0.13	0.12	0.06	0.27	-0.08	0.13
Predicted (based on observed DMI)	0.11	0.12	0.14	0.19	0.22	0.21	0.03	0.21	0.19	0.11	0.22	0.16	0.20	0.10	0.05
Dry Matter Intake, kg															
Actual	10.1	10.5	11.2	11.0	11.4	11.1	10.3	11.4	11.1	11.1	11.5	10.8	11.3	10.7	10.4
Predicted *Ad libitum*	10.8	11.2	11.0	10.8	10.9	11.0	11.1	11.0	11.0	11.3	11.1	10.9	11.1	10.9	11.1

Table C4: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) in thermal neutral conditions in the year 2002-2003 for each pen

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.09	0.00	0.10	0.15	0.01	0.08	0.01	-0.11	-0.02	0.11	-0.31	-0.16	0.00	0.09	-0.04
Predicted (based on observed DMI)	0.18	0.22	0.29	0.14	0.27	0.16	0.22	0.26	0.16	0.12	-0.08	-0.01	0.06	0.17	0.15
Actual	12.5	13.6	13.9	13.0	14.1	13.1	12.4	13.4	12.2	12.6	11.1	12.8	12.9	12.4	12.4
Predicted *Ad libitum*	11.0	11.4	11.3	11.1	11.1	11.2	11.3	11.3	11.2	11.5	11.1	11.0	11.3	11.0	12.0

Table C.5: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) using actual environmental conditions in the year 2003-2004 for each pen

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave. Daily Gain, kg															
Actual	0.29	0.14	0.14	0.16	-0.02	0.02	0.02	0.03	0.24	-0.11	-0.12	0.06	0.02	0.00	0.14
Predicted (based on observed DMI)	-0.32	0.03	-0.02	-0.12	-0.48	-0.25	-0.74	-0.06	-0.19	-0.10	-0.31	-0.21	-0.10	-0.18	-0.26
Dry Matter Intake, kg															
Actual	11.5	12.7	12.4	12.1	11.0	11.4	9.9	12.2	11.6	11.9	10.0	11.5	11.6	11.7	11.3
Predicted *Ad Libitum*	12.0	11.9	11.7	11.9	11.9	11.8	11.8	11.8	11.8	11.7	11.7	11.8	11.7	11.8	11.9

Table C.6: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) using actual environmental conditions in the year 2003-2004 for each pen

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave. Daily Gain, kg															
Actual	-0.19	0.00	0.21	0.11	0.09	0.41	0.12	0.13	0.08	0.22	0.21	0.14	0.27	0.23	0.23
Predicted (based on observed DMI)	-0.12	0.26	0.14	0.05	0.05	-0.05	0.01	0.01	0.06	0.14	0.03	0.04	0.09	0.07	0.02
Dry Matter Intake, kg															
Actual	12.6	15.0	14.1	13.5	13.2	13.5	13.3	13.5	13.8	14.0	13.3	13.5	13.8	13.9	13.5
Predicted *Ad libitum*	12.3	12.2	12.2	12.4	12.2	12.3	12.1	12.1	12.2	12.0	11.9	12.1	12.1	12.1	12.3

Table C.7: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) in thermal neutral conditions in the year 2003-2004 for each pen

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave. Daily Gain, kg															
Actual	0.29	0.14	0.14	0.16	-0.02	0.02	0.02	0.03	0.24	-0.11	-0.12	0.06	0.02	0.00	0.14
Predicted (based on observed DMI)	0.13	0.22	0.26	0.19	0.16	0.13	0.01	0.21	0.15	0.20	0.17	0.15	0.16	0.16	0.13
Dry Matter Intake, kg															
Actual	11.5	12.7	12.4	12.1	11.0	11.4	9.9	12.2	11.6	11.9	10.0	11.5	11.6	11.7	11.3
Predicted *Ad libitum*	11.2	11.1	11.0	11.2	11.1	11.0	11.0	11.0	10.9	10.9	11.0	11.0	11.0	11.0	11.1

Table C.8: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from Weiss et al. (1992) in thermal neutral conditions in the year 2003-2004 for each pen

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave. Daily Gain, kg															
Actual	-0.19	0.00	0.21	0.11	0.09	0.41	0.12	0.13	0.08	0.22	0.21	0.14	0.27	0.23	0.23
Predicted (based on observed DMI)	0.19	0.48	0.36	0.29	0.29	0.22	0.29	0.29	0.31	0.40	0.26	0.29	0.33	0.30	0.26
Dry Matter Intake, kg															
Actual	12.6	15.0	14.1	13.5	13.2	13.5	13.3	13.5	13.8	14.0	13.3	13.5	13.8	13.9	13.5
Predicted *Ad libitum*	11.5	11.5	11.6	11.4	11.6	11.5	11.3	11.3	11.4	11.2	11.2	11.3	11.3	11.3	11.5

APPENDIX D

Actual and predicted DMI and ADG for each pen by the NRC (1996) beef model using the digestibility trials to derive energy values for 2002-2003 and 2003-2004.

Table D.1: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from the 2002-2003 digestibility trial using actual environmental conditions for each pen.

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.08	0.25	0.18	0.17	0.11	0.08	0.05	0.28	0.08	0.13	0.12	0.06	0.27	-0.08	0.13
Predicted (based on observed DMI)	-0.48	-0.45	-0.27	-0.18	-0.11	-0.19	-0.52	-0.15	-0.20	-0.35	-0.14	-0.24	-0.16	-0.32	-0.45
Dry Matter Intake, kg															
Actual	10.1	10.5	11.2	11.0	11.4	11.1	10.3	11.4	11.1	11.1	11.5	10.8	11.3	10.7	10.4
Predicted *Ad libitum*	11.5	11.9	11.7	11.5	11.6	11.8	11.9	11.7	11.7	12.0	11.8	11.7	11.8	11.6	11.8

Table D.2: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from the 2002-2003 digestibility trial using actual environmental conditions for each pen.

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Ave. Daily Gain, kg															
Actual	0.09	0.00	0.10	0.15	0.01	0.08	0.01	-0.11	-0.02	0.11	-0.31	-0.16	0.00	0.09	-0.04
Predicted (based on observed DMI)	-0.26	-0.15	-0.10	-0.23	-0.02	-0.37	-0.22	-0.19	-0.39	-0.48	-1.01	-0.95	-0.13	-0.41	-0.42
Dry Matter Intake, kg															
Actual	12.5	13.6	13.9	13.0	14.1	13.1	12.4	13.4	12.2	12.6	11.1	12.8	12.9	12.4	12.4
Predicted *Ad libitum*	11.7	12.1	12.0	11.8	11.8	11.9	12.0	12.0	11.9	12.3	11.8	11.8	12.0	11.7	11.9

Table D.3: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from the 2002-2003 digestibility trial using thermal neutral conditions for each pen.

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.08	0.25	0.18	0.17	0.11	0.08	0.05	0.28	0.08	0.13	0.12	0.06	0.27	-0.08	0.13
Predicted (based on observed DMI)	0.05	0.12	0.03	0.13	0.16	0.13	0.00	0.15	0.13	0.05	0.16	0.11	0.14	0.05	0.01
Dry Matter Intake, kg															
Actual	10.1	10.5	11.2	11.0	11.4	11.1	10.3	11.4	11.1	11.1	11.5	10.8	11.3	10.7	10.4
Predicted *Ad libitum*	10.8	11.1	11.0	10.0	10.9	11.0	11.1	11.0	11.0	11.2	11.1	10.9	11.1	10.9	11.0

Table D.4: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from the 2002-2003 digestibility trial using thermal neutral conditions for each pen.

Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Ave. Daily Gain, kg															
Actual	0.09	0.00	0.10	0.15	0.01	0.08	0.01	-0.11	-0.02	0.11	-0.31	-0.16	0.00	0.09	-0.04
Predicted (based on observed DMI)	0.13	0.17	0.16	0.14	0.22	0.10	0.17	0.20	0.12	0.05	0.12	0.10	0.04	0.12	0.11
Dry Matter Intake, kg															
Actual	12.5	13.6	13.9	13.0	14.1	13.1	12.4	13.4	12.2	12.6	11.1	12.8	12.9	12.4	12.4
Predicted *Ad libitum*	10.9	11.3	11.2	11.1	11.0	11.2	11.2	11.2	11.1	11.5	11.1	11.0	11.2	10.9	11.2

Table D.5: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from the 2003-2004 digestibility trial using actual environmental conditions for each pen.

Item	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Ave. Daily Gain, kg															
Actual	0.29	0.14	0.14	0.16	-0.02	0.02	0.02	0.03	0.24	-0.11	-0.12	0.06	0.02	0.00	0.14
Predicted (based on observed DMI)	-0.45	-0.09	-0.10	-0.21	-0.59	-0.32	-0.83	-0.14	-0.26	-0.17	-0.44	-0.29	-0.25	-0.25	-0.34
Dry Matter Intake, kg															
Actual	11.5	12.7	12.4	12.1	11.0	11.4	9.9	12.2	11.6	11.9	10.0	11.5	11.6	11.7	11.3
Predicted *Ad libitum*	12.0	11.9	11.7	11.9	11.9	11.8	11.8	11.8	11.8	11.7	11.7	11.8	11.7	11.8	11.9

Table D.6: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from the 2003-2004 digestibility trial using actual environmental conditions for each pen.

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave. Daily Gain, kg															
Actual	-0.19	0.00	0.21	0.11	0.09	0.41	0.12	0.13	0.08	0.22	0.21	0.14	0.27	0.23	0.23
Predicted (based on observed DMI)	-0.27	0.18	0.06	-0.09	-0.05	-0.15	-0.08	-0.09	-0.02	0.07	-0.08	-0.06	0.03	-0.01	-0.08
Dry Matter Intake, kg															
Actual	12.6	15.0	14.1	13.5	13.2	13.5	13.3	13.5	13.8	14.0	13.3	13.5	13.8	13.9	13.5
Predicted *Ad libitum*	12.2	12.1	12.1	12.2	12.1	12.3	12.0	12.0	12.1	11.9	11.9	12.0	12.0	12.1	12.2

Table D.7: Values for DMI and ADG for wintering Beef Cows (2nd trimester) from NRC model (Cowbytes) using energy values derived from the 2003-2004 digestibility trial using thermal neutral conditions for each pen.

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave Daily Gain, kg															
Actual	0.29	0.14	0.14	0.16	-0.02	0.02	0.02	0.03	0.24	-0.11	-0.12	0.06	0.02	0.00	0.14
Predicted (based on observed DMI)	0.07	0.19	0.17	0.14	0.07	0.09	-0.07	0.16	0.12	0.15	0.13	0.10	0.12	0.12	0.08
Dry Matter Intake, kg															
Actual	11.5	12.7	12.4	12.1	11.0	11.4	9.9	12.2	11.6	11.9	10.0	11.5	11.6	11.7	11.3
Predicted *Ad libitum*	11.2	11.1	11.0	11.2	11.2	11.1	11.0	11.0	11.0	10.9	10.9	11.0	11.0	11.0	11.1

Table D.8: Values for DMI and ADG for wintering Beef Cows (3rd trimester) from NRC model (Cowbytes) using energy values derived from the 2003-2004 digestibility trial using thermal neutral conditions for each pen.

Item	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Ave. Daily Gain, kg															
Actual	-0.19	0.00	0.21	0.11	0.09	0.41	0.12	0.13	0.08	0.22	0.21	0.14	0.27	0.23	0.23
Predicted (based on observed DMI)	0.12	0.39	0.28	0.21	0.21	0.20	0.24	0.24	0.26	0.34	0.21	0.23	0.27	0.25	0.21
Dry Matter Intake, kg															
Actual	12.6	15.0	14.1	13.5	13.2	13.5	13.3	13.5	13.8	14.0	13.3	13.5	13.8	13.9	13.5
Predicted *Ad libitum*	11.4	11.4	11.3	11.5	11.3	11.5	11.2	11.2	11.3	11.1	11.1	11.2	11.3	11.3	11.4