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REVIEWS

Review: An Interdisciplinary Review of Body Condition Scoring for Dairy Cattle

J. M. Bewley,*†[1] PAS, and M. M. Schutz*
*Department of Animal Science, Purdue University, West Lafayette, IN 47907;
and †Department of Animal and Food Sciences, University of Kentucky, Lexington 40546

ABSTRACT

In this review, methods for assessing energy reserves, the role of assigning BCS in dairy management, and the impact of varying BCS on animal productivity, health, and reproduction are explored from a whole-system viewpoint. The usefulness, validity, and precision of BCS for assessing body energy reserves are well documented. Generally, BCS decrease in early lactation as cows partition energy from body reserves to support milk production, and they then begin to increase throughout the remainder of lactation. Excessive loss of energy reserves during early lactation, generally associated with cows of higher BCS at calving, often results in impaired health and reproductive performance. Among diseases, the most consistent relationship has been an increased incidence of ketosis for cows with higher BCS at calving. Although published results have varied, either high or low BCS has also been related to greater incidences of metritis, retained placenta, milk fever, lameness, cystic ovaries, dystocia, displaced abomasum, and mastitis. Losses in BCS or the actual BCS are associated with various fertility measures including days to first ovulation, days to first estrus, days to first service, first service conception rate, number of services, calving interval, and embryonic losses. Patterns of BCS change within lactation are under genetic control indicating potential for inclusion of BCS in genetic evaluations. Concerns about subjectivity and the time required for scoring have limited the use of BCS in daily management. An automated BCS might provide a more objective, less time-consuming means of estimating energy reserves in dairy cattle.

Key words: body condition scoring, energy reserve, nutritional management, reproductive management

INTRODUCTION

Body condition scoring has been widely accepted as the most practical method for assessing changes in energy reserves in many species, including dairy cattle. Although many may view BCS as a nutritional practice, management of BCS on dairy farms has implications for milk yield, herd health, reproductive performance, animal well-being, and overall farm profitability. Renewed emphasis or difficulties with reproduction, transition cow disorders, and animal well-being have increased interest in BCS recently. Both absolute BCS, particularly at calving, and changes in BCS during early lactation influence animal health and reproduction. Although some loss of BCS during early lactation is expected, dairy managers must focus on minimizing such loss. Unfortunately, because of subjectivity and time constraints, BCS as a frequent, repeated on-farm procedure has not been widely adopted. New technological developments may facilitate collection and use of BCS data. Moreover, genetic differences in cows' abilities to manage energy reserves have renewed interest for inclusion of BCS in genetic analyses. Much of the research centered on BCS has been conducted with a disciplinary focus (e.g., nutrition, reproduction, genetics). An interdisciplinary review, incorporating all of those facets, has not been published heretofore to the knowledge of the authors. The objective of this review was to incorporate much of the work published on BCS across disciplines into a single publication to gain a better understanding of the role of BCS in dairy management from a systems perspective. This review will provide a comprehensive compilation of the role of BCS in dairy cow health and well-being, which will be useful to future researchers, consultants, and dairy producers.

REVIEW AND DISCUSSION

Biological Background

From an evolutionary perspective, all mammals are designed to convert

[1] Corresponding author: jbewley@uky.edu

body stores of energy, namely, lipid, to milk during lactation. In the wild, such functionality allows the mother to provide for the nutritional needs of her offspring even during times when food may be scarce. Although some species rely almost exclusively on body reserves for producing milk (e.g., whales and polar bears), the dairy cow relies on a combination of body reserves and available feed to meet the demands of producing milk. Up to one-third of the total milk solids produced in early lactation is produced from body tissue reserves (Bauman and Currie, 1980). Although the modern dairy cow produces quantities of milk well beyond the nutritional requirements of her offspring, it is important to consider that, biologically, she is essentially producing milk to support her offspring. During the early stages of the calf's life and the mother's lactation, the cow places a high priority on perpetuation of her genetic material, through the survival of her calf, by partitioning a large portion of available nutrients toward milk production. In nature, as the calf grows older, it relies less on its mother's milk and more on other sources of food.

Although the cow also taps into reserves of protein and some minerals, the primary reserve of concern is fat or energy. Adipose tissue metabolism changes during early lactation as nutrients are partitioned to the mammary gland (Smith and McNamara, 1990). Those metabolic adaptations are under endocrine regulation and reflect a resetting of cellular structure and function (Collier et al., 1984; McNamara, 1991; Vernon and Pond, 1997; Chilliard et al., 2000). The enzyme hormone-sensitive lipase is responsible for release of free fatty acids from triacylglycerols stored in adipose tissue (Vernon and Pond, 1997). The diameter and cell volume of adipocytes decrease during early lactation while the animal is in negative energy balance and increase later in lactation during positive energy balance (Reid et al., 1986; Smith and McNamara, 1990; McNamara, 1991) following the usual changes in BCS. Indeed, changes in fat cell size, not cell numbers, are responsible for most changes in body fats in adult cows (McNamara, 1991; Waltner et al., 1994). Lipogenesis is slow during early lactation and increases during late lactation, whereas lipolysis is more prominent during early lactation and less during late lactation (Collier et al., 1984; McNamara, 1991; Vernon and Pond, 1997). Briefly, the increased lipolysis during lactation is caused by decreased serum insulin, increased sympathetic nervous activity within adipose tissue, and an increased response and sensitivity to catecholamines (McNamara, 1991; Vernon and Pond, 1997). Nonesterified fatty acids (**NEFA**) are released from adipose tissue with lipolysis of adipocyte triacylglycerols by hormone-sensitive lipase and re-esterification of liberated fatty acids (Chilliard et al., 2000). In cows losing more body fat, concentrations of NEFA are elevated (Busato et al., 2002).

Fat mobilization is a factor of both level of body fat and daily energy balance (Chilliard et al., 2000). For about 2 to 4 mo following calving, energy output exceeds input, resulting in a negative energy balance. Energy balance is defined simply as energy intake minus energy output. During lactation, DMI increases at a slower rate than milk production, exacerbating negative energy balance. About 2 to 4 mo after the cow calves, her DMI increases to a point where energy input is greater than energy output, resulting in a positive energy balance for the remainder of lactation.

Measuring Energy Reserves

Because changes in energy reserves have considerable influence on dairy cow productivity, health, and reproduction; there is a clear need to monitor optimal management of body reserves in dairy cows. The most obvious solution would be to monitor changes in body reserves using BW. In fact, technologies for automatic measurement of BW are available commercially and strategies for use of BW as a management tool have been explored in both production and research settings (Maltz, 1997; Maltz et al., 1997). Those researchers demonstrated that BW changes could be used for early detection of some health problems and as one component in an automatic estrus detection system. However, changes in BW are influenced by factors other than changes in amount of body fat, including changes in internal protein and water, gastrointestinal content, changing organ weights, fetal development, and frame size (Mulvany, 1981; Otto, 1990; Broster and Broster, 1998; Schröder and Staufenbiel, 2006).

An ideal system would quantify the actual amount of fat within the animal and detect changes over time. With a goal of determining the amount of fat within an animal's body, the highest degree of accuracy can be obtained only in a postslaughter chemical analysis of the entire body with contents of the digestive and urinary tracts removed (Otto, 1990). The fat content of the ninth through eleventh rib is highly correlated with the fat content of the entire carcass (Otto, 1990). Respiration calorimetry, body water by dilution with deuterium oxide, tritiated water, urea, or antipyrine, and mean diameters of fat cells are viable research tools for estimating energy reserves. The utility of those methods is good in research settings where focus is on accuracy rather than speed or cost (De Campeneere et al., 2000). However, because of implementation challenges and costs, they are not viable alternatives for field use (Waltner et al., 1994; De Campeneere et al., 2000; Schröder and Staufenbiel, 2006).

Metabolic and hormonal factors may be used to assess energy balance in a more timely manner than indirect measures of energy reserves, which are always retrospective. Such factors include NEFA, creatinine, albumin, BHBA, growth hormone, various enzymes, glucose, cholesterol, urea, insulin, IGF-1, triiodothyronine, and lactose (Schröder and Staufenbiel, 2006). Although those measures may provide a more objective assessment of energy balance, each has its own limitations. Those techniques, with current technologies, have the disadvantages of requiring collection of blood samples and expensive analysis equipment.

Unfortunately, those methods are too invasive, too expensive, or impossible to perform on a regular basis in a commercial setting. As a result, the primary method used within the dairy industry is a subjective analysis of the amount of body condition a cow is carrying, termed BCS. This technique is accomplished by visual or tactile observation, or both, of a cow by a trained professional.

Ultrasound and Body Condition Scoring

Because the proportion of subcutaneous body fat is highly correlated with total body fat, fat depth is a good indicator of body fat reserves (Butler-Hogg et al., 1985). The use of ultrasound as either an alternative to or a means of verifying BCS has been demonstrated in multiple research studies (Otto, 1990; Domecq et al., 1995; MacDonald et al., 1999; Mizrach et al., 1999; Schwager-Suter, 1999; De Campeneere et al., 2000; Schwager-Suter et al., 2000; Zulu et al., 2001; Jaurena et al., 2005; Schröder and Staufenbiel, 2006). Although ultrasound is more objective than traditional BCS, concerns exist with regard to ultrasound operator variability, whether subdermal fat stores reflect energy balance, the impact of differences within fat depots around the body, and inability to provide a whole cross-section scan of the body (Domecq et al., 1995; Mizrach et al., 1999; De Campeneere et al., 2000).

Otto (1990) demonstrated fat thickness at the rump, measured by ultrasound, and ribeye area to be correlated with BCS and ninth to eleventh rib section composition. The statistical relationships were improved after considering the impact of water content of the rib section. Domecq et al. (1995) measured subcutaneous fat of Holstein dairy cows at 6 different locations (right lumbar region, left lumbar region, right thurl, left thurl, right tailhead, and left tailhead). Each of the 6 locations was significantly associated with BCS ($R^2 = 0.36$ to 0.65). Because the R^2 did not improve with addition of multiple measures, one ultrasound measure from either side or any of the locations was determined to be sufficient. MacDonald et al. (1999) compared ultrasound measures of subcutaneous fat to BCS measured at the 12th rib and between the hook and pin bones using the New Zealand BCS system. They calculated correlation coefficients of 0.37 and 0.26 with rib and hip measurements, respectively, in late summer and 0.69 and 0.82 with rib and hip measurements, respectively, in late lactation. However, MacDonald et al. (1999) indicated that ultrasound was of little value in assessing differences in fat depots in cows at lower BCS.

Mizrach et al. (1999) analyzed body condition changes throughout lactation for 6 cows using ultrasound and a computer program designed to acquire and digitize the images. They concluded that ultrasound images taken from the area between the 12th and 13th ribs was superior at detecting changes than the flat area of the rear of the rump between the pin bone and tail head. Schwager-Suter et al. (2000) measured ultrasound fat thickness and LM thickness in Holstein-Friesian, Jersey, and Holstein-Jersey F_1 crosses. In that work, models relating ultrasound fat thickness and LM thickness to BCS had high coefficients of determinations ($R^2 = 0.84$ to 0.85). Zulu et al. (2001) calculated correlations between BCS and ultrasound measures at the right lumbar region, left lumbar region, right thurl, left thurl, right tailhead, and left tailhead ranging from 0.62 to 0.67. The strongest correlation coefficient (0.67) was for the mean of the lumbar measurements. Because each area was strongly correlated, the authors concluded that only one side or location of the cow is needed to assess body fat levels.

In an extensive review article, Schröder and Staufenbiel (2006) demonstrated the effectiveness of measuring backfat thickness using ultrasound technology as a means of assessing body reserves. They defined backfat as the "layer of subcutaneous fat that is terminated by the skin and the fascia trunci profunda, which in this area is located above the gluteus medius and longissimus dorsi muscles." Because it has the largest deposit of adipose tissue and a high correlation with total body fat content, the sacral examination site is the optimum site for ultrasound examination of backfat thickness. Assuming that one BCS is equivalent to 50 kg of empty body fat, and a 1-mm change in backfat thickness is equivalent to 5 kg of total body fat, those authors surmised that one BCS unit correlates to about 10 mm of backfat thickness (Table 1). Schröder and Staufenbiel (2006)

Table 1. Assessment of body condition by description, BCS, backfat thickness (BFT), and total body fat content (TBF)[1]

Description	BCS	BFT, mm	TBF, kg
Emaciated	1.0	<5	<50
Very poor	1.5	5	50
Poor	2.0	10	76
Moderate	2.5	15	98
Good	3.0	20	122
Very good	3.5	25	146
Fat	4.0	30	170
Adipose	4.5	35	194
Obese	5.0	>35	>194

[1]From Schröder and Staufenbiel (2006).

Table 2. International body condition scoring systems

Country	Scale	Interval (points)	Description source(s)	Visual or palpation
United Kingdom, Ireland	0 to 5	0.5 (11)	Lowman et al. (1976); Mulvany (1977)	Palpation
United States	1 to 5	0.25 (17)	Wildman et al. (1982); Edmonson et al. (1989); Ferguson et al. (1994)	Visual
New Zealand	1 to 10	0.5 (19)	MacDonald and Roche (2004)	Palpation
Australia	1 to 8	0.5 (15)	Earle (1976)	Visual
Denmark	1 to 9	1 (9)	Landsverk (1992)	Visual

proposed that measuring backfat thickness is preferred to BCS because of its precision, speed, and ease of use. However, because the ultrasound equipment must come in direct contact with the animal, it is unlikely to be incorporated in an automatic measurement system.

Body Condition Scoring Systems

The first reference to a subjective BCS system was in the early 1960s with a scoring system developed for sheep by Jefferies (1961). In the 1970s, Lowman et al. (1976) modified the system for beef cattle, and Earle and Mulvany created criteria for BCS of dairy cattle (Earle, 1976; Mulvany, 1977; Mulvany, 1981). During the last 25 yr, various other BCS systems have been described and researched throughout the world. All of the BCS systems incorporate a numerical scale with thin animals receiving lower scores and fat animals receiving higher scores. In Table 2, the primary BCS systems currently being used throughout the world are depicted along with the scale, interval, number of points, primary researchers, and method of evaluation for each system. An extensive review of the literature reveals that the system described by Wildman et al. (1982), later modified by Edmonson et al. (1989) and Ferguson et al. (1994) to be performed without palpating the animal, is as close to an international standard as any system (Schwager-Suter et al., 2000; Kristensen et al., 2006). In the remaining discussion, unless otherwise noted, any reference to BCS will be made to that system.

The New Zealand and United Kingdom-Ireland BCS systems involve palpating specific body parts, whereas the systems used in the United States and Australia are based entirely on visual assessment. In the United Kingdom system, a score is given following palpation of the tailhead. Then, the loin is scored similarly. If the tailhead score and loin scores differ by one point or more, the final score is based on the tailhead but adjusted by half a point (Mulvany, 1981). The New Zealand system focuses more on the contours of the cow between hooks and hocks as viewed from behind (Gregory et al., 1998).

Few formal comparisons of international BCS systems have been made. Roche et al. (2004) demonstrated that relationships between US, Irish, New Zealand, and Australian BCS systems were significant and moderately correlated. Correlations with the New Zealand 10-point scale system were as follows: US 5-point scale, $r^2 = 0.54$; Irish 5-point scale, $r^2 = 0.72$; and Australian 8-point scale, $r^2 = 0.61$ (Roche et al., 2004). The corresponding conversion equations were as follows: US = 1.5 + 0.32 × New Zealand; Irish = 0.81 + 0.4 × New Zealand; and Australian = 2.2 × New Zealand.

J. M. Bewley (unpublished data) compared scores from the United Kingdom (**UK**) BCS (Lowman et al., 1976) system to the US BCS (Ferguson et al., 1994) system, and reported the following conversion equation, which is used in the remaining discussion to convert scores to the US BCS scale, with UK scores listed initially and US scores in parentheses: US BCS = 1.5874 + 0.3658 × UK BCS + 0.1184 × UK BCS^2.

Ferguson (2002) derived mathematical equations for converting between the 0 to 5 ($CS_{5.0}$), 0 to 4 ($CS_{4.0}$), 1 to 4 ($CS_{4.1}$), 1 to 9 ($CS_{9.1}$), and 1 to 5 (BCS) scales, as follows:

$$BCS = [(CS_{9.1}) + 1]/2;\ CS_{9.1} = (BCS \times 2) - 1;$$

$$BCS = [(CS_{5.0}) \times (4/5)] + 1;\ CS_{5.0} = (BCS - 1) \times (5/4);$$

$$BCS = (CS_{4.0}) + 1;\ CS_{4.0} = BCS - 1;$$

$$BCS = [(CS_{4.1}) \times (4/3)] - (1/3);\ CS_{4.1} = [BCS + (1/3)] \times (3/4).$$

Validation of Body Condition Scoring

In a classic experiment, Wright and Russel (1984b) compared subjective BCS (Lowman et al., 1976) to body fat composition of mature, nonpregnant, nonlactating, slaughtered cows (Hereford × Friesian, Blue-Grey, Galloway, Luing, and British Friesian genotypes). Deposition of fat within fat depots varied between those genotypes. The British Friesian cows deposited more of their fat in intra-abdominal fat depots and less in subcutaneous fat whereas Hereford × Friesian cows deposited more fat in subcutaneous depots. Because BCS measures only the subcutaneous fat deposits, the British Friesian cows were fatter at any BCS whereas the Hereford × Friesian cows were thinner at any BCS. Of the indirect measures of body fat considered (live weight, skeletal size, ultrasonic subcutaneous fat depth and eye-muscle area, total body water, blood and red cell volumes, and BCS), live BW proved to be the best predictor of body fat (Wright and Russel, 1984a). Considering multiple variables within the regression equation improved the predictive ability in almost every case (maximum $R^2 = 0.90$).

Otto et al. (1991) reported dissectible seam fat and ether extract in the rib eye section to be highly correlated with BCS ($R^2 = 0.59$ and 0.57, respectively). Body fat, measured by either method, was negligible and variable for cows with scores lower than 2.5, suggesting that lower BCS are reflective of changes in tissue water in addition to fat and protein. Whereas body fat increased by 12.65% with an increase in BCS of one unit, body protein decreased by 12.19%. Waltner et al. (1994) also compared indirect measures of body fat (BCS, dilution of deuterium oxide in body water, and determination of mean fat cell size diameter of the subcutaneous, abdominal, and perirenal fat depots) to actual body fat content from slaughtered cows. Results of that work demonstrated that the best regression equations were those that combined BW with either BCS or subcutaneous fat cell diameter (maximum $R^2 = 0.61$). One of the few studies to examine the relationship between body fat and condition score over a large range of scores identified a curvilinear relationship between those 2 variables (Gregory et al., 1998).

Anatomical Correlations

Although the various BCS systems may vary slightly, the primary anatomical parts considered for BCS may include the thoracic and vertebral regions of the spine, the ribs, the spinous and transverse processes, the tuber sacrale (hip or hook bones), the tuber ischii (pin bones), the anterior coccygeal vertebrae (tail head), the depression between the hooks and pins, and the thigh region (Earle, 1976; Wildman et al., 1982; Edmonson et al., 1989; Landsverk, 1992; Ferguson et al., 1994; MacDonald and Roche, 2004; Roche et al., 2004).

Perkins et al. (1985a) stressed the importance of examining multiple locations on the animal, citing that 1 or 2 locations may be misleading. In contrast, Edmonson et al. (1989) observed that overall BCS was most closely associated with scores given in the pelvic and tailhead regions, concluding that a score from a single area may suffice for assessing a cow's BCS. Using 9 assessors with varying degrees of experience with scoring body condition, the usefulness of the chart created by Edmonson et al. (1989) was demonstrated, in part, because between cow variability was higher than between assessor variability. Ferguson et al. (1994) used principal components analysis to identify which of the following body areas were most important for determining BCS: thurl, ischial and ileal tuberosities, iliosacral, and ischio-coccygeal ligaments, transverse processes of the lumbar vertebrae, and spinous processes of the lumbar vertebrae. In their analysis, 83.6% of the variation within the body correlation matrix was explained by 4 principal component vectors. Results of that work were incorporated into a decision flowchart widely distributed by Elanco Animal Health (1996).

Body condition scores are positively and statistically ($P < 0.05$) correlated with hook height and ratio of weight to wither height and negatively and statistically correlated ($P < 0.01$) with sternum height and intercostal spaces (Wildman et al., 1982). The distances between the hooks and pins and distance between hooks have also been demonstrated to be significantly associated with BCS (Otto et al., 1991). Additionally, DIM, hip height, hip width, and energy-corrected milk were also moderately correlated with BCS at varying correlation coefficients for different breeds.

BCS and BW

Given the subjective nature of BCS and the variability of BW, it should be no surprise that there has been considerable variation in estimates obtained for the relationship between BW and BCS. In work by Enevoldsen and Kristensen (1997), correlations between BCS and BW were 0.53, 0.34, and 0.57 for Danish Friesian, Danish Jersey, and crossbred Jersey × Red Danish cows, respectively. Otto et al. (1991) calculated an R^2 of 0.62 to describe the relationship between BW and BCS in US Holstein cows. That relationship improved considerably when adjusting for the distance from hooks to pins and the distance between hooks ($R^2 = 0.83$). In a series of research studies, a one unit change in BCS has been associated with a corresponding weight change of 21 to 110 kg (Mulvany, 1981; Wright and Russel, 1984b; Chilliard et al., 1991; Otto et al., 1991; Waltner et al., 1994; Enevoldsen and Kristensen, 1997; Komaragiri and Erdman, 1997; Komaragiri et al., 1998; Samarütel et al., 2001; Jaurena et al., 2005; Berry et al., 2006). The variability among those estimates is partially explained by whether they were calculated from total live weights or only account for changes in the weight of actual lipid reserves. In addition, the regression equations used by those researchers accounted for a variety of other factors (e.g., gut fill, age, and breed). In a comparison of Danish Holstein, Danish Red, and Danish Jersey cows, Nielsen et al. (2003) documented no significant effect of breed or parity on the relationship between BW and BCS.

Consistency and Limitations of Body Condition Scoring Systems

The usefulness and relative precision of BCS is well documented (Wright and Russel, 1984a,b; Ferguson et al., 1994; Hady et al., 1994; Domecq et al., 1995; Schwager-Suter, 1999; Kristensen et al., 2006). Ferguson et al. (1994) demonstrated that human observers agreed with a modal BCS of 4 observers 58.1% of the time and varied by only 0.25 units 32.6% of the time. Thus, BCS changes of 0.25 cannot realistically be detected even with trained observers. Correlation among observers varied from 0.763 to 0.858. They concluded that BCS could be separated by 0.25 units between 2.5 and 4.0, but only by 0.5 units below 2.5 or above 4.0. Comparing scores obtained by one evaluator using the Edmonson (1989) chart with those obtained by a pair of evaluators using the Ferguson et al. (1994) decision chart, Samarütel et al. (2001) reported that 83% of scores varied by only 0 or 0.25 units with a correlation of 0.88 in Estonian Holstein, Estonian Red, Red Holstein, and Estonian Native primiparous cows. Using a combined visual and tactile BCS system, Kristensen et al. (2006) evaluated the consistency and quality of BCS using 51 practicing dairy veterinarians and 6 highly trained instructors. Kappa values were used to assess agreement among classifiers beyond agreement by chance with 0 representing no agreement and 1 representing perfect agreement. Agreement between repeated BCS obtained from the same cows on separate occasions by the instructors was high (kappa $\geq$ 0.86). On the other hand, within-classifier (kappa values between 0.22 to 0.75) and between-classifier agreement (kappa values between 0.17 to 0.78) were more variable. Given those differences, those researchers stress the importance of training and validation of assessors before comparing BCS obtained from different scorers in different herds. Although variation in subjective BCS between animals is generally larger than variation within animals (caused by variation between scorers), within animal variation is measurable (Evans, 1978). Evans (1978) suggested using a second, independent assessor to reduce that variation.

Because BCS only assesses subcutaneous fat stores, which only represent 25% of total body fat mobilized during early lactation (Butler-Hogg et al., 1985), BCS is more useful for assessing the relative amount of body fat mobilization than the absolute amount of body fat mobilization (Gregory et al., 1998). Intermuscular fat is the largest depot of fat in all physiological stages, and subcutaneous fat is the second largest (Butler-Hogg et al., 1985). Although the greatest absolute lipid weight changes occur within intermuscular fat depots, the largest proportional change with changing total fatness occurs with subcutaneous fat depots (Butler-Hogg et al., 1985). That relationship implies that subcutaneous fat is the most responsive depot to total fat reserve depletion. Jaurena et al. (2005) demonstrated that in late pregnant and early lactation cows, changes in BCS at the lower end of the scale reflect changes in LM depth more than subcutaneous body fat.

Scorers, particularly those with less experience, tend to be reluctant to score cows near the end points of the BCS scale (Kristensen et al., 2006). Additionally, some nutritionists or veterinarians may be hesitant to score cows in those ranges because of fear of offending their clientele (Ward, 2003). Overestimation of BCS may occur in early lactation, young, or lean cows, and underestimation may occur in the dry, older, or fat cows (Schröder and Staufenbiel, 2006). Using the New Zealand BCS system, Gregory et al. (1998) noted that the actual amount of body fat did not change much at lower BCS. Difficulties may also be encountered when scoring cows close to calving, as ligaments around the tailhead relax, or when scoring cows that are lying down or standing on a slope (Ward, 2003). Furthermore, scorers may be reluctant to assign scores in categories where they may have only observed few similar cows previously.

Differences Among Breeds

Generally speaking, dual-purpose dairy breeds (e.g., Brown Swiss) have more muscle than dairy breeds historically selected primarily for milk production (e.g., Holstein). Dairy breeds deposit more of their fat intra-abdominally than do beef breeds (Otto, 1990). Consequently, changes in body condition within dual-purpose cows may be more reflective of changes in muscle content than in Holstein cows for which most body condition systems were designed, where changes in body condition are primarily reflective of changes in fat content (De Campeneere et al., 2000).

Schwager-Suter et al. (2000) demonstrated that BCS of Holstein-Friesians were lower than those of Jerseys or Holstein-Friesian F_1 crosses. However, because the relationships between ultrasound measures of subcutaneous fat and LM were high for all 3 genotypes, they concluded that the Edmonson et al. (1989) BCS system was valid for all dairy cows. Similarly, Washburn et al. (2002) and Roche et al. (2007c) observed higher BCS in Jersey than in Holstein cows. On the contrary, Rastani et al. (2001) did not observe a difference in BCS between Holsteins and Jerseys. Those researchers did report a significant relationship between BCS and fat depth at the rib and thurl areas for Jerseys but not for Holsteins. In Canada, BCS were higher for Ayshire (3.07) than for Holstein cows (2.93; Moro-Mendez et al., 2008). In a Swiss study, Braunvieh and Simmental × Red Holstein crossbred cows had higher BCS than Holstein cows (Aeberhard et al., 2001). Begley et al. (2007) reported that BCS at breeding was significantly higher for Norwegian Red and Holstein-Friesian × Norwegian Red crossbred cows than for Holstein-Friesian cows. In a crossbreeding study, Jersey × Holstein crosses had significantly higher BCS (2.80) than pure Holstein cows (2.71; Heins et al., 2008).

BCS Patterns and Differences

Typically, BCS will decrease by about 0.5 units during the first 2 to 3 mo of lactation followed by a slow recovering through mid- to late-lactation (Ferguson, 1996; Broster and Broster, 1998). Fat cows tend to lose more body condition during early lactation than thin cows (Garnsworthy and Topps, 1982; Grainger et al., 1982; Garnsworthy and Jones, 1987; Ruegg et al., 1992a; Pedron et al., 1993; Ruegg and Milton, 1995; Heuer et al., 1999; Lacetera et al., 2005; Roche et al., 2007a,c). Further exacerbating that effect, fat cows take longer to begin regaining lost body condition than thin cows (Garnsworthy and Topps, 1982; Pedron et al., 1993). Thin cows have even been shown to gain body condition during early lactation (Garnsworthy and Topps, 1982; Ruegg and Milton, 1995; Heuer et al., 1999). Reid et al. (1986) demonstrated that the loss in condition for fat cows during early lactation was more related to differences in the size of muscle fibers than fat depth or adipocyte size. They suggested that the loss of muscle fiber was an indication of an acute phase response.

Primiparous cows do not lose as much body condition as multiparous cows (Ruegg and Milton, 1995; Domecq et al., 1997b; Dechow et al., 2003; Mao et al., 2004; Lee and Kim, 2006; Friggens et al., 2007; Roche et al., 2007a). On the other hand, first lactation cows may not replenish lost energy reserves as effectively as older animals, indicating a potential need for separate feeding of first lactation cows (Roche et al., 2007a). In one study, second-parity cows started lactation with a lower BCS and lost more BCS than younger or older cows reflective of a "sophomore slump" (Heuer et al., 1999; Roche et al., 2007c). Within-lactation loss in BCS tends to increase with increasing parity (Waltner et al., 1993; Coffey et al., 2002). A cumulative effect of BCS patterns throughout the lifetime of a cow also exists. Coffey et al. (2004) demonstrated in cows selected for higher milk production that the level of energy reserves progressively decreases with advancing age from parity 1 to 3. Coffey et al. (2002) proposed that energy balance must be viewed considering the cow's entire lifetime because of the "legacy" of BCS patterns as the cow ages, which affects subsequent health and fertility. If the cow never regains lost energy reserves during lactation, the energy balance situation is exacerbated as the cow ages, which may partially explain increased metabolic issues for older animals.

Higher producing cows tend to have lower BCS indicating that nutrients are partitioned toward milk production rather than increasing body reserves (Dechow et al., 2003). High producing cows in one lactation often have low BCS in the next lactation because of excessive loss of body reserves during the lactation of high production (Rao and Anitha, 2004). Between management systems, BCS have been shown to be higher in confinement systems than in pasture-based systems (Washburn et al., 2002). The rate of BCS loss is slower for cows fed a TMR compared with grazing cows, although the loss continues for a longer period of time (Roche et al., 2007a). Stocking rates exacerbate problems with calving BCS or loss in BCS (Roche et al., 2007a). Treatment with recombinant bovine somatotropin has been demonstrated to reduce gains in BCS through the treatment period by 0.5 units ($P < 0.1$; Chilliard et al., 1991). Disease and increasing milking frequency may also reduce BCS (Ferguson, 1996).

Among breeds, patterns of BCS change were similar across Braunvieh and Simmental × Red Holstein crossbred cows and Holstein-Friesian cows, although Braunvieh cows were able to recover from energy deficiency faster than other breeds (Aeberhard et al., 2001). Holstein cows lost more BCS between before calving and nadir BCS (0.59 units) than Jerseys (0.29 units) in a Connecticut study (Rastani et al., 2001). Danish Red cows had a BCS nadir 0.5 higher than Holstein or Jersey cows (Mao et al., 2004). Friggens et al. (2007) determined that Danish Holsteins mobilized more energy than Danish Red or Jersey cows. North American Holsteins have lower BCS and increased BCS loss when compared with New Zealand Holsteins (Kolver et al., 2000; Horan et al., 2005; Roche et al., 2006; McCarthy et al., 2007). Roche et al. (2006) hypothesized that this indicates that higher milk production in North American Holsteins in grazing systems is primarily a factor of mobilization of body reserves. Further, because North American Holsteins take longer to return to positive energy balance, it is likely that the 2 strains either have different hormonal concentrations, different responses to hormones, or both (Roche et al., 2006). Consequently, this has led some to conjecture that variations in genetic differences in the partition of nutrients from energy reserves should dictate the type of animal to use within different management systems. North American dairy cattle, bred largely for higher milk production in confinement systems, may not be as suitable for less intensive, pasture-based systems common in other countries.

Feed Intake and Efficiency

Most, although not all, research has demonstrated that DMI decreases with increasing BCS at calving (Broster and Broster, 1998). Generally, DMI is greater in cows carrying less condition (Garnsworthy and Topps, 1982; Treacher et al., 1986; Garnsworthy and Jones, 1987). Body fat has a negative feedback impact on DMI, with increasing levels of body fat causing a reduction in DMI (Garnsworthy, 2007). The decrease in DMI for cows with higher BCS begins during the close-up period (Hayirli et al., 2002).

Jones and Garnsworthy (1989) proposed that with high-energy diets, thin cows eat more than fat cows, leading them to produce similar amounts of milk. However, when thin cows are fed lower energy diets, milk production is substantially reduced. British work has clearly demonstrated that thin cows produce more milk directly from feed rather than from energy reserves and concluded that this made them more "biologically efficient" (Garnsworthy and Topps, 1982; Garnsworthy and Jones, 1987). On the other hand, Grainger et al. (1982) argued that thin cows used more of their feed energy for BW gain at the expense of milk production.

BCS and Milk Yield

Most studies examining the effect of BCS on milk production have failed to identify a significant or meaningful relationship (Garnsworthy and Topps, 1982; Ruegg et al., 1992a; Pedron et al., 1993; Ruegg and Milton, 1995; Hady and Tinguely, 1996; Broster and Broster, 1998; Busato et al., 2002; Ferguson, 2002). However, differences have been observed in some studies. For example, in early British work, cows calving with BCS <2 (US BCS <2.75) produced below their potential milk yield whereas those calving with BCS above 2.5 (US BCS >3.25) produced above their potential milk yield (Frood and Croxton, 1978). Treacher et al. (1986) reported that fat cows produced 500 kg less during lactation than thin cows, although that result was not significant. In a pasture setting, Grainger et al. (1982) demonstrated increased early lactation milk production with increased BCS at calving. Waltner et al. (1993) observed a 322-kg increase in milk production to 90 d when increasing BCS at calving from 2.0 to 3.0. An additional 33 kg of milk was gained by increasing BCS from 3.0 to 4.0, but increasing BCS from 4.0 to 5.0 resulted in a decrease of 223 kg of milk. Domecq et al. (1997b) observed that the change in BCS during the dry period affected milk production in the subsequent lactation. In their study, a one-point gain in BCS between dry-off and calving was associated with 545 kg more milk during the first 120 d of lactation. For dry-off BCS, an additional point was associated with 300 kg less milk during the first 120 d of lactation. Further, they indicated that cows that lost one point of BCS during early lactation produced 242 kg more milk. Markusfeld et al. (1997) calculated increases of 170.2 and 182.6 kg of 3.5% FCM during the first 90 DIM for primiparous and multiparous cows, respectively, with each additional unit of BCS at calving. Contreras et al. (2004) reported that cows with BCS ≤3.0 at dry-off tended ($P < 0.14$) to produce more milk than cows with BCS ≥3.25. In Irish cows in a grazing environment, 305-d milk yield increased with increasing BCS at calving, although increasing BCS was also associated with reduced lactation persistency (Berry et al., 2007a). Generally, increased BCS losses are associated with increased milk production (Ruegg and Milton, 1995; Berry et al., 2007d).

A curvilinear response of milk production to increasing BCS with increases occurring up to a threshold and decreasing after that may partly explain the variation in results across studies (Berry et al., 2007a,d; Roche et al., 2007b). Berry et al. (2007d) proposed that research indicating a nonlinear effect of BCS at calving on milk production suggests that maximum milk production is associated with BCS at calving of 3.25 to 3.5. Further, because many of the studies included only a small number of animals in either extreme, statistical power likely limited the ability to find differences with milk production (Suriyasathaporn et al., 1998).

BCS and Disease

Rates of metabolic diseases generally increase with increasing milk production and herd size (Oetzel, 2004). The greatest benefits from managing cows for optimal BCS at each stage of lactation likely come from improvements in animal health (Waltner et al., 1993). British research demonstrated that fat cows experienced significantly more cases of periparturient disease than thin cows (Treacher et al., 1986). However, in published research the association between absolute BCS or changes in BCS with health disorders has been variable (Ferguson, 2002). A major limitation with much of the research designed to examine the impact of varying BCS is a lack of animals in the more extreme condition score ranges (Waltner et al., 1993; Broster and Broster, 1998). In the summary below, results from studies where significant relationships between BCS and disease were demonstrated are presented individually, whereas studies where no significant relationships were observed are only listed.

Ketosis. The most consistent relationship among published studies has been the increased incidence of ketosis for cows with higher BCS at calving (Duffield, 2000; Ferguson, 2002). Ketosis is characterized by elevated ketone bodies, intermediate products of the breakdown of fats, in body tissues and fluids. During negative energy balance, NEFA levels are elevated, particularly for overconditioned cows (Busato et al., 2002; Oetzel, 2004; Lacetera et al., 2005). Continued efforts to increase milk yields in dairy herds will increase risks and concerns for ketosis (Duffield, 2000). Across 3 parity groups (1, 2, and ≥3), Dyk (1995) reported increasing incidence of ketosis with increasing BCS measured during the last 2 wk prepartum. In an Israeli study, each additional unit of BCS at calving was associated with an odds ratio of 2.2 for risk of ketosis for parity ≥3 cows, but only when length of dry period was not included in the model (Markusfeld et al., 1997). Rasmussen et al. (1999) observed that cows with BCS at calving of 3.5 (US BCS 4.25) had 2 times the risk for getting ketosis as cows calving at BCS 2.0 (US BCS 2.75). In Norwegian cattle, Gillund et al. (2001) demonstrated that the risk for ketosis for cows with BCS ≥3.5 at calving was more than 2 times that of cows with BCS ≤3.25. Further, they noted that cows with ketosis tended to lose more BCS than cows not having had ketosis. Duffield (2000) reported that both clinical and subclinical ketosis incidence increased with BCS at calving. Busato et al. (2002) demonstrated that cows with BCS >3.25 before calving and cows that lost >0.75 BCS units during the first 8 wk of lactation showed signs of subclinical ketosis. In a study of 1,424 lactations in 8 different Israeli herds, the odds ratio for ketosis was 2.3 for cows with BCS ≥3.75 at dry-off compared with cows with lower BCS (Nir, 2007). Heuer et al. (1999) did not find a significant relationship between

BCS and ketosis. Differences among studies for ketosis incidence may be partially explained by differences in case definitions between farms and difficulties in distinguishing between clinical and subclinical ketosis (Oetzel, 2004).

Metritis. Metritis is an inflammation of the lining of the uterus, most prevalent during early lactation. Butler and Smith (1989) reported significantly higher incidence of metritis in cows losing 0.5 to 1.0 BCS units (22%) or >1.0 BCS units (47%) when compared with cows losing <0.5 BCS units (6%). Markusfeld et al. (1997) demonstrated that cows losing more BCS during the dry period were more likely to experience metritis. Titterton and Weaver (1999) observed higher uterine discharge scores for cows calving with BCS ≤2.5 (≤3.25 US BCS) or ≥3.5 (≥4.25 US BCS) than for cows calving with BCS of 3.0 using the Mulvany (1977) BCS system. Heuer et al. (1999) computed a higher odds ratio (1.9) among thin cows (BCS ≤2.0) as compared with normal or fat cows. Kim and Suh (2003) observed significantly higher incidence of metritis in cows losing ≥1 point of BCS between dry-off and "near calving" than in cows that lost <1 point during the dry period. In a German study, cows with BCS at calving <3.0 were more likely to have metritis than cows with a higher BCS at calving (odds ratio = 2.95; Hoedemaker et al., 2008). Waltner et al. (1993) failed to identify a relationship between BCS and metritis.

Retained Placenta. Failure to release placental tissues from the uterus after calving is referred to as a retained placenta or retained fetal membranes. For likelihood of retained placenta or metritis, Markusfeld et al. (1997) calculated an odds ratio of 0.7 for each additional unit of BCS at calving, indicating that cows with higher BCS at calving were less likely to experience retained placentas. Similarly, they showed that the odds ratios for retained placenta were 0.6 and 1.6 for each additional unit of BCS at dry-off and units lost during the dry period, respectively. Contreras et al. (2004) demonstrated that cows with BCS ≥3.25 had a significantly higher incidence of retained placenta than cows with BCS ≤3.0. Nevertheless, most studies have failed to identify a relationship between incidence of retained placenta and BCS (Gearhart et al., 1990; Pedron et al., 1993; Waltner et al., 1993; Dyk, 1995; Heuer et al., 1999; Kim and Suh, 2003).

Milk Fever. Milk fever or parturient paresis is a paralysis of the cow caused by a deficiency in blood calcium that generally occurs during the first few days following calving. In a Dutch study, an odds ratio for risk of milk fever of 3.3 was calculated for fat cows (BCS ≥4.0) as compared with normal or thin cows (Heuer et al., 1999). Roche and Berry (2006) calculated increased odds ratios of 1.13 and 1.31 for cows calving with BCS ≤2.50 or ≥3.50, respectively. On the other hand, Dyk (1995) did not find a relationship between BCS during the last 2 wk prepartum and milk fever.

Lameness. Gearhart et al. (1990) proposed that fat cows may experience more lameness because of increased mechanical stress associated with the extra weight they carry. Indeed, in their study, cows that were overconditioned at dry-off (≥4.0–) were 7 times more likely to experience foot problems in the subsequent lactation than cows in good condition. Lameness may also initiate a decrease in BCS through reductions in DMI possibly even before clinical lameness is observed. Underconditioned cows (BCS ≤2+) were more likely to develop foot problems, although that result was based on only 3 underconditioned cows (Gearhart et al., 1990). In a German study, cows with BCS <3.0 at calving and during early lactation were more likely to be lame (Hoedemaker et al., 2008). However, other studies have failed to identify a relationship between BCS and lameness (Ruegg and Milton, 1995; Heuer et al., 1999).

Cystic Ovaries. Gearhart et al. (1990) determined that cows overconditioned at dry-off (≥4.0−) had 2.5 times the risk of cystic ovaries in the next lactation than cows in good condition at dry-off. In an Israeli study, cows with higher BCS for all parities were less likely to have inactive ovaries than cows with lower BCS (Markusfeld et al., 1997). In the same study, cows that lost more BCS during the dry period were 2.1 times more likely to have inactive ovaries for each additional BCS unit lost. Opsomer et al. (2000) calculated odds ratios for delayed ovarian function of 18.7 and 10.9 for cows losing more body condition during the first and second months of lactation, respectively. On the other hand, BCS at calving was not related to risk of cystic ovaries. Other studies have not identified a relationship between BCS and cystic ovaries (Ruegg et al., 1992b; Waltner et al., 1993; Ruegg and Milton, 1995; Heuer et al., 1999).

Dystocia. Dystocia refers to a difficult or excessively laborious parturition. Gearhart et al. (1990) demonstrated that cows losing more body condition during the dry period were at a higher risk for dystocia. However, most studies that examined that relationship did not identify a significant association (Waltner et al., 1993; Dyk, 1995; Berry et al., 2007b). Analysis of the association of BCS with dystocia is complicated considering that both measures are subjective, potentially reducing the ability to identify a statistical relationship.

Mastitis. Mastitis is an inflammation of the udder generally caused by bacteria. The direct relationship between BCS and mastitis is weak. Berry et al. (2007c) showed reduced somatic cell scores in parity 1 and 2 cows and increased somatic cell scores in parity 3 cows with increasing BCS at calving, but clinical mastitis rates were not significantly associated with BCS in that study. Most studies have not demonstrated any relationship between mastitis and BCS (Gearhart et al., 1990; Dyk, 1995; Ruegg and Milton, 1995; Heuer et al., 1999).

Displaced Abomasums

A displaced abomasum occurs when the cow's abomasum is twisted to the left or right side from its normal position. Across 3 parity groups (1, 2, and ≥3), Dyk (1995) demonstrated increasing incidence of displaced abomasums with increasing BCS measured during the last 2 wk prepartum. In a statistical analysis using data from the same data set, Cameron et al. (1998) also noted significant increases in incidence of displaced abomasums with increasing BCS. Hoedemaker et al. (2008) reported that cows with higher BCS losses during early lactation were more likely to have a displaced abomasum.

BCS and Fertility

Although increased milk production receives much of the blame for reduced fertility in modern dairy cattle and genetic selection for milk production has played a role in that decline (Khatib et al., 2008), changes in postpartum ovarian activity have generally been more related to negative energy balance (Beam and Butler, 1999). During early lactation, production is prioritized over reproduction (Ferguson, 2001). Dairy animal fertility is retarded by negative energy balance during early lactation because of changes in insulin, insulin like-growth factors, and bovine somatotropin (Spicer et al., 1990; Beam and Butler, 1999; Loeffler et al., 1999a). When a cow is in negative energy balance, the ability of the uterus to recover after calving is impaired. As tissue is mobilized, it is likely that those metabolic changes also damage oocytes. The growth hormone-IGF axis is altered, reducing the bioavailability of IGF-I. Those changes to the reproductive system ultimately increase the time to first ovulation, reduce conception rates, and impact early embryonic development (Wathes et al., 2007).

As with health, responses to varying BCS of reproduction have varied considerably within the literature (Broster and Broster, 1998). Reasons for variation in results from studies of the impact of BCS on reproduction include differences in sample size, BCS variation, analysis type, choice of trait to be analyzed, scoring frequency, and within-study animal differences (Berry et al., 2007d). Relationships with reproductive factors may be skewed because extreme cows may never have the opportunity to be inseminated because of other complications (Ferguson, 2002). Decreased reproductive performance has been more closely related to low BCS at first insemination or increased BCS loss than with BCS at calving (Ferguson, 2002). Infertility problems in dairy herds can be mitigated either by increasing the voluntary waiting period or the time when breeding begins, or by reducing the extent and duration of negative energy balance (Collier et al., 2005).

Days to First Ovulation. The recovery of daily energy balance from its most negative state is highly related to the initiation of ovarian activity (Beam and Butler, 1999). Negative energy balance alters leutinizing hormone profiles along with glucose, insulin, and IGF-I levels, which limits estrogen production by dominant follicles (Butler, 2003). Consequently, the time to first ovulation is highly related to negative energy balance. Butler and Smith (1989) observed significantly more days to first ovulation for cows losing >1.0 units of BCS as compared with cows losing <1.0 unit. Reist et al. (2000) concluded that the interval between calving and first ovulation was significantly associated with mean and minimum (from 2 wk prepartum to 6 wk postpartum) BCS. Yamada et al. (2003) demonstrated that the percentage of cows with ovarian activity before 55 DIM was significantly higher for cows bred using a synchronization protocol with a BCS of 2.75 to 3.25 at 30 DIM and around breeding time than for cows with BCS ≤2.5. Shrestha et al. (2005) reported that cows with delayed first ovulation had lower BCS at 5, 7, 9, and 11 wk postcalving than cows with normal intervals to ovulation. Additionally, they showed that cows losing >1 BCS units were at risk for increased days to first ovulation. Senatore et al. (1996) did not find a relationship between BCS at calving or BCS loss with days to first ovulation.

Days to First Estrus. In one trial, Garnsworthy and Topps (1982) showed that cows calving at a medium BCS (2.5 to 3.0 UK BCS, 3.25 to 3.75 US BCS) had significantly fewer days to first estrus than cows with high or low BCS, but that result was not observed in another trial. Grainger et al. (1982) demonstrated that increasing BCS at calving resulted in shorter days to first estrus. Butler and Smith (1989) observed significantly more days to first service for cows losing >1.0 units of BCS as compared with cows losing <1.0 unit. In a controlled study of Holstein heifers, the onset of diestrus was delayed in fat heifers that were also in negative energy balance (Villa-Godoy et al., 1990). Those researchers suggested that a negative energy balance coincident with excess condition could reduce the accuracy of timing of insemination, which would reduce fertility. Hegazy et al. (1997) reported significantly fewer days to first estrus for each 0.5-point interval from ≤1.5 to 3.5 to 4.0. Buckley et al. (2003) showed that lower BCS between 60 to 100 DIM was associated with reduced chances of being serviced in the first 21 d of the breeding season in an Irish spring-calved herd. In a New Zealand study of grazing cows, high BCS precalving, at calving, and during lactation were associated with greater probability of being detected in estrus before the planned start of mating (Roche et al., 2007c). Ruegg and Milton (1995) did not find significant differences for days to first estrus associated with BCS at calving. Similarly, in a large California herd, neither BCS at calving nor BCS loss were related to days to first estrus (Ruegg et al., 1992b).

Days to First Service. Garnsworthy and Topps (1982) showed that cows calving at a medium BCS (2.5 to 3.0 UK BCS, 3.25 to 3.75 US BCS) had significantly fewer days to first service than cows with high or low BCS in one trial, but that result was not observed in another trial. Braun et al. (1987) reported that days to first service were significantly fewer for cows with moderate BCS at calving (3.0 to 3.5), prebreeding (2.5 to 3.0), and peak milk (3.0 to 3.5) as compared with cows with higher or lower BCS. Pedron et al. (1993) showed BCS at calving to have a significant effect on days to first service. In a Dutch study, BCS losses were associated with an increase in days to first insemination (Suriyasathaporn et al., 1998). Additionally, cows with BCS <3 had a lower risk of first service than cows with BCS >3. Kim and Suh (2003) determined that the days to first service were significantly longer for cows losing ≥1.0 BCS units (103 d ± 7.8) compared with cows losing <1.0 BCS unit (87 d ± 5.3). Hoedemaker et al. (2008) reported that cows losing >0.25 BCS were more likely to have days to first service >80 d. The BCS at calving has not been associated with days to first service in other studies (Jones and Garnsworthy, 1988; Ruegg et al., 1992b; Waltner et al., 1993; Ruegg and Milton, 1995; Gillund et al., 2001).

First Service Conception Rate. The loss in BCS during the postpartum period appears to have a strong relationship with first service conception rate, but the absolute BCS at calving does not have a strong relationship with first service conception rate. Butler and Smith (1989) reported significantly lower first service conception rates (17%) for cows losing >1 BCS compared with cows losing 0.5 to 1 units (53%) or <0.5 units (65%). Domecq et al. (1997a) concluded that multiparous cows that lost 0.40 and 0.80 points of BCS were respectively 0.85 and 0.74 times more likely to conceive at first service than cows that did not lose BCS. Suriyasathaporn et al. (1998) concluded that cows with BCS 2 to 2.75 after 45 DIM were more likely to conceive at first service than cows with BCS <2 or BCS ≥ 3. Increased losses in BCS were also associated with decreased risk of conception. Gillund et al. (2001) demonstrated that cows with marked losses (≥1.25) in BCS were half as likely to conceive at first insemination as cows with modest (0.75 to 1.00) losses in BCS. Loeffler et al. (1999b) determined that the likelihood of becoming pregnant was highest for cows with a BCS of 3.0 at first service with lower odds ratios, 0.74 and 0.65 for cows with BCS ≥3.5 or ≤2.5, respectively. In another study from that same research group (Loeffler et al., 1999a), BCS at first insemination was not significant, but the loss in BCS during the first 100 d of lactation was significant with cows losing more BCS being less likely to conceive.

Heuer et al. (1999) observed reduced odds for first service conception (odds ratio = 0.4) for fat cows (≥4.0) as compared with normal or thin cows. In a study of cows on different synchronization protocols, Stevenson et al. (1999) concluded that each additional unit of BCS at 46 to 66 DIM resulted in an 8.6% (±4%) increase in conception rate. In a timed AI program at first service, pregnancy rates were significantly lower at 27 and 45 d after insemination for cows with BCS <2.5 and BCS ≥2.5 at 63 DIM (Moreira et al., 2000). Ferguson (2001) showed that first service conception rate progressively decreased from 55.9% for cows losing 0.51 to 1.0 units of BCS to 28.6% for cows losing >1.0 unit of BCS from calving to breeding. In estrus synchronized Japanese Holsteins, conception rates were significantly higher for cows with BCS of 2.75 to 3.25 at 30 DIM and day of Ovsynch (53.8 and 59.0%, respectively) when compared with those with BCS ≤2.5 (11.1 and 20%, respectively; Yamada et al., 2003). Further, cows with BCS 3.75 to 4.25 prepartum had higher conception rates than cows with BCS ≤3.5. Buckley et al. (2003) demonstrated that cows with a low BCS nadir had reduced conception rates compared with cows with moderate or high BCS nadir. In a meta-analysis, Lopez-Gatius et al. (2003) reported that the relative risks of conception at first service were 0.91 and 1.04 for cows at calving with BCS <2.5 or >3.5, respectively, compared with cows with BCS 2.5 to 3.5. In the same report, significant differences were not calculated for BCS at first service or BCS loss during early lactation. Roche et al. (2007c) demonstrated that higher BCS at calving and BCS at first service significantly affected pregnancy at first service. Patton et al. (2007) showed that cows with lower BCS at first service had significantly lower conception rates.

Markusfeld et al. (1997) failed to observe a relationship between BCS at calving and first service conception rate. Similarly, Walsh et al. (2007) did not find a relationship between calving BCS, BCS at 60 DIM, or BCS change with the probability of pregnancy at first service.

Number of Services. Garnsworthy and Topps (1982) showed that cows calving at a medium BCS (2.5 to 3.0 UK BCS, 3.25 to 3.75 US BCS) had significantly fewer services per conception than cows with high or low BCS in one trial, but that result was not observed in another trial. Hegazy et al. (1997) determined that the number of services per conception was lower for cows scoring ≤1.5 or 2.0 at service than for cows with BCS ≥2.5. The BCS before submitting to a synchronization protocol did not affect the number of services by 365 d postpartum in a Florida study (Moreira et al., 2000). The BCS at calving is less likely to influence number of services per conception (Jones and Garnsworthy, 1988; Ruegg et al., 1992b; Pedron et al., 1993; Waltner et al., 1993; Ruegg and Milton, 1995; Gillund et al., 2001).

Calving Interval and Days Open. Garnsworthy and Topps (1982) showed that cows calving at a medium BCS (2.5 to 3.0 UK BCS, 3.25 to 3.75 US BCS) had significantly fewer days to conception than cows with high or low BCS in 1 trial, which was not observed in another trial. Wildman et al. (1982) reported significantly different average BCS of 2.66, 2.92, and 3.22 for cows with days open <60, 60 to 100, and >100, respectively. Braun et al. (1987) observed days open to be significantly lower for cows with moderate BCS at calving (3.0 to 3.5), prebreeding (2.5 to 3.0), and peak milk (3.0 to 3.5) as compared with cows with higher or lower BCS. Ruegg et al. (1992b) showed that cows with BCS <3.50 at calving had fewer days open than cows with BCS ≥3.50 at calving. In primiparous cows, Markusfeld et al. (1997) reported that the calving interval was 6.3 d shorter for each additional unit of BCS at calving. Hegazy et al. (1997) reported that days open decreased significantly for each BCS at service interval up to score 3.0. Fagan et al. (1989) demonstrated that cows with a BCS <2.5 had longer calving intervals than those with BCS ≥2.5.

In a meta-analysis, Lopez-Gatius et al. (2003) reported that cows with BCS <2.5 or >3.5 had 5.9 more or 5.8 fewer days open, respectively, compared with cows with BCS 2.5 to 3.5 at calving. In the same analysis, cows with BCS <2.5 at first service had 12.2 more days open and cows with BCS >3.5 had 11.9 fewer days open than cows with BCS 2.5 to 3.5. For BCS change in early lactation with <0.5 points loss as the reference category, cows that lost 0.5 to 1.0 or >1.0 BCS had 3.5 or 10.6 more days open, respectively. Cows that increased BCS during early lactation had 3.7 fewer days open. Wathes et al. (2007) noted that cows with a BCS ≥3.0 (US BCS ≥3.75) took 3 wk longer to conceive than cows with a BCS of 2.0 to 2.9 (2.75 to 3.5 US BCS). In an Irish study, lower BCS nadir significantly increased days open (Patton et al., 2007). Other studies have failed to find a relationship between BCS at calving and days open (Jones and Garnsworthy, 1988; Ruegg et al., 1992b; Pedron et al., 1993; Ruegg and Milton, 1995; Moreira et al., 2000).

Embryonic Losses

In a pasture-based production system, the risk for embryonic losses between d 28 to 84 of gestation increased linearly (for BCS change between 28 to 56 DIM categorized at quarter point intervals) from an odds ratio of 0.28 for an increase of 1.0 BCS unit to an odds ratio of 3.23 for a decrease of 1.0 unit (Silke et al., 2002). In that study, embryonic losses were 11.6% for cows that lost BCS, 4.7% for cows that maintained BCS, and 5.7% for cows that increased BCS between 28 to 56 DIM. Likewise, Lopez-Gatius et al. (2002) reported that a one-unit decrease in BCS between calving and 30 DIM increased pregnancy loss between 38 to 90 d of gestation by a factor of 2.4.

BCS and Physiological Factors

Cows with high BCS (≥3.5) have been shown to have lower overall antioxidant potential and higher TNF-α (an inflammatory cytokine) expression than cows with normal BCS (2.5 to 2.7), which may partially explain their increased disease susceptibility (O'Boyle et al., 2006). In an Italian study, Bernabucci et al. (2005) demonstrated that cows with higher BCS had higher plasma reactive oxygen metabolites, thiobarbiuric acid-reactive substances, and thiol groups, and lower superoxide dismutase and erythrocyte thiol groups, all indicating that overconditioned cows are more sensitive to oxidative stress. Overconditioned cows (BCS ≥3.5) secrete less Ig and interferon-gamma than medium (BCS 2.6 to 3.4) or thin (BCS ≤2.5) cows, further demonstrating the mechanism for observed immunosuppression during early lactation for fat cows (Lacetera et al., 2005).

In the last 10 yr, researchers have also begun to explore the role of leptin in management of energy reserves in dairy cattle. Leptin plays a key role in body homeostasis, energy intake, storage, and expenditure and immune function (Chilliard et al., 2000, 2005). It stimulates adipose tissue lipolysis and reduces lipogenesis (Chilliard et al., 2005). Adipose tissue is the primary source of leptin (Chilliard et al., 2005; Kadokawa and Martin, 2006). Generally, leptin levels are higher in fat cows than in thin cows (Meikle et al., 2004; Chilliard et al., 2005; Kadokawa and Martin, 2006). Leptin yield is decreased with underfeeding, β-adrenergic stimulation, and short day length, whereas it is increased by insulin and glucocorticoids (Chilliard et al., 2000). Kadokawa and Martin (2006) demonstrated that leptin decreased during early lactation toward a nadir then stabilized around the time of first ovulation. Meikle et al. (2004) demonstrated that the decrease in leptin around parturition began before parturition. Lactation decreases leptin levels even when the cow is in positive energy balance (Block et al., 2001). Decreased leptin levels in periparturient cows lead to increased DMI and prioritize energy partitioning away from reproduction (Block et al., 2001). Because changes in BCS and leptin during lactation are similar, leptin plays a key role in physiological management of energy reserves. Furthermore, changing leptin levels may also be related to the aforementioned health and reproductive changes associated with excessive loss of BCS during early lactation.

BCS and Animal Well-Being

It is important to discuss the animal well-being and public perception of BCS of dairy cows (Coffey et al., 2003a, Roche, 2005). Body condition score is often identified by consumers as an important indicator of dairy animal well-being. Roche (2005) stated that "looking outside the farm gate, allowing cows to lose excess BCS postcalving paints a poor picture of the dairy industry in the eyes of our customers and urban neighbors." For most people who have never been around dairy cows, the site of a "bony" cow with prominent hooks, pins, ribs, and vertebrae can be a concern. Although public perception is that thin cows are a welfare concern, little research exists to support that concept (Berry et al., 2007c). Although an interesting paradox exists in that the overly fat cows are actually the most problematic, there are certainly welfare concerns of having overly thin cows. Given the pain and physiological stress resulting from disease, extreme BCS in either direction may indeed have potential as an indicator of animal well-being. Moreover, because extreme BCS may be indicative of management shortcomings (e.g., inadequate feed or lameness), it may be used as an objective measure of overall well-being.

Although some may conjecture that dairy producers should be breeding and managing cows that do not lose any weight during early lactation regardless of what they are fed, the underlying physiology to mobilize body fat in early lactation will remain (Roche, 2005). It is more likely that the concern of most consumers relates to the concept of undernutrition. Providing adequate nutrition is a "fundamental requirement for the welfare of all livestock (Agenäs et al., 2006)." Undernutrition may occur when overall husbandry standards are low, when profitably is low, or when the industry is changing rapidly (Agenäs et al., 2006). The BCS is only one indicator of undernutrition, and its usefulness for welfare assessment has been limited by the subjective nature of the technique (Agenäs et al., 2006). In a review of potential indicators of undernutrition in cattle, Agenäs et al. (2006) noted that none of the commonly considered blood parameters were particularly useful for identification of undernutrition. They defined a theoretical ideal indicator as one that would determine the degree of undernutrition at all degrees of severity. As the consuming public continues to become more aware of the perils of obesity in humans, the reductions in animal well-being resulting from overconditioned dairy cows should be easier to convey.

Dairy producers should be cognizant of the concerns of the general consumer with regard to BCS. Nutritional, management, and genetic programs should be designed with a long-term view of that concern. In the future, many countries are likely to see either mandatory animal well-being guidelines or marketing differentiation niches centered on BCS.

Genetics of BCS

Genetic studies have clearly demonstrated differences among sires for condition score curves (Jones et al., 1999; Koenen et al., 2001; Coffey et al., 2003b; Mao et al., 2004; Friggens et al., 2007; Wall et al., 2007). Regardless of the shape of the curve, considerable evidence exists to indicate that each cow has a genetically predetermined BCS nadir that they typically reach (Berry et al., 2002; Friggens, 2003; Chagas et al., 2007; Friggens et al., 2007; Garnsworthy, 2007). Although daughters of most bulls lose condition in early lactation and recover that difference in later lactation, the daughters of some bulls lose condition over a longer period and never completely regain condition during lactation (Coffey et al., 2003b; Wall et al., 2007). Those differences are reflected in the rate of BCS loss, the time of BCS nadir, and the subsequent rate of BCS gain (Jones et al., 1999). Although the phenotypic trend for increasing losses in BCS during early lactation with increasing BCS at calving is well documented, higher BCS at calving is associated genetically with less BCS loss during early lactation (Dechow et al., 2002, 2003).

Heritability estimates for BCS have ranged from 0.08 to 0.60 depending largely on the stage of lactation being examined (Koenen and Veerkamp, 1998; Agnew and Yan, 2000; Pryce et al., 2000; Gallo et al., 2001; Koenen et al., 2001; Berry et al., 2002; Dechow et al., 2003; Lassen et al., 2003a; Wall et al., 2003; Pryce and Harris, 2006; Berry et al., 2007d). Not surprisingly, genetic correlations have been lower in studies in which BCS was assessed by different evaluators (Dechow et al., 2003). For BCS change, heritabilities are generally lower (Pryce et al., 2001; Berry et al., 2002; Dechow et al., 2002). Genetic correlations between BCS at varying stages of lactation have ranged from 0.74 to 1.00 (Koenen and Veerkamp, 1998; Gallo et al., 2001; Dechow et al., 2003; Lassen et al., 2003a; Banos et al., 2004; Pryce and Harris, 2006). As a genetic trait, BCS changes through the progression of lactation (Banos et al., 2004).

Genetic variation in BCS may be included in genetic indexes as an indirect trait for improvement in reproductive performance (Agnew and Yan, 2000; Pryce et al., 2002; Coffey et al., 2003b; Wall et al., 2003). Indeed, Irish and British genetic evaluations already include BCS as an indicator trait for fertility (Berry et al., 2007d). Generally, thinner, more angular cows experience more reproductive difficulties (Pryce et al., 2000). Cows with lower average BCS are genetically predisposed to have longer intervals to commencement of luteal activity postpartum (Royal et al., 2002). Increasing BCS have been demonstrated to have favorable genetic correlations with days to first heat, conception rates at first service, intervals to first service, calving intervals, and the number of services per cow (Agnew and Yan, 2000; Dechow et al., 2002; Pryce et al., 2000; Pryce et al., 2002; Berry et al., 2003; Dechow et al., 2003; Wall et al., 2003; Banos et al., 2004; Dechow et al., 2004a; Pryce and Harris, 2006; Wall et al., 2007). Dechow et al. (2003) reported that the genetic correlations were higher than the phenotypic correlations.

Milk, fat, and protein yields have negative genetic correlations with BCS (Berry et al., 2003). Milk yield has been shown to be positively genetically correlated with BCS loss in early lactation (Berry et al., 2002; Dechow et al., 2002). Scottish researchers have demonstrated that cows selected for higher milk production lose more BCS on both high and low concentrate diets during early lactation (Agnew and Yan, 2000; Coffey et al., 2004). From that result, they concluded that breeding cows for higher milk production has led to increased reliance on body reserves in early lactation to support milk production. Dechow et al. (2002) suggested that genetic selection should aim to increase milk yield without increasing the amount of BCS loss during early lactation, which would result in more efficient dairy production.

Positive genetic correlations between energy reserve changes and SCC or clinical mastitis have been noted, although those correlations were fairly small (Sondergaard et al., 2002; Lassen et al., 2003b; Banos et al., 2006; Pryce and Harris, 2006; Wall et al., 2007). Dechow et al. (2004b) calculated a genetic correlation of −0.79 between BCS and a composite of all diseases occurring between 14 d before calving and 150 DIM. Lassen et al. (2003b) reported the genetic correlation to be higher between BCS and diseases other than mastitis than for BCS and mastitis in first-parity cows. This indicates that cows that tend to be thinner have a higher incidence of disease.

The genetic correlations of BCS with dairy form and strength were −0.73 and 0.72, respectively, in a US study (Dechow et al., 2003). Dairy form is a subjective type evaluation trait described by openness and angle of rib, angularity, flatness of bone, and length of neck. Angular dairy cows with high dairy form scores tend to have lower BCS than more round cows. Because the heritabilities for dairy form and strength were higher than for BCS, and the genetic correlation between disease and days open and dairy form was higher than for disease and BCS, those researchers suggested that selecting for lower dairy form may be more appropriate than for BCS (Dechow et al., 2004a,b). On the other hand, the comparative ease of evaluation of BCS as compared with dairy form, along with the potential advantage of breeding for higher BCS being more palatable to producers than breeding for lower dairy form, leave some advantages to BCS over dairy form (Dechow et al., 2004a).

Incorporating the patterns in changes of BCS of daughters of a bull would allow for more balanced genetic selection strategies aimed at increasing milk production and improving fertility and health simultaneously. That strategy has been described as selecting for a cow that "produces a lot of milk, but doesn't look like she produces a lot of milk."

An Interdisciplinary Debate

The increase in milk production since the advent of AI is remarkable and is a testament to the merits of successful implementation of genetic selection. The corresponding decrease in fertility is undesirable and has been the subject of a controversial interdisciplinary debate. Some researchers have proposed that such reduction in fertility is related to a dangerous level of metabolic stress that is preventing cows from becoming pregnant. Metabolic stress results when the duration or intensity of metabolic load, which affects physiological functions, is increased (Nielsen, 1999). They argue that such stress may be indicative of an even greater animal health and welfare problem. Wiltbank et al. (2007) suggested that higher levels of milk production necessitate higher levels of DMI. In turn, high levels of estrogen and progesterone are metabolized in the liver resulting in reduced reproductive performance. Other researchers have stated that such reduction in fertility is simply a protective mechanism.

Ingvartsen et al. (2003) indicated that the time course of energy metabolism matched with disease incidence patterns more than either milk production or DMI. They categorized lipid metabolism as being either compromised or noncompromised, based on environmental factors. Even when the environment is not compromised, the cow will still metabolize some level of body reserves to meet energy demands of early lactation before reaching a positive energy balance and a favorable BCS by time of breeding. Stressors such as food shortages, pathogen burdens, injury, or immune challenges may increase lipid metabolism above a noncompromised level.

Collier et al. (2005) stated that "the fact that some high producing cows have a delay in the time to first ovulation is not evidence of metabolic stress, but rather indicates that the biological controls are coordinating physiological processes similar to what occurs in all mammals and what is homeorhetically predictable." Collier et al. (2005) posed that the metabolic load issues are stress-induced rather than a condition associated with high genetic merit for milk production. Such stress is a result of an input-output imbalance and an inability to rapidly adjust metabolism. Indeed, Knight et al. (2004) demonstrated that cows of high and low genetic merit for milk production had a similar susceptibility to or capacity to cope with metabolic load resulting from extreme output induced by frequent milking, use of bovine somatotropin, and thyroxine (T_4).

Friggens (2003) stated that "for a particular species, the length of the reproductive cycle can be seen as the optimal trade-off between number of pregnancies and the postnatal maternal investment in offspring viability, within the resource availability of the evolutionary niche." From an evolutionary perspective, as priority for a nursing calf decreases, there is a corresponding increase in the priority given toward a future calf (Friggens, 2003). Reproductive failure may not necessarily indicate a problem. In fact, it may be the animal's way of sensing that her current environment is too harsh by avoiding the additional physiological stress of pregnancy (Friggens, 2003). Thinking in terms of protection of a calf in nature, body reserves are a means of circumventing lactational failure. As the calf progresses toward weaning, the consequences of lactational failure decrease, resulting in less need for mobilization of body reserves (Friggens, 2003). In the wild, a fat animal is in more danger of predation, presenting another evolutionary explanation for the animal's tendency to shed excess weight (Knight, 2001). Additionally, perhaps the dam had less time available for grazing and foraging while caring for the newborn; thus, mobilization of body reserves could be a resultant adaptive benefit. Knight (2001) conjectured that extended 18-mo lactations would alleviate a portion of that imbalance, leading to increased longevity and improved welfare. Using pharmaceutical solutions for dealing with reproductive adaptation may actually compromise animal welfare by taking away the animal's ability to cope with metabolic stress by delaying pregnancy (Nielsen, 1999).

Managing BCS

Garnsworthy (2007) suggested that "body condition score is probably the most useful management tool available to dairy producers for assessing the nutritional status of cows." Although the biological reasons for the changing patterns in milk production and body condition may seem simple, the actual management of such a scenario is extremely complex. Additionally, nutritional, health, reproductive, and environmental decisions are made by the dairy producer that have a major impact on changes in body reserves for both individual cows and groups of cows. It is important to note that a BCS is also limited in that it only provides a historical snapshot of what has happened with the animal in recent weeks without providing an indication of what is currently happening. Knight (2001) compared BCS to an odometer on a car. Consequently, tracking changes in body condition through a scoring system is probably of greater value than identifying absolute, snapshot measures of body condition.

Ideal BCS. In discussions of BCS, the ideal cow could be described as a "Goldilocks" cow—one that is neither too thin nor too fat, but rather "just right." Difficulties will arise from having cows that are either too thin or too heavy. The previously mentioned genetically driven target BCS is proof of biological recognition of an intermediate ideal. Of course, that adds to the challenges of managing body condition because it is usually harder to hit a target in the middle of a range compared with a target at either end of a range. The ideal BCS is the level of body fat that allows the cow to optimize milk production while simultaneously minimizing metabolic and reproductive disorders (Perkins et al., 1985b; Spain, 1996). The ideal BCS is highly dependent on lactation stage (Ferguson, 1996). In reality, the ideal level of BCS loss is unknown and highly dependent on the production system in which cows are managed (Coffey et al., 2004).

Current recommendations are based on the research results and practical experience of consultants working with producers, both of which have indicated that cows within the recommended ranges will maintain the best performance. Contreras et al. (2004) suggested that cows with lower BCS (2.75 to 3.0) at dry-off outperform those with higher BCS with modern transition cow management programs in place. Busato et al. (2002) proposed that farmers strive for a BCS around 3.25 during the dry period and for <0.75 units of loss during the first 2 mo of lactation. Ferguson (2001) indicated that decreased fertility begins when cows lose >0.67 units of BCS during early lactation. Chagas et al. (2007) presented the "ideal BCS profile" with focus on minimizing the effects of negative energy balance on reproduction. In their profile, the suggested range for BCS at calving is 3.0 to 3.5 with a nadir of 2.5 to 3.0 and with scores increasing progressively through the remainder of lactation. The shape of the BCS curve is dependent on the animal's (1) genetic target BCS, (2) predisposition to partition nutrients between nutrition and production, and (3) difference in feed conversion efficiency (Chagas et al., 2007).

When to Manipulate BCS. The most effective time period to manipulate body condition is during late lactation, when the cow is in positive energy balance. Thus, the window of opportunity to influence the body condition and, ultimately, the health and production of a given lactation actually occurs 4 to 6 mo before that lactation begins. During that period, a thin cow can be provided a high-energy ration to ensure that she gains the weight needed to calve at the proper BCS. Conversely, a cow that is already carrying too much condition or approaching that point may be placed on a "diet" with a lower energy ration. The goal of the dry period is to simply maintain body condition. Lactating cows are about 15% more efficient at converting feed energy to body tissue than dry cows, which can be explained by the increased energy levels in lactating rations and a decreased utilization of acetate in nonlactating cows (Moe et al., 1971). Thus, increasing the body condition of a dry cow is not only economically inefficient but also difficult to achieve. Loss of body condition during the dry period may also be detrimental, as some research has indicated such a scenario will increase the risk of dystocia and culling (Ferguson, 1996). Thus, the key to managing BCS at calving is to ensure that cows are dried off at the proper BCS and that they do not lose weight during the dry period.

Because of the inherent challenges associated with calving and initiating a new lactation, it is nearly impossible to manipulate BCS during early lactation. Instead, the strategy for managing BCS during early lactation consists of doing everything possible to ensure that the cow only loses a manageable amount of condition during that period. This strategy focuses heavily on doing everything imaginable to maximize DMI and cow comfort while minimizing stress. The repletion of lost body condition will begin somewhere between 7 and 12 wk after calving. Ferguson (1996) suggested that this occurs at a rate of 0.2 body condition units per 6 wk, whereas Ruegg and Milton (1995) noted 0.13 body condition units per 6 wk.

Grouping Cows by BCS. Dividing cows into multiple groups based on BCS provides the opportunity to deliver targeted rations to groups of animals designed to more closely meet the nutritional needs of each group. In practice, many dairy producers maintain a single TMR, feeding the same TMR to every cow in the milking herd. The logic provided for that strategy focuses primarily on convenience, cost, and maintaining feed consistency for rumen stability. Relatively few producers group cows based on BCS, although that strategy has been promoted (Braun et al., 1987; Upham, 1990).

Grouping cows by BCS would be beneficial during peak milk yield and in later lactation when the animal is replacing energy reserves. During peak milk yield, particularly high producing or thin cows could be grouped together and provided a more energy dense ration. During mid- to late lactation, cows already carrying sufficient or excess energy reserves may be placed on a less nutrient dense, lower cost ration (Upham, 1990). Finally, grouping cows in this manner may allow for targeted use of feed additives such as monensin or rumen-protected choline in early lactation rations to reduce the prevalence or severity of clinical and subclinical ketosis. For example, a recent meta-analysis demonstrated that the use of monensin increased BCS by 0.03 units (Duffield et al., 2008).

Management Strategies. Ferguson (1996) proposed 3 dimensions of incorporation of BCS for managing dairy herds: changes in condition with stage of lactation, changes between successive scoring periods, and comparison of condition between groups within the farm. The availability of BCS, recorded at regular intervals, allows the dairy producer to determine the best strategy to manage the body reserves of the herd. Those BCS may be used to manage individual cows in an effort to prepare them for their next lactation by ensuring they are provided with a ration that suits their specific energy needs. Alternatively, BCS may be used to measure groups or cohorts of cows to assess the effectiveness of previously implemented management strategies. In turn, the producer can learn from prior successes and mistakes to ensure that subsequent groups of animals are effectively managed. In a similar manner, BCS may be used to compare across herds in benchmarking programs.

An alternative strategy to managing BCS is to simply look for outlying cows that could be deemed too fat or too thin (Ferguson, 1996). Then, the dairy producer could determine the general nutrition status of the herd by examining the percentage of cows in each of those categories. Having 10 to 15% of the animals in those outlying categories is likely acceptable, given that there will be some problem cows in all herds. Anything above 15% suggests that corrective action is needed. This strategy for assessing BCS requires considerably less time and resources than one aimed at tracking all cows (Ferguson, 1996).

Utilizing recorded BCS to ensure cows calve close to their ideal BCS will result in a reduced incidence of transition cow disorders, which often results from having cows carrying too much or too little condition. Additionally, the reproductive performance of cows calving within the ideal range of BCS is far superior to that of either thin or fat cows. Body condition scores may also be used to increase BCS of cull cows to increase their slaughter value, resulting in further financial benefits.

Frequency of Scoring

To track changes in body condition within a lactation, BCS must be recorded at multiple points within the lactation, hopefully at dry-off, calving, and 30, 60, 90, 150, and 200 DIM (Braun et al., 1987; Linn and Raeth-Knight, 2000; Spain, 1996). Although many of those scores may be obtained in conjunction with another management event (i.e., calving, reproductive exam), perhaps the most critical time to score is at the inconvenient suggested time during mid- to late lactation. This is critical because it is the most likely time for the dairy producer to intervene and correct problems in body condition for an individual animal (Braun et al., 1987; Ward, 2003). Hady et al. (1994) concluded that BCS recorded every 30 d provides enough useful information to be a valuable management tool. In small herds, recording the BCS of every cow is necessary. In larger herds, sampling of 30 to 50% of a group of animals is adequate to assess the overall mean of the group (Hady et al., 1994; Ferguson et al., 2006). In sampling only a portion of a herd, it is important to make every effort to score a representative sample (Perkins et al., 1985b). The human eye is drawn toward animals in the extreme ranges. Consequently, it is possible to score only problematic cows, which will overestimate the existence of a problem within the herd.

Utility of Automatic Body Condition Scoring

Although the benefits of regular BCS are intuitive to most dairy producers, nutritionists, and consultants; relatively few dairy farms incorporate it as part of their dairy management strategy (Hady et al., 1994; Schwager-Suter, 1999). There are reasons for the lack of adoption of the technique. Hady and Tinguely (1996) indicated that BCS was not adopted in large herds because of data and time concerns with a large number of animals, lack of evidence for utility as a management tool, and lack of proof in large western dairies for the relationship between BCS and production and profitability. Ward (2003) suggested that BCS is not widely implemented "because it looks simple and does not produce a computerized report, and because it must be learned practically and revised frequently."

Despite a considerable base of scientific literature on the subject, debate remains as to how accurately BCS reflects actual changes in body fat content given its subjective nature (Leroy et al., 2005; Pompe et al., 2005). Thus, one advantage of an automated BCS system would be that a more objective, consistent measure of BCS would be provided than those recorded by human observers. For example, a human observer could score the same cow on consecutive weeks, or even consecutive days, and have 2 scores that vary by 0.25 points when the animal actually experienced no change in body condition. An objective, automated system would remove that source of error and detect true changes in body condition rather than changes resulting from shortcomings in the ability of a human observer to detect small changes. An automated BCS system would also allow for more meaningful within-herd and across-herd comparisons of changes in BCS.

Despite its simplicity, BCS is a time-consuming task (Hady et al., 1994; Ferguson, 1996; Leroy et al., 2005; Pompe et al., 2005). Upham (1990) documented that it took 45 min for 2 people to score and enter data for a string of 220 cows locked in stanchions, for a total of 0.41 min/cow. An additional 1 h was allotted to examining the data and grouping cows within a 1,300-cow dairy. Perkins et al. (1985b) estimated that BCS would take less than 1 min/cow. In contrast, Drame et al. (1999) indicated it could be accomplished in only 10 to 14 s/cow.

Done properly, it will likely take 30 to 60 s/cow. Thus, if every cow in a 1,000-cow herd were scored, it would take 8 to 16 h per scoring session. To be included in a monitoring system, the task should be conducted either weekly (416 to 832 h/yr in a 1,000-cow herd) or biweekly (208 to 416 h/yr in a 1,000-cow herd). Time and error are also associated with recording each cow's identification and transcribing scores obtained in the pen or field into a computer or notebook for analysis. Considering the time commitment of regular BCS, particularly in larger herds, it is easy to see why the technique has not been universally adopted. There may even be unrecognized benefits of combining BCS patterns obtained from an automatic system with other variables collected on farm (milk production, activity, temperature, etc.) that have not yet been recognized because such a system has not been available.

Automated BCS could be incorporated into animal health tracking systems or within integrated monitoring systems (Coffey, 2003). Increasing metabolic disease rates have increased the need for quantitative monitoring of disease rates and risk factors (Oetzel, 2004). Within an expert system, those data could be used in a proactive "management by exception" strategy (Coffey, 2003). Further, comparisons could be made between animals within a specific cohort, allowing for identification of problem animals (Berry et al., 2007d). Whereas most Precision Dairy Farming technologies identify events before, during, or after occurrence, an automated BCS system could be used to predict at-risk cows in advance of a problem, allowing for an adjustment to be made to prevent or minimize consequences (Berry et al., 2007d). To be useful, data from an automated BCS system need to be incorporated with other management information systems and include decision support software to guide the producer toward appropriate action (Berry et al., 2007d).

The opportunity to include BCS patterns within genetic analyses exists, but has been difficult to implement for those same reasons. Having a system available that would allow for objective, repeated measures of BCS would increase both the quality and the quantity of information available for that trait (Coffey, 2003). Automated BCS systems, strategically placed in progeny test herds by AI organizations could provide massive quantities of valuable information for a relatively small investment. The primary limitation to this opportunity is the same consideration for all genetic traits regarding who pays for the system.

Automatic BCS may also have a role within the animal welfare arena. An increasing number of countries are adopting some type of animal welfare certification program, often involving third-party audits. A major area of contention with those programs is their subjective nature. Thus, any system that provides a more objective means of measuring traits of interest would improve the acceptability and validity of those programs for both producers and consumers. In developing such programs around BCS, it is important to consider that zero-tolerance programs, focused on having no animals less than or greater than an arbitrary standard, are counterproductive. In any well-managed dairy, there will be a few cows outside of ideal ranges for various reasons outside of the producer's control. Instead, the focus should be on accepting a minimum percentage of animals outside recommended ranges. In addition to mandatory certification programs, marketing niches for animal products produced in settings appealing to the consumers represent another application for automatic BCS.

Potential for Digital Imaging

Technologies to collect BW of dairy cows are available commercially and have been used to a limited degree in commercial settings. As previously discussed, changes in BW do not necessarily accurately reflect changes in energy reserves. Although BW could be combined with measures of energy reserves in a more robust index, a need for a more accurate, objective means of measuring energy reserves exists. De Campeneere et al. (2000) suggested the use of video image analysis to measure conformation and body size traits of cattle in an objective manner. Digital imaging has been applied for assessment of body shape, weight, and fatness in live pigs (Brandl and Jørgensen, 1996; Schofield et al., 1999; Szabo et al., 1999; Doeschl et al., 2004; Wu et al., 2004). Brandl and Jørgensen (1996) calculated live weights of pigs using image analysis with 5 to 6% deviations. They suggested that calibration for individual herds would be required in practice. Schofield et al. (1999) used an automatic image analysis system to track the growth rates of 3 strains of pigs, using different algorithms for each breed. Dirt and color variation presented challenges in analysis of data. However, those authors concluded that it would be more appropriate to capture large quantities of lower quality images, deleting those with problems using software techniques, than to increase hardware costs and complexity in efforts to obtain perfect images. Doeschl et al. (2004) reported significant relationships between shapes provided by analyzed images and body fat, lipid, muscle, and protein weights. The imaging system calculated 7 linear and 4 area measurements of each pig. Those measurements described a considerable amount of the variation in lipid weights ($R^2 = 0.41$ to 0.70) and were useful for 3 different types of pigs. The trunk region provided the most information for fat and lipid levels, and the ham region provided the most information for muscle and protein levels. Wu et al. (2004) used a stereo imaging system incorporating 6 high-resolution cameras and 3 flash units to capture 3-dimensional images of pigs. One important limitation to their system was that it required 90 min of computer processing time for construction of each 3-dimensional pig model. De Wet et al. (2003) used image analysis to assess growth rates of broiler chickens. Image surface area and image periphery area were calculated from the images. The relative errors for prediction of BW were 11 and 16% for image surface area and image periphery, respectively.

Ferguson et al. (2006) proposed the use of digital images, which could be provided to remote farm advisors, for assessment of BCS in nutritional management of dairy cows. Those researchers concluded that the differences observed with those digital photographs were similar to what would be observed within and between scorers in a typical live scoring scenario. Nevertheless, few research groups have examined the feasibility of automatic BCS of dairy cattle (Coffey et al., 2003a; Leroy et al., 2005; Pompe et al., 2005). Pompe et al. (2005) used a black-and-white charge-coupled device camera and a line laser to collect a series of images from the rear of a cow. A 3-dimensional analysis of the images provided an outline of the left pin, left hook, and tailhead. No statistical analysis comparing image analysis to BCS was reported. Leroy et al. (2005) used a digital camera positioned 1.5 to 2 m from the rear of the cow to obtain a silhouette image of the cow from the tail to the legs. The contours of 19 predefined points corresponding to visual features were incorporated to determine the overall contour of each animal from which a BCS was calculated.

The most extensive work on automated BCS for dairy cattle was conducted by Coffey (2003) at the Scottish Agricultural College, working with collaborators from the Silsoe Institute. Manual BCS (Lowman et al., 1976) were obtained from 3 scorers, one from the Holstein UK, one untrained scorer, and a long-term employee of the Langhill Farm where the study was conducted. Digital images were collected after cows left the milking parlor using a digital camera activated by a remote control. Light lines were created on the back of the cow using a red laser light. The camera was mounted to a rig, with sliding rails for cows of varying sizes and positioned at 45° to the horizontal plane of the cow's back. The laser lines were used in manual extractions of curvatures over the cow's tailhead and buttocks. The curvatures of those shapes were then modeled. The stripe over the buttock at the pin bone provided the best correlation with condition score (52%) and with scores obtained from visual assessment (68%). Images were often of poor quality, largely relating to problems with lighting. Another problem they observed was that some cows receiving similar scores by the human observers looked considerably different in images. Hence, there were subtle differences the trained observers picked up when viewing the live animals that could not be observed in the images. Further, as with most body condition scoring research, there were few animals in the extreme ranges of the BCS scale, which had considerable impact on the results. The correlation coefficient between tailhead curvature and subjective BCS evaluated by experienced observers was 0.55, and the correlation coefficient of the curvature of the right buttock as measured across the pin bone was 0.52. Coffey et al. (2003a) warn that a limitation of any system that uses shape to assess body condition is the fact that the protrusion of bones on a cow may not necessarily mean she is thin.

IMPLICATIONS

This review has demonstrated that changes in BCS throughout lactation can have an impact on milk yield, herd health, reproductive performance, and animal well-being. Management of BCS certainly plays a key role in maximization of animal potential. Given the dairy industry's current struggles with reproduction and with transition cows, along with increased consumer concern with regard to animal well-being, dairy producers should reconsider inclusion of regular BCS within management schemes. Dairy consultants should evaluate current recommendations for optimal BCS with consideration of the results presented here for varying disease incidence and reproductive performance coinciding with varying BCS. Additional research is needed, particularly in large US dairy farms where cows are housed in free-stall barns, to better quantify the real impact of nonoptimal BCS on animal health and reproduction. The potential to include some measure of genetic differences in ability to manage energy reserves in genetic analyses exists and should be explored further. The development of automated monitoring technologies to provide frequent, repeated BCS measurements may facilitate the practice of on-farm BCS.

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