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*Original article*

# Investigation on body condition score, milk yield, reproductive performance, and health of dairy cows in four intensive dairy farms during lactation cycle

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## Abstract

This study aimed to evaluate the impact of body condition score (BCS) on the milk yield, reproductive performance, and health status of lactating dairy cows. Data were collected from 1,960 cows across four dairy farms at 21 days prepartum, on the day of calving, and at 21, 50, 150, 200, and 250 days postpartum. The dataset included BCS, lactation performance, reproductive performance, disease incidence, and economic benefits for each cow. The cows were divided into seven groups based on BCS: ≤ 2.5, 2.75, 3.0, 3.25, 3.5, 3.75, and ≥ 4, with 40 cows per group at each time point (ten cows were selected from each of the four farms based on BCS differences at each time point for the experiment). The results demonstrated significant differences in BCS, milk yield, reproductive performance, and disease incidence among cows from different dairy farms. From 21 days prepartum to the day of calving, cows with BCS of 3.25 and 3.5 exhibited superior milk yield, reproductive performance, and economic benefits, as well as lower disease incidence. From 21 to 250 days postpartum, cows with BCS values of 3.0 and 3.25 continued to show improvements in milk yield, reproductive performance, and economic benefits, along with a reduction in disease incidence. These findings suggest that the ideal BCS for cows at 21 days prepartum and on the day of calving is 3.5, while BCS of 3.25 is optimal for cows at 21 days postpartum, and BCS of 3.0 is recommended for cows from 50 to 250 days postpartum.

**Keywords:** dairy cows, body condition score, milk yield, reproductive performance, disease, economic benefits

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## Introduction

Body condition score (BCS) serves as a critical metric for assessing fat reserves, energy metabolism, dry matter intake, milk yield, and the incidence of diseases in dairy cows during the early lactation period (Akbar et al. 2015, Truman et al. 2022). Effective BCS management is paramount for sustaining the overall health and productivity of dairy cows (Dale et al. 2017). Originally introduced and subsequently refined, the BCS evaluation method has gained widespread acceptance (Edmonson et al. 1989). This method involves the assessment of specific anatomical landmarks through palpation, particularly the thoracolumbar region and the bones surrounding the tailhead. Scores are assigned on a 5-point scale, ranging from 1 (emaciation) to 5 (obesity), with increments of 0.25 (Wildman et al. 1982). While BCS standards may exhibit slight regional variations, the core principles remain universally consistent, aiming to provide a quantitative measure of an animal's condition, from underweight to overweight (Roche et al. 2019).

The profitability of the dairy industry faces ongoing challenges associated with milk yield, reproductive performance, and animal health (Liang et al. 2021). Managing BCS in dairy cows is crucial for addressing these issues, as BCS serves as a key indicator of energy reserves, informing decisions related to nutrition, breeding, and health management (Rodriguez et al. 2023). Research consistently demonstrates that maintaining optimal BCS throughout the lactation cycle significantly enhances milk yield, reproductive efficiency, and overall health in dairy cows (Montiel-Olguín et al. 2019, Antanaitis et al. 2021, Frizzarin et al. 2023, Pinedo et al. 2023). Both excessively high and low BCS levels have been shown to negatively impact milk yield, reproduction, and disease susceptibility (Mullins et al. 2019). Cows with elevated BCS ($\geq 3.5$) tend to exhibit reduced feed intake and milk yield, alongside increased fat mobilization (Alharthi et al. 2021). Excessive BCS loss in dairy cows is associated with diminished milk yield capacity (López-Gatius et al. 2003). Achieving optimal BCS at calving and during the reproductive cycle is critical for reproductive success, as cows with lower BCS experience reduced conception rates at first service, increased services per conception, and prolonged calving intervals (Patton et al. 2007). Rathbun et al. (2017) established a significant correlation between BCS and the prevalence of metabolic disorders in dairy cows, noting that cows with BCS of 4 or higher tend to experience more severe and prolonged negative energy balance postpartum compared to cows with lower BCS (Rathbun et al. 2017). Consequently, cows with higher BCS at calving are more susceptible to conditions such as ketosis and displaced abomasum (López-Gatius et al. 2003). Moreover, significant BCS loss during the dry period elevates the risk of metritis and postpartum metabolic diseases (Kim et al. 2003). Similarly, cows with higher BCS at calving are at greater risk of postpartum BCS loss, thereby increasing the likelihood of developing milk fever and fatty liver (Roche et al. 2013). Thus, maintaining an optimal BCS can help mitigate the incidence of reproductive disorders such as metritis and dystocia (Gearhart et al. 1990). Effective BCS management is reflective of sound practices in nutrition, feeding, and overall cow health. By consistently monitoring and managing BCS, dairy cows can achieve improved milk yield, enhanced reproductive performance, and reduced disease risks. Regular monitoring of BCS, along with adjustments to feeding strategies and continuous health assessments, is essential for maintaining an ideal BCS in dairy cows, underscoring its critical impact on both the economic viability and biological efficiency of dairy farming.

BCS changes during the transition period are well-documented to impact reproductive performance, milk yield, and overall health in dairy cows (Roche et al. 2013, Barletta et al. 2017, Zhao et al. 2019, Antanaitis et al. 2021). However, limited research has specifically addressed the effects of varying BCS on these parameters during the dry period, early lactation, and mid-lactation. In this study, we systematically investigated the patterns of BCS fluctuations in dairy cows in Heilongjiang Province, China, across these critical stages. Additionally, we conducted a comprehensive analysis of the associations between BCS changes at each stage and their subsequent effects on milk yield, reproductive performance, and disease incidence. The goal of this study was to provide evidence-based recommendations for optimizing BCS management in dairy cows, thereby promoting improved health outcomes and enhancing both production and reproductive efficiency.

## Materials and Methods

### Animals and management

The animal study protocol was approved by the Ethics Committee of Heilongjiang Bayi Agricultural University (protocol code DWKJXY2023057). A total of 1,960 dairy cows from four large farms, each housing over 3,000 cows, in Heilongjiang Province, China, were included in this study. All cows were between their second and fifth lactation cycles. BCS was assessed using a five-point scale (Montevecchio et al. 2003), with evaluations conducted by two trained assessors to ensure consistency. BCS was recorded at seven specific time points: 21 days prepartum, at calving, and at 21, 50, 150, 200, and 250 days postpartum. Based on their BCS at each time point, cows were categorized into seven groups: BCS≤2.5, BCS=2.75, BCS=3, BCS=3.25, BCS=3.5, BCS=3.75, and BCS≥4. For each group, 40 cows were selected (10 cows per farm from the four participating farms). All cows were fed a scientifically formulated total mixed ration (TMR) in accordance with NRC standards (NRC, 2001). Although the diet composition for lactating cows varied slightly between farms, it generally consisted of maize silage, imported high-quality oat hay, alfalfa, wheat straw, and supplements such as soybean meal, corn gluten, and minerals. Cows had ad libitum access to drinking water throughout the study.

### Data collection

This study systematically collected detailed lactation data, including 305-day milk yield, peak daily milk yield, daily milk yield, and average daily milk yield (calculated as total 305-day milk yield divided by the number of lactation days). Reproductive parameters included the interval from calving to first estrus, number of services per conception, calving intervals, overall conception rate, empty rate, conception rate at estrus, and the conception index, which was calculated as total conception rate × conception rate at estrus × [1 - empty rate]. All health, milk yield, and reproductive data were meticulously recorded in the farm database (Afifarm, Afimilk, Kibbutz Afikim, 1514800, Israel) by trained veterinarians. The disease occurrence times are calculated based on the number of diseases occurring in the current parity of the cow. Additionally, data on feed costs, treatment expenses, the unit cost of frozen semen, and the number of services per conception were recorded. Sales data, provided by the farm manager, included the unit prices of milk and calves. A simple benefit analysis was employed to calculate the daily net profit. Due to challenges in accurately capturing indirect costs such as electricity, labor, and equipment depreciation, this analysis primarily focused on the direct difference between sales revenue and supply costs, offering a preliminary assessment of the farm's economic performance.

### Disease definition

Cows with a serum calcium concentration below 2.0 mmol/L were diagnosed with milk fever (Venjakob et al. 2018). Clinical ketosis was diagnosed when serum β-hydroxybutyrate (BHBA) concentrations were ≥ 3.0 mmol/L, while subclinical ketosis was identified with serum BHBA levels > 1.2 mmol/L (Macmillan et al. 2017). A somatic cell count in milk exceeding 200,000 cells/mL was indicative of mastitis (Rhoda et al. 2012). Retained placenta was diagnosed if the placenta had not been naturally expelled within 12 h postpartum (Lv et al. 2022). Metritis was characterized by uterine enlargement and foul-smelling, purulent discharge within 14 days postpartum (McCarthy et al. 2018). Displaced abomasum was diagnosed based on symptoms including lethargy, decreased appetite, marked abdominal asymmetry, and the detection of a metallic, tubular sound upon percussion (Braun et al. 2022). Dystocia was defined as any calving event requiring assistance (Stevenson et al. 1988). Abortion was diagnosed in cows that exhibited visible signs of abortion after pregnancy confirmation, returned to estrus after confirmed pregnancy, or had a failed pregnancy diagnosis upon reconfirmation (Risco et al. 1999).

### Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics version 26.0. One-way ANOVA was employed to assess differences in BCS, daily milk yield, 305-day milk yield, average daily milk yield, peak daily milk yield, number of services, calving to first estrus interval, calving interval, and daily net profits. Tukey's Honest Significant Difference post hoc test was applied to identify specific inter-group differences while adjusting for multiple comparisons. Chi-square tests and correlation analyses were conducted for total conception rate, estrus conception rate, empty rate, and disease incidence among the groups, using cross-tabulation in descriptive statistics. Pairwise comparisons were performed using the Z-test. Statistical significance was determined by probability (p) values, with $p<0.05$ considered significant and $p<0.01$ considered highly significant.

## Results

### BCS and BCS loss

Figure 1 presents a comparison of BCS and BCS loss during the lactation cycle among cows from four different farms. Cows from Farm A consistently maintained higher BCS throughout the lactation period, whereas those from Farm B exhibited the lowest BCS levels. The BCS of cows from both Farms A and B gradually declined after calving, reaching their lowest levels at 50 days postpartum, with Farm A cows remaining significantly higher than those from farm B ($p<0.01$). Cows from Farms C and D started with relatively high BCS values at 21 days prepartum but experienced a sharp decline by 21 days postpartum, reaching

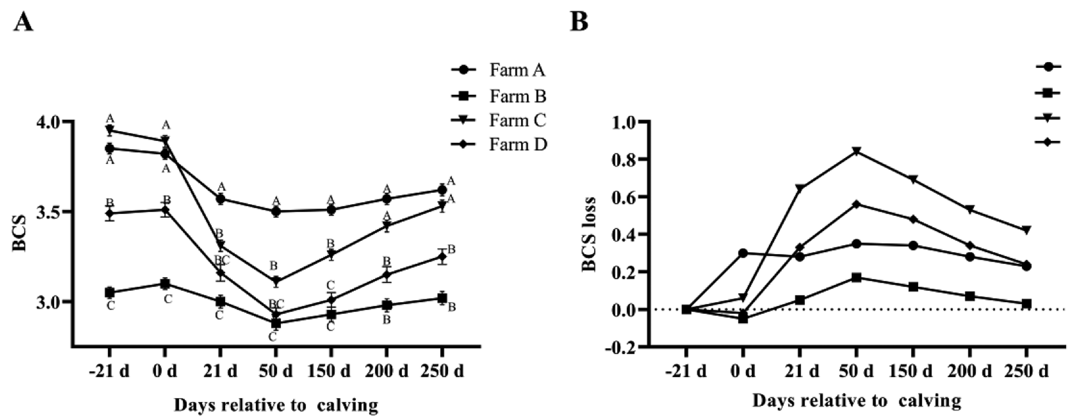


Fig. 1. Comparison of BCS (A) and BCS loss (B) during the lactation cycle of cows from four farms. BCS = Body condition score. Extremely significant (p<0.01) are indicated by different capital letters.

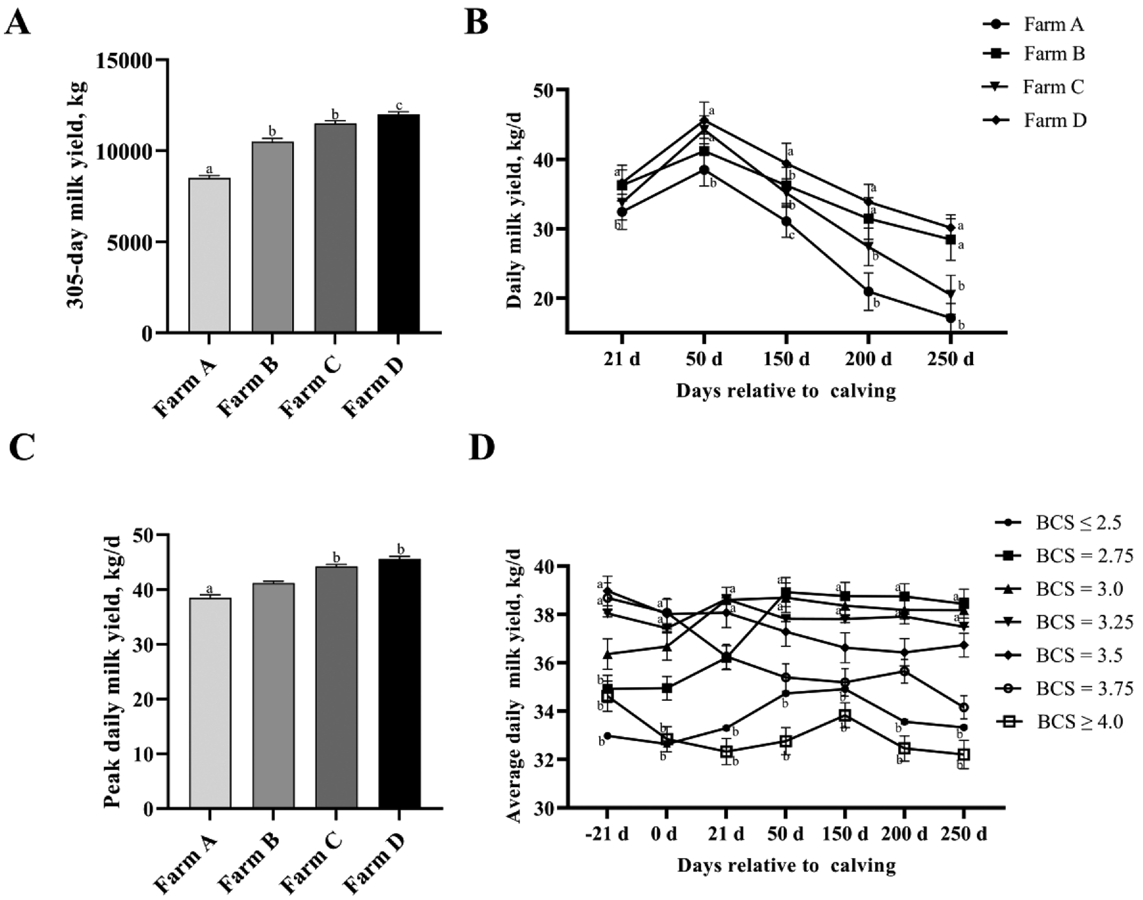


Fig. 2. Comparison of 305-day milk yield (A), daily milk yield (B), and peak daily milk yield (C) of cows from four farms and the influence of different BCS on the average daily milk yield (D) of cows during the lactation cycle. BCS = Body condition score. Significant differences (p<0.05) are indicated by different lowercase letters.

their lowest BCS at 50 days postpartum (Fig. 1A). Across all farms, BCS loss peaked at 50 days postpartum. Although BCS gradually recovered after this point, differences in recovery persisted throughout the later stages of lactation. Cows from Farm B exhibited the smallest BCS loss and the fastest recovery, whereas those from Farm C experienced the greatest BCS loss and the slowest recovery (Fig. 1B).

## Milk yield

Cows from Farm D exhibited the highest 305-day milk yield, which was significantly greater than that of cows from Farms A, B, and C (p<0.05). There was no significant difference in 305-day milk yield between cows from Farms B and C; however, both had higher yields compared to those from Farm A (p<0.05) (Fig. 2A). At 21 days postpartum, the daily milk yield

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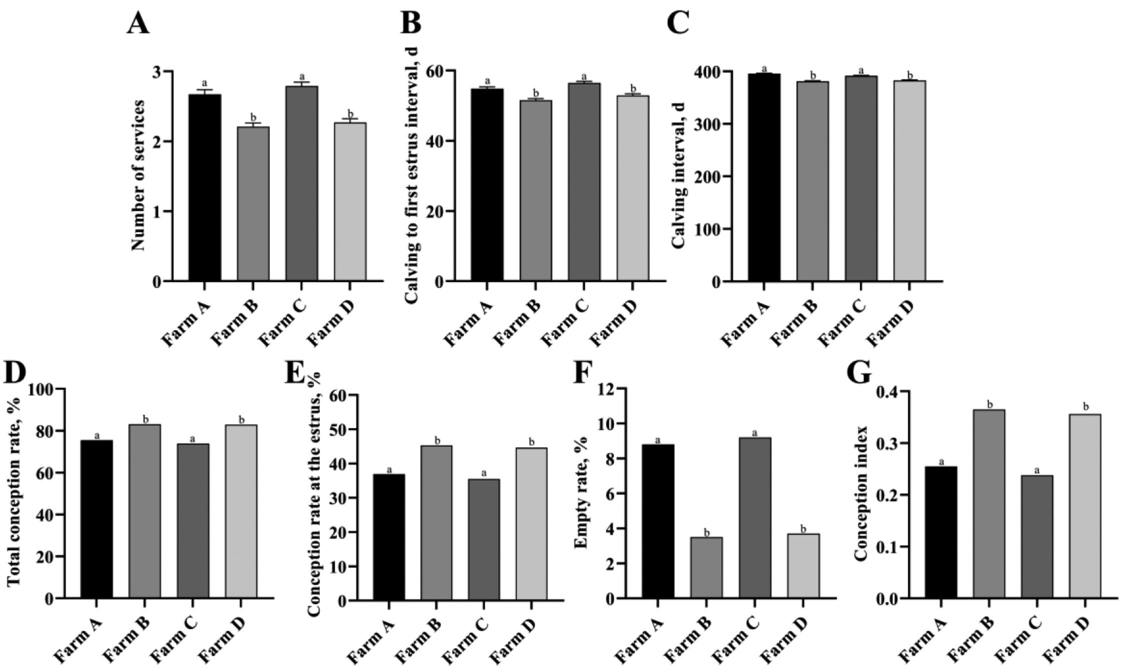


Fig. 3. Comparison of number of services (A), calving to first estrus interval (B), calving interval (C), total conception rate (D), conception rate at the estrus(E), empty rate (F), and conception index (G) of cows from four farms during the lactation cycle. Significant differences ($p<0.05$) are indicated by different lowercase letters.

of cows from Farm A was lower than that of cows from Farm D ($p<0.05$), with no significant differences observed between Farms B and C. Milk yield peaked at 50 days postpartum across all four farms, with cows from Farms C and D demonstrating higher yields than those from Farm A ($p<0.05$), and slightly higher than those from Farm B. From 50 to 250 days postpartum, daily milk yield gradually decreased across all farms, with Farm D consistently maintaining the highest yield and Farm A the lowest throughout this period (Fig. 2B). The peak milk yield of cows from Farm A was lower than that of cows from Farms C and D ($p<0.05$) and slightly lower than that of cows from Farm B (Fig. 2C). From 21 days prepartum to 21 days postpartum, cows with BCS of 3.25 and 3.5 had significantly higher average daily milk yields compared to those with BCS ≤ 2.5 or BCS ≥ 4.0 ($p<0.05$). From 50 to 250 days postpartum, cows with BCS of 2.75 and 3.0 also exhibited significantly higher daily milk yields than those with BCS ≤ 2.5 or BCS ≥ 4.0 ($p<0.05$) (Fig. 2D).

## Reproductive performance

The reproductive performance of cows from the four farms was compared across several parameters, as illustrated in Figure 3. Cows from Farms A and C demonstrated higher numbers of services, longer calving-to-first-estrus intervals, extended calving intervals, and elevated empty rates compared to cows from Farms B and D ($p<0.05$) (Fig. 3A, B, C, and F). The total conception rate, conception rate at estrus, and conception index in cows from Farms A and C were significantly lower than those from Farms B and D ($p<0.05$) (Fig. 3D, E, and G).

From 21 days prepartum to the day of calving, the number of services, calving-to-first-estrus interval, and calving interval for cows with BCS of 3.25 and 3.5 were significantly lower than for cows with BCS ≤ 2.5 or BCS ≥ 4.0 ($p<0.05$). Between 21 and 150 days postpartum, the number of services required for cows with BCS of 3.0 and 3.25 was significantly lower than that for cows with BCS ≤ 2.5 ($p<0.05$). From 21 to 200 days postpartum, cows with BCS of 3.0, 3.25, and 3.5 had significantly shorter calving-to-first-estrus intervals compared to cows with BCS ≤ 2.5 ($p<0.05$). Similarly, from 21 to 200 days postpartum, cows with BCS of 3.0 and 3.25 exhibited significantly shorter calving intervals than cows with BCS ≤ 2.5 ($p<0.05$). At 250 days postpartum, cows with BCS of 3.25 and 3.5 had significantly shorter calving-to-first-estrus intervals and calving intervals compared to those with BCS ≤ 2.5 ($p<0.05$) (Table 1).

## Disease status

The incidence of ketosis, retained placenta, metritis, dystocia, and mortality in cows from Farms B and D was significantly lower than in those from Farm C ($p<0.05$). Additionally, the incidence of displaced abomasum in cows from farm B was lower than in those from Farm C ($p<0.05$). The overall incidence of disease in cows from Farms B and D was significantly lower

Table 1. Reproductive performance of cows with different body condition score (BCS) at seven time points.

| Reproductive performance | Time (d) | BCS | | | | | | | p-value |
|---|---|---|---|---|---|---|---|---|---|
| | | 2.50 ≤ (n = 40) | 2.75 (n = 40) | 3.00 (n = 40) | 3.25 (n = 40) | 3.50 (n = 40) | 3.75 (n = 40) | ≥ 4.00 (n = 40) | |
| Number of services | -21 | 2.87±1.10$^{a}$ | 2.34±1.24 | 2.22±0.83 | 2.01±0.77$^{b}$ | 2.02±1.21$^{b}$ | 2.32±1.73 | 2.60±1.71$^{a}$ | 0.032 |
| | 0 | 2.72±1.57$^{a}$ | 2.32±1.45 | 2.16±1.13 | 2.03±1.21$^{b}$ | 2.0±1.17$^{b}$ | 2.19±1.43 | 2.68±1.92$^{a}$ | 0.024 |
| | 21 | 2.70±1.15$^{a}$ | 2.20±1.51 | 2.06±1.01$^{b}$ | 2.05±1.48$^{b}$ | 2.17±1.02 | 2.27±1.90 | 2.60±1.58$^{a}$ | 0.027 |
| | 50 | 2.62±1.27a | 2.33±1.52 | 2.10±1.78$^{b}$ | 2.05±1.54$^{b}$ | 2.18±1.59 | 2.29±0.97 | 2.37±1.49 | 0.013 |
| | 150 | 2.77±1.04$^{a}$ | 2.26±1.45 | 2.14±1.80$^{b}$ | 2.18±1.61$^{b}$ | 2.22±1.04 | 2.21±1.50 | 2.4±1.73 | 0.047 |
| | 200 | 2.45±1.42 | 2.32±1.25 | 2.16±1.42 | 2.17±0.91 | 2.14±1.16 | 2.17±0.84 | 2.42±1.34 | 0.356 |
| | 250 | 2.45±1.43 | 2.39±1.25 | 2.17±1.23 | 2.13±1.04 | 2.14±0.90 | 2.37±1.02 | 2.42±1.34 | 0.114 |
| Calving to first estrus interval | -21 | 59.50±10.58$^{a}$ | 53.83±8.43 | 52.25±10.39 | 50.77±8.92$^{b}$ | 50.32±9.81$^{b}$ | 53.67±9.53 | 58.18±10.36$^{a}$ | 0.015 |
| | 0 | 62.10±11.84$^{a}$ | 57.72±9.37 | 53.53±9.94 | 51.74±9.28$^{b}$ | 51.24±7.36$^{b}$ | 57.78±10.39 | 59.91±9.66$^{a}$ | 0.013 |
| | 21 | 60.45±10.36$^{a}$ | 54.64±8.87 | 51.27±8.89$^{b}$ | 50.10±7.38$^{b}$ | 50.70±8.46$^{b}$ | 54.43±8.15 | 56.95±8.47 | 0.025 |
| | 50 | 60.02±10.51$^{a}$ | 53.93±9.46 | 51.25±10.27$^{b}$ | 50.42±10.10$^{b}$ | 50.68±10.70$^{b}$ | 53.05±10.43 | 54.77±10.95 | 0.042 |
| | 150 | 60.87±11.82$^{a}$ | 54.46±10.62 | 51.41±10.05$^{b}$ | 51.78±9.78$^{b}$ | 51.99±10.85$^{b}$ | 53.41±11.95 | 54.61±11.19 | 0.031 |
| | 200 | 60.81±12.32$^{a}$ | 54.72±10.71 | 51.36±9.25$^{b}$ | 51.57±6.01$^{b}$ | 50.94±9.97$^{b}$ | 53.57±7.01 | 55.82±10.41 | 0.034 |
| | 250 | 61.65±14.24$^{a}$ | 57.19±9.01 | 56.52±9.72 | 52.73±9.21$^{b}$ | 51.57±10. 14$^{b}$ | 55.77±11.21 | 56.19±11.72 | 0.019 |
| Calving interval | -21 | 417.72±38.50$^{a}$ | 402.73 ±63.25 | 391.86±46.95 | 381.94±40.66$^{b}$ | 382.81±50.06$^{b}$ | 391.13±77.09 | 418.02±30.02$^{a}$ | 0.028 |
| | 0 | 421.93±44.18$^{a}$ | 403.18±46.09 | 395.86±43.92 | 382.81±39.94$^{b}$ | 383.61±37.61$^{b}$ | 393.25±35.69 | 414.25±38.34$^{a}$ | 0.029 |
| | 21 | 421.71±47.24$^{a}$ | 402.59±47.86 | 385.2±44.41$^{b}$ | 384.04±30.66$^{b}$ | 392.28±36.84 | 395.57±37.30 | 408.31±46.62 | 0.042 |
| | 50 | 424.53±37.11$^{a}$ | 401.39±45.09 | 388.87±49.89$^{b}$ | 383.63±39.87$^{b}$ | 391.52±31.98 | 396.57±45.57 | 406.65±37.81 | 0.049 |
| | 150 | 419.81±49.02$^{a}$ | 403.19±20.15 | 387.62±20.75$^{b}$ | 386.67±30.35$^{b}$ | 388.99±42.25$^{b}$ | 398.62±30.75 | 407.92±39.57 | 0.037 |
| | 200 | 419.21±35.29$^{a}$ | 404.08±32.25 | 389.04±30.57$^{b}$ | 388.35±31.65$^{b}$ | 387.41±34.36$^{b}$ | 397.35±37.67 | 404.23±43.33 | 0.014 |
| | 250 | 419.47±43.12$^{a}$ | 407.28±34.25 | 397.78±34.12 | 382.09±39.21$^{b}$ | 383.35±37.21$^{b}$ | 396.66±35.12 | 407.28±42.25 | 0.030 |

BCS – Body condition score.
Significant differences (p<0.05) are indicated by different lowercase letters.

Table 2. Comparison of disease incidence in cows from four farms.

| Item | Groups | | | |
|---|---|---|---|---|
| | Farm A (n = 490) | Farm B (n = 490) | Farm C (n = 490) | Farm D (n = 490) |
| Milk fever | 3.1%(15/490) | 1.4%(7/490) | 3.5%(17/490) | 1.4%(7/490) |
| Ketosis | 14.5%(71/490) | 8.6%(42/490)$^{a}$ | 38.8%(190/490)$^{b}$ | 13.9%(67/490)$^{a}$ |
| Retained placenta | 7.8%(38/490) | 2.1%(10/490)$^{a}$ | 17.0%(83/490)$^{b}$ | 2.4%(12/490)$^{a}$ |
| Metritis | 4.3%(21/490) | 3.5%(17/490)$^{a}$ | 9.4%(46/490)$^{b}$ | 3.5%(17/490)$^{a}$ |
| Displaced abomasum | 4.3%(21/490) | 1.2%(6/490)$^{a}$ | 6.4%(31/490)$^{b}$ | 2.0%(10/490) |
| Dystocia | 14.7%(72/490) | 8.6%(42/490)$^{a}$ | 17.8%(87/490)$^{b}$ | 8.6%(42/490)$^{a}$ |
| Mastitis | 14.5%(71/490) | 13.7%(67/490) | 18.8%(92/490) | 13.9%(67/490) |
| Abortion | 10.2%(50/490) | 6.9%(34/490) | 10.8%(53/490) | 8.8%(43/490) |
| Death rate | 6.0%(29/490) | 1.9%(9/490)$^{a}$ | 8.4%(41/490)$^{b}$ | 2.6%(12/490)$^{a}$ |
| Disease occurrences times | 0.93±0.61$^{a}$ | 0.42±0.51$^{Bb}$ | 1.35±0.51$^{A}$ | 0.54±0.68$^{Bb}$ |

Significant differences (p<0.05) are indicated by different lowercase letters. Extremely significant (p<0.01) are indicated by different capital letters.

than in those from Farm A (p<0.05) and markedly lower than in those from Farm C (p<0.01). No significant differences were observed in the incidence of milk fever, mastitis, or abortion among cows from the four farms (Table 2).

At 21 days prepartum, on the day of calving, and at

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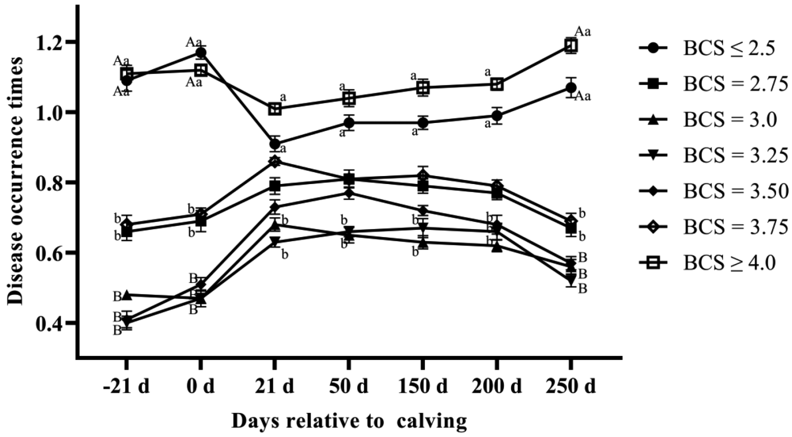


Fig. 4. Comparison of disease occurrences times of cows at seven time points during the lactation cycle. BCS = Body condition score. Significant differences ($p<0.05$) are indicated by different lowercase letters. Extremely significant ($p<0.01$) are indicated by different capital letters.

Table 2. Comparison of disease incidence in cows from four farms.

| Item | Groups | | | |
|---|---|---|---|---|
| | Farm A (n = 490) | Farm B (n = 490) | Farm C (n = 490) | Farm D (n = 490) |
| Milk fever | 3.1%(15/490) | 1.4%(7/490) | 3.5%(17/490) | 1.4%(7/490) |
| Ketosis | 14.5%(71/490) | 8.6%(42/490)$^{a}$ | 38.8%(190/490)$^{b}$ | 13.9%(67/490)$^{a}$ |
| Retained placenta | 7.8%(38/490) | 2.1%(10/490)$^{a}$ | 17.0%(83/490)$^{b}$ | 2.4%(12/490)$^{a}$ |
| Metritis | 4.3%(21/490) | 3.5%(17/490)$^{a}$ | 9.4%(46/490)$^{b}$ | 3.5%(17/490)$^{a}$ |
| Displaced abomasum | 4.3%(21/490) | 1.2%(6/490)$^{a}$ | 6.4%(31/490)$^{b}$ | 2.0%(10/490) |
| Dystocia | 14.7%(72/490) | 8.6%(42/490)$^{a}$ | 17.8%(87/490)$^{b}$ | 8.6%(42/490)$^{a}$ |
| Mastitis | 14.5%(71/490) | 13.7%(67/490) | 18.8%(92/490) | 13.9%(67/490) |
| Abortion | 10.2%(50/490) | 6.9%(34/490) | 10.8%(53/490) | 8.8%(43/490) |
| Death rate | 6.0%(29/490) | 1.9%(9/490)$^{a}$ | 8.4%(41/490)$^{b}$ | 2.6%(12/490)$^{a}$ |
| Disease occurrences times | 0.93±0.61$^{a}$ | 0.42±0.51$^{Bb}$ | 1.35±0.51$^{A}$ | 0.54±0.68$^{Bb}$ |

Significant differences ($p<0.05$) are indicated by different lowercase letters. Extremely significant ($p<0.01$) are indicated by different capital letters.

250 days postpartum, cows with BCS of 3.0, 3.25, and 3.5 exhibited significantly lower disease incidence rates compared to cows with BCS≤2.5 or BCS≥4.0 ($p<0.01$). Similarly, cows with BCS of 2.75 and 3.75 had significantly lower disease occurrence rates than those with BCS≤2.5 or BCS≥4.0 ($p<0.05$). Between 21 and 150 days postpartum, cows with BCS of 3.0 and 3.25 experienced significantly fewer disease events compared to cows with BCS≤2.5 or BCS≥4.0 ($p<0.05$). By 200 days postpartum, cows with BCS of 3.0, 3.25, and 3.5 also showed significantly lower disease occurrence rates than those with BCS≤2.5 or BCS≥4.0 ($p<0.05$). No significant differences in disease occurrence were observed during the lactation cycle among cows with BCS values ≤2.5, ≥4.0, or between 2.75 and 3.75 (Fig. 4).

## Economic benefit

The daily rearing costs, which include expenses for feed, treatment, and breeding, were highest for cows in Farm D (¥71.91 per cow), followed by Farm C (¥70.54 per cow), Farm A (¥67.26 per cow), and were lowest in Farm B (¥65.06 per cow). Farm D also recorded the highest daily sales income (¥66.53 per cow), followed by Farm B (¥61.74 per cow), Farm C (¥60.27 per cow), with Farm A having the lowest income (¥56.88 per cow). In terms of daily net profit, Farm D led with ¥9.65 per cow higher than Farm A, followed by Farm B with an increase of ¥4.86 per cow, and Farm C with an increase of ¥3.39 per cow (Table 3).

From 21 days prepartum to the day of calving, cows with BCS of 3.25 and 3.5 demonstrated significantly higher daily net profits compared to those with BCS≥4.0 ($p<0.05$) or ≤2.5 ($p<0.01$). Cows with BCS of 3.0 and 3.75 also had higher daily net profits than cows with BCS≤2.5 ($p<0.05$) during this period. At 21 days postpartum, cows with BCS of 3.0 and 3.25 achieved higher daily net profits compared to those with BCS≥4.0 ($p<0.05$) or ≤2.5 ($p<0.01$). Additionally, cows with BCS of 3.5 recorded higher daily net profits than those

Table 3. Economic benefits of dairy cows in four farms.

| Items (¥/ per cow) | | Farm A (n=490) | Farm B (n=490) | Farm C (n=490) | Farm D (n=490) |
|---|---|---|---|---|---|
| Daily feeding cost | Feed | 63.84 | 62.46 | 66.53 | 69.13 |
| | Treatment | 2.54 | 1.87 | 3.09 | 2.03 |
| | Breeding | 0.88 | 0.73 | 0.92 | 0.75 |
| | Total | 67.26 | 65.06 | 70.54 | 71.91 |
| Daily sales revenue | Milk | 111.71 | 112.89 | 118.72 | 124.80 |
| | Calf | 12.43 | 13.91 | 12.09 | 13.64 |
| | Total | 124.14 | 126.8 | 130.81 | 138.44 |
| Daily net profit | - | 56.88 | 61.74 | 60.27 | 66.53 |
| Daily net profit difference | - | 0 | 4.86 | 3.39 | 9.65 |

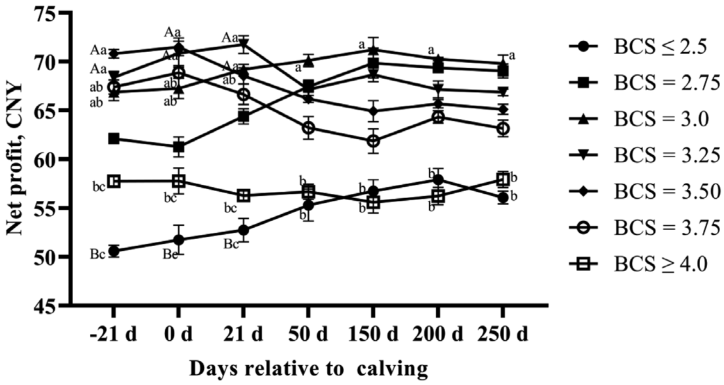


Fig. 5. Comparison of daily net profit (per cow) of different BCS cows at seven time points in lactation cycle. BCS = Body condition score. Significant differences ($p<0.05$) are indicated by different lowercase letters. Extremely significant ($p<0.01$) are indicated by different capital letters.

with BCS≤2.5 ($p<0.01$) at 21 days postpartum. Between 50 and 250 days postpartum, cows with BCS of 3.0 showed significantly higher daily net profits compared to cows with BCS≤2.5 or ≥4.0 ($p<0.05$) (Fig. 5).

## Discussion

Research has demonstrated that cows with higher BCS often exhibit reduced milk yield during the postpartum period (Zhao et al. 2019). This reduction is primarily attributed to decreased dry matter intake in cows with elevated BCS, resulting in greater reliance on body fat mobilization, which increases the risk of metabolic disorders and impairs lactation performance (Esposito et al. 2014). In contrast, cows experiencing greater BCS loss during early lactation are often associated with increased milk yield (Dechow et al. 2002). In this study, cows from Farm A, which had the highest BCS, exhibited the lowest milk yield, whereas cows from Farm B, despite having the lowest BCS, showed only a slight improvement in milk yield compared to those from Farm A. Across all lactation periods, cows with BCS≤2.5 or ≥4.0 produced lower milk yields. The superior lactation performance observed in cows from Farm D may be attributed to more effective BCS management practices. In contrast, cows from Farm C experienced a significant decline in lactation sustainability after 150 days postpartum, likely due to rapid fluctuations in BCS. Based on the findings of this study, optimal BCS recommendations vary across different stages of the lactation cycle. The ideal BCS values are 3.25 to 3.75 during the early transition period, 3.0 to 3.5 during the late transition period, and 2.75 to 3.0 during the lactation and late lactation periods. These specific BCS targets help balance energy requirements with lactation performance, reduce the risk of metabolic disorders, and improve reproductive performance and economic efficiency. These findings highlight the critical importance of precise BCS management in lactating dairy cows and provide a scientific basis for future BCS management strategies.

An excessive increase or decrease in BCS is widely recognized as a significant factor affecting reproductive performance in dairy cows (Dochi et al. 2010). The BCS at calving is particularly crucial in determining the timing of postpartum conception (D'Occhio et al. 2019). Research confirmed that cows with lower BCS at the time of first service exhibit reduced conception rates (Montiel-Olguín et al. 2019). Consequently, limiting BCS loss to within 0.5 units during parturition and the first service period is recommended to avoid negatively impacting reproductive performance (Buckley et al. 2003). This study demonstrated that both high and low BCS were associated with poor reproductive outcomes, including an excessive number of services, prolonged calving intervals, and extended intervals from calving to first estrus. Additionally, cows from Farms A and C, which exhibited higher and more volatile BCS values, had lower total conception rates and estrus conception rates, coupled with longer calving intervals and relatively low pregnancy indices. Given that both elevated and reduced BCS can adversely affect reproductive performance, it is recommended to maintain BCS of 3.25 to 3.5 during the early transition period, 3.0 to 3.25 during the early and mid-lactation periods, and 3.25 to 3.5 during the late lactation period. This management strategy would improve reproductive efficiency and overall production performance in dairy herds.

Cows experiencing greater BCS loss during lactation are more susceptible to various illnesses (Antanaitis et al. 2021). Compared to cows with optimal or lower BCS, those starting with a higher BCS tend to exhibit more significant reductions during early lactation, which can impair immune function and elevate the risk of mastitis and other diseases (Lacetera et al. 2005). BCS loss of 0.5 points or more during the transition period can disrupt calcium homeostasis in prepartum and early postpartum cows, thereby increasing the likelihood of subclinical hypocalcemia (Çolakoğlu et al. 2019). Research has shown that cows with excessive BCS loss postpartum are at a heightened risk of developing ketosis, fatty liver, and other metabolic disorders (Stevenson et al. 2020). In the present study, the highest incidence of ketosis was observed in cows from Farm C, which was associated with their higher initial BCS and subsequent BCS loss around the time of calving. Across the four intensive dairy farms studied, cows from Farms A and C had the highest BCS and poorer health outcomes. Notably, cows in Farm C experienced greater BCS losses, contributing to the highest disease incidence. Based on the findings of this study, maintaining optimal health in dairy cows requires specific BCS targets: BCS of 3.0 to 3.5 during the early transition period, 3.0 to 3.25 during the early to mid-lactation period, and 3.0 to 3.5 in the late lactation period.

Among the four farms investigated, Farm D exhibited the highest economic returns, followed by Farm B, with Farm C showing lower returns and Farm A yielding the lowest. Differences in labor costs and depreciation across the farms, which were excluded from the economic analysis, were controlled to better isolate the benefits of the interventions. Cows from Farm A faced challenges related to elevated BCS, poor reproductive performance, and increased disease incidence. As a result, Farm A had the lowest milk sales revenue, along with comparatively high medical and breeding costs, leading to the lowest net profit. For Farm A, reducing BCS is essential to mitigate disease incidence and enhance milk yield. Meanwhile, cows in Farm B displayed lower milk yields, indicating a need for improvements in lactation performance. Poor BCS of Farm C management led to suboptimal reproductive performance and health outcomes, indicating that feeding strategies should be adjusted to minimize losses. Based on a comprehensive evaluation of BCS, milk yield, reproductive performance, and economic outcomes across the four farms, it is recommended to target BCS of 3.25 to 3.5 during the early transition period, 3.0 to 3.25 during the late transition period, and to maintain BCS of approximately 3.0 throughout lactation. This targeted BCS management strategy is expected to optimize reproductive efficiency and overall farm profitability.

## Conclusions

This study assessed the BCS, milk yield, reproductive performance, and health status of 1,960 dairy cows across four dairy farms in Heilongjiang Province, China. The findings indicate that effective management of BCS is essential for enhancing productivity and overall health. Specifically, maintaining cows at BCS of 3.5 prepartum and at calving, BCS of 3.25 at 21 days postpartum, and BCS of 3.0 from 50 to 250 days postpartum can significantly improve milk yield, reproductive performance, and economic efficiency while reducing disease incidence. Variations in management practices among farms resulted in notable differences in cow health and milk yield, underscoring the necessity for precise BCS management standards. These results offer valuable insights for optimizing farm management and suggest that future research should further investigate the long-term effects of these strategies.

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