THE EFFECTS OF A DAIRY COW BODY CONDITION SCORING SYSTEM ON SELECTED PRODUCTION AND METABOLIC PARAMETERS

by

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INTRODUCTION

Average milk production per dairy cow in the United States has increased by more than 2.5 percent annually during the past five years. This increase can be attributed to improvements in numerous management areas including genetics, health, reproduction, and nutrition. However, production increases are usually accompanied by physical stress and a consequential increase in the incidence of related metabolic diseases. Body condition, or cow fitness pertaining to the degree of body fat, at parturition is known to influence the occurrence of a number of metabolic disorders (24), but the ideal body condition of pregnant, non-lactating dairy cows prepartum for maximum milk production and minimum metabolic disorders has not been defined. Nutrition of the lactating dairy cow has progressed to a complex science in recent years. Computer programs make use of increasingly rapid and accurate nutrient analysis of feeds, differences in body weight, percent milk fat, milk production levels, and numerous other parameters to formulate rations for individual or groups of cows. The goal is to feed each cow to produce at the peak of her genetic potential with minimal metabolic disorders and therefore, theoretically, maximize profit.

The increased incidence of metabolic diseases in high producing dairy cows indicates a need for concern with each stage of the cow's production cycle and effects on subsequent production cycles. Body condition of the dairy cow during each stage of the production cycle must be taken into account. A long neglected area of dairy production research has been dry cow management. Historically, dairy cows have been dried off, turned out to pasture, and essentially ignored until parturition. More recently, with increased use of dry lot feeding, dry cows are fed high energy and protein rations which are similar to the rations fed to lactating herds. Neither of these systems is an objective means of preparing dry cows for parturition and lactation. High energy intake during the dry period can cause excessive weight gain, and high protein intake increases the incidence of "alert downer" cow syndrome, an apparent myoparalytic disease of the parturient dairy cow (13).

Recommendations for satisfying the nutritional requirements of dairy cows are based on maintenance needs of a cow at a given weight and with additional needs for milk production or gestation or both. No consideration is given to the body condition of the cow in relation to frame size, which is size pertaining to bone structure. A dairy cow may need to gain or lose weight, particularly during the last third of lactation, to be in proper condition for parturition and lactation. On a practical basis, neither dairy farmers not advisors agree on what constitutes good body condition for a dairy cow. Dairy scientists have not developed the necessary objective research to properly advise dairy farmers on the optimum body condition of dairy cows. It would be beneficial to have a practical means of determining optimum body condition for dairy cows during any given stage of the lactation cycle, especially the last third of lactation and the dry period, in preparation for parturition and the subsequent lactation (4).

This dissertation represents an attempt to clarify the need for and benefits of a practical scoring system for determining the body condition of dairy cows at any point in the production cycle. The broad objectives of this study were: 1) to determine practical means for identifying body condition of dairy cows; 2) to determine the optimum body condition of dairy cows during any stage of the production cycle; and 3) to determine the levels of selected blood components of dairy cows at any point in the production cycle.

EXPERIMENTAL PROCEDURE

Herd Selection

Thirty Virginia dairy herds were selected for cooperation in this field study. All herds were enrolled in the Dairy Herd Improvement Association (DHIA). One herd was removed from DHIA and consequently, was dropped from the study. The remaining twenty-nine herds were selected for level of milk production according to DHIA rolling herd averages. Nine herds with 6,350 kg of milk or less, ten herds with between 6,350 and 7,257 kg of milk, and ten herds with 7,258 kg of milk or greater participated in the study. This procedure assured a cross-sectional herd sample of production levels in Virginia dairy herds. All herds were enrolled in the DHIA electronic somatic cell counting program which further restricted the number of herds considered for the study.

Cow Selection

One aspect of this study concerned dairy cow blood profiles which required samples from a minimum of five cows per production grouping for the data to be statistically significant (17, 27). Therefore, within herd, 28 cows were selected to allow for a sufficient number of cows for four groups plus a fifth group of first lactation cows. The 28 cows were selected by using semiannual DHIA Estimated Relative Producing Ability (ERPA) reports. Five cows with ERPA's of +680 kg of milk or greater, five cows between +227 and +680 kg of milk, five cows between -227 and +227 kg of milk, and five cows with -227 kg of milk or less were chosen as a representative sample of each herd. Eight first lactation cows were also selected to reflect breeding progress in the herd and to be representative of the milking herd.

Within ERPA group, each cow was selected by means of a random number table and a list of the last two digits of the eartag or registration number of each cow. As study cows were culled from each herd by the dairy farm, substitute study cows from within the appropriate ERPA grouping were selected by matching, as closely as possible, the last two digits of the eartag or registration number to those of the cow that was culled from the herd. Since cows changed from one ERPA group to another during the study, due to numerous management factors, substitute study cows were selected from ERPA groups lacking the original complement of cows. This procedure maintained the 28-cow sample to being as representative of the original 28-cow group as possible.

Body Condition Scoring System

A body condition scoring system was devised by the author as a means of determining the body condition, or fitness pertaining to degree of body fat, of a dairy cow at any point during the production cycle. Cows were scored on appearance and palpation of the back and hind-quarters only. Usually, stage of lactation and other prejudicial factors were unknown. An effort was made not to be influenced by frame size which refers to bone structure, milk production level, health or any factor other than those described for each condition score. The factors considered were the thoracic and lumbar regions of the vertebral column (chine, loin, and rump), spinous processes (loin), anterior coccygeal vertebrae (tail head), tuber sacrale (hooks), and tuber ishii (pin bones). A single factor may be misleading; however, all factors considered together should provide an accurate score.

Condition Score 1 (Plates 1 and 2). The individual spinous processes of cows with this condition score had limited flesh covering, were sharp to the touch, were prominent, and together gave a definite shelf effect to the loin area. Individual vertebrae of the chine, loin, and rump regions were prominent, hooks and pin bones were sharp with limited flesh covering, and there were marked depressions between hooks and pin bones. The area below the tail head and between the pin bones was depressed, causing the vulva to appear prominent.

Condition Score 2 (Plates 3 and 4). The spinous processes of cows with this condition score were visually discernable, but were not prominent. They were sharp to the touch, had greater flesh covering than cows with condition score 1, and did not have as distinct a shelf effect. Although the individual vertebrae of the chine, loin, and rump regions were not visually prominent, they were distinguishable by palpation. Hooks and pin bones were prominent, but the depression between them was less pronounced than in condition score 1. The area between the pin bones and the tailhead showed limited depression; however, the depression was not sufficient to cause the vulva to appear prominent.

Condition Score 3 (Plates 5 and 6). The spinous processes of the loin region of these cows were discernible by applying minimal pressure.

Together they appeared smooth and the shelf effect was not noticeable. The vertebrae of the chine, loin and rump regions appeared as a rounded ridge and the hooks and pin bones were rounded and smooth. The area between the pin bones and around the tailhead appeared smooth without sign of subcutaneous fat deposition.

Condition Score 4 (Plates 7 and 8). The spinous processes of these cows could only be discerned by firm palpation and the series appear to be flat or rounded with no shelf effect. The vertebral column of the chine region was discernable to a limited extent, but the loin and rump regions appeared flat. The hooks were decidedly rounded and the span between the hooks was flat. The area around the tailhead and pin bones was decidedly rounded, with evidence of subcutaneous fat deposition.

Condition Score 5 (Plates 9 and 10). The bone structures of the vertebral column, spinous processes, hooks, and pin bones were not apparent and visual evidence of subcutaneous fat deposition was prominent. The tailhead appeared to be buried in fat tissue.

DHIA Records

Computer tapes of complete monthly DHIA records for each study cow in each of the 29 cooperator herds were obtained from the Southern Region Dairy Records Processing Center, Raleigh, North Carolina, for use in analyzing the usefulness of the body condition scoring system. Data obtained from the tapes included date of test, test day milk and percent fat, cow status, days in milk, persistency of lactation, days open, and age at calving. For statistical purposes, DHIA

Plate 1. Body condition score 1 - rear view.

Plate 2. Body condition score 1 - side view.

Plate 3. Body condition score 2 - rear view.

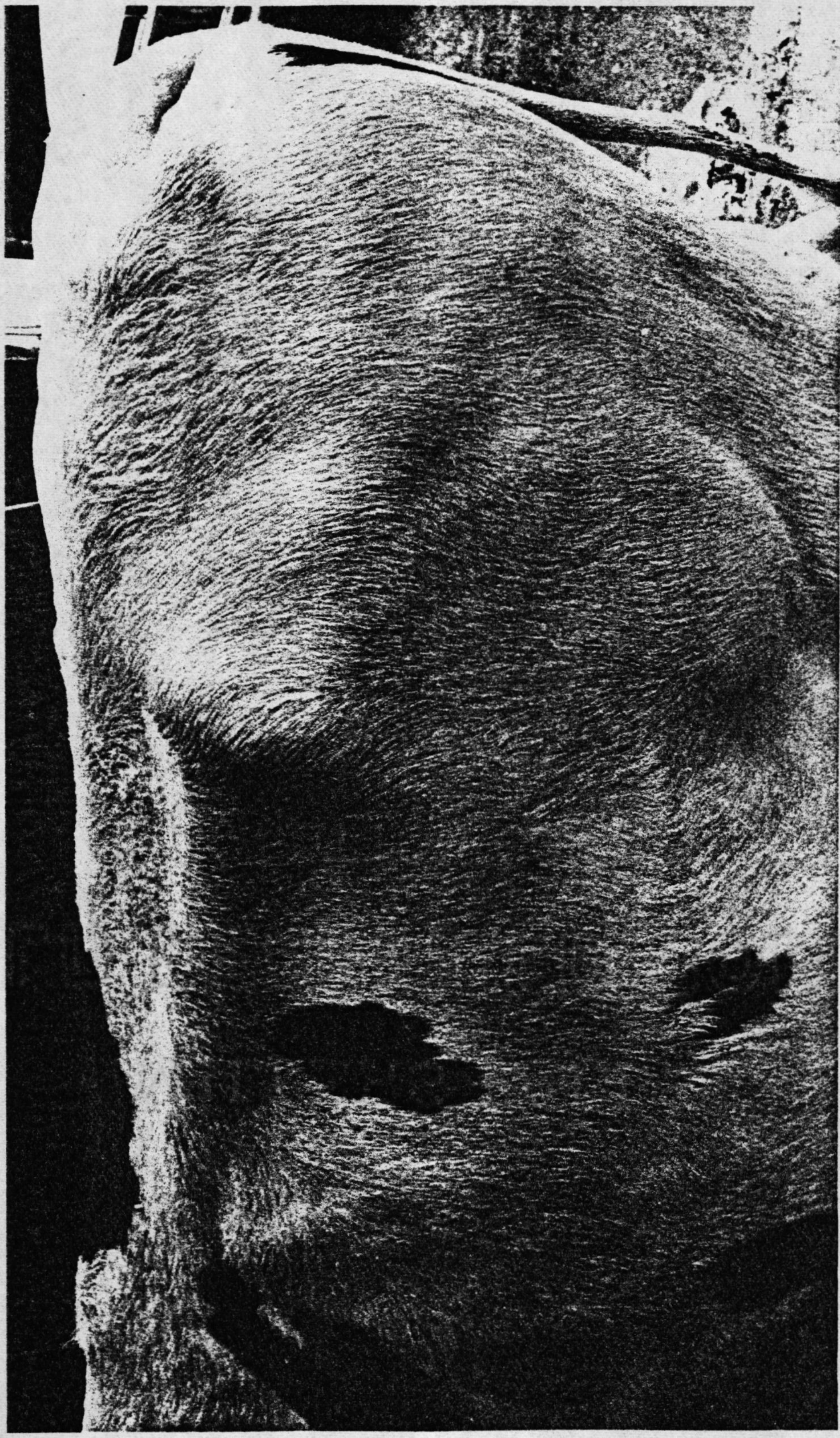

Plate 4. Body condition score 2 - side view.

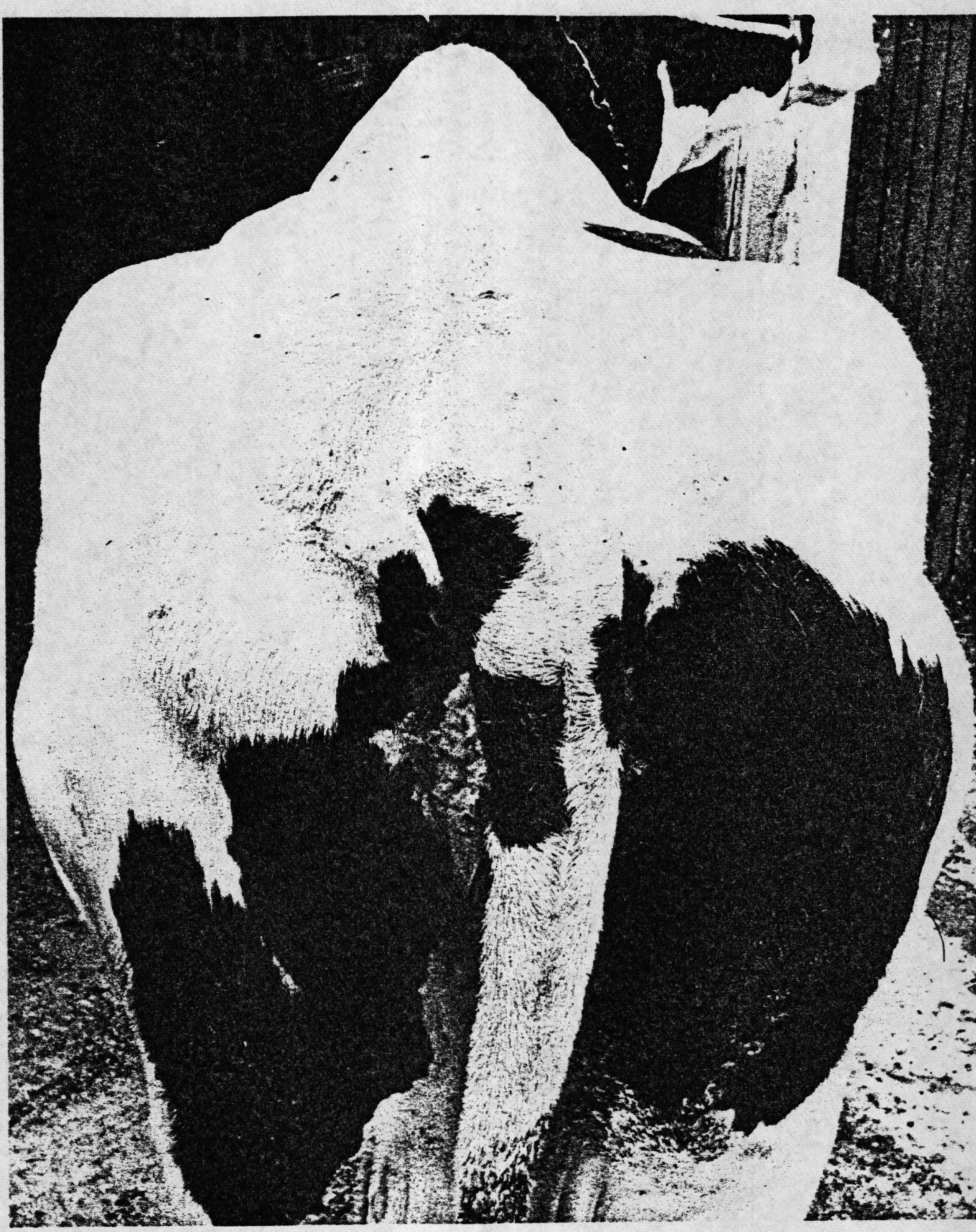

Plate 5. Body condition score 3 - rear view.

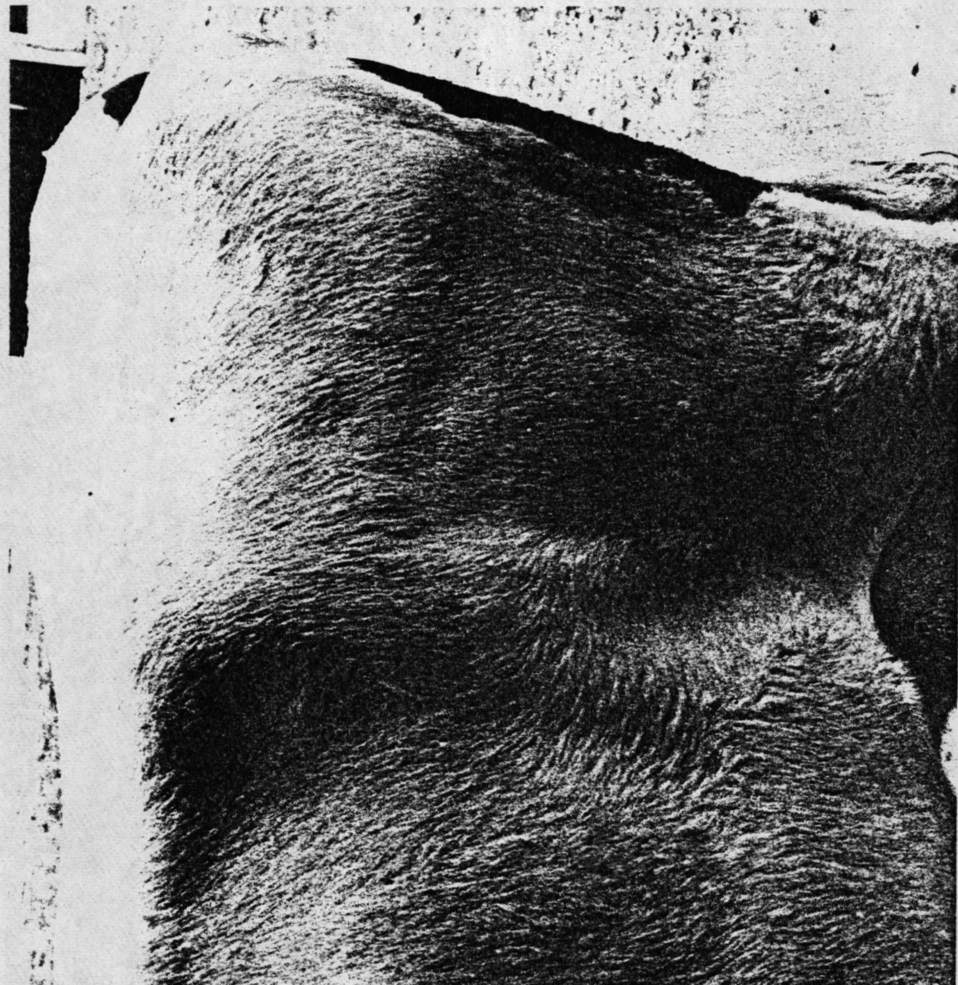

Plate 6. Body condition score 3 - side view.

Plate 7. Body condition score 4 - rear view.

Plate 8. Body condition score 4 - side view.

Plate 9. Body condition score 5 - rear view.

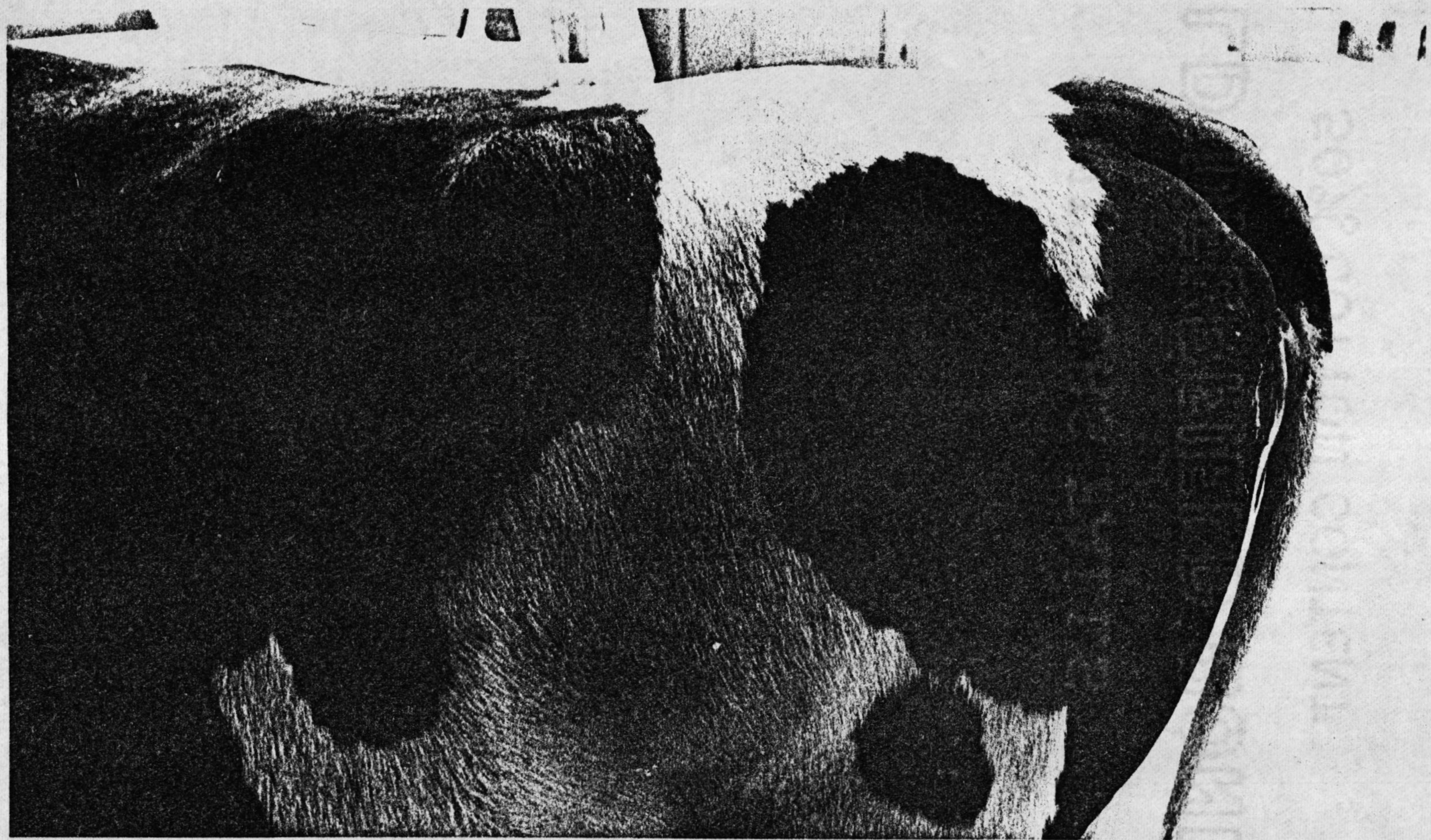

Plate 10. Body condition score 5 - side view.

production and related parameters were each divided into levels as described in Table 1. Dairy merit is the term used by Chandler (3) and is determined by the equation: 4% Fat-Corrected-Milk divided by metabolic weight, or 4% $FCM/W^{.75}$. Four percent FCM was calculated from DHIA monthly test day milk (in kilograms) of individual cows rather than total lactation milk production. Metabolic size was calculated in kilograms. Dairy merit is based on the proposition that partial efficiency, in this case milk production, is independent of body size. Feed capacity is in general proportional to the metabolic body size, and, therefore, production capacity is proportional to metabolic body size (14). Dairy merit is used in this study as a measure of milk production efficiency or milk production per unit of metabolic size.

Table 1. Description of the levels of DHIA milk production and related parameters used in the statistical analysis.

ITEM	LEVEL
Persistency of Lactation - (%)	1) Less than 90 2) 90 - 110 3) Greater than 110
Dairy Merit[a]	1) Less than .16 2) .16 - .22 3) Greater than .22
Days Open - (days)	1) Less than 60 2) 60 - 100 3) Greater than 100
Stage of Lactation - (days)	1) Less than 80 2) 80 - 159 3) 160 - 239 4) Greater than 239 5) Dry period
Age at Calving - (months)	1) Less than 30 2) 30 - 60 3) Greater than 60
Season - (months)	1) December - March 2) April - July 3) August - November

[a]Dairy Merit - daily 4% FCM/$W^{.75}$

EXPERIMENT I

The objectives of experiment I were to determine the relationship between cow weight, frame size measurements, the number of intercostal spaces, and DHIA milk production and related parameters with the body condition scoring system and to establish the optimum body condition score for each stage of the lactation cycle.

Materials and Methods

Data Collection. Each of the 29 cooperative herds was visited (ten per month) at approximately 90-day intervals during a period of 18 months. At each visit, body measurements were recorded for each of the 28 study cows. Cows were given individual body condition scores according to the criteria of the body condition scoring system previously described. The estimated weight of each cow was obtained by using a Nasco weight-by-breed dairy management tape[1]. The wither, sternum, and hook heights of each study cow were measured using a caliper-like measuring device and the number of discernable intercostal spaces was determined by palpation of each cow's ribs.

Presentation of Data. Multiple regression analysis (2) was used to evaluate the relationship between the body condition scoring system, body weight, the number of intercostal spaces, frame size measurements, and DHIA milk production and related parameters. Significant effects were tested by least squares analysis of variance procedure (1).

[1]Nasco, Fort Atkinson, Wisconsin.

Correlation coefficients were determined between all dependent and independent variables. Adjusted means (1) were tested for significance of all possible comparisons by the Scheffe procedure (33).

Results and Discussion

The Relationship of Body Weight, the Number of Intercostal Spaces and Frame Size Measurements to the Body Condition Scoring System. The analysis of variance for the effects of body weight, the number of intercostal spaces, and frame size measurements on body condition score are presented in Table 2. Complete data were obtained from only 12 of the 29 cooperator herds, since facilities for taking frame size measurements were not adequate on the other dairy farms.

Within herd, only body weight, wither height, and the number of palpatable intercostal spaces had a significant effect upon variability within the condition scoring system ($P<.01$). A significant herd effect was also observed ($P<.05$). None of the possible interactions of the independent variables was found to have a significant effect on the body condition scoring system ($P<.05$).

Correlation coefficients (Table 3) show that as body weight increased, a concurrent increase occurred in body condition. However, this explained only 19% of the variation in the body condition scoring system. Similarly, the ratio of body weight to wither height increased as body condition increased, but only accounted for 26% of the variation in the body condition scoring system. The number of palpable intercostal spaces were counted for each study cow at the time of each

Table 2. Analysis of variance for the effects of body weight, the number of apparent intercostal spaces, and frame size measurements on the body condition scoring system.

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Herd	11	.581	1.903*
Weight	1	76.341	249.912**
Wither Height	1	8.974	29.378**
Sternum Height	1	0.083	0.271
Hook Height	1	0.007	0.024
Intercostal Spaces	1	22.264	72.883**
Residual	723	0.305	
Total	739		

** ($P < .01$)

* ($P < .05$)

Table 3. Correlation coefficients for body condition scores, body weight, the number of apparent intercostal spaces, frame size measurements and the ratio of weight to wither height.

	CONDITION	WEIGHT	WITHER HEIGHT	STERNUM HEIGHT	HOOK HEIGHT	INTERCOSTAL SPACES
Weight	0.44**					
Wither Height	0.04	0.62**				
Sternum Height	-0.15**	0.18**	0.49**			
Hook Height	0.08*	0.61**	0.86**	0.41**		
Intercostal Spaces	-0.49**	-0.29**	-0.09**	0.24**	-0.12**	
Ratio[a]	0.51**	0.96**	0.39**	0.04**	0.42**	-0.28**

[a]Ratio = Weight/Wither Height

* (P < .05)

** (P < .01)

condition scoring. As anticipated, the number of spaces decreased with increased body conditioning. However, this measure explained only 23% of the variability in the body condition scoring system.

The correlation coefficients (Table 3) for wither height, sternum height, and hook height all approached zero, indicating that the procedure for the body condition scoring system was not influenced by frame size. Body weight was correlated with each of the frame size measurements and, therefore, could be used as an indicator of frame size, but not as an indicator of body condition as previously defined.

The use of body condition scoring for beef and dairy cows to estimate the effects of condition on production and reproduction parameters has had varying degrees of success. In addition, height, length, and heart girth measurements have been used in an attempt to define body size and determine the effects of obesity on productive and reproductive parameters.

Hokenboken _et al_. (8) calculated the ratio of beef cow weight to height and used the deviations from within treatment regression of weight on height to correct cow and calf performance for fatness. Klosterman _et al_. (15) reported that ratio of weight to height had correlation coefficients of .51 with ultrasonic fat measurements within beef breeds and had correlation coefficients of .89 with body condition scores in dry, open beef cows. Body condition scores were based on a 1 to 5 scale (thin to fat) which was not defined. He further stated that beef cows in average condition have a weight to height ratio of about 4 and from this derived an equation for calculating the amount of digestible energy required for maintenance of cows of different body condition. The results of the present study using dairy cows do not support the results obtained with beef cows. The weight to height ratios had correlation coefficients of only .51 with the body condition scoring system (Table 3).

Klosterman (16), citing the work of Wilson and Lindsey (39), concluded that there was a negative linear relationship between cow weight and weaning weight of the calf, but a curvilinear relationship between the weight to height ratio of the brood cow to the weight of the calf. He also reports that weight alone is not a good measure of cow size due to the effect of body condition, which is in agreement with the findings of the present study. The physical condition scoring system takes into account a factor other than weight or frame size and suggests that the system is indeed an indicator of the degree of fitness of dairy cows.

The Relationship of DHIA Milk Production and Related Parameters to the Body Condition Scoring System. The analysis of variance for the effects of selected DHIA milk production or related parameters on the physical condition scoring system are presented in Table 4. These data were obtained from all 29 cooperator herds.

Within herd, persistency of lactation, dairy merit, days open, stage of lactation, age at calving, season, and the interaction of dairy merit and stage of lactation were all significant ($P<.01$). Adjusted means for body condition score were determined for each level of each independent variable and the differences were

Table 4. Analysis of variance for the effects of selected DHIA milk production and related parameters on the body condition scoring system.

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Herd	28	3.486	9.382**
Persistency of Lactation	2	1.896	5.101**
Dairy Merit	2	14.880	40.044**
Days Open	2	2.043	5.498**
Stage of Lactation	4	14.744	39.680**
Age at Calving	2	2.612	7.029**
Season	2	2.662	7.163**
Dairy Merit x Stage of Lactation	6	2.716	7.308**
Residual	3024	0.372	
Total	3072		

** $(P < .01)$

statistically analyzed for significance. The means for persistency of lactation, dairy merit, days open, and stage of lactation levels were adjusted for herd, age at calving, and season effects. The means for age at calving and season levels were adjusted for herd effect only.

Body condition score means were significantly different ($P<.05$) between each stage of lactation level except levels 4 and 5 which represent cows in milk greater than 239 days and dry cows (Table 5 and Figure 1). This showed that body condition decreased sharply during early lactation, increased from approximately the peak of lactation through the end of lactation, and then was maintained during the dry period. Present dry cow nutrition practices consider gestation and weight only and therefore, body condition at the end of lactation would be expected to remain constant through the dry period. The change in body condition throughout the lactation cycle responded as expected and showed that the body condition scoring system, as defined in this study, accurately differentiated the fitness of cows in various stages of lactation.

All mean body condition scores were significantly different ($P<.05$) at each level of dairy merit (Table 5). Efficient producing cows maintained a body condition score average of 2.5 for the lactation cycle, whereas inefficient producers maintained a greater body condition score of 3.3. Either low producing cows do not have the ability to efficiently utilize body fat for milk production or they are inefficient milk producers and consequently, deposit body fat with greater efficiency. Cows producing at average efficiency are

Table 5. Mean values of body condition score for levels of selected DHIA milk production and related parameters.

ITEM	LEVEL	N	BODY CONDITION SCORE
Stage of Lactation[a] (days)	1) Less than 80	570	2.516[c]
	2) 80 - 159	595	2.708[d]
	3) 160 - 239	649	2.959[e]
	4) Greater than 239	797	3.390[f]
	5) Dry Period	462	3.375[f]
Dairy Merit[a] (4% FCM/W$^{.75}$)	1) Less than .16	1577	3.306[c]
	2) .16 - .22	876	2.815[d]
	3) Greater than .22	620	2.496[e]
Persistency of Lactation[a] (%)	1) Less than 90	650	2.677[c]
	2) 90 - 110	1698	3.010[d]
	3) Greater than 110	725	3.278[e]
Days Open[a] (days)	1) Less than 60	628	2.656[c]
	2) 60 - 100	1041	2.917[d]
	3) Greater than 100	1404	3.221[e]
Age at Calving[b] (months)	1) Less than 30	226	3.066[c]
	2) 30 - 60	1731	3.032[c]
	3) Greater than 60	1116	3.045[c]
Season[b] (months)	1) December - March	917	3.056[c]
	2) April - July	1129	3.077[c]
	3) Aug. - Nov.	1027	2.984[d]

[a]Mean values were adjusted for herd, age at calving, and season effects.

[b]Mean values were adjusted for herd effects.

[c,d,e]Mean values within an item with different letters were significantly different ($P < .05$).

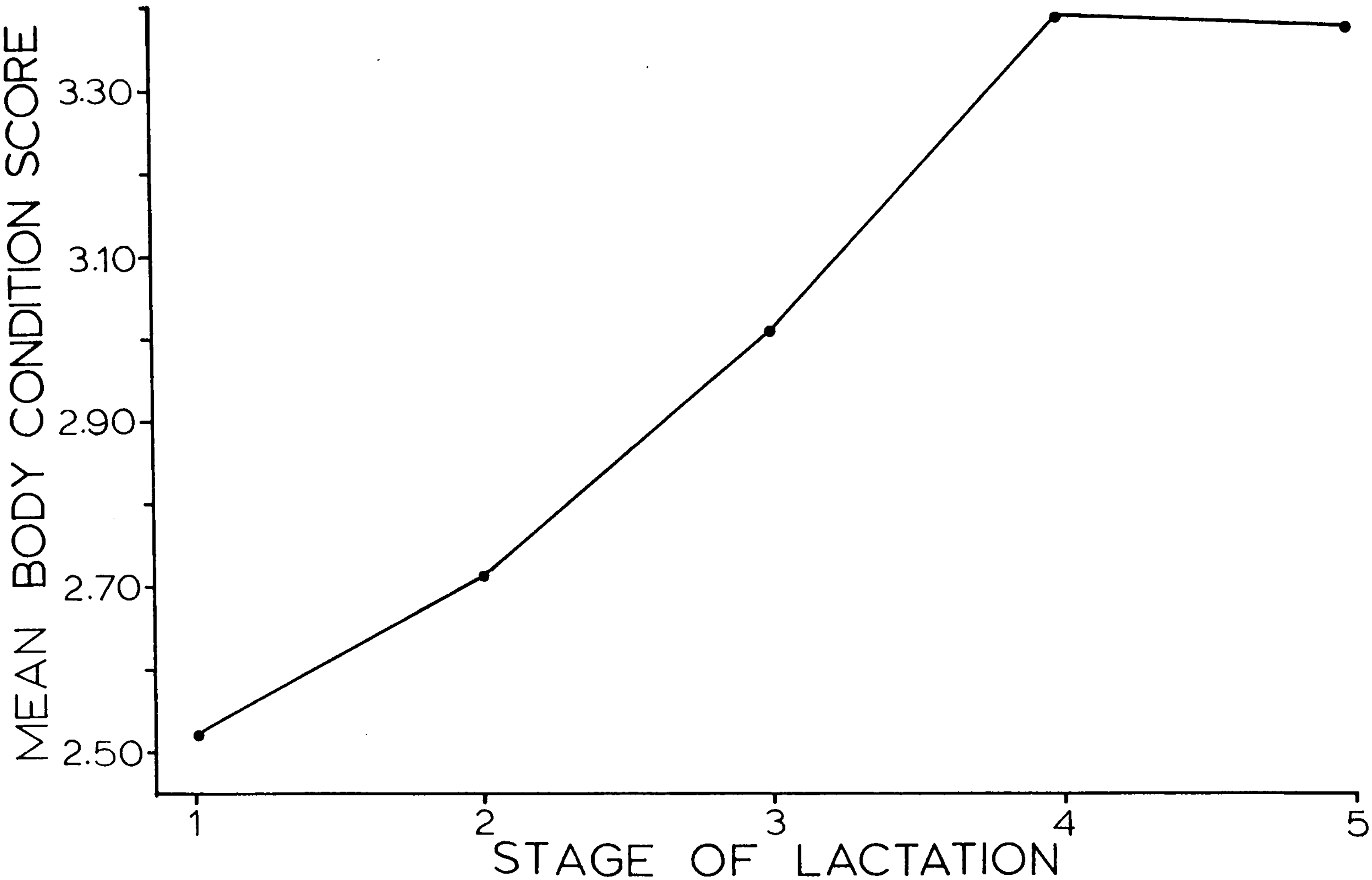

Figure 1. Mean values of body condition score for each stage of lactation.

intermediate in body condition (2.8).

Average body condition scores were all significantly different (P<.05) between each level of persistency of lactation (Table 5). Cows of greater persistency of lactation were found to have a body condition score average of 3.3 and low persistency cows had an average of 2.7. Average persistency cows were intermediate with an average body condition score of 3.0. Hence, as average body condition score increased, persistency of lactation increased. The interaction of persistency of lactation and dairy merit was not significant (P<.05), and therefore, the contradiction of the dairy merit and persistency of lactation results are difficult to explain. It is possible that since persistency of lactation is based on each month's projected 305-day mature equivalent 4% fat-corrected-milk, the interaction was confounded and therefore, insignificant. Since DHIA uses a single average lactation curve as a basis on which to compare the persistency of each cow, an efficient producing cow may have an "abnormal" lactation curve, as compared with the average curve, but such a lactation curve may be desirable. The greater slopes, ascending and descending, project low persistency of lactation, but overall production for the lactation could be greater than that of the average producing cow. If indeed this is the case, then lower body condition cows could have been more efficient producers and yet less persistent.

Average body condition scores at different days open were significantly different (P<.05; Table 5). Body condition score increased as days open increased. Cows open less than 60 days were found to have an average score of 2.6, but cows open greater than 100 days had an average of 3.2. Cows open 60 to 100 days were intermediate (2.9). The fetus is considered to have a negligible effect on the energy requirements of the dam until after 200 days (25). Thus, the stage of a cow being open or pregnant should have no effect on body condition. There are numerous factors affecting days open, one of which may be that she is overconditioned.

Body condition score was not affected by age at calving (P>.05). For season, only August through November (level 3) was significantly different (P<.05) from the other periods of the year. Although different statistically, the average body condition scores for each season were not different for practical purposes.

The effect of dairy merit, within stage of lactation, upon body condition is shown in Tables 6 and 7. Figure 2 presents graphs of each of the three dairy merit levels by mean body condition score for each stage of lactation.

For the low production group (dairy merit level 1), body condition score increased significantly as the lactation progressed (P<.05; Table 6). For the medium production group (dairy merit level 2), cows at 160 to 239 days in milk had a significant increase in body condition compared to cows during early lactation (less than 80 days; P<.05). Body condition score increased with advancing lactation. For the highest production group (dairy merit level 3), body condition did not increase with advancing lactation.

Mean body condition scores were not significantly different

Table 6. Mean values of body condition score for stage of lactation level by dairy merit level.[a]

LEVELS		N	BODY CONDITION SCORE
Dairy Merit (4% FCM/W$^{.75}$)	Stage of Lactation (Days)		
1) Less than .16	1) Less than 80	97	2.569[b]
	2) 80 - 159	126	2.952[c]
	3) 160 - 239	289	3.194[d]
	4) Greater than 239	603	3.500[e]
2) .16 - .22	1) Less than 80	131	2.595[b]
	2) 80 - 159	284	2.754[bc]
	3) 160 - 239	282	2.812[c]
	4) Greater than 239	179	3.077[d]
3) Greater than .22	1) Less than 80	342	2.472[b]
	2) 80 - 159	185	2.470[b]
	3) 160 - 239	78	2.617[b]
	4) Greater than 239	15	2.725[b]

[a]Mean values were adjusted for herd, age at calving, and season effects.

[b,c,d,e]Mean values within a dairy merit level with different letters were significantly different ($P < .05$).

Table 7. Mean values of body condition scores for dairy merit level by stage of lactation level.[a]

LEVELS: Stage of Lactation (Days)	LEVELS: Dairy Merit (4% FCM/$W^{.75}$)	N	BODY CONDITION SCORE
1) Less than 80	1) Less than .16	97	2.569[b]
	2) .16 - .22	131	2.595[b]
	3) Greater than .22	342	2.472[b]
2) 80 - 159	1) Less than .16	126	2.952[b]
	2) .16 - .22	284	2.754[c]
	3) Greater than .22	185	2.470[d]
3) 160 - 239	1) Less than .16	289	3.194[b]
	2) .16 - .22	282	2.812[c]
	3) Greater than .22	78	2.617[d]
4) Greater than 239	1) Less than .16	603	3.500[b]
	2) .16 - .22	179	3.077[c]
	3) Greater than .22	15	2.725[c]

[a]Mean values were adjusted for herd, age at calving, and season effects.

[b,c,d]Mean values within a stage of lactation level with different letters were significantly different ($P < .05$).

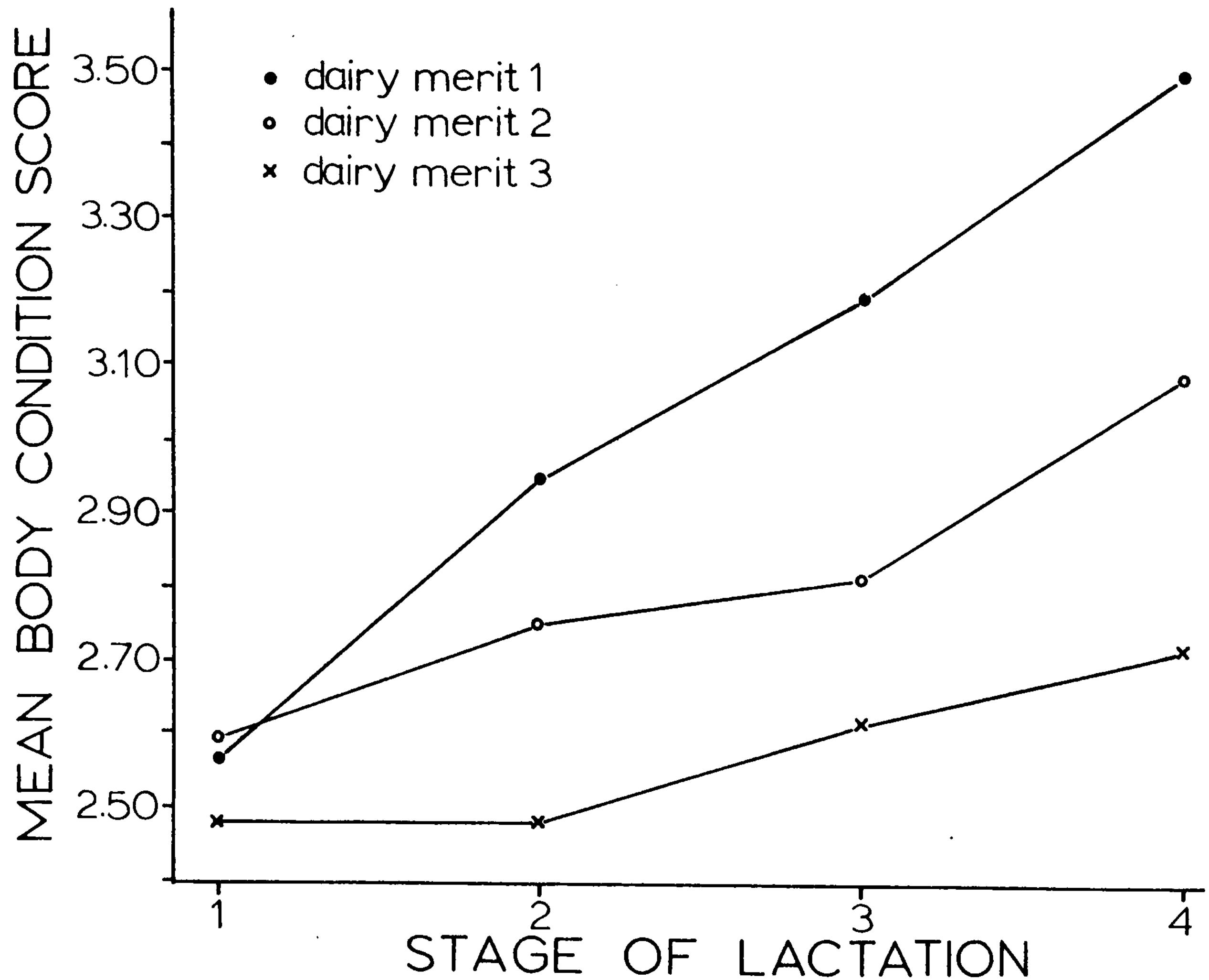

Figure 2. Mean values of body condition score for each stage of lactation within dairy merit level.

($P > .05$) between low, medium, and high producing cows (dairy merit levels 1, 2, and 3) in early lactation (less than 80 days; Table 7). For cows in lactation 80 to 239 days (stages of lactation 2 and 3), mean body condition scores decreased significantly as production level (dairy merit level 1 to 3) increased ($P < .05$). For cows in lactation greater than 239 days (stage of lactation 4), low producing cows (dairy merit level 1) had significantly greater mean body condition scores than medium or high producing cows (dairy merit levels 2 and 3; $P < .05$). Mean body condition decreased as production level increased.

The results show that all cows tended toward a common body condition during the first 80 days of lactation. The more efficient, higher producing dairy cows did not change significantly in body condition throughout lactation ($P > .05$). However, inefficient producers increased significantly in body condition ($P < .05$) and apparently were more efficient in converting energy to body fat than to milk.

The analysis of variance for the effects of the body condition scoring system and selected DHIA milk production and related parameters on dairy merit is presented in Table 8. The effects of herd, body condition score, stage of lactation, age at calving, as non-continuous independent variables, and the interaction of body condition score with age at calving were all significant ($P < .01$) as were the effects of season and the interaction of body condition score and season ($P < .05$). The interaction of body condition score and stage of lactation was not significant ($P > .05$).

The means for dairy merit, adjusted for herd, age at calving, and season effects, for each body condition score are presented in Table 9

Table 8. Analysis of variance for the effects of body condition score and selected DHIA milk production and related parameters on dairy merit.

SOURCE	DEGREES OF FREEDOM	MEAN SQUARE	F RATIO
Herd	28	.025	18.790**
Body Condition	4	.015	11.547**
Stage of Lactation	3	.013	10.008**
Age at Calving	2	.010	7.576**
Season	2	.004	3.016*
Condition x Stage	8	.002	1.456
Condition x Age	6	.004	2.824**
Condition x Season	7	.003	2.196*
Residual	1732	.001	
Total	1792		

* (P < .05)

** (P < .01)

Table 9. Mean values[1] of dairy merit for each body condition score.

BODY CONDITION SCORE	N	DAIRY MERIT (4% FCM/W$^{.75}$)
1	4	0.26[a]
2	260	0.22[a]
3	1094	0.18[b]
4	397	0.14[c]
5	38	0.11[d]

[1]Mean values were adjusted for herd, age at calving, and season effects.

[a,b,c,d]Means with different letters were significantly different ($P < .05$).

and Figure 3. The means of dairy merit for each body condition score were significantly different ($P < .05$), except between undercondition cows (scores 1 and 2). As body condition scores increased, dairy merit decreased by greater than 50%. Therefore, the overconditioned dairy cow is inefficient for milk production.

Kress et al. (18) found a negative relationship between beef cow weight and efficiency of production and concluded that fat cows are inefficient, which is in agreement with the present study. However, weight has been shown to be less accurate as an indicator of fitness than the body condition scoring system, as previously stated.

Dickenson et al. (6), in agreement with Hooven et al. (9), Mason et al. (20) and Stone et al. (34), found that there was a consistent negative relationship between efficiency of feed utilization for production and body size. Similar findings to the present study showed that efficiency of milk production decreased with increased body condition. Dickenson et al. (6) used three measurements to determine body size, chest girth, wither height, and body length. These measurements only partially accounted for body condition as shown by the present study. The body condition scoring system is a means of accounting for degree of fitness or body condition per se.

Morris and Wilton (23) stated that the heritability of weight change during lactation was low and therefore, weight change is mainly associated with feed consumption. They reported that feed efficiency for lactation decreased as excess body weight increased during lactation. Similarly, the present study showed that efficiency of

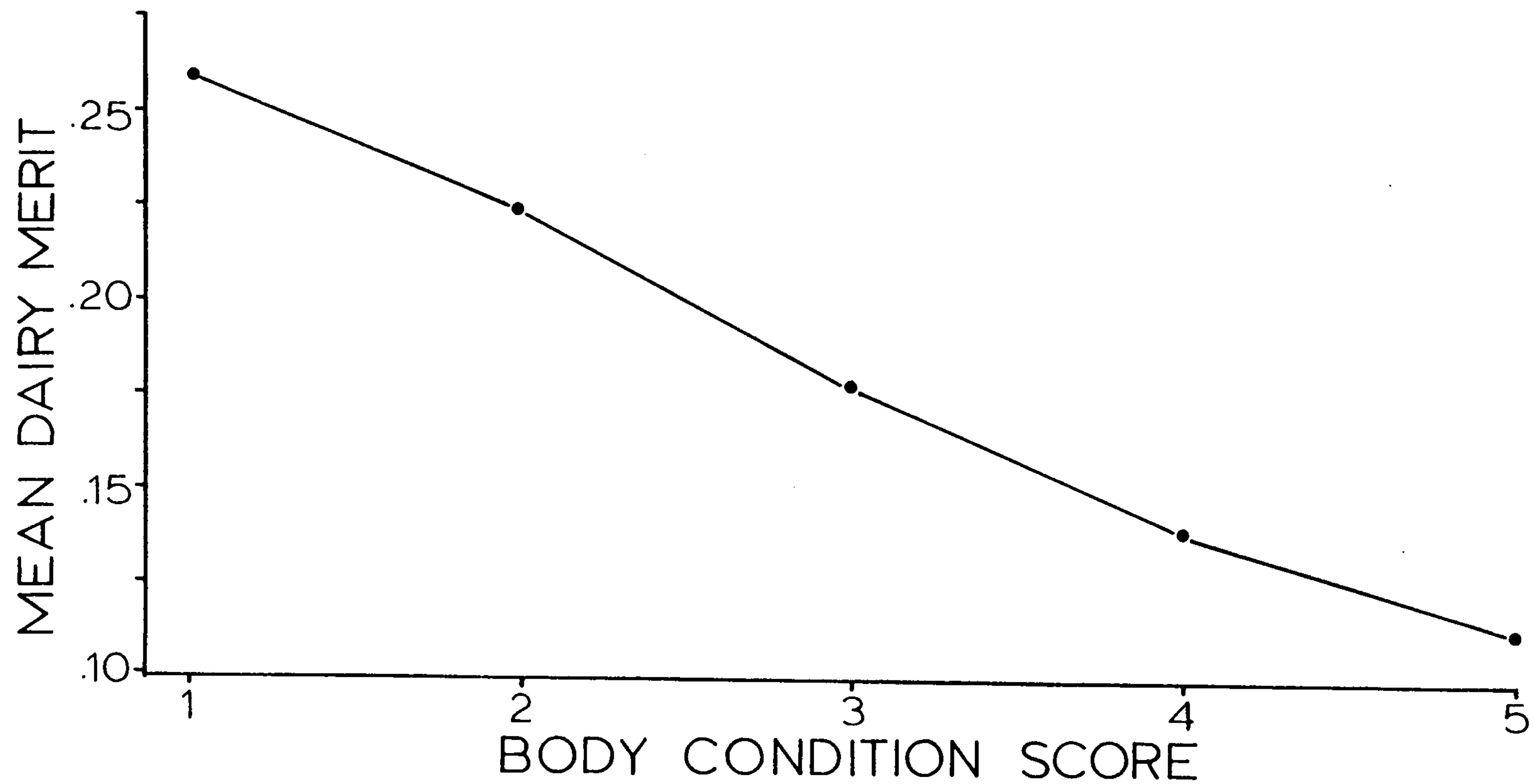

Figure 3. Mean values of dairy merit for each body condition score.

production decreased as body condition increased during lactation; body condition being independent of frame size. Belyea *et al*. (4) found that, on the average, dairy cows gain 66% of their total production cycle weight increase during lactation and the remaining 34% during the dry period. In the present study, cows remained in relatively constant body condition from the end of lactation through the dry period. Belyea *et al*. (4) further stated that replenishing body tissue reserves should occur during the latter part of lactation, since lipogenesis during that time is more efficient than it is during the dry period. The experience of the present study showed that a greater number of dairy cows were in good to overcondition by the dry period than were undercondition. The problem may be to control excess lipogenesis in late lactation to prevent fat cow syndrome after parturition for the subsequent lactation as stated by Troutt (37) and by Morrow (24). Moe *et al*. (21) showed that efficiency of body weight gain in late lactation is equal to that of milk production. Moe *et al*. (22) showed that energetic efficiency of fat deposition during lactation is 82% compared to 59% during the dry period.

General Discussion

A technique for condition scoring of beef cattle was developed by Lowman *et al*. (19). The scoring system of one to five, light to heavy, respectively, has proved to be accurate and valuable in reducing the incidence of calving difficulties, and improving subsequent lactation performance. Services per conception, calving interval, and percentage of barren cows were all reduced by the use of condition scoring for control of cow fitness. Although a subjective technique, farmers were able to feed their livestock to meet specified condition scores during a given point in the production cycle.

In a study of factors affecting forage intake, Johnson et al. (11) used a visual rating scale for body condition of 1 (very fat) to 6 (very thin). They reported that the average body condition rating for the three year study of Holstein cows was 3.3 and found little effect of body condition on forage intake. This is in disagreement with the work of Reid et al. (30) who found that overconditioned cows had depressed appetite post-partum.

Work with beef cattle has shown that a condition scoring system can be accurate and used as a management tool to improve reproductive and productive performance. The present study showed that the body condition scoring system is an accurate means of determining the degree of fitness in dairy cows, independent of cow frame size.

The present study was not able to examine the effects of the body condition scoring system on health parameters. Weight gains of up to .30 kg per day with no visual appearance of excess body weight gain and no increase in health problems have been reported by Wagner (38) in a review of the literature. These reports did not indicate the rate of weight gain, nor increase in body condition, that will cause increased health problems. Since efficiency of weight gain is greatest during lactation, it would be of benefit to control excess weight gain prior to the dry period by using the body condition scoring system.

Everson, et al. (7), Morrow (24), and Troutt (37) suggested that cows that gain excessive weight during mid to late lactation are more susceptible to health disorders at parturition. Morrow (24) reported that the predominent disorders were milk fever, ketosis, displaced abomasum, downer cow syndrome, mastitis, retained placenta, and metritis. Troutt (37) used the term "fat cow syndrome" to describe the combination of these various metabolic, digestive, infectious, and reproductive conditions that affect overconditioned cows post-partum. Jorgenson (12) reported that overconditioned cows were more susceptible to milk fever, ketosis, and fatty liver. Coppock (5), Schultz (31), and Shaw (32) concurred with the increased occurrence of ketosis in overconditioned dairy cows. The incidence of displaced abomasum was found by Ide and Henry (10) to be more prevalent in overconditioned cows.

The present study showed that dairy cows of greatest milk production efficiency were cows that did not increase significantly in body condition throughout lactation. They maintained a body condition score of between 2.5 and 2.8, had fewer days open, but persistency of lactation was less, which may not actually be detrimental. Dairy cows that increased significantly in body condition were less efficient milk producers, had a greater number of days open, and reached body condition scores of greater than 3.0. Presumably, cows in this body condition may have had a greater incidence of health disorders, however, this needs to be further examined. The effect of overconditioning over a number of lactations, using the body condition scoring system, would provide greater insight into the relationship between health disorders and body condition.

SUPPLEMENT TO EXPERIMENT I

The effect of body condition during the dry period on dairy merit within stage of lactation during the subsequent lactation is presented in Table 10 and Figure 4. However, the number of observations for body condition scores 1 and 2 were relatively few and, therefore, no significant differences ($P > .05$) were found between means of dairy merit for cows with different body condition score during the previous dry period. Nevertheless, the trends found are of interest and are thus presented as nonstatistically evaluated data.

Cows that were slightly overconditioned during the previous dry period (score 4) tended to have greater dairy merit values during the first 80 days (state of lactation 1) than cows of lower or higher body condition (scores 2, 3, and 5). Cows in milk 80 to 159 days (stage of lactation 2) that were in normal condition or slightly overcondition (scores 3 and 4) tended to have greater dairy merit values. Cows in milk greater than 160 days (stages of lactation 3 and 4) and in lower body condition (score 2) during the previous dry period had greater dairy merit values than cows that had greater body condition during the previous dry period (scores 3, 4, and 5).

The implication is that cows that were greatly overconditioned during the previous dry period (score 5) were never as efficient in milk production as cows that were in normal condition to slightly overcondition during the previous dry period (score 3 and 4). Although underconditioned cows were more efficient during the second half of lactation (stages of lactation 3 and 4), such cows would not be in

Table 10. Mean values[1] of dairy merit for body condition score during the previous dry period by stage of lactation.

Stage of Lactation (days)	Body Condition Score	N	Dairy Merit (4% FCM/$W^{.75}$)
1) Less than 80	2	37	0.21
	3	354	0.23
	4	250	0.24
	5	18	0.22
2) 80 - 159	2	27	0.18
	3	335	0.20
	4	246	0.20
	5	11	0.18
3) 160 - 239	2	12	0.17
	3	233	0.16
	4	161	0.16
	5	5	0.14
4) Greater than 239	2	2	0.16
	3	76	0.13
	4	66	0.14
	5	4	0.12

[1]Mean values were adjusted for herd, age at calving, and season effects.

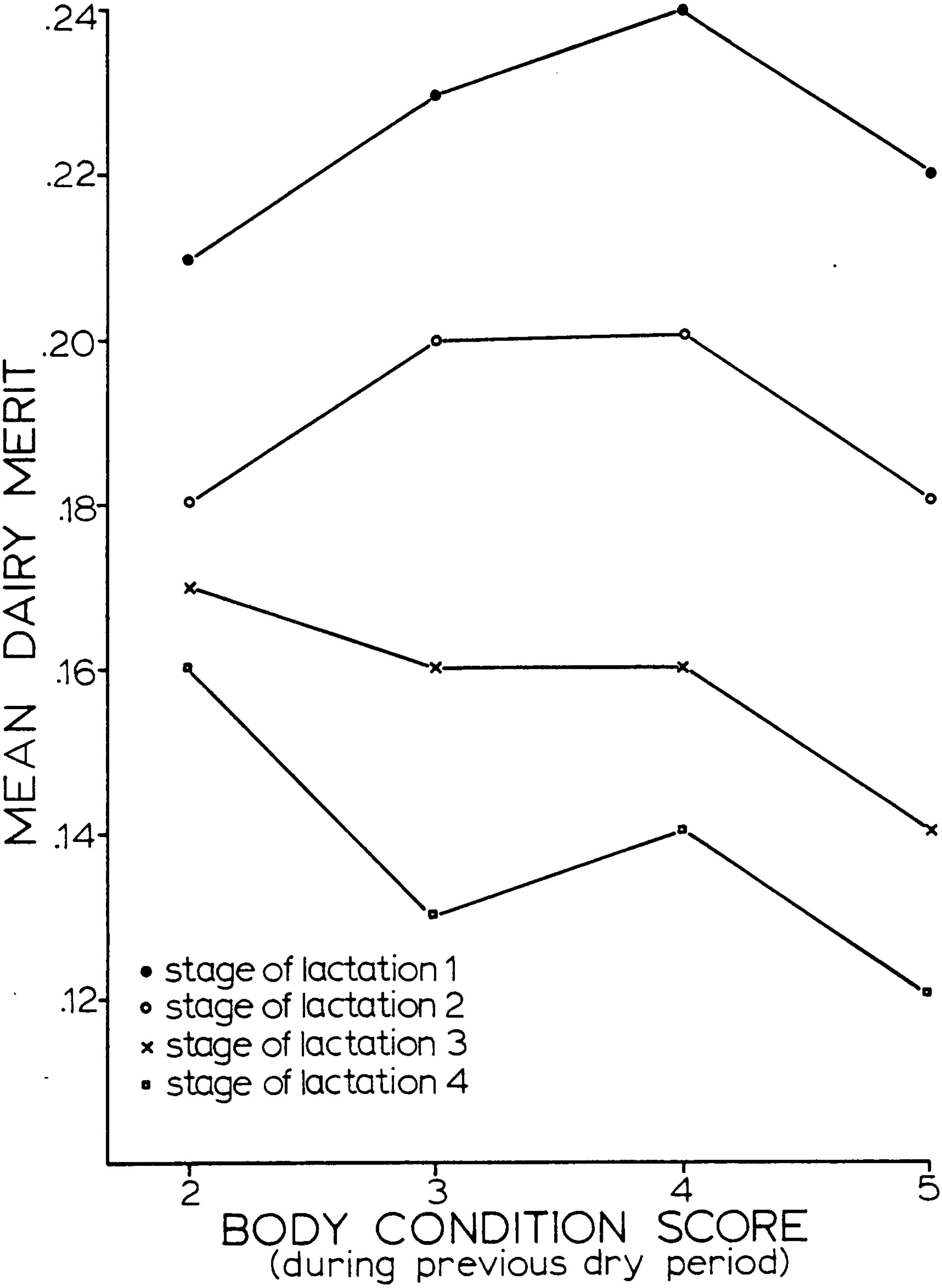

Figure 4. Mean values of dairy merit for each body condition score during the previous dry period within stage of lactation.

proper body condition in preparation for the subsequent lactation. The data indicate that cows should be in normal condition to slightly overcondition during the dry period for maximum milk production efficiency during the subsequent lactation. However, further research with a greater number of cows is necessary to substantiate these results.

EXPERIMENT II

The objective of experiment II was to determine the effects of the body condition scoring system, within stage of lactation and within dairy merit level, on blood profiles of dairy cows.

Materials and Methods

Sample Collection. Each of the 29 cooperator herds was visited (ten per month) at approximately 90-day intervals during a period of 18 months. At each visit, blood samples were drawn from the coccygeal artery or vein of each of the 28 study cows using vacutainer tubes, single sample needles, and needle holders[2]. One serum tube, a second tube containing sodium fluoride, and a third containing heparin or ethylenediamine tetraacetic acid (EDTA) were used in obtaining the samples from each cow. Samples were cooled immediately in an ice chest and serum or plasma removed within 12 hours and frozen.

Sample Analysis. Each serum sample was analyzed for phosphorus, magnesium, albumin, globulins (alpha, beta-1, beta-2, and gamma), blood urea nitrogen, creatine phosphokinase, alkaline phosphatase, and serum glutamic oxaloacetic transaminase. Phosphorus and magnesium content were determined by spectrophotometry, using the Pierce Rapid State Kits[3]. Albumin and the alpha, beta-1, beta-2, and gamma

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[2]Becton, Dickinson and Company, Rutherford, New Jersey.

[3]Pierce Chemical Company, Rockford, Illinois.

globulin contents were determined by Serum Protein Electrophoresis[4], utilizing the Seprophore III Cellulose Polyacetate Membrane with the Sepratek System and the quantitiative method of scanning with a Gelman DCD-16. Blood urea nitrogen, creatine phosphokinase, alkaline phosphatase, and serum glutamic oxaloacetic transaminase contents were determined by spectrophotometry, using the Worthington Kits[5].

Each sodium fluoride sample was analyzed for glucose. The glucose content was determined by spectrophotometry, using the Worthington Glucose Kit[5].

Each heparin or EDTA sample was analyzed for red blood cells, white blood cells, hematocrit, mean corpuscular volume, hemoglobin, calcium and total protein. The ZBI Coulter Hemoglobinometer and Coulter RBC/MCV/HCT Computer System was used to determine hemoglobin, red blood cells, white blood cells, mean corpuscular volume, and hematocrit of each sample. Calcium and total protein contents were determined by spectrophotometry using the Pierce Calcium Rapid Stat Kit[3] and the Worthington Total Protein Kit[5].

Presentation of Data. Multiple regression analysis (2) was used to evaluate the relationship between the body condition scoring system, stage of lactation, dairy merit, and blood parameters. Significant effects were tested by least-squares analysis of variance procedure (1). Adjusted means (1) were tested for significance of all possible

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[4]Gelman Instrument Company, Ann Arbor, Michigan.

[5]Worthington Biochemical Corporation, Freehold, New Jersey.

comparisons by the Scheffe procedure (33).

It should be noted that the number of observations is different for each condition score group. Therefore, two means each of a large number of observations have a greater chance of being significantly different than two means that each have a lesser number of observations. This is because the formula for Scheffe's test considers unequal numbers of observations. For example, three means may decrease from first to third. However, the first and third mean may not be significantly different whereas the middle mean may be significantly different from each of the other two means. This is due to the first and third means each having few observations while mean two had a large number of observations. The number of observations for each mean, as well as the numerical difference between means must be considered in evaluating the practical significance of these data.

Results and Discussion

The Relationship of the Body Condition Scoring System, Stage of Lactation and Dairy Merit to Blood Parameters in Dairy Cows. The analysis of variance for the effects of body condition score and the interactions of body condition score with stage of lactation and dairy merit levels on blood parameters were evaluated. Adjusted mean values of each blood parameter were tested only if the F ratio for that parameter was significant ($P < .05$). Significant differences between body condition scores were found for red blood cells (RBC), hematocrit (HCT), mean corpuscular volume (MCV), hemoglobin (Hb), calcium (Ca), phosphorus (P), albumin, serum glutamic oxaloacetic transaminase

(SGOT), and α, β-1, β-2, and γ globulins ($P < .05$, Table 11). White blood cells (WVC), magnesium (Mg), glucose, total protein (TP), creatine phosphokinase, and alkaline phosphatase were not tested, since the F-tests on these parameters were not significant ($P > .05$).

As body condition score (BCS) increased, RBC, HCT, MCV, and Hb all increased. The means of RBC were not significantly different ($P > .05$) between cows categorized as in normal condition (BCS 3) and cows in excessive body condition (BCS 4 and 5). Extremely thin and thin cows (BCS 1 and 2) each had lower RBC levels ($P < .05$). Increasing body condition was accompanied by higher HCT and HB levels, except at the highest body condition (BCS 5; $P < .05$). MCV increased ($P < .05$) from underconditioned cows (BCS 2) to cows with excessive body condition (BCS 5). Thinner cows and cows categorized as normal (BCS 2 and 3) had higher MCV values than the thinnest cows (BCS 1), but differences were not significant ($P > .05$). Although Ca increased with increasing body condition, statistically there was little relationship between body condition and Ca or P.

The means of albumin were significantly less and the means of γ globulin were significantly greater ($P < .05$) for severely underconditioned cows (BCS 1) than for cows of greater body condition. Although sigificant differences were found between the other levels of body condition (BCS 2-5), the means did not differ enough to be of practical application. No significant differences were found between body condition groups for α and β-2 globulins.

The means of SGOT were significantly different between each of

Table 11. Mean values of red blood cells, hematocrit, mean corpuscular volume, hemogloblin, calcium and phosphorus by body condition score.[a]

Body Condition Score	N	Red Blood Cells ($10^6/mm^3$)	Hematocrit (mg/100ml)	Mean Corpuscular Volume (^{3}/cell)	Hemoglobin (g/100 ml)	Calcium (mg/100ml)	Phosphorus (mg/100ml)
1	32	5.65[b]	27.07[b]	47.65[bc]	10.26[b]	8.61[b]	6.09[bc]
2	572	6.14[c]	29.65[c]	48.46[b]	11.03[c]	8.92[b]	6.25[bc]
3	1625	6.45[d]	31.65[d]	49.15[c]	11.83[d]	9.06[c]	6.29[b]
4	596	6.55[d]	33.60[e]	51.38[d]	12.42[e]	9.14[c]	6.12[c]
5	65	6.48[d]	34.80[e]	53.89[e]	12.45[e]	9.24[c]	5.92[bc]

[a]Mean values were adjusted for herd, age at calving, and season effects.

[b,c,d,e]Mean values within a column with different letters were significantly different ($P < .05$).

Table 11. Continued. Mean values of albumin, α globulin, β-2 globulin, γ globulin, and serum glutamic oxaloacetic transaminase (SGOT) by body condition score.[a]

Body Condition Score	N	Albumin (g/100ml)	α Globulin (g/100ml)	β-2 Globulin (g/100ml)	γ Globulin (g/100ml)	SGOT (I.U./1)
1	32	2.94^{b}	1.03^{b}	1.03^{b}	1.98^{b}	56.28^{bcd}
2	572	3.37^{c}	1.01^{b}	0.97^{b}	1.64^{c}	54.11^{b}
3	1625	3.48^{d}	1.00^{b}	0.94^{b}	1.46^{d}	51.48^{c}
4	596	3.51^{d}	0.99^{b}	0.95^{b}	1.40^{d}	48.72^{d}
5	65	3.50^{cd}	1.01^{b}	0.97^{b}	1.53^{cd}	42.34^{bcd}

[a] Mean values were adjusted for herd, age at calving, and season effects.

[b,c,d,e] Mean values within a column with different letters were significantly different ($P < .05$).

the middle three body condition groupings (BCS 2-4). Means for severely underconditioned and highly overconditioned cows (BCS 1 and 5) were not significantly different from the other condition score groupings. However, as body condition increased SGOT blood levels decreased.

Increasing body condition score was positively associated with increasing levels of RBC, HCT, MCV, Hb, Ca, albumin and decreasing γ globulin and SGOT levels. These results indicate that body condition may affect the practical interpretation of dairy cow blood profiles and that the body condition scoring system can separate cows into distinct groups.

Significance between means of RBC, HCT, MCV, Hb, albumin, and α, β-1, and γ globulins for each body condition score within each dairy merit level was tested (Table 12). These were the only blood parameters having significant ($P < .05$) F ratios for the physical condition-dairy merit interaction. There was no extremely overconditioned cows (BCS 5) in the higher producing groups of cows (dairy merit levels 2 and 3).

For low and medium production cows (dairy merit 1 and 2), means of RBC increased ($P < .05$) as body condition increased from very thin to normal (BCS 1-3). Cows of higher body condition did not differ ($P > .05$). RBC levels for high production cows (dairy merit 3) did not change with increasing body condition ($P > .05$).

Means of HCT increased from severely overconditioned to overcondition (BCS 1-4) for low production cows (dairy merit 1) and from severely overconditioned to normal condition (BCS 1-3) for medium

Table 12. Mean values[1] of red blood cells, hematocrit, mean corpuscular volume, hemoglobulin, albumin, α globulin, β-1 globulin, and γ globulin by body condition score within dairy merit level.

Dairy Merit (4% FCM/W.75)	Body Condition Score	N	Red Blood Cells ($10^6/mm^3$)	Hematocrit (mg/100ml)	Mean Corpuscular Volume (μ^3/cell)	Hemoglobulin (g/100ml)	Albumin (g/100ml)	α globulin (g/100ml)	β-1 globulin (g/100ml)	γ globulin (g/100ml)
1) Less than .16	1	13	5.72[a]	25.64[a]	46.20[a]	9.73[a]	2.62[a]	0.93[a]	0.772[a]	2.08[a]
	2	142	6.16[b]	29.95[b]	48.76[ab]	11.15[b]	3.22[b]	1.03[a]	0.964[b]	1.68[ac]
	3	744	6.54[c]	32.24[c]	49.45[b]	12.02[c]	3.46[c]	1.00[a]	0.955[b]	1.48[b]
	4	501	6.56[c]	33.82[d]	51.55[c]	12.50[d]	3.50[c]	0.99[a]	0.977[b]	1.41[b]
	5	61	6.44[bc]	34.62[d]	54.08[d]	12.40[cd]	3.49[c]	1.01[a]	0.963[b]	1.53[bc]
2) .16-.22	1	9	5.37[a]	26.25[a]	48.43[ab]	9.83[a]	3.05[ab]	1.00[a]	0.994[a]	1.79[ab]
	2	192	6.27[b]	30.10[b]	48.34[a]	11.00[a]	3.36[a]	1.00[a]	0.989[a]	1.69[a]
	3	551	6.51[c]	31.77[c]	48.80[a]	11.80[b]	3.50[b]	0.99[a]	0.975[a]	1.42[b]
	4	80	6.62[c]	32.91[c]	50.41[b]	12.13[b]	3.59[b]	1.00[a]	0.966[a]	1.28[b]
	5	0	--	--	--	--	--	--	--	--
3) Greater than .22	1	10	5.82[a]	29.66[ab]	48.83[a]	11.32[ab]	3.25[a]	1.21[a]	0.99[a]	2.02[a]
	2	238	6.02[a]	29.11[a]	48.38[a]	10.98[a]	3.48[a]	1.01[b]	0.98[a]	1.58[a]
	3	330	6.14[a]	30.15[b]	49.05[a]	11.43[b]	3.51[a]	1.01[b]	0.99[a]	1.48[a]
	4	15	5.89[a]	30.18[ab]	51.07[a]	11.12[ab]	3.43[a]	1.00[b]	1.00[a]	1.66[a]
	5	0	--	--	--	--	--	--	--	--

[1] Mean values were adjusted for herd, age at calving, and season effects.

[a, b, c, d] Mean values within dairy merit level with different letters were significantly different ($P < .05$).

production cows (dairy merit 2; $P < .05$).

Means of MCV increased as body condition increased for low production cows (dairy merit 1) with the differences between very thin and thin cows (BCS 1 and 2) and thin and normal cows (BCS 2 and 3) showing no significance ($P > .05$). For the medium production group (dairy merit 2), overconditioned cows (BCS 4) had greater levels of MCV than thin or normal cows (BCS 2 and 3; $P < .05$) but not severely underconditioned cows (BCS 1). There were no differences between MCV means as body condition changed within the high production (dairy merit 3) group of cows.

Means of Hb increased from very thin to overconditioned cows (BCS 1-4) in the low production group (dairy merit 1; $P < .05$). In the medium production group (dairy merit 2), MCV means increased as body condition increased, although only the differences between underconditioned cows (BCS 1 and 2) and normal and overconditioned cows (BCS 3 and 4) were significant ($P < .05$). For the high production group (dairy merit 3), MCV means were greater for normal cows (BCS 3) than thin cows (BCS 2; $P < .05$). However, there does not seem to be any trend of practical application for this cow group.

Albumin means increased from severely underconditioned to normal cows (BCS 1-3) in the low production group (dairy merit 1; $P < .05$). Normal and overconditioned cows (BCS 3 and 4) had greater albumin means than thin cows (BCS 2) in the medium production group (dairy merit 2; $P < .05$). The high production group (dairy merit 3) showed no significant difference between albumin means as body condition increased.

The means of α globulin differed only in the high production group (dairy merit 3) where very thin cows (BCS 1) had greater α globulin levels than cows of greater body condition (BCS 2-4; $P < .05$). The means of β-1 globulin differed only in the low production group (dairy merit 1) where very thin cows (BCS 2) had lower β-1 globulin levels than cows of greater body condition (BCS 2-5; $P < .05$).

The means of γ globulin were greater for severely underconditioned cows (BCS 1) than for cows of greater body condition (BCS 2-5) in the low production group (dairy merit 1; $P < .05$). In the medium production group (dairy merit 2), thin cows (BCS 2) had greater γ globulin levels than normal or overconditioned cows (BCS 3 and 4; $P < .05$). γ globulin levels did not differ within the high production group (dairy merit 3) as body condition changed ($P > .05$).

There were no significant differences between body condition scores within each level of dairy merit for the means of various blood parameters. This indicates that the body condition scoring system is capable of separating cows into distinct groups within a given level of dairy merit. However, the differences between blood parameter means, although they may be statistically significant ($P > .05$), are small and may be difficult or impossible to use in the practical interpretation of dairy cow blood profiles.

Significance among mean RBC, HCT, MCV, WBC, Hb, glucose, Ca, Mg, P, TP, albumin, and β-1, β-2 and γ globulin levels for each body condition score within each stage of lactation was tested (Table 13). Those blood parameters not having significant ($P > .05$) F ratios for the body condition-stage of lactation interaction, thus not tested,

Table 13. Mean values of red blood cells, hematocrit, mean corpuscular volume, white blood cells, hemoglobin, glucose, calcium, magnesium, phosphorus, total protein, albumin, β-1 globulin, β-2 globulin, and γ globulin by body condition score within stage of lactation.[a]

Stage of Lactation (days in milk)	Body Condition Score	N	Red Blood Cells ($10^6/mm^3$)	Hematocrit (mg/100ml)	Mean Corpuscular Volume (μ^3/cell)	White Blood Cells ($10^3/mm^3$)	Hemoglobulin (g/100ml)	Glucose (mg/100ml)
1) Less than 80	1	24	5.61^{c}	26.91^{b}	47.39^{b}	8.75^{b}	10.14^{b}	60.78^{b}
	2	222	5.82^{b}	28.31^{b}	48.54^{b}	8.32^{b}	10.60^{b}	59.34^{b}
	3	274	5.94^{b}	29.79^{c}	50.00^{c}	8.25^{b}	11.19^{b}	59.26^{b}
	4	27	5.79^{b}	30.78^{c}	52.77^{d}	8.49^{b}	11.20^{ab}	58.06^{b}
	5	0	--	--	--	--	--	--
2) 80-159	1	0	--	--	--	--	--	--
	2	173	6.16^{b}	29.97^{b}	48.74^{b}	8.26^{b}	11.11^{b}	60.04^{b}
	3	338	6.48^{c}	31.60^{c}	48.97^{b}	8.99^{b}	11.73^{c}	62.69^{c}
	4	40	6.84^{c}	34.24^{d}	50.56^{b}	8.45^{b}	12.35^{c}	62.82^{b}
	5	0	--	--	--	--	--	--
3) 160-239	1	0	--	--	--	--	--	--
	2	99	6.64^{b}	31.28^{b}	47.27^{b}	9.05^{b}	11.66^{b}	60.35^{b}
	3	420	6.67^{b}	32.16^{b}	48.16^{b}	9.24^{b}	12.09^{b}	61.86^{b}
	4	89	6.83^{b}	33.81^{c}	42.79^{c}	8.58^{b}	12.66^{c}	63.06^{b}
	5	0	--	--	--	--	--	--
4) Greater than 240	1	0	--	--	--	--	--	--
	2	41	6.39^{b}	30.45^{b}	48.63^{b}	7.96^{b}	11.22^{b}	62.03^{b}
	3	392	6.51^{b}	32.05^{b}	49.30^{b}	8.54^{b}	11.91^{c}	61.98^{b}
	4	279	6.56^{b}	33.74^{c}	51.28^{c}	8.51^{b}	12.41^{d}	61.86^{b}
	5	34	6.37^{b}	34.61^{c}	53.87^{d}	7.68^{b}	12.28^{cd}	62.08^{b}
5) Dry Period	1	0	--	--	--	--	--	--
	2	37	6.28^{b}	30.96^{b}	49.65^{b}	9.25^{b}	11.29^{b}	57.85^{b}
	3	201	6.51^{b}	32.46^{b}	50.08^{b}	8.44^{b}	12.15^{c}	58.90^{b}
	4	161	6.41^{b}	33.56^{c}	52.41^{c}	8.12^{b}	12.52^{c}	60.62^{b}
	5	26	6.45^{b}	34.14^{c}	53.91^{c}	8.16^{b}	12.43^{c}	60.39^{b}

[a] Mean values were adjusted for herd, age at calving, and season effects.

[b,c,d] Mean values within stage of lactation with different letters were significantly different ($p<.05$).

Table 13 - Continued

Stage of Lactation (days in milk)	Body Condition Score	N	Calcium (mg/100ml)	Magnesium (mg/100ml)	Phosphorus (mg/100ml)	Total protein (g/100ml)	Albumin (g/100ml)	β-1 globulin (g/100ml)	β-2 globulin (g/100ml)	γ globulin (g/100ml)
1) Less than 80	1	24	8.70[ab]	1.86[b]	5.82[b]	7.61[b]	3.01[b]	0.87[b]	1.09[b]	1.98[b]
	2	222	8.85[a]	2.01[c]	6.27[b]	7.64[b]	3.38[b]	0.96[b]	0.95[bc]	1.72[c]
	3	274	9.04[c]	1.99[c]	6.28[b]	7.62[b]	3.42[c]	0.98[b]	0.95[bc]	1.67[c]
	4	27	8.86[bc]	1.92[bc]	6.10[b]	7.73[b]	3.34[ab]	1.01[b]	0.85[c]	1.82[bc]
	5	0	--	--	--	--	--	--	--	--
2) 80-159	1	0	--	--	--	--	--	--	--	--
	2	173	8.99[b]	1.99[b]	6.40[b]	7.71[b]	3.43[b]	1.00[b]	0.98[b]	1.60[b]
	3	338	9.04[b]	2.01[b]	6.37[b]	7.60[bc]	3.52[b]	0.99[b]	0.95[b]	1.41[c]
	4	40	9.01[b]	1.94[b]	5.93[b]	7.30[c]	3.31[b]	0.98[b]	0.97[b]	1.34[bc]
	5	0	--	--	--	--	--	--	--	--
3) 160-239	1	0	--	--	--	--	--	--	--	--
	2	99	8.98[b]	2.02[b]	6.15[b]	7.62[b]	3.40[b]	1.01[b]	0.96[b]	1.55[b]
	3	420	9.07[b]	1.98[b]	6.28[b]	7.45[b]	3.50[b]	0.96[b]	0.96[b]	1.34[c]
	4	89	9.09[b]	1.96[b]	6.10[b]	7.41[b]	3.58[b]	0.97[b]	0.98[b]	1.25[d]
	5	0	--	--	--	--	--	--	--	--
4) Greater than 240	1	0	--	--	--	--	--	--	--	--
	2	41	9.03[b]	1.98[b]	6.13[b]	7.56[b]	3.16[b]	1.00[b]	1.10[b]	1.70[b]
	3	392	9.12[b]	1.99[b]	6.29[b]	7.44[b]	3.50[c]	0.97[b]	0.94[c]	1.43[bc]
	4	279	9.19[b]	2.00[b]	6.23[b]	7.44[b]	3.56[c]	0.99[b]	0.98[bc]	1.39[c]
	5	34	9.18[b]	2.01[b]	6.07[b]	7.44[b]	3.41[bc]	0.98[b]	0.97[bc]	1.43[bc]
5) Dry Period	1	0	--	--	--	--	--	---	--	--
	2	37	8.78[b]	1.94[b]	5.75[b]	7.04[b]	3.25[b]	0.92[b]	0.89[b]	1.50[b]
	3	201	9.03[bc]	1.97[b]	6.20[b]	7.29[b]	3.45[b]	0.93[b]	0.89[b]	1.51[b]
	4	161	9.16[cd]	1.98[b]	5.97[b]	7.36[b]	3.47[b]	0.95[b]	0.91[b]	1.45[b]
	5	26	9.42[d]	1.99[b]	5.79[b]	7.89[c]	3.56[b]	0.93[b]	0.96[b]	1.64[b]

[a]Mean values were adjusted for herd, age at calving, and season effects.

[b,c,d]Mean values within stage of lactation with different letters were significantly different ($p<.05$).

were α globulin, CPK, alkaline phosphatase, and SGOT.

The group of cows in milk less than 80 days (stage of lactation 1) had no severely overconditioned cows (BCS 5; Table 15). The groups of cows in milk between 80 and 159 days and between 160 and 239 days (stages of lactation 2 and 3) had no severely underconditioned or extremely overconditioned cows (BCS 1 and 5). The group of cows in milk greater than 240 days and dry cows (stages of lactation 4 and 5) had no severely underconditioned cows (BCS 1).

The means of RBC were significantly different ($P < .05$) only in the group of cows that were in milk between 80 and 159 days (stage of lactation 2). Thin cows (BCS 2) had lower RBC levels than cows in higher body condition (BCS 3 and 4).

The means of HCT were less ($P < .05$) for thin and normal cows (BCS 2 and 3) than for cow in overcondition (BCS 4 and 5) in all stage of lactation groups except for cows in milk between 80 and 159 days. These cows had increasing HCT levels as body condition increased (BCS 2-4). HCT levels consistently increased as body condition increased within each stage of lactation, although not all increases were statistically significant ($P > .05$). Similarly, MCV levels increased as body condition increased. However, for the early lactation group (less than 80 days), MCV levels were not significantly different ($P > .05$) between severely underconditioned cows (BCS 1) and thin cows (BCS 2). There were no significant differences ($P > .05$) within the group of cows in milk between 80 and 159 days. For cows in milk between 160 and 239 days, cows in milk greater than 240 days, and dry cows, thin cows (BCS 2) and normal cows (BCS 3) did not have significantly different MCV levels (P >.05). Dry cows also did not have significantly different (P < .05) MCV levels between the two categories of overcondition (BCS 4 and 5).

Means of WBC did not vary with body condition within stage of lactation grouping (P > .05).

For the early lactation group (less than 80 days), underconditioned cows (BCS 1 and 2) had lower Hb levels than normal cows (BCS 3; P < .05). For the group in milk between 80 and 159 days, thin cows BCS 2) had lower levels of Hb than normal or overconditioned cows (BCS 3 and 4; P < .05). Thin and normal cows (BCS 2 and 3) in the 160 to 239 days in milk group had lower HB levels than overconditioned cows (BCS 4; P < .05). For the late lactation group (greater than 240 days), thin cows (BCS 2) had lower (P < .05) Hb levels than cows of greater body condition (BCS 3-5) and normal cows (BCS 3) were lower than overconditioned cows (BCS 4; P < .05). Within the dry cow group, thin cows (BCS 2) had lower Hb levels than cows of greater body condition (BCS 3-5; P < .05).

The means of glucose were not significantly different (P > .05) for various levels of body condition except within the group of cows in milk between 80 and 159 days. In this group, thin cows (BCS 2) had significantly lower (P < .05) glucose levels than cows of greater body condition (BCS 3 and 4).

Only early lactation cows (less than 80 days) and dry cows had significantly different Ca levels (P < .05). Thin cows (BCS 2) had lower calcium levels than normal cows (BCS 3) within the early lactation group. Thin cows (BCS 2) had lower Ca levels than overconditioned cows (BCS 4 and 5) and normal cows (BCS 3) had lower Ca levels than extremely overconditioned cows (BCS 5) within the dry cow group.

Significant differences ($P < .05$) between condition scores for mean levels of Mg were found only in the early lactation group (less than 80 days). Severely underconditioned cows (BCS 1) had lower Mg levels than normal and overconditioned cows (BCS 3 and 4).

The means of P did not vary with body condition within any stage of lactation grouping.

The means of TP differed significantly ($P < .05$) between body condition scores within the group of cows in milk between 80 and 159 days. Thin cows (BCS 2) had greater TP levels than cows in overcondition (BCS 4). Also, within the dry cow group, excessively overconditioned cows (BCS 5) had greater TP levels than cows in lower body condition (BCS 2-4).

Only early lactation cows (less than 80 days) and late lactation cows (greater than 240 days) differed significantly ($P < .05$) in mean albumin levels between various body condition scores. For the early lactation group, severely underconditioned cows (BCS 1) had lower albumin levels than thin or normal cows (BCS 2 and 3). For the late lactation group, thin cows (BCS 2) had lower albumin levels than normal and overconditioned cows (BCS 3 and 4).

The means of β-1 globulin did not vary with body condition within any stage of lactation grouping.

Only early lactation cows (less than 80 days) and late lactation cows (greater than 240 days) differed significantly ($P < .05$) in mean β-2 globulin levels between various body condition scores. For the early lactation group, severely underconditioned cows (BCS 1) had greater β-2 globulin levels than overconditioned cows (BCS 4). For the late lactation group, thin cows (BCS 2) had greater β-2 globulin levels than normal cows (BCS 3).

Within the early lactation group, γ globulin levels were greater ($P < .05$) for severely underconditioned cows (BCS 1) than for thin or normal cows (BCS 2 and 3). Thin cows (BCS 2) had greater mean γ globulin levels ($P < .05$) than normal cows (BCS 3) within the group of cows in milk between 80 and 159 days. γ globulin levels decreased as body condition increased ($P < .05$) within the group of cows in milk between 160 and 239 days. Thin cows (BCS 2) had greater ($P < .05$) mean γ globulin levels than cows in overcondition (BCS 4) within the late lactation group (greater than 240 days). There were no significant differences ($P > .05$) between body condition levels within the dry cow group.

General Discussion

Although not as many blood parameters showed significant differences for the body condition x stage of lactation interaction as for the body condition x dairy merit interaction, the data do further substantiate the ability of the body condition scoring system to differentiate between levels of cow condition, in this case, within stage of lactation group. Again, however, the differences between all blood parameter means, although they may be statistically significant ($P < .05$), are small and may be difficult or impossible to use for practical application.

Payne *et al*. (26) introduced the concept of metabolic profile testing for dairy herds. The profile consists of a battery of biochemical and cellular tests selected on the basis of applicability to diagnosis of specific metabolic diseases on a herd basis. Using 47 herds, he found that the tests used were in agreement with previous work, including the studies of Tashjian *et al*. (35) with individual herds. However, Payne showed that there were significant between herd differences which must be taken into account. Payne *et al*. (28) defined an abnormality as a condition which differed from the mean by two standard deviations within a lactational group. They suggested that it is not only valid statistically, but appears to have value clinically. Payne *et al*. (29), in a survey of the results of metabolic profile tests on 191 dairy herds, reconfirmed the normal values for blood chemistry of dairy cows. However, they were able to attribute much of the variation in blood chemistry to herd, season, and stage of lactation. They state, therefore, that the metabolic profile is a test of a lactation group within a herd, within a season. The present study shows that body condition should also be a factor considered within production level and within stage of lactation may also need to be considered.

Kradel *et al*. (17) used metabolic profile testing to develop normal values for high producing herds having a minimum of health problems. They found that MCV, Hb, and Mg levels may best reflect overall herd health status within herds having obscure health or production problems. They observed that, for most blood parameters, values of greater than 1.3 standard deviations from the mean constituted an abnormality.

Thompson et al. (36) stated that many factors contributed to variations in blood parameters. Herd, age, season, gestation, lactation, and nutritional differences all affect blood parameters. They stated that, although blood profiles can be used to detect nutritional defects, profiles can not be used over a wide range of dairy herds to advise on suitable levels of dietary supplementation to overcome deficiencies.

The present study has shown that when herd, age at calving, season, and stage of lactation or dairy merit were taken into account during the analysis of metabolic profiles, the effect of body condition is significant and, therefore, should be considered in evaluating metabolic profiles. As many factors as possible that affect dairy cow blood profiles must be identified and quantified. Multiple regression equations must then be designed for use in predicting mean blood parameter values within specific herds. Variation from such values would be of greater use in diagnosing and correcting health, reproduction, and nutritional problems.

The present study has also shown that the body condition scoring system can separate cows into distinct groups as shown by statistical differences between means of certain blood parameters. Further, there may be differences between means of certain blood parameters, most probably hematocrit and hemoglobin, that are of practical application in evaluating dairy cow blood profiles. However, due to the small differences between means of all blood parameters for various levels of body condition within dairy merit groups and within stage of lactation groups, these means may not be of practical importance in evaluating dairy cow blood, or metabolic, profiles.

SUMMARY

A dairy cow body condition scoring system was devised by the author as a practical means of determining the body condition, or fitness pertaining to degree of body fat, of dairy cows at any point during the production cycle. Cows were scored on appearance and palpation of the thoracic and lumbar regions of the vertebral column (chine, loin, and rump), spinous processes (loin), anterior coccygeal vertebrae (tail head), tuber sacrale (hooks), and tuber ishii (pin bones). All of these factors were considered in determining a single body condition score. Each cow was scored on a 1 to 5 scale with a score of 1 indicating greatly underconditioned cows and a score of 5 indicating greatly overconditioned cows.

Twenty-nine Virginia DHIA dairy herds cooperated in this study. During a period of 18 months, each herd was sampled once very 3 months. Herds were selected by rolling herd average milk production to assure a cross-sectional sample of production levels. Twenty-eight study cows within each herd were selected at random within 5 ERPA groupings to be representative of the herd. Data collection included body condition scores, body weights, frame size measurements, blood samples, and complete DHIA records.

The results of analysis of the relationship of body weight, the number of palpatable intercostal spaces, and frame size measurements to the body condition scoring system showed that within herd, only herd, body weight, wither height, and the number of palpatable intercostal spaces had a significant effect upon variability within

the condition scoring system. Correlation coefficients showed that as body condition increased, a concurrent increase occurred in body weight and the ratio of body weight to wither height. As expected, the number of palpatable intercostal spaces decreased with increased body condition. The correlation coefficients for wither height, sternum height, and hook height all approached zero, indicating that the procedure for the body condition scoring system was not influenced by frame size. Therefore, the body condition scoring system is independent of frame size and only moderately associated with body weight, the number of palpatable intercostal spaces, and the ratio of body weight to wither height. The body condition scoring system measures traits other than these parameters; presumably cow fitness as it pertains to the degree of fatness.

The results of the relationship of DHIA milk production and related parameters to the body condition scoring system showed that within herd, persistency of lactation, dairy merit, days open, stage of lactation, age at calving, season, and the interaction of dairy merit and stage of lactation were all significant. Means of body condition within stage of lactation showed that body condition decreased sharply during early lactation, increased from approximately the peak of lactation through the end of lactation, and then was maintained through the dry period. Present dry cow nutrition practices consider only gestation and body weight and therefore, body condition at the end of lactation would be expected to remain constant through the dry period. The change in body condition throughout the lactation cycle responded as expected and showed that the body condition scoring system accurately differentiated the fitness of dairy cows in various stages of lactation.

Means of body condition scores within each dairy merit level showed that as body condition increased, efficiency of milk production decreased.

Either low producing cows do not have the ability to efficiently utilize body fat for milk production or they are inefficient milk producers and consequently, deposit body fat with greater efficiency.

Mean body condition scores within each level of persistency of lactation showed that as mean body condition increased, persistency of lactation increased. This would seem to contradict the dairy merit results. However, since DHIA uses a single average lactation curve as the basis on which to compare the persistency of each cow, an efficient producing cow may have an "abnormal" lactation curve, as compared with the average curve, but such an "abnormal" curve may be desirable. The greater descending slope of such a curve projects low persistency, but production for the total lactation could be greater than that of the average producing cow. If indeed this is the case, then lower body condition cows could be more efficient producers and yet less persistent.

Mean body condition scores within level of days open showed that body condition score increased as days open increased. The fetus is considered to have a negligible effect on the energy requirements of the dam until after 200 days. Thus pregnancy should have no effect on body condition. There are numerous factors affecting days open, one of which may be that she is overconditioned.

On a practical basis, body condition score was not affected by age at calving or season.

The effect of dairy merit, within stage of lactation, upon body condition showed that all cows tended toward a common body condition during the first 80 days of lactation. The more efficient producing dairy cows did not change greatly in body condition throughout lactation. However, inefficient producers increased in body condition and apparently were more efficient in converting energy to body fat than to milk.

The relationship of the body condition scoring system to selected DHIA milk production and related parameters to dairy merit showed that the effect of herd, body condition, score, stage of lactation, age at calving, season, and the interactions of body condition score with age at calving and with season were all significant. Mean dairy merit for each body condition score showed that as body condition increased dairy merit decreased by greater than 50 percent. Therefore, the overconditioned dairy cow is inefficient for milk production.

Nonstatistical data of the relationship of dry cow body condition to the subsequent lactation showed trends indicating cows that were overconditioned while dry were inefficient producers during the subsequent lactation. It appears that cows should be in normal to slightly overcondition during the dry period for greatest milk production efficiency during the subsequent lactation.

Analysis of the relationship of the body condition scoring system, stage of lactation, and dairy merit to blood parameters showed that increasing body condition was positively associated with increasing levels of RBC, HCT, MCV, Hb, Ca, albumin and decreasing γ globulin and SGOT levels. These results indicate that body condition may affect the practical interpretation of blood profiles and that the body condition scoring system can separate cows into distinct groups.

Means of blood parameters for each body condition score within each dairy merit level showed that there were differences between body condition scores within each level of dairy merit for the means of various blood parameters. This indicates that the body condition scoring system is capable of separating cows into distinct groups within a given level of dairy merit. However, the differences between blood parameter means, although they may be significant, are small and may be difficult or impossible to use in the practical interpretation of dairy cow blood profiles.

Means of blood parameters for each body condition score within each stage of lactation showed that, although differences were found, only HCT, Hb and possibly MCV have reasonably consistent trends within each stage of lactation. Again, however, the difference between all blood parameter means, although they may be statistically significant, are small and may be difficult or impossible to use for practical application.

The present study has shown that the body condition scoring system is capable of differentiating between cows of varying degrees of fitness. Dairy cows of greatest milk production efficiency were cows that do not increase significantly in body condition throughout lactation. They maintained a relatively low body condition, had fewer days open, but persistency of lactation was less, which is probably not detrimental. Dairy cows that increased greatly in body condition were less efficient milk producers, had a greater number of days open, and reached relatively high body condition scores. The differences between blood parameter means, although statistically significant, are of little practical importance in evaluating dairy cow blood, or metabolic, profiles when separated into body condition groupings.

CONCLUSIONS

1. The dairy cow body condition scoring system developed in this study is a practical means of quantitating body condition of dairy cows.
2. Body condition as measured by this system is independent of frame size and only moderately associated with body weight, intercostal spaces, and the ratio of body weight to wither height.
3. Cows of high dairy merit maintain relatively low body condition during each stage of lactation and do not increase significantly throughout lactation.
4. Blood profiles are probably not of practical value in evaluating the body condition of dairy cows.
5. It appears that overconditioned dry cows maintain relatively low milk production efficiency during the subsequent lactation and that normal condition to slightly overcondition is desirable during the dry period.
6. The method developed can be used to quantitate the effects of body condition on health parameters and production over multiple lactations.

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THE EFFECTS OF A DAIRY COW BODY CONDITION SCORING
SYSTEM ON SELECTED PRODUCTION AND METABOLIC PARAMETERS

by

Edward Embree Wildman II

(ABSTRACT)

A dairy cow body condition scoring system was devised by the author as a practical means of determining the body condition, or fitness pertaining to the degree of body fat of dairy cows at any point during the lactation cycle. The factors considered were the thoracic and lumbar regions of the vertebral column (chine, loin and rump), spinous processes (loin), anterior coccygeal vertebrae (tailhead), tuber sacrale (hooks), and tuber ishii (pin bones). All factors in the body condition scoring system must be considered while appraising each cow. Each cow was scored on a 1 to 5 scale with 1 indicating severe undercondition and 5 indicating severe overcondition. During an 18-month period, 28 cows in each of 29 Virginia dairy herds were used for obtaining body condition scores, body weight, frame size measurements and blood samples. Herds were chosen according to rolling herd milk production average and cows were chosen at random from within five Estimated Relative Producing Ability groupings to insure a representative sample of herds across and levels of production in Virginia and of cows within each herd. Herds were sampled at 3-month intervals and complete Dairy Herd Improvement Association records were obtained for each cow in each herd. The relationships of dairy cow body weight,

frame size measurements, milk production and related parameters, and blood profiles to the body condition scoring system were determined. Body condition using this method was found to be independent of frame size and only moderately correlated with body weight, the number of intercostal spaces and the ratio of body weight to wither height. Body condition was found to be relatively low during early lactation and to increase through late lactation and remain constant during the dry period. Dairy cows of greatest milk production efficiency did not increase significantly in body condition throughout lactation, had fewer days open, but had less persistency of lactation. Dairy cows that increase significantly in body condition throughout lactation were less efficient milk producers, had a greater number of days open, had relatively high body condition scores in late lactation, but had greater persistency of lactation. Blood parameters, although statistically significant in many cases, were found to be of little or no practical value when compared between body condition, stage of lactation, and dairy merit groupings. The dairy cow body condition scoring system is a practical means of quantitating body condition of dairy cows.