

Research Advances in Body Condition Scoring for Dairy Production: Postprint

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Abstract

Dairy cow body condition scoring (BCS) is a practical tool that reflects the degree of energy reserve, nutritional status, and nutritional management level in dairy cows. Currently, dairy production sites both domestically and internationally employ manual methods of palpation and visual assessment to measure BCS. These methods are highly subjective; although recent research has demonstrated that a folding goniometer can effectively measure BCS, they generally suffer from poor stability and accuracy. Presently, the latest research has utilized ultrasonic imaging technology and image information systems to replace manual methods. Ultrasonic measurements have revealed that for each 1-point increase in BCS, the thickness of the cow's rump increases by 10 mm; meanwhile, image information systems have shown promising applications in dairy cow BCS. Different camera types can satisfy various production requirements: visible-light cameras primarily rely on analyzing animal contours, thermal imaging cameras utilize the reception and measurement of infrared radiation from object surfaces as the basis for BCS determination, and depth cameras can extract more detailed information from the cow's dorsal region, thereby enhancing accuracy. In dairy production, particular attention should be devoted to BCS during late lactation and the dry period. Excessively high BCS during this period elevates the risk of disease and reproductive disorders, whereas excessively low BCS places cows in a state of negative energy balance during early lactation. Therefore, through appropriate methods combined with scientific management, BCS can become an indispensable practical tool in dairy production.

Full Text

Research Progress of Body Condition Score in Dairy Cow Production

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Abstract

Body condition score (BCS) is a practical tool for monitoring energy reserves, nutritional status, and nutritional management in dairy cows. Currently, BCS is measured manually through visual observation and palpation on dairy farms worldwide, but these methods suffer from strong subjectivity and poor stability and accuracy, although recent studies have shown that folding protractors can effectively measure BCS. Recent research has explored replacing manual methods with ultrasound imaging technology and image information systems. Ultrasound measurements reveal that each one-point increase in BCS corresponds to a 10 mm increase in rump thickness. Image information systems show promising applications for dairy cow BCS, with different camera types meeting various production needs: visible light cameras analyze animal contours, thermal imaging cameras measure infrared radiation from body surfaces, and depth cameras extract detailed information from the cow's back to improve accuracy. In dairy production, particular attention should be paid to BCS during late lactation and the dry period, as excessive BCS during these stages increases disease and reproductive disorder risks, while low BCS leads to negative energy balance in early lactation. Therefore, appropriate methods combined with scientific management can make BCS an indispensable tool in dairy production.

Keywords: body condition score; dairy cow; image information technology; production and application

Body condition score (BCS) primarily assesses fat deposition in dairy cows to directly evaluate fat reserves, indirectly measure energy accumulation, and gauge energy metabolism status. It further reflects herd nutritional management, health status, reproductive performance, and production efficiency, making it an essential tool in dairy cattle management. Since its introduction to dairy management in the 1970s, researchers and producers abroad have continuously refined BCS as a key monitoring tool, achieving favorable results in practice. In recent years, scientists have integrated BCS with computer technology, image analysis, and artificial intelligence to enable faster and more accurate evaluation of animal condition, reducing labor intensity and workload while substantially improving efficiency and economic benefits.

China's livestock industry is transitioning from small-scale household operations to large-scale, mechanized production. As dairy production levels and feeding intensification increase, individual cows frequently become over-conditioned or under-conditioned, negatively affecting herd productivity. To address this issue, large dairy farms in China have begun adopting BCS technology to monitor management practices. Dairy cows mobilize body fat to varying degrees during growth, calving, and early lactation to meet different energy demands. Pro-

ducers can estimate the average BCS of a herd through extensive data and identify individuals that deviate significantly from this average, enabling timely correction of management strategies. By adjusting nutrient supply to regulate body fat reserves, metabolic disorders and reproductive failures can be minimized while maximizing production efficiency. Therefore, proper management and assessment of dairy cow body condition through BCS technology are crucial for reducing production costs and fully exploiting individual production potential. This review summarizes recent advances in BCS measurement methods and their application effects in production management.

1.1 Manual Scoring

Different countries and regions employ varying BCS standards. The United States and Ireland use a 5-point system, Australia and New Zealand use 8-point and 10-point systems respectively, and Denmark uses a 9-point system. China most widely adopts the American 5-point BCS system, which increments by 0.25 points, with 1.00 representing the minimum score for severely thin cows and 5.00 representing excessive fatness (Table 1).

Scorers require professional training and practice to accurately master the anatomical structures of evaluation sites. During scoring, cows must maintain normal standing posture, and evaluators assess BCS through visual observation combined with palpation according to established standards. First, the pelvic region is observed laterally to examine the line connecting the hook bone and sacrum to the tailhead (the angle formed by the ischial tuberosity, hook bone, and lumbar angle), which presents three primary shapes: triangular (V-shape, Fig. 1 [Figure 1: see original paper]-a), crescent (U-shape, Fig. 1-b), and linear (Fig. 1-c). When BCS approaches 3.00 or 3.25, the pelvic region becomes a critical discriminating factor as other features cannot effectively differentiate between the two scores. Finally, the tailhead area is examined from behind to determine the depth of depressions on both sides of the tailhead for final scoring.

[Figure 1: see original paper]

Recent research has utilized folding protractors for BCS measurement. The protractor is opened vertically and placed above the tailhead on the cow's rump, and the opening angle is observed (Fig. 2 [Figure 2: see original paper]). Red indicates thinness, green represents moderate condition, and yellow signifies obesity. The regression formula relating measurement results to BCS is: $y = 9.94x + 77.76$ [coefficient of determination (R^2) = 0.67; $P < 0.001$].

[Figure 2: see original paper]

Despite mature theoretical analyses of dairy cow BCS and its influencing factors, manual scoring remains questionable due to its strong subjectivity. Moreover, in large-scale intensive farms with numerous cows, manual methods are time-consuming, labor-intensive, costly, and exhibit poor repeatability. Therefore,

developing convenient, rapid, and accurate alternatives to manual BCS recording for individual animals in a herd is essential.

1.2 Ultrasound Imaging Technology for Rump Thickness Measurement

To overcome BCS instability caused by inter-observer variability, researchers have adopted an indirect method using ultrasound imaging technology to measure rump thickness (RT). RT refers to the subcutaneous fat layer thickness between the skin and deep fascia of the gluteal muscle, measured at the 1/5-1/4 point from posterior to anterior along the line connecting the hook bone and ischial tuberosity (Fig. 3 [Figure 3: see original paper]). This measurement effectively assesses subcutaneous fat content in dairy cows, and ultrasound technology enables direct, effective, and objective RT measurement. Studies have found that the correlation coefficient (r) between BCS and RT varies with lactation stage, with the highest correlation occurring when RT is 10-35 mm and BCS is 2.5. BCS increases by 10 mm for each one-point increase in score. In summary, RT measurement provides more objective and stable results for reflecting energy utilization and fat accumulation and can partially replace BCS. However, compared with visual and tactile assessment of nutritional status, RT measurement is less operationally convenient and not an efficient method for large-scale intensive farms, while also increasing production costs through ultrasound equipment purchases.

[Figure 3: see original paper]

1.3 Machine Vision and Image Processing Technology

Machine vision technology is an emerging artificial intelligence technology with broad agricultural application prospects due to its advantages of automation, non-contact, zero stress, and high convenience, particularly as imaging technology continuously improves, costs decrease, and image quality and sensitivity increase. Consequently, machine vision systems provide more objective, time-saving, and economical methods for BCS evaluation.

Image collection is the first step in machine vision systems. When an animal passes through the image acquisition area, cameras capture rump features within seconds to determine BCS. To ensure high-quality images for BCS assessment, researchers have employed visible light cameras, thermal imaging cameras, and three-dimensional (3D) cameras for animal image collection over the past decade. Different cameras provide different image parameters. Visible light cameras clearly capture cow rump contours for BCS calculation. Azzaro et al. compared various computational models for dairy cow body profile analysis and found that incorporating body variability factors reduced error rates and improved recognition accuracy. Thermal imaging cameras operate similarly to visible light cameras but measure infrared radiation from object surfaces to capture heat information, which is then converted to radiative temperature readings. Sheehy

et al. hypothesized that fatter cows have rounder rumps that better fit parabolic shapes, while lower BCS rumps deviate from parabolic forms. Combining thermal imaging cameras with automatic BCS recognition achieved a correlation of 0.94 with manual scoring.

With technological improvements and cost reductions, 3D cameras (depth cameras) have become core components of many machine vision systems. In imaging, 3D cameras emit pulses and measure the time difference for light to return from the object to the detector, enabling capture of three-dimensional rump information. Compared with two-dimensional (2D) imaging, 3D cameras obtain not only rump contours but also additional details such as the depression degree between the sacrum and ischial tuberosity and spinal prominence (Fig. 4 [Figure 4: see original paper]), thereby enabling more accurate BCS measurement. Early research in animal image information systems developed precise BCS measurement using Fourier algorithms with 3D cameras, and the feasibility of low-cost 3D cameras for BCS application was later demonstrated. Additionally, different image processing methods affect BCS accuracy, with Fourier algorithms achieving a mean absolute error (MAE) of 0.34 and principal component analysis (PCA) achieving errors of 0.31-0.33.

[Figure 4: see original paper]

2.1 BCS and Dairy Cow Nutrition

Cow body condition reflects feed formulation rationality and nutritional metabolic stability. Excessive thinness results in insufficient body fat reserves, leading to low peak milk yield, short lactation persistence, and low milk production during early lactation, while also increasing susceptibility to negative energy balance. Conversely, over-conditioned cows experience numerous metabolic diseases and reproductive disorders, though energy balance is difficult to monitor directly, necessitating indirect assessment through BCS.

Although many studies have reported appropriate BCS ranges for early lactation and transition cows, optimal strategies for BCS regulation remain unclear. Dale et al. designed two methods to improve pre-calving BCS in thin cows: extending the dry period or providing low-protein, high-starch diets during late lactation. Results showed that low-protein, high-starch diets did not significantly improve pre-calving BCS and reduced dry matter intake (DMI) and milk fat and protein content. While extending the dry period significantly increased BCS at calving, the improvement was modest and poorly sustained postpartum, offering no beneficial effects on production performance or health from a dairy production perspective.

Considering that energy metabolism before the lactation peak depends on post-calving energy reserves, BCS changes correlate with residual feed intake (RFI) and DMI. Rathbun et al. found that BCS changes in early lactation significantly affected RFI, though the effect was minimal, questioning its accuracy. Research indicates that early-lactation cows tend toward negative energy balance, causing

BCS to decline, but the decrease should not exceed 1.50 points. Therefore, maximizing feed intake during early lactation prevents excessive BCS loss and emaciation. BCS declines rapidly within 60 days postpartum (0.50–1.00 points), requiring additional feed during mid-lactation for gradual recovery. Normal-yielding cows in late lactation, dry periods, and low-yielding cows typically maintain positive energy balance with relatively higher BCS. Table 2 presents ideal BCS values for different production stages. Days 225–250 postpartum represent a critical period for body condition adjustment; thin cows should receive supplemental high-quality forage and increased concentrate, as metabolic energy conversion to body fat is highly efficient during this stage.

2.2 BCS and Dairy Cow Health

Appropriate BCS during different periods is an indicator of high production and good health. Research demonstrates that body energy reserves correlate strongly with health status, and observing BCS changes during the transition period or early lactation can effectively predict the probability of diseases such as displaced abomasum, ketosis, milk fever, and ovarian disorders. This review focuses on recent major findings regarding BCS and dairy cow health.

Studies consistently indicate that BCS during the dry period should not be excessively high. Duffield et al. demonstrated that cows with BCS 4.00 during the dry period had 1.6 times higher ketosis incidence postpartum than low-BCS cows. Rathbun et al. validated this conclusion but found that calving BCS was ineffective for predicting ketosis risk, contradicting previous findings that BCS >3.5 at calving increased ketosis incidence. Barletta et al. analyzed this discrepancy, suggesting that BCS changes before calving were inconsistent: among 234 cows, 28% increased BCS postpartum, 22% maintained BCS, and 50% decreased BCS, making calving BCS an unreliable reference for ketosis prediction.

Blood non-esterified fatty acid (NEFA) and β -hydroxybutyric acid (BHBA) concentrations generally correlate highly with calving BCS. The mechanism may involve the negative correlation between BCS and DMI, combined with the influence of negative energy balance and immunosuppression on blood NEFA and BHBA concentrations. For example, poor cow health is associated with high calving BCS or rapid postpartum BCS loss, resulting in elevated blood NEFA and BHBA concentrations. Sheehy et al. confirmed that pre-calving BCS loss increased blood NEFA and BHBA concentrations, thereby increasing ketosis risk. Further research indicates that BCS during the 42-day transition period positively correlates with blood NEFA and BHBA concentrations. Therefore, lower BCS during the dry period stabilizes body condition around calving, whereas higher BCS leads to more dramatic changes (either increase or decrease) during this period. Additionally, De Koster et al. found that adiponectin negatively correlates with dry-period BCS while positively correlating with insulin response and fatty acid metabolism.

2.3 BCS and Dairy Cow Reproduction

BCS affects reproductive efficiency and performance through multiple pathways, with different reproductive stages requiring different BCS values. Appropriate BCS yields higher reproductive rates. Excessive dietary energy leads to excessive fat deposition, causing cows to become over-conditioned and potentially obstructing reproductive tracts (e.g., oviduct openings), thereby impairing conception. Over-conditioned cows also develop reproductive diseases, resulting in retained placenta, dystocia, and reproductive failure.

Both under-conditioned and over-conditioned cows exhibit lower reproductive efficiency, longer calving intervals, and earlier return to estrus cycles. Postpartum BCS loss reduces pregnancy rates, and low BCS (<2.5 points) with excessive or rapid postpartum loss decreases reproductive performance. When postpartum BCS loss is <1.00 point, conception rates are 50%; with 1.00-2.00 points loss, conception rates drop to 24%; and with >2.00 points loss, conception rates fall to 21%. Research shows that BCS loss from pre-calving to 30 days postpartum increases pregnancy failure risk by 2.4 times. Postpartum BCS level and change magnitude significantly affect first-service conception rate, open days, time to first estrus, and time to first ovulation. Low BCS cows affect reproduction by delaying postpartum ovulation and reducing progesterone concentrations, manifested as rapid progesterone secretion reduction. With high BCS, this effect is initially mild and less observable, but continued feed intake reduction leads to ovulation delay and decreased blood progesterone concentration. Thus, both BCS loss and low BCS reduce reproductive rates by decreasing progesterone concentrations. Severe body condition loss during the dry period may cause abortion, and excessively low BCS at calving can reduce ovulation numbers and pregnancy rates.

3 Summary

BCS effectively reflects dairy cow energy levels and serves as a convenient, rapid, and practical measurement tool in production. Manual measurement methods are widely applied in dairy farms domestically and internationally. Against the backdrop of technological advancement, artificial intelligence methods represented by image information systems are being continuously tested in production. However, current applications of image information technology show inconsistent results due to variable operating environments, different shooting angles, lighting conditions, and facility differences. Future research should collect more BCS image data across diverse environmental patterns to gradually improve the technical system. BCS can effectively manage negative energy balance in early lactation, and greater attention should be paid to BCS changes during the dry period, as changes during this stage directly affect ketosis and reproductive disorder incidence, as well as lipid and glucose metabolism levels around calving. Currently, limited manpower and technology prevent continuous long-term BCS monitoring, and BCS changes under stress conditions such as feed transitions, heat stress, or health challenges remain unclear. Future re-

search should clarify the effects of BCS on cow stress responses under different production conditions when conditions permit.

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