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Winter Adaptiveness and its Effect on Performance of Range Beef Cows

by

L. A. MacLaren

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF Master of Science

IN

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Abstract

A study was conducted to determine if resistance to the stresses of winter had been a correlated response to selection for productivity in beef cows raised under range conditions, and to see if it was related to productivity under current range conditions.

Range cows of four major breeding groups from The University of Alberta Beef Breeding Ranch were used, ranging in age from two to sixteen years. The breeding groups varied in the length of time they had been raised under range conditions, from the traditionally used Hereford to the dairy-beef type which has only been introduced in the last few years.

Records of body height, weight throughout the year and weight change patterns were kept on 521 cows bred to calve in the spring of 1982. Hair coat insulation was estimated by a visual score, an average coat depth measurement of three locations, measurements of guard hair and undercoat length, and weight of hair for a fixed area of skin. Skin fold thickness was also measured. Midwinter condition estimates included a visual score and a backfat thickness measurement over the ribeye between the 12th and 13th rib. October to postcalving weight loss and calf crop were used to evaluate cow performance. Calving date, sex of calf and calf performance to weaning were also recorded.

Least squares analyses of variance and covariance for unequal subclass numbers were used to identify breed and age

differences in the traits measured. The breed types that had been selected longest under range conditions were smaller, had more condition, and were more heavily insulated midwinter than the breed types just recently introduced to range production.

Least squares multiple regression was used to determined the relationships of the adaptability related traits to cow and calf performance. Insulation, midwinter condition and winter weight loss were not found to be important sources of variation in cow or calf performance. Insulation also did not influence midwinter condition or winter weight loss.

Generally there were breeding group differences in adaptability related traits, indicating that adaptability to range conditions may have been important enough to cause a correlated response to selection under these conditions in the past, but under present conditions winter hardiness was not important to cow or calf performance.

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I. GENERAL INTRODUCTION

In Alberta, pregnant beef cows maintained over the relatively long cold season are usually fed minimally, with or more often without supplementation for the requirements of extreme cold and pregnancy. Consequently, winter is usually associated with weight loss, or at least condition loss, in beef cows. However, there is a great deal of variation in weight loss and subsequent performance among individuals and breed types of animals. Calving performance, milk yield, summer weight gain, rebreeding performance and weaning weight of calf also vary. The relationships between these traits and winter hardiness are not clear. In addition, presumably the response to winter stress in one year can have carry over effects in the subsequent year.

Winter adaptability of the beef cow can be defined as the ability to withstand a harsh winter under a minimal nutritional regime and to perform satisfactorily thereafter. Satisfactory performance includes calving unassisted early in spring and raising the calf to as high a weaning weight as is economically possible on pasture, while at the same time regaining any weight lost over winter and becoming pregnant early in the breeding season. Breaking it down further, it would be expected that winter adaptability would involve the size of the animal, its condition or energy reserve status, and its insulation. Economic emphasis is frequently put on adaptive traits, yet a large scale study on the relative importance of these factors to beef cow productivity has not been done thus far. The objectives of this study were to examine size, condition, weight change patterns and insulation of a large population of beef cows selected for productivity under range conditions, and to assess how, if at all, these factors relate to productivity.

II. REVIEW OF LITERATURE

A. Cow Size, Weight and Condition

1. Introduction

Cow size and condition are factors influencing cow adaptability since they will influence feed requirements and productivity. Cow bodyweight is most frequently used as the only estimate of cow size and/or condition, even though it has obvious limitations in this respect. A tall, thin cow may weigh the same as a short, overweight cow even though they are very different in size and condition. This is probably why there is so much variation in results obtained when trying to relate cow body weight to performance traits. Jeffery and Berg (1972a) found a simple correlation between post-calving weight of cow and the pre-weaning gain of the calf of +0.29 - +0.38 in central Alberta range conditions, however this was confounded with cow age and milk yield. A review by Morris and Wilton (1976) indicated a significant positive correlation of 0.25 between cow weight throughout the year and birthweight of her calf, with slightly higher correlations for cow weight and pre- or post-weaning gains of calf. Although these correlations are generally significant, they are low and other workers have found no correlation between cow weight and preweaning traits of the calf (Singh *et al.* 1970, Urick *et al.* 1971). In 1969, Godley and Tennant found a significant positive correlation between cow weight and calf weaning weight in Angus animals but not in Herefords. Conversely, the same workers (Godley *et al*. 1970) found a significant positive relationship between cow weight at breeding and weight per day of age of her calf in the Hereford but not in the Angus breed.

In contrast, condition score at breeding had a significant positive correlation with weight per day of age of both Hereford and Angus calves in their study. (Appendix I presents an example of a condition scoring procedure.) Thus perhaps the inconsistency of the relationship between cow bodyweight and calf performance is a reflection of the relationship between cow bodyweight and cow condition - as mentioned, this may be positive but is not necessarily so. Jeffery and Berg (1972b) suggested that if body weight was to be used as a criterion for comparing the efficiency of different body sizes, then the population should be uniform in condition or mathematically adjusted to a common base. Similarily, Klosterman *et al*. (1968) suggested that maintenance requirements calculated on the basis of body weight should be adjusted for condition by the use of a weight to height ratio, since they found significant high positive correlations between weight to height ratio, subjective condition score and subcutaneous backfat thickness (determined ultrasonically). Their recommendation that four kg per cm was an average weight to height ratio for a mature cow was repeated by Jeffery (1971) on the basis of his results with 173 cows of varied breeding. The use of a weight to height ratio is generally more desirable than that of a condition score, which is totally subjective and varies from observer to observer, or of backfat thickness, which is far too expensive and impractical at the farm level. A possible problem with this ratio is that it does not take length into account.

Cow size in terms of frame structure obviously will influence maintenance requirements and thus input cost. However, the heritability of frame size is high and correlated with post-weaning average daily gain (Cartwright 1979), so calves of large cows will be larger and should gain more rapidly than those of small cows to compensate for added costs. With the introduction of the larger European breeds to America in the sixties, much research was carried out in an attempt to determine the relative efficiencies of different sizes. Most indications were that when all costs are considered, the biological efficiency of different sizes was similar (Review by Morris and Wilton 1976, Smith 1979).

2. Changes in Bodyweight and Condition

Although bodyweight appears to have an inconsistent relationship with cow condition, changes in body weight have a high positive correlation with changes in condition (Klosterman *et al*. 1968, Kropp *et al*. 1973, Brown *et al*. 1980). There are few reports concerning the actual patterns of change in condition over the year in temperate regions, though the recent report by Brown and coworkers (1980) concludes what would be expected naturally - cows tend to be lowest in bodyweight and condition after calving in early spring prior to pasture improvement, and highest after weaning in the fall. In central Alberta, a similar pattern would be expected with the high fall bodyweight being more or less maintained up until calving. However the condition of the cow would be decreasing and the weight of the fetus and associated fluids would be increasing throughout this period (Degen and Young 1980). In other words, although bodyweight may not change over winter during pregnancy, condition might. Note that a weight to height ratio would not be a good indicator of condition in this case, and also that condition would not be well correlated with changes in body weight. Since this is only conjecture, more work is needed in this area and one of the objectives of this project is to clarify the effects of winter, pregnancy and condition on the productivity of beef cows.

Changes in bodyweight and condition in relation to lactation and suckling are better documented. In dairy cows, increases in body weight are negatively correlated with milk yield (Hooven *et al*. 1968, Review by Morris and Wilton 1976). Similarily, increases in body weight of beef cows during lactation may be negatively correlated with calf performance, although this tends to be a low correlation (Vaccaro and Dillard 1966, Singh *et al*. 1970, Review by

Morris and Wilton 1976). Godley and Tennant (1969) found that cow weight change during suckling did not affect calf weaning weight, but an increase in cow condition negatively affected weight of calf per day of age. Butson (1981) found that cow weight change during lactation was not important in determining calf weaning weight. The differences in these reports is probably due to variation in the genetic potential of the dams for milk production and their nutrition. For example, Brown *et al.* (1980) observed in cows on a relatively low plane of nutrition that those that gave less milk regained weight more rapidly and became fatter as the grazing season progressed, again illustrating a negative correlation between weaning weight and increasing cow condition throughout the suckling period. However, on a high plane of nutrition, Holloway *et al.* (1979) observed that cows giving similar amounts of milk still varied in weight gain and subcutaneous fat, and that there was no correlation between calf performance and weight or condition changes. In general, it would be expected that there would be a negative but low correlation between condition and weight increases of dam over lactation and calf performance to weaning if nutrients for milk yield are limiting, but otherwise not. In any case, the correlations are low, and are much less important in determining calf performance to weaning than the dam's milk yield (Butson 1981).

Calf post-weaning performance is not affected by cow weight changes or condition (Vaccaro and Dillard 1966, Jeffery and Berg 1972a). Cow weight does not appear to affect the number of calves produced per year or the number of productive years in the herd (Singh *et al.* 1970), although no reports relate cow condition to the number of productive years in the herd. Neither weight change during pregnancy nor condition affects the number of services per conception, however peripartum condition can affect calving interval in terms of time to estrus postpartum (Whitman *et al.* 1975, Lowman *et al.* 1979).

B. Effects of Winter on Beef Production Efficiency

1. Introduction

Since the temperature in central Alberta is below freezing for most of the winter, it would be expected that beef cows wintering under these conditions will be different in terms of nutritional requirements, weight and condition change patterns, metabolic efficiency and perhaps even optimum size, hair coat, color, etc. than those raised in more moderate climates. The beef cow is a homeotherm, and thus has to maintain her internal body temperature constant regardless of environmental temperature. She does this by maintaining a balance between heat exchanged with the environment through the normal processes of conduction, convection, radiation and evaporation, and heat produced in normal metabolic processes. The environmental range in which this balance is maintained without altering the metabolic rate is defined as the "thermoneutral zone". As the temperature drops, the animal will be losing more heat as the temperature gradient increases between it and the environment, and eventually it will have to increase heat production or body temperature will drop. Heat production can be classified into two categories; shivering and non-shivering thermogenesis. Shivering heat production is very energy demanding since the involuntary muscle contractions cause movement, increasing convective heat loss, and produce heat superficially - away from the body core where heat is required and close to the skin surface increasing the surface heat loss. Non-shivering heat production (NST) is defined here as a general term referring to all heat produced except that produced by shivering.

Although there has been some controversy in the past over the importance of thermoregulatory NST in larger mammals (Scholander 1950a,b, Heldmaier 1970, Donhoffer 1970), it is fairly well established that farm animals can increase heat production over and above what can be accounted for by increased feed intake (Young 1975). Non-shivering heat production involves skeletal muscle, internal organs, brown adipose tissue in animals which have it (mature cattle do not appear to) and probably also the brain (Donhoffer 1970). As mentioned, heat production is influenced by ambient temperature. The temperature at which additional heat production becomes necessary is defined as the lower critical temperature (TC) and is the lower boundary of the thermoneutral zone. The amount of heat produced below TC is influenced by many interacting factors, and an alteration in one is likely to produce compensatory changes in others. These factors include the catecholamines, thyroid hormones, cortical hormones, feed plus other unexplained factors (Seller *et al.* 1970). The catecholamines have been implicated as being very important regulators of NST in small mammals (Sellers *et al.* 1970), and have recently been shown to be associated with the heat increment of feeding in cattle and sheep (Christopherson *et al.* 1982).

Heat production over that produced at the resting metabolic rate requires an additional input of energy, either directly as an increased feed requirement or indirectly as weight loss to the animal. Thus, it is expected that the lower the TC is, the lower the additional energy cost over winter. TC depends upon the specific housing conditions of the animal, breed type, nutrition, the length of time since feeding, behaviour and the thermal adaptation status (Young 1979). Thermal adaptation status refers to the degree of acclimation or acclimatization of the animal. Acclimation is usually associated with animals kept under lab conditions where only one factor has been altered, in this discussion, it would be temperature. The term refers to the physical, behavioural and metabolic changes resulting from continued exposure to that temperature. Acclimatization refers to those changes that occur in the animal under more natural conditions; in this case, temperature fluctuates, amount and type of precipitation changes, photoperiod varies, etc. as winter approaches. The state of acclimation or acclimatization to a cold climate has been described by Slee (1971) as involving an increased BMR, an increased metabolic capability to respond to cold, a greater reliance on NST, elevated skin temperature, increased resistance to cooling and increased survival at low temperatures. In other words, the animal has a lower TC and a better ability to respond to extremely cold weather than a non-acclimated or non-acclimatized animal. The cost associated with this process is the increased BMR, which means an increased energy requirement. Fortunately, it appears that animals acclimatized under Alberta conditions tend to minimize the energy cost of cold exposure when compared to animals acclimated to similar cold temperatures in the lab. In experiments with sheep (Webster 1970), acclimatized animals consumed 12% less feed, had a less rapid increase in BMR, a smaller metabolic response to severe cold but equally good resistance to body cooling as acclimated animals. Generally, for wintering beef cows in Canada, it can be expected that feed requirements will increase somewhere between 30 and 70% (Young 1979). This is a large range, and work is needed to determine how animals can be raised in the lower end of this spectrum.

2. **Cow Winter Weight Loss**

Little data is available in the area of the effects of cow weight loss during pregnancy on calf performance and the evidence that exists is conflicting. Vaccaro and Dillard (1966) reported that there was some influence of cow weight change during the last 90 days prepartum on preweaning performance but that this influence disappears by weaning. Morris and Wilton (1976) cite Brinks *et al.* as reporting a low positive correlation between cow pre-calving gain and calf pre-weaning gain and weaning weight. However Russel *et al.* (1979) found that the pre-calving gain of the cows was related only to birthweight and that subsequent calf performance was not affected. Results with range cattle in central Alberta (Butson *et al.* 1980, Butson 1981) indicate a positive correlation of approximately 0.4 between cow winter weight loss and calf birthweight, and between weight loss and weaning weight of approximately 0.2. The correlation with pre-weaning gain is lower still. Also in Alberta, Hironaka and Peters (1969) found that cows on a low plane of nutrition over winter lost more weight and their calves had lower preweaning gains than those on a medium or high plane of nutrition, although birthweight was not affected. It is probable that nutrition is an important variable among these reports.

It is fairly consistent in the literature that the cow's pre-calving gain or loss will affect her subsequent regaining performance during suckling. Butson *et al.* (1980)

reported a positive correlation in the order of 0.6 between winter weight loss and cow gain from calving to weaning. Russel *et al.* (1979) found similar results in that cows that gained the least weight prepartum gained the most postpartum. It appears that cows will approach the same condition when nutrition permits. In practical terms, this means that cows pregnant during the relatively harsh Alberta winters on restricted feed, can lose weight, maintain calf performance once spring arrives, and regain this lost weight over the summer when nutrition is better. However, presumably there is a limit to this relationship, and it is necessary to find it in order to determine how much weight cows should be allowed to lose to minimize input costs without jeopardizing productivity.

3. Cow Size in a Cold Environment

The 57th Annual Feeders Day Report of the University of Alberta (Bolduc *et al.* 1978) reported that larger cows were more efficient since they produced larger calves in an experiment where cows of all sizes required the same amount of feed per day. In other words, larger cows produced more kilograms of calf weaning weight per kilogram of feed consumed than small cows. There are two possible reasons for this, if it is assumed that the animals were spending a relatively high proportion of the time below their lower critical temperature. Below TC, animals must consume extra energy to increase heat production to maintain body temperature, and the amount of extra energy required depends on how far below the critical temperature the animals are. Larger animals would spend less time below their critical temperature (it will be lower because their surface area to bodyweight ratio will be lower - surface area is generally proportional to weight to the two-thirds power). In addition, the larger cow would be directing more energy towards the deposition of fetal tissue since she will have a larger calf at birth. The efficiency of fetal deposition is only about 10%, thus appoximately 90% of the metabolizable energy directed towards fetal deposition will be released as heat (Moe and Tyrell 1972). Thus the larger animal has a relatively larger heat load due to pregnancy than the small one, which can be used to maintain her body temperature during cold stress. The small cow has to consume energy to do this, presumably bringing their absolute daily metabolizable energy requirements closer together.

4. Cow Condition in a Cold Environment

It would be expected that in a thermoneutral environment, it would be most efficient to have cows in average to thin condition, thus reducing maintenance energy requirements of the cow, as long as performance is not adversely affected. However during prolonged cold exposure, maintenance requirements of animals will increase to compensate for the elevated basal metabolic rate associated with cold acclimatization. The increase in metabolic rate is related to the degree of cold stress, which in turn depends upon the animals lower critical temperature, determined by a number of factors including size of the animal and thermal insulation. Animals in fat condition will be larger than animals in thin condition of the same skeletal size and thus relatively less cold stessed.

Dietz (1971) found that although chronic cold stress resulted in greater increases in the energy requirements of thin than fat cows, the absolute requirements of thin cows of comparable skeletal size to fat cows were less, presumably due to the cost of maintaining the larger tissue mass of the fat cows. Fat cows fed to the requirements of thin cows were not as severely stressed (that is, their energy requirements did not increase as much) as thin cows at the same level of intake. They appeared to utilize their fat stores over the winter to meet their energy requirements.

Thus, to be most efficient, it would be expected that cows should be in good (average to slightly fat) condition in fall, then fed during winter to the requirements of thin cows of the same skeletal size, minimizing both feed requirements and cold stress.

C. Reducing Heat Loss during Cold Stress

1. Introduction

As previously discussed the animal has two primary means of protecting itself from the cold. The first is to increase heat production, which is undesirable economically because it means higher input costs in terms of energy consumed, for the same output of product. The second is to increase insulation of the animal, which would increase energy efficiency. The relative importance of these alternatives is not known with regards to the beef cow, however, under the minimal nutritional conditions usually afforded beef cows, the latter would be expected to be the most important. In addition, it would be expected that insulation would play a more important role in cows that are considered 'most efficient' in the herd, since presumably these animals are using as high a proportion as possible of their energy intake for production. One of the primary objectives of this series of experiments is to see whether this is indeed true, that is, whether insulation has been a key factor contributing to the higher productivity of some animals and breed types of animals over others. In addition, it must be remembered that the animal can alter its insulation by various behavioural reflexes, such as piloerection of the hair coat or simply huddling at a particular angle to the wind.

Insulation of an animal is usually divided into tissue insulation and external insulation, each of which will be discussed in the following sections.

2. Tissue Insulation

Tissue insulation is defined as the gradient of temperature from the rectum to the skin surface divided by the total heat produced per unit area per unit time (Blaxter and Wainman 1964). This insulation can be varied within an animal by vasomotor control of skin and tissue temperature directly under the skin (Scholander *et al*. 1950a, Blaxter and Wainman 1961). Vasoconstriction of capillaries under the skin has the effect of increasing tissue insulation; in steers this can amount to three to four mm of skin such that tissue insulation accounts for about 25% of the total insulation (Blaxter and Wainman 1961). It would be expected that skin thickness would be an indicator of tissue insulation. However, the importance of skin thickness in temperature regulation has not been clearly established for wintering beef cattle. Skin is generally a poorer insulator than fur (Scholander 1950a, Blaxter and Wainman 1961) and contributes relatively little to insulation in arctic mammals in comparison to fur (Scholander 1950a). However the conclusions of Blaxter and Wainman (1961) that a four mm depth of vasoconstricted skin may contribute up to 25% of the total insulation in steers make one suspect that it may be important in cattle. Skin samples and skin-fold thickness measurements taken from Hereford, Angus and Shorthorn steers in a temperate environment indicate seasonal variation and breed differences (Tulloh 1961). Dowling (1955b) and Nay and Hayman (1963) found that skin and skin-fold thicknesses of Bos taurus, Bos indicus and crossbreds between these types also showed seasonal variation and breed differences. Dowling (1955b), Tulloh (1961) and Hayman and Nay (1963) also reported that skin thickness varies with the condition of the animals. Fatter cows tended to have a thicker papillary layer and thus a thicker total skin thickness and skin-fold thickness (Dowling 1955a). He proposed that this was due to increased deposition in the adipose tissue layers and the corium of the skin. For our considerations of tissue insulation, this is important since the plexus of blood closest to the skin surface is in the corium, and this is the plexus that would be constricted during vasoconstriction. Thus if there is more fat in this layer, there will be a lower proportion of blood vessels, and the layer will be a better insulator. Webster *et al.* (1970) found that tissue insulation does increase with fatness in agreement with this theory.

As for subcutaneous fat, although instinctively it would seem to be important to tissue insulation, there has been very little work to substantiate this. Scholander *et al* (1950a) reported that subcutaneous fat was a heavy and poor insulator compared to fur and does not seem to play a role in the insulation of terrestrial arctic mammmals. It would be expected that subcutaneous fat could contribute to tissue insulation when the blood vessels to the skin are constricted, however the primary contribution would be to increase the entire mass of the animal so that less heat must be produced per unit surface area, as discussed previously.

3. External Insulation

External insulation is defined as the gradient of temperature from the skin surface to the air divided by the sensible heat production (Blaxter and Wainman 1964). It is a measure of the sum of the insulation of the coat, the convective insulation of the interface of air at the coat surface, and the radiative insulation at the coat surface, and is markedly affected by coat thickness (Blaxter and Wainman 1964). Coat depth can also be related to external insulation (Webster 1970). Coat thickness or depth can be altered by the animal by piloerection or by climatic factors such as wind, rain and snow. The insulative value of the coat is also determined by the weight of hair per unit area - this in turn is the sum of the number of hairs per unit area, the degree of medullation and diameter of the hairs, and hair length. Besides affecting external insulation, the coat cover can affect tissue insulation. Blaxter and Wainman (1964) found that in steers exposed to cold, shearing to 2 mm of hair coat decreased tissue insulation. In summary, the coat cover of cattle can be regarded as quite important to total insulation. For this reason, it will be discussed in considerable detail.

Cattle have two distinct hair coats in one year in seasonal climates; a summer coat, which is presumably adapted for heat dissipation, and a winter coat, designed to insulate against the cold (Bonsma 1949, Yeates 1955, Dowling 1959, Dowling and Nay 1960, Berman and Volcani 1961, Hayman and Nay 1961). The winter coat is thicker, with a higher weight of hair per unit area (Yeates 1955, Dowling 1959, Dowling and Nay 1960, Berman and Volcani 1961 and Hayman and Nay 1961). The increase in thickness and weight is thought to be due to increased length of the hairs (Yeates 1955, Dowling and Nay 1960, Berman and Volcani 1961, Hayman and Nay 1961) and not due to an increase in the number of hairs, which is determined by the number of follicles at birth and the size of the animal (Dowling 1955a, Dowling and Nay 1960, Turner, Nay and French 1962). In cattle with shorter coats, an undercoat develops in winter of short, thin, curled or semi-curled hairs (Bonsma 1949, Hayman and Nay 1961), which does not necessarily appear in animals with long coats (Hayman and Nay 1961). Although it was thought the winter coat was composed of thinner hairs than the summer coat (Bonsma 1949, Dowling 1959, Dowling and Nay 1960), it has been found in other studies than hair diameter does not necessarily change with season (Berman and Volcani 1961, Hayman and Nay 1961). Summer coats of all breeds tend to be flat, short, glossy and of uniform length (Bonsma 1949, Yeates 1955, Dowling 1959, Dowling and Nay 1960, Berman and Volcani 1961, Hayman and Nay 1961). Summer coats tend to have a higher percentage of medullated hairs to facilitate heat dissipation (Bonsma 1949, Dowling 1959).

The winter coat is not an elongation of the summer coat, since there are two distinct periods of shedding each year, one in autumn and one in spring. During shedding, most if not all hairs are replaced (Dowling 1959, Dowling and Nay 1960, Berman and Volcani 1961, Hayman and Nay 1961). Thus most follicles grow at least two hairs per year. Some hairs are continually being shed, but the proportion is low (Berman and Volcani 1961, Hayman and Nay 1961). Although Yeates (1955) found that photoperiod (and not temperature) was responsible for initiation of shedding and growth of the new hair coat, Berman and Volcani (1961) found that hair quantity per unit area and coat thickness were influenced by temperature - cooler temperatures resulted in thicker, heavier coats. They concluded on the basis of their own results and those of Yeates (1955) that the thyroid gland may be the common link to both thermally and photoperiodically induced change in the coat of cattle, since thyroid secretion could be affected by temperature as well as light. They suggest that day length changes cause the cyclic nature of the coat, whereas air temperature changes can modify the cycle.

Although it is generally accepted that there are two periods of shedding per year, the exact pattern of shedding is not known. Dowling (1959) suggested that the rate of shedding in the spring is rapid compared to fall - this results in the summer coat being quite uniform in length, but the winter coat being quite variable in length. This may be an important factor in stabilizing an insulating layer of air in the winter coat. However the results of Berman and Volcani (1961) do not support the idea of rapid spring shedding. They suggest that shedding is a very gradual process, with the trend depending on whether daylight is increasing or decreasing. Similarly, Hayman and Nay (1961) report that it takes approximately four months to complete the spring shedding, since there is such a dramatic change in the coat compared to fall in terms of how much hair must be shed.

In addition to season to season variation, characteristics of the hair coat of cattle vary over the body. Pan (1964) compared several characteristics of the hair coats of mature Sahiwal Zebu and Jersey cows at more than 20 locations over the body. He suggested from his results that the commonly used midside samples were seldom representative of the whole animal, and in addition the position that may be most indicative for a given hair characteristic in one breed may not be the same for that same characteristic in another breed. For example, hair length increased posteriorly in both breeds, but posteriorly and ventrally in the Jersey as opposed to posteriorly and dorsally for the Zebu. Hair diameter tended to increase posteriorly and ventrally in both breeds, also being greatest over the hind quarters. Other characteristics, such as hair length to diameter ratio, varied considerably over the body but showed no particular pattern. As a general rule, he suggested that sampling should be repeated along a line extending from just over the brisket to just in front of the hooks.

III. EXPERIMENTAL

A. Animals and their Management

The management, selection and breeding programs at Kinsella have been described elsewhere in more detail by Berg (1978,1980). Briefly, the breeding herd at The University of Alberta Ranch, Kinsella, was maintained as close as possible to conditions that would exist in a commercial cow-calf herd in Alberta. All cows were bred in July and August to calve in April and May, and heifers were bred for the first time to calve as two-year-olds. The animals ranged on the native shortgrass year-round, with some supplementary feed provided during winter. Levels of supplementary feed varied with the severity of the winter and the age of the cows. Cows four years of age and older were allowed to lose weight over winter, but the animals were visually assessed and feed adjusted accordingly to make sure they would not become so thin health would be affected. In the exceptionally severe winter of 1981-1982, cows were started on grain in early December, gradually increasing up to 4.5 kg of barley per head per day by the end of the month. If the weather was particularly cold for a few days, the grain ration was increased to 5.5 kg per head per day during that period. Limited amounts of green feed and straw were also given, alternating every other day such that the cows received approximately 5 kg total supplemented roughage per head per day.

Heifers pregnant for the first and second time were kept separate from the main cow herd and were fed to gain a moderate amount of weight, 10 to 20 kg. In 1981-1982, they received an average of 3 kg of an 85% barley, 15% canola ration plus 2 to 3 kg of roughage per head per day over winter, starting in early December. Like the older cows, the grain ration was increased if the weather was exceptionally severe, at the discretion of the herdsperson.

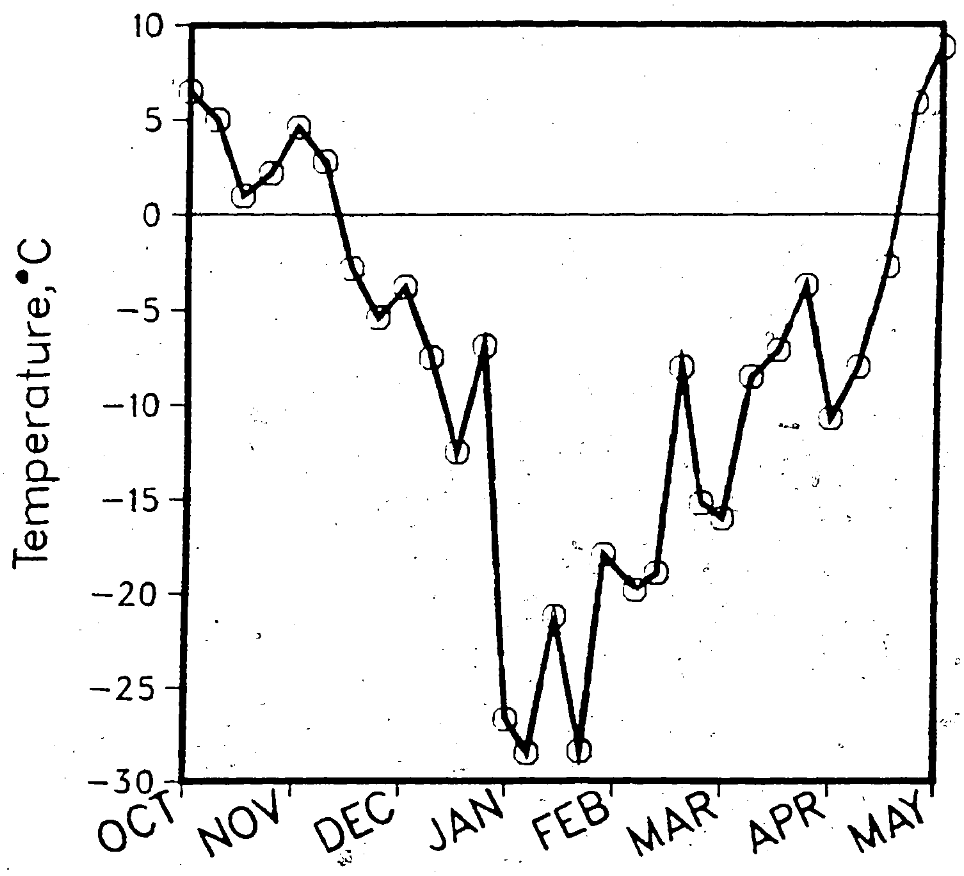
Mature cows calved on range although assistance was usually available if necessary. The first- and second-calf cows were confined at calving so they could be supervised more closely. All supplementary feeding ceased as soon as spring grass became available and the cows and calves could be turned out of the calving pastures.

There was no creep feed available for the calves, and they were weaned at approximately five months. Heifer calves were maintained on a 50:50 ratio of concentrate to roughage from weaning to breeding at approximately 14 to 15 months of age.

B. Climatic conditions

Daily minimum and maximum temperatures were recorded over the fall and winter of 1981-82. Daily mean temperatures were calculated as the mean of the maximum and minimum for the day. Figure III.1 shows the weekly means for temperature.

Figure III.1. Mean Weekly Temperatures for the Winter 1981–1982, Kinsella.



The number of days with a mean daily temperature below -15°C was 7 for December, 28 for January, 19 for February and 5 for March. Since -15°C is an approximate TC for cattle (Webster et al. 1970), this indicates the approximate number of days that the cows would be spending a high proportion of their time exposed to cold stess.

C. Selection Criteria

The female population at Kinsella was selected for reproductive and maternal performance under range conditions. Cows must have weaned a calf each fall after their second birthday to remain in the herd. As well they were culled for poor udders, bad feet and legs and inadequate mothering ability. Severe calving problems, including the need for caesarian section, were also cause for culling. Little or no selection was made for feedlot traits through the female side, however all males were put on feedlot test. The better indexing bulls were used for breeding, so that there was some tendency for rate of gain to increase in the females as well as the males, however, the yearly increases in female 540 day weight were modest compared to the yearly increases in male yearling weights (Berg 1978).

D. Breeding Groups

521 cows of four major breeding groups were included in the study; 62 Hereford (HE), 116 Hereford Crossbred (HX), 228 Beef Synthetic(SY), and 115 Dairy Cross (DA). The HE group was a purebred population, open to artificial insemination from superior industry bulls and originally established as a control line for the other breeding groups. The HX herd included non-purebred animals with more than 50 per cent Hereford breeding. The SY population was initiated in 1960 and stabilized at about 35 per cent Angus, 35 per cent Charolais, 20 per cent Galloway breeding, with the remaining 10 per cent made up of other beef breeds. The DA group was 50 to 70 per cent Holstein, Brown Swiss or Simmental, or some combination of these breeds, with the remaining 30 to 50 per cent made up from beef breeds.

. Measurements

A summary of the variables considered in this study (and their abbreviations) is presented in Table III.1.

1. Cow Size

Cow bodyweights were taken in October (FW), January, February and March. As soon as practical after calving (generally within one to three days), the cows were weighed to obtain a postcalving weight. They were weighed again in June and October so a full year's weights were available.

Table III.1. Summary variables measured and data recorded

Classification	Abbreviation	Variable name, units
Cow Size	FW	October 1981 weight, kg
		January 1982 weight, kg
		February 1982 weight, kg
		March 1982 weight, kg
		Postcalving weight, kg
		June 1982 weight, kg
		October 1982 weight, kg
	H	Hip height, cm
Midwinter Condition	CS	Condition score, 0-100
	BF	Backfat thickness, mm
Insulation	CT	Coat score, 0-100
	DP	Average coat depth, mm
	GL	Guard hair length, mm
	UL	Undercoat length, mm
	DN	Coat density, g/sq.cm
	ST	Skin thickness, mm
Performance	WL	Winter weight loss, kg
	BW	Calf birthweight, kg
	DG	Preweaning daily gain, kg
	WW	Calf 180-day weight, kg
	BE	Calves born/cow exposed, %
	WE	Calves weaned/cow exposed, %
	WP	Calves weaned/cow pregnant, %

Height was measured in mid-February by pulling a tape suspended from the ceiling over the chute down to the backbone of the animal between the hook bones. Care was taken to ensure that the animal was standing in a relaxed position, and not arched up or down.

2. Body Condition

Estimates of the condition of the cows were made in mid-February. Subjective scores by two separate groups of two observers were made, so that each animal had two condition scores ranging from one to five (See appendix I for details of the scale). In addition, subcutaneous backfat thickness (BF) was measured between the 12th and 13th rib over the ribeye with an ultrasonic backfat probe (Krautkramer Model USM2, Made in Germany. Supplied by Agriculture Canada).

3. Hair Coat Insulation

Several estimates of the insulative value of the hair coat were made to ensure that a representative picture could be obtained of this variable characteristic. Firstly, a subjective coat score (CT) was made, ranging from one to seven, with 21 possible categories (see Appendix II for details of the coat scoring procedure). Only one observer was involved, to maintain consistency.

The depth of the coat was measured in three locations along an imaginary line extending from just above the brisket to just in front of the hooks, as suggested by Pan (1964). A metal depth gauge (Moore and Wright, England) was inserted between the hairs to the skin, and the crossbar of the instrument pushed down to the level that most of the hairs were lying. The instrument could then be removed and the depth accurately read. The three measurements were averaged to obtain a mean coat depth value (DP).

A hair sample was also taken from each animal. The position selected for sampling was the left hindquarter, just below the traditional branding site. Although this may not be a representative sample of the hair coat of the entire animal, it is consistently one of the heaviest covered areas (Pan 1964), and thus should indicate relative differences in hair coat between different animals. To obtain the sample of hair for a fixed area of skin, the center teeth of the blade of a pair of small animal clippers (Oster Model A2 Small, Blade size 40, USA) were removed, leaving a gap of 15 mm. When these clippers were run along the sampling area in the direction of the hairs, a strip of hair 15 mm wide was left with shaven skin on either side of it (see appendix 3). This strip was brushed to remove hairs remaining from the clipping procedure (as little shedding was apparent, this should not have affected insulation as determined by weight of hair per unit area). A second clipper (Oster Model A2-22, Blade Size 40, USA),that had no teeth removed, was then used to cross-sect the 15 mm tract at right angles, thus removing a sample of hair covering 15 mm by the width of the second blade, 40 mm.

The hair samples were air dried for one week at room temperature and weighed to the nearest mg. This weight was divided by the area of skin the sample was taken from to give an estimate of coat density (DN). Previous work by Peters and Slen (1964) had indicated that it was not necessary to clean the samples before weighing.

The lengths of the guard hairs (GL) and the undercoat hairs (UL) in the samples were measured at the time of sampling.

4. Depth of Skin

Skin-fold thickness was used to estimate skin thickness (ST). A sample of skin was pinched between the fingers and thumb and pulled away from the animal to allow an engineering caliper (Model 965, Moore and Wright, England) to measure the thickness of the fold at a constant pressure. The sample was taken at a position located between the 12th and 13th rib, approximately half-way down the animal's side. The animals were not clipped or shaven first. The sampling area was determined to be a representative area by a preliminary trial of several locations over the body, as long as care was taken to avoid the inclusion of the superficial muscles under the skin. The skin-fold thickness measurement was divided by two to obtain an estimate of skin depth.

5. Animal Performance

Records of cow performance included midwinter condition, cow weight loss from October to postcalving, and calf birthweight, daily gain to weaning and 180-day weaning weight. Health records of both the dam and calf were kept. In addition, calf crop percentages, on a per cow exposed to breeding and per cow pregnant as determined by an early winter pregnancy test, were calculated for each breed-age subclass.

F. Statistical Analysis

1. Categorical Traits

The subjective condition and coat scores for each animal were assigned a numerical score ranging from 0 to 100 by the method outlined by Tong and coworkers (1977) for categorical data. The residual deviations of the transformed scores were approximately normal, unlike the original scores which were kurtotic. Animal rankings would not changed by this procedure (Tong et al. 1977). The scores derived were 0,23,43,60,81 and 100 for the average of the two condition scores given to each animal and 0,9,13,18,25,32,38,43,50,55,63,75,87 and 100 for the coat score.

2. Repeatability

Repeatability values were calculated for subjective coat score, average coat depth and skin-fold thickness by least squares multiple regression analysis, on the basis of repeated measurements on 90 two-year-old cows. Date of measurement was included in the model. Analysis of variance was also used to determine if breed of cow and date of measurement were significant sources of variation.

3. Least Squares Analyses

Model 1. Least squares analyses of variance for unequal subclass numbers (Harvey 1975) were computed with the effects of breed of dam, age of dam and breed x age of dam interaction as sources of variation for the height, condition, depth of skin and haircoat measurements. Levels for the main effects were:

1. Breed of Dam (B), classified as HE, HX, SY and DA;
2. Age of Dam (A), classified as 2, 3, 4, 5, 6 and 7 years or older.

Least squares means were then calculated for the dependent variables in the following model:

$$Y_{ijk} = u + B_i + A_j + BA_{ij} + e_{ijk}$$

where

Y_{ijk} = height, condition or insulation measurement of the ith breed and jth age of dam,

u = overall population mean,

B_i = effect of the ith breed of dam,

A_j = effect of the jth age of dam,

BA_{ij} = effect of the interaction of the ith breed and jth age of dam,

e_{ijk} = random error.

Model 2. In the second part of the analysis, bodyweights, October to postcalving weight loss, calf birthweight, average daily gain to weaning and 180-day weaning weight were analyzed as dependent variables by Harvey's least squares analysis of covariance for unequal subclass numbers. Least squares means were computed adjusting for the effects of breed of dam, age of dam, breed x age of dam interaction, and sex of calf as main sources of variation, and calving date as a covariate. Levels for the main effects of B, A and BA were as in the previous model, and

3. Sex of calf (S), classified as male and female;

4. Calving date (D), the covariate was recorded as the sequential day of the year.

The model used was

$$Y_{ijkl} = u + B_i + A_j + BA_{ij} + S_k + b_l X_{ijkl} + e_{ijkl}$$

where

Y_{ijkl} = bodyweight or performance dependent variable of the ith breed and jth age of dam with the kth sex of calf,

u = overall population mean for X = 0,

B_i = effect of the ith breed of dam,

A_j = effect of the jth age of dam,

BA_{ij} = effect of the interaction of the ith breed and jth age of dam,

S_k = effect of the kth sex of calf,

$b_l X_{ijkl}$ = partial regression of the lth bodyweight or performance variable on the date of calving,

e_{ijkl} = random error.

Student-Newman-Keuls multiple comparisons were used to test differences between individual least squares means when significant differences were established by the least squares analyses.

4. Calving Data

R x C tests of independence using a G-test (Sokal and Rohlf 1981) were used to test differences between calf crop means.

In addition, cows were grouped according to whether they weaned a calf, carried a calf to term but did not wean it, or did not complete gestation even though they had a positive pregnancy test mid-January. Insulation (CT, DP, GL, UL, DN, ST) and condition (CS, BF) least squares means were computed for each group, adjusted for the effects of breed and age of cow. Differences between means were tested by Student-Newman-Keuls multiple comparisons.

5. Regression Analyses

Multiple regression analysis was used to determine the relationships of insulation, midwinter condition, and winter weight loss to the various measures of cow performance. All the following models were run in the "Test" subcommand of the regression command in SPSSX (SPSS, 1983). This method builds the full model outlined and then removes designated subsets from the full model. Tests of significance were based on the change in R-squared due to subset removal. In the following models, the regression output was examined for the effects of removing subset 5:

Models 1A and 1B. These models were used to determine the importance of the insulation traits (CT, DP, GL, UL, DN, ST) to the cow and calf performance traits. Preliminary regression analysis indicated that there was no difference whether the insulation variables were entered stepwise or simultaneously. Standardizing and combining the variables to create a composite insulation variable also did not affect results. It was decided to enter all insulation variables simultaneously as a subset to indicate the maximum amount of variation they could explain.

The dependent variables in Model 1A were cow midwinter condition (BF, CS) and winter weight loss (WL). The model included the following subsets:

1. Breed of dam (B)
2. Age of dam (A)

3. Height of dam (H)
4. Fall weight of dam (FW)
5. Insulation variables (CT,DP,GL,UL,DN,ST)

Model 1B was used for the dependent calf performance variables (BW, DG, WW), and was composed of the following subsets:

1. Breed of dam (B)
2. Age of dam (A)
3. Sex of calf (S)
4. Date of calving (D)
5. Insulation variables (CT, DP, GL, UL, DN, ST).

Model 2. The independent variables being tested for their importance to performance in this series of regressions were the midwinter condition variables, BF and CS. The dependent or performance variables were weight loss (WL), calf BW, DG, and WW. The full model included the following subsets:

1. Breed of dam (B)
2. Age of dam (A)
3. Sex of Calf (S)
4. Calving date (D)
5. Backfat (BF), Condition Score (CS)

Since there were only 261 records containing backfat data, the regressions were rerun using all animals and omitting backfat from subset 5. Results were similar thus were not included.

Model 3. This model was used to determine the relationships between winter weight loss (WL) and calf performance (BW, DG, WW). The full model was composed of the following subsets:

1. Breed of dam (B)
2. Age of dam (A)
3. Sex of calf (S)
4. Calving date ( )
5. Winter weight loss (WL)

Table IV.1. Repeatability of Coat Score, Coat Depth, and Skinfold Thickness, With Literature Comparisons

Trait	Repeatability	Workers
Coat Score	0.53	Present Study
	0.62	Schleger & Turner (1960)
Coat Depth	0.57	Present Study
Skin Thickness	0.60	Present Study
	0.94	Tulloh (1961)
	0.80	Dowling (1955b)

Table IV.2. Analysis of Variance of Repeated Estimates of Coat Score, Coat Depth and Skin Thickness, by Breed of Cow and Date of Measurement. Kinsella, 1982.

Source of Variation	Degrees of Freedom	Coat Score			Coat Depth			Skinfold Thickness		
		Mean Square	F	Significance of F	Mean Square	F	Significance of F	Mean Square	F	Significance of F
Breed	3	13.4	4.6	0.004	14.4	1.4	0.247	3.1	11.6	0.000
Date	1	2.6	0.9	0.357	63.4	6.1	0.014	2.5	9.3	0.003
B x D	3	2.3	0.8	0.495	10.9	1.1	0.368	0.1	0.3	0.846
Error	162	2.9	-	-	10.3	-	-	1.7	-	-
Total	169									

IV. RESULTS AND DISCUSSION

A. Insulation Estimates

1. Repeatability

Repeatabilities for coat score (CT), average coat depth (DP) and skin thickness (ST) are presented in Table IV.1, along with literature values. The repeatability of coat score was 0.53, highly significant (P>0.001). Schleger and Turner (1960) obtained an only slightly higher value, 0.62, on the basis of repeated observations on 500 Hereford and Shorthorn cows. The analysis of variance of coat score in this study (Table IV.2) indicated that there was no significant difference in mean coat score between the first set of measurements and the second (effect of date), also in accordance with Turner and Schleger (1960). As expected from their work, breed had a significant effect (P>0.001) on coat score in this study.

Repeatability of coat depth was found to be 0.57, highly significant (P>0.001). Analysis of variance of coat depth (Table IV.2) indicated that date was a significant source of variation (P>0.05), since the overall mean for coat depth was higher in the first sampling than the second. The average daily temperatures when the first measurements were taken were -14.5°C and -21°C, compared to 1°C when the second measurements were taken. Since an approximate critical temperature for beef cows is -15°C (Webster *et al.* 1970), piloerection of the hair coat as a response to cold could have affected coat depth measurements.

The repeatability of skin thickness was 0.60, again highly significant (P>0.001). Dowling (1955b) and Tulloh (1961) obtained higher repeatability estimates for this trait, 0.80 and 0.94 respectively. However in Dowling's study both measurements were made on the same day, so there was no significant effect of date (temperature) as there was in this study (Table IV.2). Colder temperatures when the first set of measurements were taken could have caused vasoconstriction of the blood vessels near the skin and thus lower skin thickness measurements. Tulloh (1961) used measurements repeated on five animals only, and did not say how much time there was between measurements, although cold stress was not involved.

Generally, the repeatabilities obtained for coat score, coat depth and skin thickness were not particularly high, even though significant. It was thought they were in a range acceptable for this study since several estimates of insulation were available for each animal.

2. Correlations

The simple phenotypic correlations between the insulation traits are presented in Table IV.3. The correlations between skin thickness and the hair coat traits

Table IV.3. Phenotypic Correlations Between Insulation Traits. Kinsella 1982.

	CT	DP	GL	UL	DN
ST	0.14	0.13	ns	ns	0.11
CT		0.36	0.34	0.11	0.19
DP			0.32	0.20	0.20
GL				0.62	0.40
UL					0.45
DN					

ns - Correlation is non-significantly different from zero ($P < 0.05$).

ranged from non-significant to 0.14, all low and positive. Although a strong relationship would not be expected between these traits, some association was indicated by the work of Blaxter and Wainman (1964). They found that decreasing the hair coat of an animal by shearing decreased the tissue insulation, which is primarily determined by skin thickness.

The hair traits were all significantly (P>0.05) positively correlated, in the low to medium range. The correlations between coat score and the other hair traits were lower than those reported by Turner and Schleger (1960), who developed the score. However there were not as many different coat types to classify as in this study, since all animals were similar in age, size and breed. The correlations between guard hair length or undercoat length and coat density were similar to those reported by Peters and Slen (1964) in Alberta. Generally, the correlations obtained were as expected by the nature of the traits; relationships existed but not particularly strong ones.

B. Least Squares Analysis

1. Size

The least squares means and standard errors of height and fall bodyweight are presented in Table IV.4. Over all breed and age groups examined, the average height and fall weights were 129.0±0.3 cm and 491±3 kg respectively. They ranged from 126.3±0.4 cm and 394±5 kg for two-year-olds to

Table IV.4. Least Squares Means and Standard Errors of Height and Fall Weight, By Breed and Age of Cow. Kinsella 1981-1982.

	No.	Height (cm) Mean	SE	Fall Weight (kg) Mean	SE
Overall	521	129.0	0.28	491	3.2
2 yrs	141	126.3a	0.40	394a	4.5
3 yrs	117	128.7bc	0.47	432b	5.4
4 yrs	69	129.3bcd	0.64	484c	7.3
5 yrs	47	130.5cd	0.77	527d	8.8
6 yrs	38	130.9d	1.02	558d	11.6
7 yrs	109	128.3b	0.63	552d	7.1
HE	62	125.6a	0.74	481a	8.4
HX	116	128.6b	0.63	495ab	7.2
SY	228	130.1c	0.33	503b	3.8
DA	115	131.7d	0.44	487a	5.1

abcd
Means in same column by breed or by age with different subscripts are significantly different (P>0.05)

128.3±0.6 cm and 552±7 kg for cows seven years and older. For both traits there was an increase across the age groups up to a maximum at six years, followed by a significantly lower (P>0.05) height value for cows seven years and older but a non-significantly lower weight value. A similar decline in height after maturity has been observed by Nelson and coworkers (1982), who quoted that it may be attributable to normal shrinkage of the body with advancing age.

Breeding group differences in fall weight followed a similar pattern to height, increasing in size from HE to HX to SY. This ranking was expected from the relative sizes of the original breeds making up the different breed groups. The DA group was different in its ranking for weight than for height; the animals in this breed group weighed significantly less (P>0.05) than those in the SY group, however they were significantly taller. This may have been due to the influence of the Holstein and Brown Swiss breeds in the DA. These breeds have had more emphasis on milk production in their past than meat production, and would not be expected to have as much body mass at the same height as the beef breeds. It may also be because the DA group had less condition than the other breeding groups.

2. Midwinter Condition

Least squares means for the transformed average condition scores (CS) and backfat thickness (BF) are presented in Table VI.5. The overall means were 64±0.9 for

Table IV.5. Least Squares Means* and Standard Errors of Midwinter Condition Estimates, by Age and Breed of Dam. Kinsella, 1982.

	Condition Score (0-thin,100-obese)			Backfat Thickness (mm)		
	N	Mean	SE	N	Mean	SE
Overall	521	64	0.9	261	6.8	0.15
2 yrs	141	64a	1.3	-	-	-
3 yrs	117	62a	1.6	-	-	-
4 yrs	69	55b	2.1	69	6.7	0.24
5 yrs	47	63a	2.6	47	6.7	0.29
6 yrs	38	69a	3.4	38	7.1	0.38
7 yrs plus	109	67a	2.1	108	6.8	0.23
HE	62	70a	2.5	27	7.1	0.39
HX	116	69a	2.1	31	6.8	0.34
SY	228	62b	1.1	134	7.1	0.16
DA	115	53c	1.5	69	6.4	0.21

ab Means in same column with same alphabet subscript were not significantly different within breed or age group ($P<0.05$)

*Main effects B, A and BA Interaction

condition score and 6.8±0.15 mm for backfat thickness. Neither condition score nor backfat thickness showed a significant pattern of change from young to old cows, however cows six and seven years or older had slightly higher condition scores than two, three and four-year-olds.

Four-year-olds had significantly lower ($P>0.05$) condition scores than the other groups, however backfat thickness was similar in four-year-olds to the older cows. The correlation between condition score and backfat thickness was low, on the order of 0.17. It is probable that the four-year-olds did have less condition, in spite of their backfat measurements. This was their first winter with the mature cow herd under harsh nutritional conditions and with competition from older, larger cows.

HE and HX had similar condition scores, these were significantly higher ($P>0.05$) than those of SY cows, which in turn were significantly higher than those of the DA group. These breeding group differences partly reflect different selection histories. The HE and HX were composed primarily of early fattening breeds, whereas the SY was composed partly of Charolais, a later maturing, later fattening breed that would not be as well conditioned at any time of the year as Herefords. The DA would be expected to have even less condition due to the influence of the Holstein and Brown Swiss breeds. In addition, these breeding group differences may reflect different abilities to withstand the cold and nutritional stresses of winter.

Without information on the relative condition of the animals prior to winter, no conclusions can be drawn with respect to the relative importance of these influences.

There were no significant breeding group differences in backfat thickness, although as in condition score, the DA ranked lowest. Since there are breed differences in fat distribution among the various fat depots (Berg and Butterfield 1976, Cianzio *et al.* 1982), the absence of significant breed differences in subcutaneous fat, which is what is best estimated by the ultrasonic probe at the 12-13th rib (Cianzio *et al.* 1982), does not necessarily indicate that there were no significant breed differences in body condition. Body condition would be more indicative of total body fat (Berg and Butterfield 1976).

3. Insulation

Table IV.6 presents the least squares means and standard errors for the hair coat traits and skin thickness by age and breed of dam.

Overall least squares means and standard errors for hair coat parameters were 50.7±0.7 for coat score, 17.3±0.2 mm for average coat depth, 44.2±0.6 mm for guard hair length, 25.9±0.3 mm for undercoat hair length and 35.6±0.5 g/sq.cm for coat density. There was a trend for coat score, coat depth, guard hair length and coat density to be maximum in two-year-olds and decline in the three or four-year-old age groups, significant for all variables mentioned except

Table IV.6. Least Squares Means* of Insulation Traits, by Age and Breed of Dam. Kinsella 1982.

	N	Skin Thick (mm)	**Coat Score (0-100)	Coat Depth (mm)	Guardhair Length (mm)	Undercoat Length (mm)	Coat Density (g/cm^2)
Overall	521	5.63	50	17.3	44.2	25.9	35.6
Standard Error		0.04	0.7	0.2	0.6	0.3	0.5
2 yrs	141	5.69a	56a	17.9	49.9a	25.2a	39.3a
3 yrs	117	5.41b	52b	16.9	44.9b	24.1a	31.9b
4 yrs	69	5.73a	49bc	17.6	45.0b	28.0b	35.6c
5 yrs	47	5.71a	46c	17.1	41.2b	25.7a	34.0bc
6 yrs	38	5.77a	49bc	17.0	41.6b	26.2a	36.4c
>6 yrs	109	5.47a	47c	17.0	42.4b	26.2a	36.3c
HE	62	5.94a	59a	18.3a	45.4a	26.2ab	36.3ab
HX	116	5.67b	50b	17.3ab	45.5a	26.5a	37.7a
6Y	228	5.70b	49b	16.9b	44.5a	26.0ab	35.3b
DA	115	5.22c	42c	16.5b	41.3b	24.9b	33.0c

abc Means in same column with same alphabet subscript were not significantly different, within breed and age group ($P<0.05$)

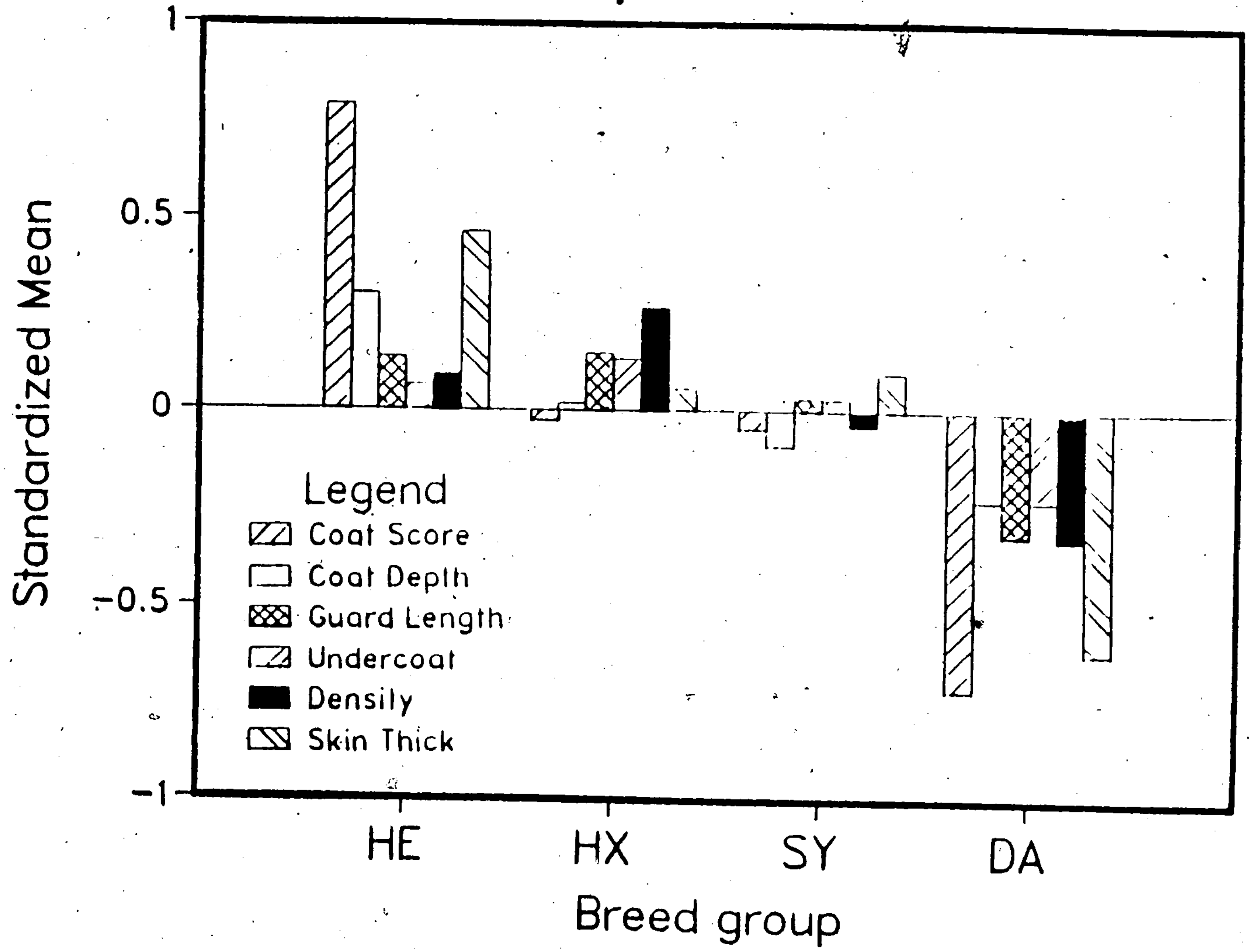
*Main effects B, A and BA interaction

**0-Light coat, 100-heavy coat

coat depth (P>0.05). Undercoat length did not exhibit this trend. Previous work (Dowling 1955a, Schleger and Turner 1960) indicated that age would have an influence on hair coat characteristics since all the hair follicles are laid down at or shortly after birth and spread out as the size of the animal increases. This would reduce weight of hair per unit area, coat score and possibly hair depth. Turner and Schleger (1960) also noticed decreases in coat scor with age. However, stretching of the skin does not explain why guard hair length would decrease with age, so other factors are probably involved, such as nutrition and management. It was noted at Kinsella that young animals involved in another trial, on a much higher plane of nutrition than the cows in the present study, had much heavier looking coats. Since two and three-year-old cows were on a better plane of nutrition than the older cows, it may be that nutrition was related, although no conclusions could be reached on the basis of these casual observations.

Breeding group differences in all of the coat traits were significant (P>0.05) and followed a similar, though not identical pattern. Figure IV.1 presents the breeding group least squares means for each of these traits, standardized to mean zero and variance one. It can be seen that HE consistently ranked above the overall average for these traits, the HX and SY intermediate, and the DA consistently below average. If heavier insulation was related to adaptability to range conditions, this would be the ranking

Figure IV.1. Standardized Least Squares Means for Insulation Traits, by Breed of Dam, Kinsella 1982



expected. The HE is the traditional range breed and has been longest selected under these conditions, the DA have only recently been used on range and the HX and SY would be intermediate to these two extremes.

Most literature reports of hair coat parameters are derived from work in hot climates with heat resistance, thus are not comparable in terms of the actual magnitude of the values to this study. However, breed of cow is consistently a significant source of variation (Dowling and Nay 1960, Schleger and Turner 1960, Hayman and Nay 1961, Pan 1964, Peters and Slen 1964). Peters and Slen (1964) at Manyberries, Alberta, reported a value for coat density of 36.7±2.3 g/sq.cm for Hereford cows during winter, similar to the value obtained in this study. They reported a mean hair length value of 29.1±0.09 mm, which is lower than the average of the least squares means of guard hair and undercoat length (35.8±2.3) for HE in this study. However, their samples were from the midrib region, not the hindquarter as in this study, and hair length increases posteriorly (Pan 1964).

The overall mean for skin thickness as determined by skin-fold thickness was 5.63±0.04 mm (Table IV.6). There were significant ($P>0.05$) age of dam effects, but no particular pattern across the age groups. The three-year-olds had a significantly lower ($P>0.05$) skin thickness value than the other age groups. Breeding group of cow was also a significant source of variation. The HE had the thickest (P>0.05) skin, the HX and SY were intermediate and significantly thicker (P>0.05) than the DA.

Although limited work has been done in this area, these results generally agree with the work that was done in the late 1950's in Australia (Table IV.7). Dowling (1955b) reported an overall mean of 4.55±0.05 mm for skin thickness determined by skin-fold. Tulloh (1961) reported means of 3.98, 4.79 and 4.84 for Shorthorn, Angus and Hereford cows respectively. However, the sites were clipped before taking the skin-fold measurement in both of these trials, which would lower the means by an average of 0.94±0.12 mm (Tulloh 1961).

Dowling (1955b) found no significant effect of age of dam, although there were significant breed effects on actual skin thickness as determined by skin biopsy. (He also reported that skin biopsy had a high positive correlation with skin thickness as determined by skin-fold.) His ranking of Hereford, Shorthorn and Angus cows for skin thickness was the same as that found by Tulloh (1961) for skin-fold thickness measurements. These reports indicated that Herefords have the thickest skin which agrees with the current study.

Dowling (1955b) also reported skin thickness values for the Friesian and Jersey; the Friesian ranked intermediate between the Angus and Hereford, the Jersey lower even than the Shorthorn. These rankings conflict with those in the present study. In spite of the Holstein breeding in the DA

Table IV.7. Literature Values for Skin Thickness, Determined by Skin Fold and Biopsy.

No.	Mean	SE	Breed	Workers
Determined by Skin-fold Thickness				
12	4.55	0.05	Shorthorn Cows	Dowling 1955b
25	4.84	0.78*	Hereford Cows	Tulloh 1960
18	4.79	0.23*	Angus Cows	
13	3.98	0.24*	Shorthorn Cows	
Determined by Skin Biopsy				
50	6.77	0.07	Hereford	Dowling 1955b
20	5.75	0.11	Angus	
41	5.69	0.08	Shorthorn	
20	6.08	0.11	Friesian	
12	5.46	0.15	Jersey	
50	5.72	-	High Nutrition	
50	5.16	-	Low Nutrition	

* These were the standard errors of the actual skin-fold thickness measurements.

group, it had a lower mean skin thickness than HX and SY cows. It is possible that under the conditions at Kinsella, the DA cows were under sufficient nutritional stress that less fat was laid down, thus skin-fold thickness was affected. Dowling's results (1955b) support this idea since cows on a high plane of nutrition had significantly (P>0.001) thicker skins than those on a low plane of nutrition in his experiments.

4. Weight Change Patterns and Winter Weight Loss

Least squares means and standard errors for bodyweight at different times of the year are presented in Table IV.8 by age of dam. Overall means were 490, 468, 502, 466, 496 and 523 kg for October 1981, January 1982, March 1982, postcalving, June and October 1982 weights respectively, with an average standard error of 3 kg. Figure IV.2 illustrates the weight change pattern throughout the year for the different age groups. On average the cows increased in weight through the age groups up to a maximum at si years of age, although tests of significance frequently did not indicate any sig icant increase in weight after five years of age (Table IV.8). The additional care and better nutrition that the two and three-year-olds received over winter at Kinsella was reflected in their weight patterns; they actually gained weight over winter. This gain reflected skeletal as well as muscle and fat growth, whereas in the older cows it ould be expected that most of the weight

Table IV.8. Least Squares Means[1] and Standard Errors for Cow Bodyweight Throughout the Year, by Age of Dam. Kinsella 1981-1982.

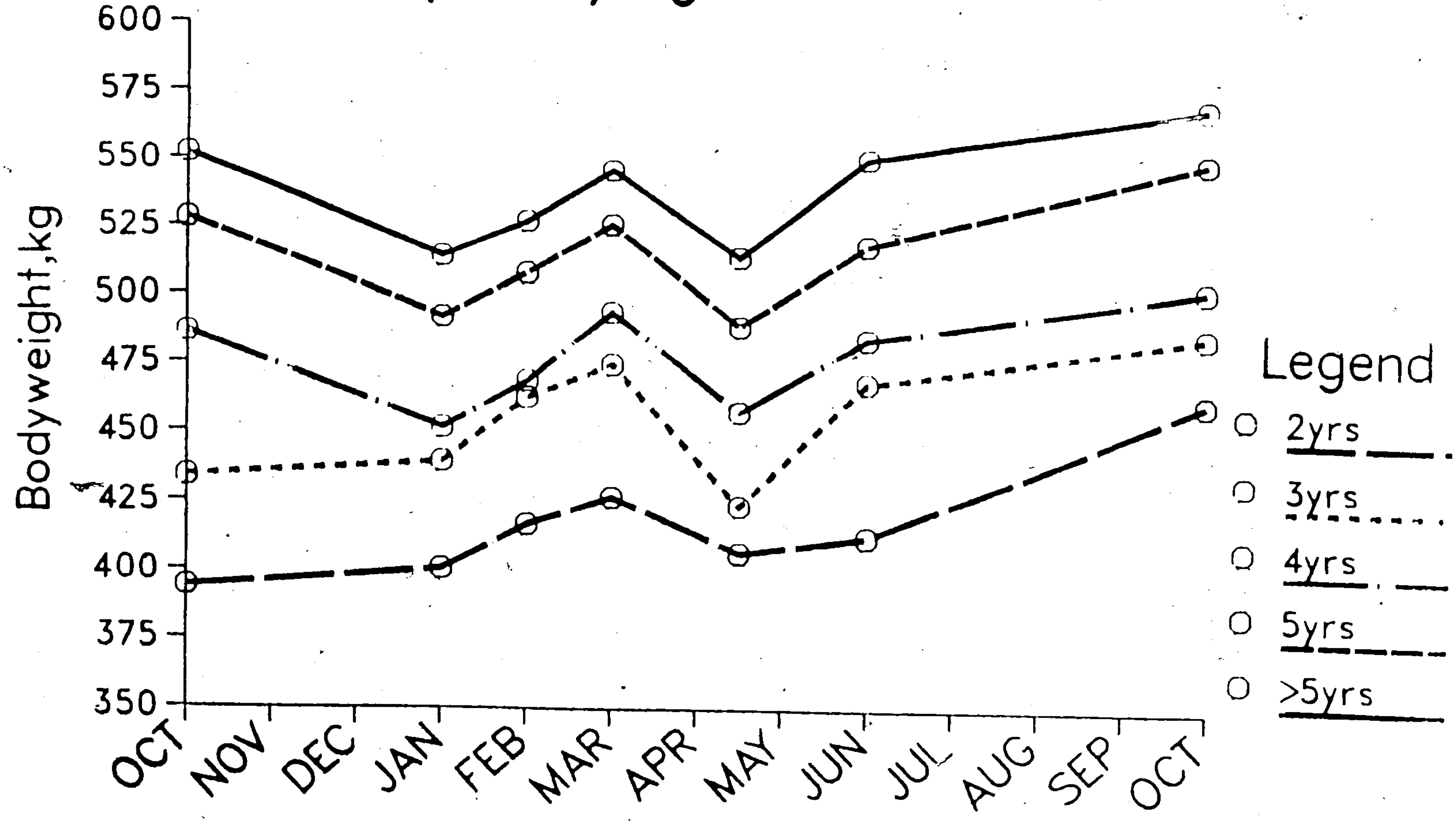
	No.	S.E.[2]	Bodyweight (kg) Oct'81	Jan'82	Mar'82	Post-Calving'82	Jun'82	Oct'82
Overall	457	3	490	468	502	466	496	523
2 yrs	118	6	394a	401a	427a	407a	413a	462a
3 yrs	98	6	434b	440b	475b	424b	469b	486b
4 yrs	64	7	486c	452b	494c	458c	485c	503b
5 yrs	44	8	527d	492c	526d	489d	519d	550c
6 yrs	32	12	552d	514c	546d	514d	551c	570c
7 yrs	101	9	546d	512c	546d	504d	542c	570c

abcd Means within same colum with same subscripts are non-significantly different ($P < 0.05$)

1 Least squares means adjusted for Breed of Dam, calving date and sex of calf

2 Standard error is average of standard errors for means in row

Figure IV.2. Bodyweight Least Squares Means Throughout the year, by Age of Dam. Kinsella, 1981–1982



fluctuations would be due to alterations in condition. By four years of age, the weight change pattern over the year became consistent. Cows lost weight from October to January, when the increasing size of the fetus and associated tissues and fluids caused cow weight to increase again until calving. The net loss from October to postcalving was called winter weight loss (WL). After calving, the cows regained lost weight as nutrition and climatic conditions improved, and reached their previous fall weight by June. They continued to gain weight over the summer of 1982 until October, resulting in an average net gain from the fall of 1981 to the fall of 1982 of 27 kg.

Breeding group least squares means are presented in Table IV.9. Breeding group differences were significant (P>0.05). Figure IV.3 plots the breed least squares means versus time of year. Rankings remained similar throughout the year except for the postcalving weights. Although not significantly different, the HE weighed less at calving than the other breed groups, consistent with its ranking throughout the rest of the year. The other three breeding groups weighed within 3 kg of each other postcalving, in spite of a 15 kg range at other times of the year. Consequently there were significant (P>0.05) breed group differences in winter weight loss. As can be seen in Table IV.10, SY cows lost significantly more (P>0.05) weight than DA cows. HE and HX cows lost an intermediate amount of weight. Within breed group-age class least squares means are

Table IV.9. Least Squares Means[1] and Standard Errors of Bodyweight Throughout the Year, by Breed of Dam. Kinsella 1981-1982.

			Bodyweight (kg)					
	No.	S.E.[2]	Oct'81	Jan'82	Mar'82	Post-Calving'82	Jun'82	Oct'82
Overall	457	3	490	468	502	466	496	523
HE	55	8	479a	451a	486a	453a	476a	509a
HX	95	8	494ab	476bc	506bc	469a	502bc	518a
SY	202	4	502b	481c	516c	472a	511c	541b
DA	105	5	485a	465b	501b	471a	496b	525a

abc Means within same column with same subscripts are non-significantly different ($P<0.05$)

1 Means adjusted for age of cow, calving date and sex of calf

2 Standard error is average of standard errors for means in same row

Figure IV.3. Bodyweight Least Squares Means Throughout the year, by Breed of Dam. Kinsella, 1981-82.

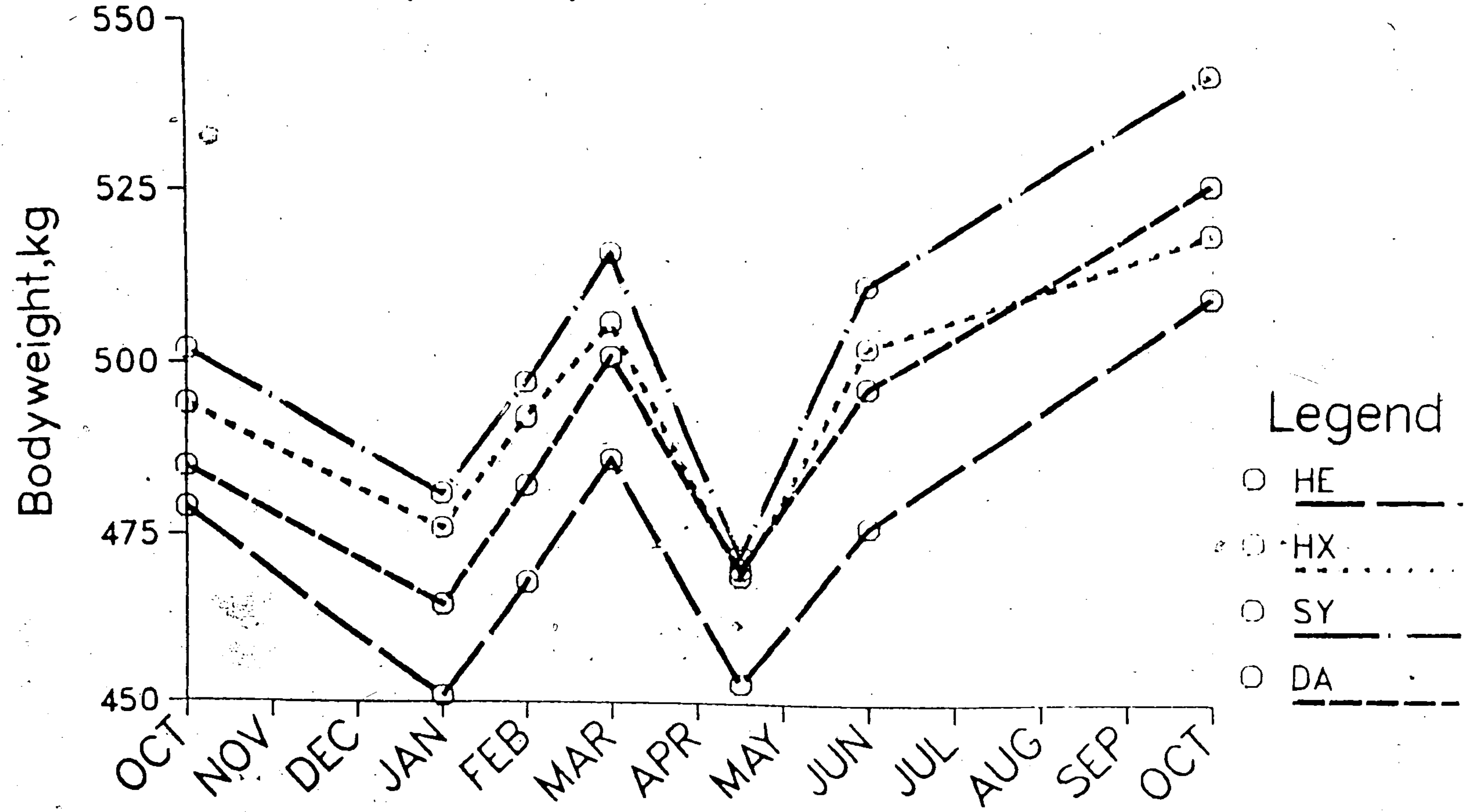


Table IV.10. Least Squares Means[1] and Standard Errors for October to Postcalving Weight Loss, by Breed and Age of Dam, Kinsella 1981-1982.

		Weight Loss (kg)	
	No.	Mean (kg)	S.E.
Grand Mean	464	23.2	2.2
HE Overall	58	25.1ab	5.6
2	18	-17.5	7.6
3	15	- 2.7	8.6
4	5	25.7	14.4
5	9	50.7	10.9
6	2	39.6	22.6
7	9	55.1	10.8
HX Overall	96	23.4ab	5.3
2	38	- 8.5	5.2
3	31	14.4	5.8
4	16	15.2	8.2
5	4	29.9	16.3
6	4	38.4	16.0
7	3	50.7	18.6
SY Overall	205	29.8b	2.5
2	41	-14.5	5.0
3	40	9.3	5.1
4	30	46.4	5.9
5	15	38.9	8.3
6	18	50.4	7.6
7	61	48.1	4.1
DA Overall	105	14.4a	3.4
2	23	-11.4	6.7
3	14	3.4	8.6
4	13	24.3	9.1
5	16	38.0	8.0
6	10	21.1	10.1
7	29	10.9	6.0

ab Breed overall means with different subscripts are significantly different (p>0.05)

1 Means adjusted for B,A, BXA, Sex of Calf and Calving Date

presented (Table IV.10), since the analysis of covariance (Table IV.11) indicated highly significant (P>0.01) breeding group by age interaction effects for this trait. Figure IV.4 is a plot of the least squares means for weight loss by breed versus age of dam. All breeding groups increased their mean weight loss until four or five years of age. However, older DA cows tended to lose less weight than cows in the other breeding groups. There was no obvious explanation for this.

Overall, the values for winter weight loss contrasted sharply with those of Butson (1981). In the same herd, she obtained a mean weight loss of 52 kg, with no significant breed differences. This contrast was surprising, since the winters under which Butson's data were collected were much less severe than the winter of 1981-1982. It also indicated that in 1981-82, the cows were more than amply compensated for the subnormal temperatures with the grain supplementing program. Because of this, the question arose as to whether the cows were actually under severe enough stress in the current study to test their winter hardiness. This will be discussed later.

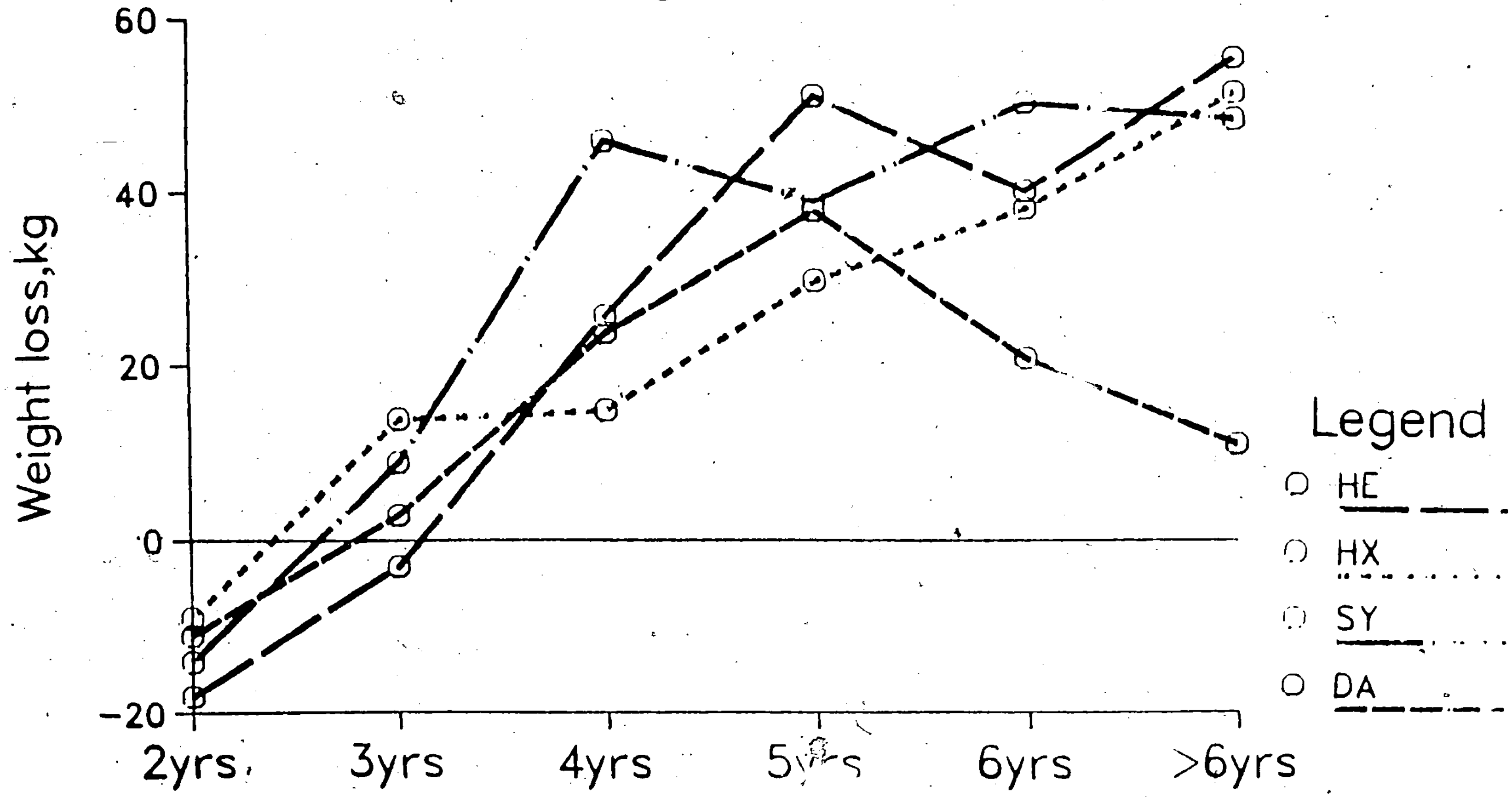
The breeding group differences in winter weight loss observed in this study also differed from previous reports. Deutscher and Whiteman (1971) and Wyatt *et al*. (1977) observed that cows with dairy breeding lost more weight than Hereford cows. This would be expected if the animals with dairy breeding were less adapted and under more stress than

Table IV.11. Least Squares Analysis of Covariance of Weight Loss from October 1981 to Postcalving 1982, Kinsella.

Source of Variation	Degrees of Freedom	Mean Square	F	Significance of F
Breed	3	4580.5	4.484	.0041
Age	5	2852.9	27.929	.0000
Sex	1	110.8	0.109	.7420
B x A	15	2231.6	2.185	.0063
B x S	3	794.8	0.778	.5065
A x S	5	90.1	0.088	.9940
Calving Date[1]	1	24112.8	23.612	.0000
Remainder	430	1021.2		
Total	463			

[1]Linear covariate

Figure IV.4. Breed by Age Interaction For Cow Winter Weight Loss. Kinsella 1981-82.



the others. However, dairy type animals appeared to have less of a tendency to put on condition than beef types. It is possible that the observed high weight loss in the beef breeding groups relative to the DA was reflecting a loss of excess condition built up over the late summer and fall. As noted previously, information on the condition of the animals prior to winter would have been useful.

Although Butson (1981) did not report significant breed differences in winter weight loss, she did note significant age group and within age group differences. As in the present study, mature cows demonstrated a significantly higher (P>0.05) weight loss than younger cows. In both cases, this can be attributed to the preferred treatment given young cows at Kinsella. Other workers (Deutscher and Whiteman 1971, Wyatt *et al.* 1977) have shown that young cows tend to lose more weight than mature cows if feeding and management were similar.

5. Calf Performance

Least squares means and standard errors for calf birthweight (BW), average daily gain to weaning (DG) and 180-day calf weight (WW) are presented in Table IV.12. The BA interaction was a significant (P>0.05) source of variation for birthweight (Table IV.13), however the variation appeared erratic (Figure IV.5). Overall, birthweight was highest for HX and DA, approximately 40±0.9 kg, intermediate for SY (38.2±0.4 kg), and lowest for HE,

Table IV.12. Least Squares Means* of Calf Performance. Kinsella, 1982.

	N	Birthweight (kg)	Preweaning Daily Gain (kg)	180-Day Weaning Weight (kg)
Overall	457	38.5	1.02	221
Standard Error		0.4	0.01	2
2 yrs	118	34.9a	0.90a	197a
3 yrs	98	38.0b	0.98b	215b
4 yrs	64	38.2b	1.06c	230c
5 yrs	44	39.2b	1.07c	232c
6 yrs	32	38.5b	1.06c	230c
>6 yrs	101	42.1c	1.01b	234c
HE	55	35.5a	0.95a	206a
HX	95	40.1b	1.02b	223b
Y	202	38.2c	1.04b	225b
DA	105	40.2b	1.06b	231b

abc Means in same column with same alphabet subscript were not significantly different by breed/age comparison (P<0.05)

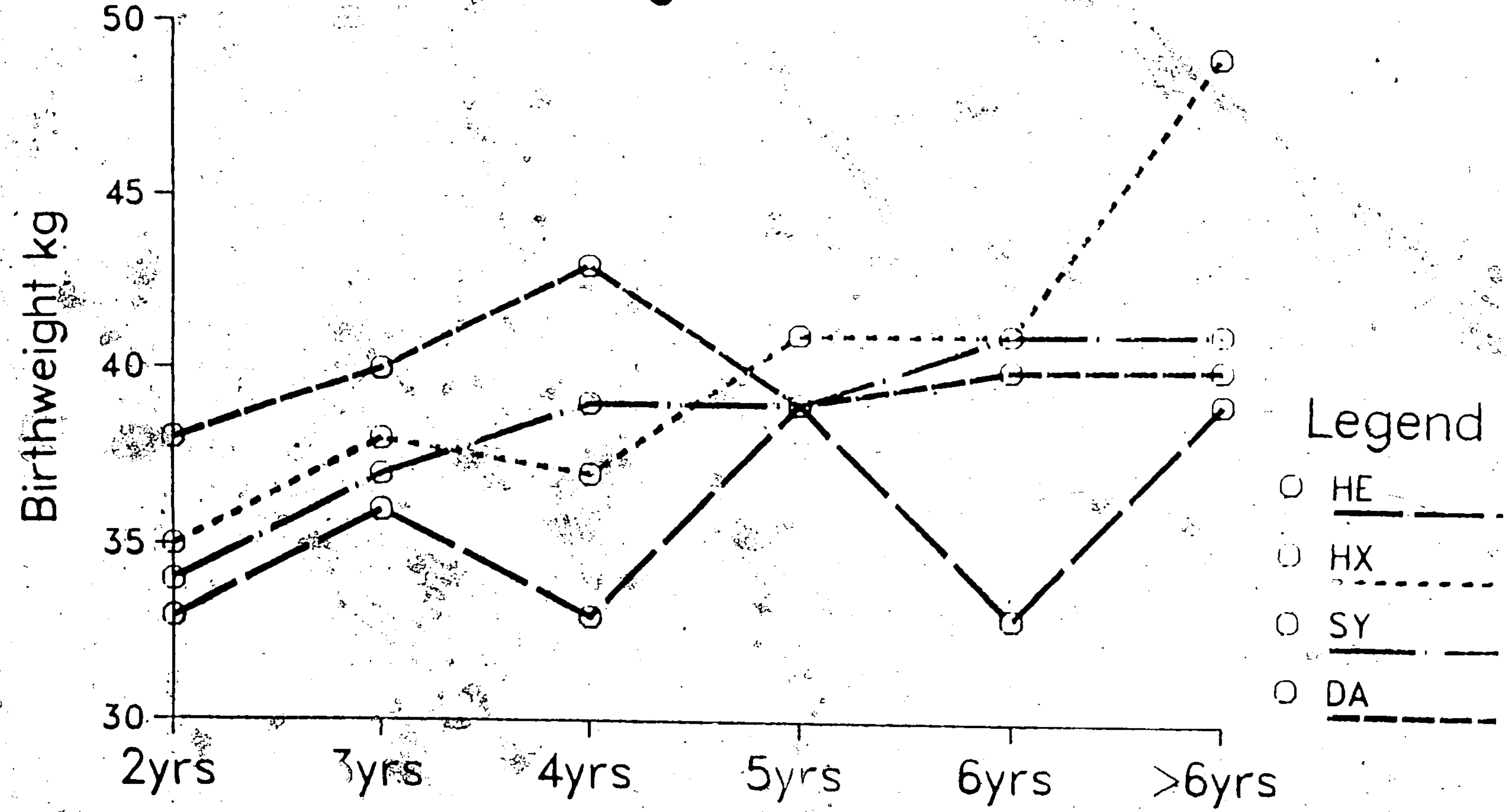
*Main effects B, A, S and D

Table IV.13. Least Squares Analysis of Covariance for Calf Birthweight. Kinsella, 1982.

Source of Variation	Degrees of Freedom	Mean Squares	Significance of F - Statistic
Mu	1	303584.9	.0000
Breed of Dam	3	215.1	.0000
Age of Dam	5	300.6	.0000
Sex of Calf	1	493.7	.0000
B x A	15	54.3	.0097
B x S	3	16.7	.5869
A x S	5	34.8	.2464
Calving Date[1]	1	14.8	.4589
Remainder	423		
Total	457		

[1]Linear Covariate

Figure IV.5. Breed by Age Interaction For Calf Birthweight. Kinsella 1981-82.



35.5±0.9 kg. This concurs with previous years' results in this herd (Butson 1981, Arthur *et al.* 1982) and others (Singh *et al.* 1970).

The overall least squares means for preweaning daily gain and 180-day calf weight were 1.02±0.01 kg per day and 221± 2 kg respectively (Table IV.12). Daily gain and 180-day weaning weight increased across the age groups, plateauing at four years of age. Daily gain was lower in the seven years plus group, reflecting that some cows in this groups would be past their prime. Breed effects on preweaning daily gain and 180-day weight were significant (P>0.05). There was a trend for DA cows to outperform SY and HX cows, who in turn significantly (P>0.05) outranked the HE herd. This was consistent with previous reports from Kinsella (Butson 1981, Arthur *et al.* 1982).

C. Calving Data

Means for calf crop traits are presented in Table IV.14. Overall, per cow exposed to breeding, the number calves born (BE) was 0.82 and the number weaned (WE) was 0.75. The number of calves weaned per cow with a positive pregnancy test in early winter (WP) was 0.91. There were no significant differences between means. There was a trend for performance to increase with age class to approximately four years of age, then level off in the older animals. DA was lower with only .787 calves born per cow exposed. The DA also ranked lower than the other breeding groups for calf

Table IV.14. Unadjusted Calving Data by Breed and Age of Dam. Kinsella 1982.

	Cows Exposed	Percent Calf Crop		
	N	BE	WE	WP
Overall	622	81.5	75.1	90.7
Hereford				
2 yrs	25	76	72	90
3 yrs	18	83	83	100
4 yrs	7	86	71	83
5 yrs	12	75	75	100
6 yrs	2	100	100	100
>6 yrs	12	83	75	90
Hereford Crossbred				
2 yrs	52	81	73	88
3 yrs	50	76	64	80
4 yrs	16	100	100	100
5 yrs	6	67	67	100
6 yrs	5	100	100	100
>6 yrs	7	72	43	50
Beef Synthetic				
2 yrs	59	80	69	87
3 yrs	49	90	84	93
4 yrs	37	86	81	91
5 yrs	24	75	63	83
6 yrs	21	90	86	95
>6 yrs	74	86	82	94
Dairy Cross				
2 yrs	41	66	56	85
3 yrs	21	71	67	93
4 yrs	17	82	76	93
5 yrs	16	76	76	100
6 yrs	12	92	83	83
>6 yrs	34	85	85	100

crop weaned per cow exposed, only 73.8%, although very close to HX, 74.5%. The SY ranked intermediate (77.5%), and the HE highest (79.3%). The HE and DA ranked highest for calf crop weaned per cow pregnant (93% and 92.3% respectively), followed by SY (90.5%) and HX (86.3%).

These results contrasted with those obtained previously at Kinsella (Berg and Makarechian 1980, Butson 1981, Arthur *et al*. 1982), which indicated that cows with dairy breeding performed as well or better than those with beef breeding. However, Deutscher and Whiteman (1971) reported that high producing cows tended to have lower reproductive rates.

The reasons for the lower overall calf crop born and calf crop weaned per cow exposed for DA were the low values for young cows (Table IV.14). Calf crop born weaned only 56 and 67%, for two and three-year-olds respectively, per cow exposed. Since calf crop weaned per cow pregnant was in a similar range to the other breeding groups for this trait, the two and three-year-old DA cows did not have as high a conception rate (or ability to maintain pregnancy up to the time of the winter pregnancy test) as the other breeding groups. This particular trait would not be expected to be related to winter adaptability.

D. Relationship of Insulation to Performance

1. **Midwinter Condition and Winter Weight Loss**

The results of the multiple regressions of condition and weight loss are presented in Table IV.15. Values are given for R-squared when only the insulation traits were included in the model, when the full model 1A was used, and the change in R-squared when insulation was added to the restricted model 1A.

The insulation traits explained 2.8% (significant, P>0.05) of the total variation in condition score after accounting for breeding group, age, height and fall weight of dam. Even if the main effects were not included in the model, only 7.3% of the total variation in condition score was explained by insulation. Similarly, the insulation traits explained 5.6% (significant, P>0.05) of the total variation in backfat thickness of cows four years of age and older, over and above that explained by the main effects (B,A,H,FW). Though significant, these values were not high, and it does not appear that insulation was an important determinant of midwinter condition.

Insulation as determined in this study was not a significant source of variation in winter weight loss once B, A, H, and FW were accounted for.

The weak relationships between the insulation variables and estimates of midwinter condition and winter weight loss were surprising considering the severity of the winter. However, as mentioned previously, the cows may not have been under severe stress, as shown by the low weight loss figures

Table IV.15. Results of Multiple Regression of Condition Estimates and Winter Weight Loss on Insulation, Using Model 1A*. Kinsella 1982.

Dependent Variable	Per cent Variation Explained			Significance of F-Statistic**
	Insulation Only	Full Model	Adding Insulation*	
Condition Score	7.3	26.0	2.8	0.01
Backfat Thickness	6.6	14.0	5.6	0.02
Weight Loss	8.1	39.0	0.9	0.38

*Main effects B, A, H, FW in restricted model; full model also includes all insulation variables

**Tests the significance of the change in R-squared between full and restricted models

relative to other years. Also, the midwinter condition scores indicated the the cows were in fair to good condition, not what would be expected if they had gone through the month of January under extreme duress.

It is possible that midwinter condition depends more heavily on prewinter condition than the animal's resistance to winter, and it was unfortunate these data were not available. Further work in this area should include prewinter estimates of condition other than bodyweight and height. Although a weight to height ratio has been recommended as a useful estimate of condition (Klosterman *et al.* 1968, Jeffery and Berg 1972a), breed effects on the ratio were confounded with condition effects in the present study. In addition, comparisons of pre- and mid-winter weight to height ratios could not be done because of the influence of the fetus and associated fluids (Degen and Young 1980).

The fact that a statistically significant, though biologically small, relationship did exist between the insulation traits and midwinter condition variables may mean that if energy was more limiting or the environmental conditions more stressful, insulation would be important.

2. Calf Performance

Table IV.16 presents the results of regressing calf performance on the insulation variables, both alone or in model 1B, and of adding insulation to the restricted model

Table IV.16. Results of Multiple Regression of Calf Performance on Insulation, Using Model 1B*. Kinsella 1982.

Dependent Variable	Per cent Variation Explained			Significance of F-Statistic**
	Insulation Only	Full Model	Adding Insulation*	
Birthweight	7.0	19.0	1.5	0.22
Preweaning Gain	7.1	28.0	1.7	0.09
180-Day Weight	7.7	31.0	1.9	0.05

*Main effects B, A, S, D in restricted model; full model also includes all insulation variables

**Tests the significance of the change in R-squared between full and restricted models

1B.

The insulation traits explained less than 2% (non-significant) of the total variation in calf performance (BW, DG, WW) after accounting for the main effects of breed and age of dam, sex of calf and calving date. This was not surprising since insulation did not influence cow weight loss. It would be expected that if insulation did affect calf performance it would be through a relationship to the cow's resistance to cold stress and ability to produce. Turner and Schleger (1960) in Australia reported a correlation between coat score of the dam and daily gain of the calf of -0.3. They hypothesized that the increased heat load of the dam with a heavy coat sufficiently stressed her that lactation performance was affected. However, later studies by the same authors (Turner and Schleger 1970) did not show the same results. Obviously, even if environmental stress can affect calf performance under some conditions, it was not an important factor in 1981-1982 at Kinsella.

3. Calf Crop

Table IV.17 presents the comparative means for the insulation and condition traits according to calving status. There were no significant differences in any of the insulation variables between cows weaning calves, cows giving birth but not weaning calves, or cows not giving birth but that had a positive pregnancy test midwinter. Thus the percent of calves born or weaned were not influenced by

Table IV.17. Least Squares Means* of Insulation and Condition Estimates by Calving Status. Kinsella 1982.

Trait	Cow Pregnant, No calf born		Calf Born, Not weaned		Calf Weaned	
	Mean	SE	Mean	SE	Mean	SE
N	14		40		467	
Coat Score, 0-100	47.5	2.2	51.3	1.6	50.0	1.3
Coat Depth, mm	26.0	6.5	24.3	4.8	24.4	3.8
Guard Hair Length, mm	43.4	1.7	43.6	1.3	44.5	1.0
Undercoat Length, mm	24.7	0.9	25.6	0.6	26.0	0.5
Coat Density, g/cm^2	45	15	41	11	42	9
Condition Score, 0-100	59.4	2.8	66.2	2.1	63.6	1.6
Backfat Thickness**, mm	[illegible]	0.7	6.7	0.4	6.8	0.4

*Main Effects B, A and BA interaction

**Cows over 3 yrs of age only

cow insulation.

As with calf performance, these results were expected since there was little influence of insulation on condition or weight loss. In addition, the number of cows which were pregnant in winter but did not carry through to term was small relative to the other groups, and statistically difficult to compare. This was particularly important in these data, since the cattle were entering their last trimester of pregancy when most measurements were taken. These cattle were not accustomed to handling, and it is conceivable that 14 out of 521 cows could have mechanically aborted simply because of the stress of handling. If that was the case, it would not be expected that the animals that did not carry to term would be any differently insulated than the others. Unfortunately, this will remain a problem in future work of this nature, since it is necessary to take insulation measurements in winter, unless the cattle can be handled frequently enough that mechanical abortion is unlikely.

E. Relationship of Midwinter condition to performance

1. Winter Weight Loss

The results of the Model 2 regressions of performance on condition are presented in Table IV.18.

Midwinter condition as estimated by backfat thickness and condition score was not a significant source of

Table IV.18. Results of Multiple Regression of Weight Loss and Calf Performance on Midwinter Condition, Using Model 2*. Kinsella 1982.

Dependent Variable	Per cent Variation Explained		Significance of F-Statistic**
	Full Model	Adding Condition*	
Weight Loss	13.0	0.3	0.66
Birthweight	17.0	4.5	0.00
Preweaning Gain	16.0	0.9	0.29
180-Day Weight	18.0	1.1	0.21

*Main effects B, A, S, D in restricted model; full model also includes condition variables, CS and BF

**Tests the significance of the change in R-squared between full and restricted models

variation in winter weight loss when included in Model 2 (main effects B, A, S and D). This was suprising, since it was expected that condition would be re d to weight loss. However, as mentioned previously, no ac ment could be made for fall condition. Preliminary analysis indicated that inclusion of fall weight and height as main effects did not affect multiple R-squared, probably because of the confounding of breed with weight to height ratio as mentioned before. Further investigations should have fall condition data available.

2. Calf Performance

Midwinter condition was a significant (P>0.05) but small source of variation in calf birthweight, explaining 4.5% of the total variation after accounting B, A, S and D (Table IV.18). The relationship was positive, indicating that there was a tendency for cows which had thicker backfat measurements and higher condition scores to have heavier calves at birth. However, condition was not a significant source of variation in calf preweaning gain or 180-day weight when included in model 2 containing B, A, S and D. These results generally agree with those of previous workers (Vaccaro and Dillard 1966, Russel *et al.* 1979) who reported that precalving gain of dams (thus precalving condition) was positively correlated with birthweight, but the correlation was low and the influence disappeared by weaning.

3. Calf Crop

Table I' !' ' 'ates the condition score and backfat thickness lea squ es means of the cows grouped according to calving status. None of the differences were significant, and there were no apparent trends. If there had been any differences, it was expected that animals that did not carry to term or wean a calf w ıld have been in poor condition midwinter. However, as discussed, there were few animals that were very thin in the herd. It is unlikely that their ability to carry a calf to term or their lactation performance would be affected unless they were past a threshold thinness. Also, as mentioned, it is possible that the stresses of handling the cows had more of an effect on calving status than the stresses of winter.

F. Relationship of Weight Loss to Performance

1. Calf Performance

The results of the Model 3 regressions of calf performance on B, A, S, D and winter weight loss (WL) are presented in Table IV.19. Winter weight loss accounted for 1.6% of the total variation in calf birthweight, a small but significant (P>0.01) proportion. This relationship was positive, which is logical since postcalving weight was used to calculate WL. It would be expected that the heavier the ca was, the higher the demands on the dam and her weight loss at calving. This logic implies that birthweight was the

Table IV.19. Results of Multiple Regression of Calf Performance on Cow Winter Weight Loss, Using Model 3*. Kinsella 1982.

Dependent Variable	Per cent Variation Explained: Full Model	Per cent Variation Explained: Adding Weight Loss*	Significance of F-Statistic**
Birthweight	23.0	1.6	0.00
Preweaning Gain	33.0	0.4	0.09
180-Day Weight	36.0	0.1	0.33

*Main effects B, A, S, D in restricted model; full model also includes winter weight loss

**Tests the significance of the change in R-squared between full and restricted models

independent variable, and weight loss the dependent. However, since fall condition was suggested to be involved in determining weight loss, and since midwinter condition influenced birthweight, either birthweight or weight loss could be considered dependent.In any case, proportion of variation in birthweight by weight loss explained is low, and not important relative to other sources of variation in either trait.

WL was not a significant source of variation in calf preweaning gain or 180-day weight (Table IV.19). Butson (1981) found that winter weight loss was a much less important determinant of weaning weight than milk yield of the dam. She obtained low, positive correlations between weight loss and milk yield or weaning weight, but the weight loss values were much higher than those obtained in the present study. Presumably, the biological basis for the correlations is that the animal was severely stressed over winter, lost weight proportionately to the stress, and could not produce up to its' maximum postcalving. However there is probably a threshold effect, that was obviously not important under the management conditions in 1981-1982 at Kinsella. Hironaka and Peters (1969), at Lethbridge, Alberta, raised cows at varying levels of winter nutrition under conditions similar to those at Kinsella. Weight loss values obtained from cows on a medium to high plane of nutrition were similar to those obtained in this study, whereas weight loss in cows on a low plane of nutrition were more comparable to those obtained by Butson (1981) at Kinsella. Although birthweights were similar across nutrition groups, preweaning gains were lower in the low nutrition, high weight loss group than the others, supporting the idea of a threshold effect.

V. CONCLUSIONS

The objectives of the study were to study winter hardiness-related traits of range beef cows and to see if these traits were related to productivity. Significant differences were found in cow size, midwinter condition, October to post-calving weight loss and insulation of the four breed groups that have been selected for different lengths of time under range conditions. The breed groups that had been selected longest under range conditions were smaller, heavier in condition midwinter, and were more heavily insulated than the breed groups that had just recently been introduced to and selected on range.

Winter weight loss was determined to be much lower than in previous years, despite the exceptionally severe winter. It was thought that this indicated that the level of supplementary feeding compensated for the energy shortage caused by the cold weather.

Insulation was not an important factor in determining midwinter condition, winter weight loss, calf performance or calf crop per cow exposed to breeding or per cow pregnant. Midwinter condition was not an important source of variation in winter weight loss, calf performance or calf crop. Similarly, winter weight loss did not greatly influence calf performance to weaning. Overall, traits related to winter adaptability did not affect cow or calf performance. Under the conditions present in cow-calf operations in Canada, winter hardiness should not be considered directly as a selection criterion. However, weak but significant relationships among insulation, winter weight loss, midwinter condition, and calf birthweight did exist. It is possible that if the animals had not been supplemented to the extent that they were, stronger associations would have been evident. Further studies in this area should use estimates of body condition throughout the year as well as bodyweight to examine these relationships more closely.

Literature Cited

ARTHUR, P.F., A.K. SHARMA and R.T. BERG. 1982. Use of large dairy breeds for beef production. The 61st Annual Feeders' Day Report. The University of Alberta. pp 3-7.

BERG, R. T. 1978. The University of Alberta beef breeding project-Report No. 9. The 57th Annual Feeders' Day Report. The University of Alberta. pp 2-7.

BERG, R. T. 1980. The University of Alberta Kinsella Ranch-The first twenty years. The 59th Annual Feeders' Day Report. The University of Alberta. pp. 3-9.

BERG, R. T. and R. M. BUTTERFIELD. 1976. In *New Concepts of Cattle Growth*, Sydney University Press, Sydney.

BERG, R. T. and M. MAKARECHIAN. 1980. Breed influences on cow reproduction and productivity at The University Ranch, Kinsella. The 59th Annual Feeders' Day Report. The University of Alberta. pp 14-16.

BERMAN, A. AND R. VOLCANI. 1961. Seasonal and regional variations in coat characteristics of dairy cattle. Aust. J. Agric. Res. 12: 528-538

BLAXTER, K. L. and F. W. WAINMAN. 1961. Environmental temperature and the energy metabolism and heat emission of steers. J. Agric. Sci. 56: 81-90

BLAXTER, K. L. and F. W. WAINMAN. 1964. The effect of increased air movement on the heat production and emission of steers. J. Agric. Sci. 62: 207-214

BOLDUC, D., R. T. BERG and G. W. MATHISON. 1978. Influence of biological-type of cow on winter maintenance requirements. The 57th Annual Feeders' Day Report, University of Alberta. pp. 8-11

BONSMA, J. C. 1949. Breeding cattle for increased adaptability to tropical and sub-tropical environments. J. Agric. Sci. 39: 204-221

BROWN, W. F., J. W. HOLLOWAY and W. T. BUTTS, Jr. 1980. Patterns of change in mature Angus cow weight and fatness during the year. J. Anim. Sci. 51: 43-50

BUTSON, S.L. 1981. Biostatistical analyses of factors influencing lactation performance of range cows and weaning weights of their cows. M. Sc. Thesis, University of Alberta.

BUTSON, S.L., R.T. BERG and R.T. HARDIN. 1980. Factors affecting weaning weights of range beef and dairy-beef calves. Can. J. Anim. Sci. 60: 727-742

CARTWRIGHT, T. C. 1979. Size as a component of beef production efficiency: Cow-calf production. J. Anim. Sci. 48: 974-980

CHRISTOPHERSON, R. J., J. R. THOMPSON and R. BERZINS. 1982. Are adrenalin and noradrenalin involved in the heat increment of feeding ruminants? The 61st Annual Feeder's Day Report, University of Alberta. pp.51-53

CIANZIO, D. S., D. G. TOPEL, G. B. WHITEHURST, D. C. BEITZ, and H. L. SELF. 1982. Adipose tissue growth in cattle representing two frame sizes: Distribution among depots. J. Anim. Sci. 55: 305-312.

DEGEN, A.A. and B.A. YOUNG. 1980. Liveweight, total body-water and maternal body-solid changes in pregnant and lactating beef cows. J. Agric. Sci., Camb. 95: 1-5

DEUTSCHER, G.H. and J.V. WHITEMAN. 1971. Productivity as two-year-olds of AngusXHolstein crossbreds compared to Angus heifers under range conditions. J. Anim. Sci. 33: 337-342.

DIETZ, W. 1971. Maintenance energy requirements of beef cows. M. Sc. Thesis, University of Alberta

DIETZ, W. and B. A. YOUNG. 1972. Effects of body condition on winter energy requirements of beef cows. Can. J. Anim. Sci. 52: 588 (Abst.)

DONHOFFER, S. 1970. Nonshivering Thermogenesis: Past and present. In *Nonshivering Thermogenesis*. Edited by L. Jansky. Academia, Czechoslovakia. pp. 11-26

DOWLING, D. F. 1955a. The hair follicle and apocrine gland populations of Zebu (Bos indicus L.) and Shorthorn (Bos taurus L.) cattle skin. Aust. J. Agric. Res. 6: 645-654.

DOWLING, D.F. 1955b. The thickness of cattle skin. Aust. J. Agric. Res. 6: 776-785.

DOWLING, D.F. 1959. The medullation characteristic of the hair coat as a factor in heat tolerance of cattle. Aust. J. Agric. Res. 10: 737-742

DOWLING, D.F. and T. NAY. 1960. Cyclic changes in the follicles and hair coat in cattle. Aust. J. Agric. Res. 11: 1064-1071

GODLEY, W. C. and C. O. TENNANT, Jr. 1969. Influence of dam's weight on calf performance. J. Anim. Sci. 28: 129

(Abst.)

GODLEY, W. C., RAMAGE, D. E. and J. R, HILL, Jr. 1970. The influence of cow size and condition on calf performance. J. Anim. Sci. 30:320 (Abst.)

HARVEY, W.R. 1975. Least-squares analysis of data with unequal subclass numbers. USDA, ARS H-4. Beltsville, Md.

HAYMAN, R.H. and T. NAY. 1961. Observations on hair growth and shedding in cattle. Aust. J. Agric. Res. 12: 513-527

HELDMAIER, G. 1970. Relationship between nonshivering thermogenesis and body size. In *Nonshivering Thermogenesis* . Edited by L. Jansky. Academia, Czechoslovakia. pp. 73-79

HIRONAKA, R. and H. F. PETERS. 1969. Energy requirements for wintering mature pregnant beef cows. Can. J. Anim. Sci. 49: 323-330.

HOLLOWAY, J. W., W. T. BUTTS, Jr., J. D. BEATY, J. T. HOPPER and N. S. HALL. 1979. Forage intake and performance of lactating beef cows grazing high or low quality pastures. J. Anim. Sci. 48: 692-700

HOOVEN, N. W., Jr., R. H. MILLER and R. D. PLOWMAN. 1968. Genetic and environmental relationships among efficiency, yield, consumption and weight of Holstein cows. J. Dairy Sci. 51: 1409-1419

JEFFERY, H. B. 1971. Biometical analyses of cow and calf variables. Ph.D. Dissertation, University of Alberta.

JEFFERY, H. B. and R. T. BERG. 1972a. Influence of cow size and other factors on weight gain of beef calves to 365 days of age. Can. J. Anim. Sci. 52: 11-21

JEFFERY, H. B. and R. T. BERG. 1972b. An evaluation of several measurements of beef cow size as related to progeny performance. Can. J. Anim. Sci. 52: 23-37

KLOSTERMAN, E. W., L. G. SANFORD and C. F. PARKER. 1968. Effect of cow size and condition and ration protein content upon maintenance requirements of mature beef cows. J. Anim. Sci. 27: 242-246

KROPP, J. R., D. F. STEPHENS, J. W. HOLLOWAY, J. V. WHITEMAN, L. KNORI and R. TOTUSEK. 1973. Performance on range and in drylot of 2-year-old Hereford, Hereford'Angus and Holstein females as influenced by level of winter supplementation. J. Anim. Sci. 37: 1222-1232

LOWMAN, B. G., R. A. EDWARDS and S. H. SOMERVILLE. 1979. The effect of plane of nutrition in early lactation on the performance of beef cows. Anim. Prod. 29: 293-303

MOE, P. W. and H. F. TYRELL. 1972. Metabolizable energy requirements of pregnant dairy cows. J. Dairy Sci. 55: 480-483

MORRIS, C. A. and J. W. WILTON. 1976. Influence of body size on the biological efficiency of cows: A review. Can. J. Anim. Sci. 56: 613-647

NAY, T. and R. H. HAYMAN. 1963. Some skin characters in five breeds of European (Bos taurus L.) dairy cattle. Aust. J. Agric. Res. 14: 294-302.

NELSEN, T. C., C. R. LONG and T. C. CARTWRIGHT. 1982.

Postinflection growth in straightbred and crossbred cattle. I. Heterosis for weight, height and maturing rate. J. Anim. Sci. 55: 280-292.

PAN, Y. S. 1964. Variation in hair characters over the body in Sahiwal Zebu and Jersey cattle. Aust. J. Agric. Res. 15: 346-356.

PETERS, H. F. and S. B. SLEN. 1964. Hair coat characteristics of bison, domestic x bison hybrids, cattalo, and certain domestic breeds of beef cattle. Can. J. Anim. Sci. 44: 48-57.

RAHNEFELD, G. W., R. J. PARKER, S. YODSERANEE and E. W. STRINGHAM. 1980. Influence of body weight and changes in body weight of cow on preweaning traits of the calf. Can. J. Anim. Sci. 60: 599-607

RUSSELL, A. J., J. N. PEART, J. EADIE, A. J. MACDONALD and I. R. WHITE. 1979. The effect of energy intake during late pregnancy on the production from two genotypes of suckler cow. Anim. Prod. 28: 309-327

SCHLEGER, A. V. and H. G. TURNER. 1960. Analysis of coat characters of cattle. Aust. J. Agric. Res. 11: 875-885.

SCHOLANDER, P. F., V. WALTERS, R. HOCK and L. IRVING. 1950a. Body insulation of some artic and tropical mammals and birds. Biol. Bull. 99: 225-236.

SCHOLANDER, P. F., R. HOCK, V. WALTERS and L. IRVING. 1950b. Adaptation to cold in artic and tropical mammals and birds in relation to body temperature insulation and basal metabolic rate. Biol. Bull. 99: 261-271.

SELLERS, E. A., G. STEINER, K. V. FLATTERY, A. SCHUM, G. E. JOHNSON and E. SCHONBAUM. 1970. Activity of the sympathetic nervous system during cold exposure. In *Nonshivering Thermogenesis.* Edited by L. Jansky. Academia, Czechoslovakia.

SINGH, A. R., R. R. SCHALLES, W. H. SMITH and F. B. KESSLER. 1970. Cow weight and preweaning performance of calves. J. Anim. Sci. 31: 27-30.

SLEE, J. 1971. Physiological factors affecting the energy cost of cold exposures. Proc. Nutr. Soc. 30: 215-221.

SMITH, G.M. 1979. Size as a component of beef production efficiency: Feedlot performance and integrated efficiency. J. Anim. Sci. 48: 966-973

SOKAL, R. R. and F. J. ROHLF. 1981. In *Biometry*, W.H. Freeman and Co., San Francisco.

SPSS Inc. 1983. SPSSX User's Guide, McGraw-Hill, U.S.A.

TONG, A. K. W., J. W. WILTON and L. R. SCHAEFFER. 1977. Application of a scoring procedure and transformations to dairytype classification and beef ease of calving categorical data. Can. J. Anim. Sci. 57: 1-5.

TULLOH, N. M. 1961. Variations in the skin and skin-fold thickness of beef cattle. Aust. J. Agric. Res. 12: 992-1004.

TURNER, H. G. and A. V. SCHLEGER. 1960. The significance of coat type in cattle. Aust. J. Agric. Res. 11: 645-663.

TURNER, H. G., T. NAY and G. T. FRENCH. 1962. The hair follicle population of cattle in relation to breed and body weight. Aust. J. Agric. Res. 13: 960-973.

TURNER, H. G., and A. V. SCHLEGER. 1970. An analysis of growth processes in cattle coats and their relations to coat type and body weight gain. Aust. J. Biol. Sci. 23: 201-218.

URICK, J. J., B. W. KNAPP, J. S. BRINKS, D. F. PAHNISH and T. M. RILEY. 1971. Relationships between cow weights and calf weaning weights in Angus, Charolais and Hereford breeds. J. Anim. Sci. 33: 343-348.

VACCARO, R. and DILLARD, E. V. 1966. Relationships fo dam's weight and weight changes to calf's growth rate in Hereford cattle. J. Anim. Sci. 25: 1063-1068.

WEBSTER, A. J. F. 1970. Direct effects of cold weather on the energetic efficiency of beef production in different regions of Canada. Can. J. Anim. Sci. 50: 563-573.

WEBSTER, A. J. F., J. CHLUMECKY and B. A. YOUNG. 1970. Effects of cold environments on the energy exchanges of young beef cattle. Can. J. Anim. Sci. 50: 89-100

WHITMAN, R. W., E. E. REMENGA andJ. N. WILTBANK. 1975. Weight change, condition and beef cow reproduction. J. Anim. Sci. 41: 387 (Abst.)

WYATT, R.D., K.S. LUSBY, J.V. WHITEMAN, J.V. GOULD and R. TOTUSEK. 1977. Performance of 4- and 5-year old Hereford, HerefordXHolstein and Holstein cows on range and on drylot. J. Anim. Sci. 45: 1120-1130.

YEATES, N. T. M. 1955. Photoperiodicity in cattle. I. Seasonal changes in coat character and their importance in heat regulation. Aust. J. Agric. Res. 6: 891-902.

YOUNG, B. A. 1975. Effects of winter acclimatization on resting metabolism of beef cows. Can. J. Anim. Sci. 55: 619625.

YOUNG, B. A. 1979. Effects of low temperatures on cattle production. Paper presented at 1979 meeting of A.S.A.E. and C.S.A.E., University of Manitoba, Winnipeg.

APPENDIX I. Condition Scoring of Cattle

-1-

Hip bones, tail head and ribs project prominently, no fat around tail head.

-2-

Some tissue cover around tail head, over hip bones and flank; ribs still felt with slight hand pressure but not visually obvious.

-3-

Can easily f[illegible]l fat around tail head, hips less prominent and feel rounded.

-4-

Fat around tail head is soft and round, hips are covered and soft, folds of fat starting over the ribs and thighs.

-5-

Blocky looking, bones are not noticeable, can hardly find hip bones and tail head. Folds of fat are apparent over ribs and thighs, mobility affected by great amount of fat cover.

APPENDIX II. Coat Scoring of Cattle

-1-

Very short. Coat sleek, hairs short and coarse, lying flat,just able to be lifted.

-2-

Short. General appearance smooth-coated, hairs lifted easily, fairly coarse.

-3-

Fairly short. Coat not completely smooth, patches of hairs turned outwards.

-4-

Long. Hairs lying loosely, sufficient length to be easily ruffled, erect patches over neck and rump.

-5-

Wooly. Most hair erect, giving fur-like appearance, fingers can be partly buried in coat, undercoat is soft.

-6-

Curly. More extreme than 5, greater length and body, fingers buried easily in soft undercoat, heavy cover over most of body.

-7-

Very long and wooly. Most extreme, shaggy with very thick undercoat. [1]

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[1]Adapted from Turner and Schleger, 1960