Performance Profile of Dairy Animals Under Compromise with Dynamics in Body Condition Score. A Review

ASHAQ MANZOOR¹, MADEEHAA UNTOO¹, BUSHRAZAFFAR¹, INSHA AFZAL¹, AALIYAFAYAZ¹, ZAHOOR AHMAD DAR², SEHRISH SHAFIQ¹

¹Division of Livestock Production Management; ²Division of Veterinary Microbiology, Faculty of Veterinary Science and Animal Husbandry, Shuhama, SKUAST-K, 190006, Jammu and Kashmir, India.

Abstract | Body condition scoring being the subjective and non-invasive yardstick gives the access about the body reserves of cow without intervention of any technology and expenses. It provides an instant apprehension of animal’s body state and is readily utilized in operational decision making. Body condition score (BCS) dynamics affects production profile of milk yield, peak milk yield, persistency and the milk constituents; also affects reproductive traits of oestrous, ovulation, conception rate, calving interval; dry period influences production and reproductive profile. BCS affects body weight. High as well as low BCS cows are prone to metabolic and related disorders. Mobilization of body tissues increases blood glucose, fatty acids, urea and total protein with advancement of calving and lactation affecting production, reproductive and health traits. Ideal body condition optimizes production, minimizes reproductive and health disorders, and maximizes economic returns.

Keywords | Body condition score, Milk yield, Persistency, Reproductive traits, Health

INTRODUCTION

Effective management of dairy animals gets compromised by challenges related to the nutrition, production, reproduction, metabolic diseases, etc. (Ashaq et al., 2017). Proper identification of these problems through specific managemental tools can mitigate them. Body condition score (BCS) is one such managemental tool which can subjugate these challenges and improve profitability in a dairy farm. BCS is a subjective measure to evaluate energy reserves regardless of body measurement (Manzoor et al., 2017; Mushtaq et al., 2012). Body condition scores can be used to identify the cows needing special attention and to determine whether extra feed is needed.

BCS systems have been worked out by many scientists like Lowman et al. (1976) using a 0 to 5 scale in beef cattle, eight grade scale in dairy cows by Earle (1976) and 6 point scale by Prasad (1994). Currently at various parts of the globe many body condition scoring systems are in use (Table 1). Body condition scoring provides a yardstick to assess the condition of cow without involvement of high technology and extra cost (Ashaq et al., 2017). It can be taken up by the farmer himself with some practice and can adjust the adequate nutritional program to attain desired body condition at various stages of lactation. The chine, loin, rump, pin bone, hook bone, ribs, and lumbar vertebrae are landmarks to determine the score (Mishra et al., 2016; McNamara, 2011). Ideal body condition should augments milk production, decreases reproductive and health disorders, and exploits economic returns (Manzoor et al., 2017). The aim of this review is to elucidate the understanding of relationship of BCS with physiological stage, production, reproduction, dry period, physical characteristics, blood...
profile and health of dairy animal.

**Table 1:** Body condition scoring system in various countries of the world

| Country       | Scale | Interval | Points |
|---------------|-------|----------|--------|
| New Zealand   | 1-10  | 0.5      | 19     |
| Denmark       | 1-9   | 1.0      | 9      |
| Australia     | 1-8   | 0.5      | 15     |
| USA           | 1-5   | 0.25     | 17     |
| UK/Ireland    | 0-5   | 0.5      | 11     |

**Body Condition Score and Physiological Stage**

BCS decreases as lactation proceeds from calving until reaching the lowermost body condition score. Lean Holstein and Brown Swiss cows lost 0.41 points, the ones with medium body condition – 0.76 and the ones with good body condition – 1.05 points (Gergovska et al., 2011), whereas, Manzoor et al. (2017) found a loss of 0.92 points, 0.66 and 0.47 points in higher, moderate and thinner BCS crossbred cows, respectively; and Rao et al. (2002) found loss of 3.12, 3.06 and 0.87 (on 5-point scale) in Holstein Friesian crosses at 60, 90 and 120 days of lactations, respectively. Cows with high BCS level before calving retained a good degree of BCS in the first five months of lactation (Jilek et al., 2008). BCS decreases to minimum by the second month of lactation, affecting energy balance and impairing health and reproductive performance (Bewley and Schutz, 2008; Grummer et al., 2004; Theurer et al., 2003). High producer cows with relatively low feed intake during transition becomes victim of negative energy balance (Mulligan et al., 2006). Crossbred cows calving at higher body condition lost larger portion of condition score during early lactation (Ashaq et al., 2017; Singh et al., 2015; Singh et al., 2009). Desirable body condition score at different physiological and lactation stages are mentioned in Table 2 and 3.

**Table 2:** Desirable body condition score at different physiological stage

| Stage of lactation | Body condition score (1-5 scale) |
|--------------------|----------------------------------|
| Less than 80 days  | 2.5                              |
| 80-159 days        | 2.7                              |
| 160-239 days       | 3.39                             |
| Dry period         | 3.38                             |
| Days open          |                                  |
| Less than 60 days  | 2.66                             |
| 60-100 days        | 2.92                             |
| >100 days          | 3.22                             |

**Body Condition Score and Parity**

Dynamics of BCS gets significantly affected by parity, as first parity dairy cows drain more BCS in early lactation and gets synergized by lower net energy intake potentiating negative energy balance for longer compared to later parity cows. Higher producing cow in 1st parity lost 6.5% of her body weight (BW) from calving to 29 days in lactation, while 2nd and more parity cows lost 8.5 and 8.4% of their body weight in 34 and 38 days of lactation, respectively (Straten et al., 2008). Energy balance turned positive at 71, 60 and 73 days of lactation for 1st, 2nd and 3rd parity cows, respectively. 1st parity cows recovered body weight comparatively at higher rate than older parity cows, while trend in body weight was nonlinear (Berry et al., 2006).

**Dry Period**

There occurs a significant reduction (p<0.001) in BCS fr-
om dry period (3.40 points) to the 2nd month of lactation (2.86 points) in Mont-Beliad cows (Moufok et al., 2013). Dry period of 60 days has significant effect on total milk yield, days of lactation and persistency, fat and protein yield in the subsequent lactation (Al-Anbari et al., 2012; Kuhn et al., 2006) while change in body condition score from drying-off to calving had no significant effect (P<0.01) on total milk yield, milk fat percentage, milk energy or milk lactose percentage, days of lactation and persistency; however, milk protein percentage was less for high BCS cows (Al-Anbari et al., 2012; Lake et al., 2005). Dry periods of 20 days or less resulted considerable losses in fat and protein yield in the subsequent lactation. When adjusted for milk yield, short dry periods actually led to higher cell scores and poorer fertility in the compared to 60 days in the subsequent lactation (Kuhn et al., 2006). Dry period of 8 weeks seems optimal to gain the body condition score in cows at drying off (Friggens et al., 2004). Correlation coefficient between BCS and production traits are presented in Table 4.

### Body Condition Score and Reproduction Traits

BCS could be used as a potential indicator of fertility and functional traits (Tiezzi et al., 2013; Kadannideen and Wegmann, 2003). Negative energy balance inhibits LH pulse frequency and lowers level of blood glucose, insulin and insulin like growth factor, collectively limits the estrogen production by dominant follicles and resulting in extended period of post-partum anestrus and reduced fertility (Hess et al., 2005; Pushpakumara et al., 2003; Butler, 2000). Holstein cows with BCS one point higher than average at 10th week of lactation had 5.4 days shorter to first observed heat, calving interval 14.6 day shorter, days to first service 6.2 day shorter, a 9% better conception rate and 1.9 kg less daily milk than average (Pryce et al., 2001). High producing first parity dairy cows losing ≥ 12% and second parity cows losing ≥ 15% of their body weight (BW) from calving to nadir body weight had decreased response to conception at first AI. Cows experienced marked losses in BCS had half first service conception rate than that experienced modest losses in BCS (Gillund et al., 2001). Conception at first AI increased by 53% with each additional unit in BCS from 40 to 60 days in milk (Straten et al., 2009; Krpalkova et al., 2014). Pregnancy rate at first AI significantly decreased by 10% in cows calving in poor condition (BCS <2) (Gatiusa et al., 2003). However, Mullniks et al. (2012) reported that body condition score had no effect on pregnancy rate. Cows loosing ≥1 unit BCS after calving had a prolonged interval to luteal activity restoration (Shrestha et al., 2005; Tamadon et al., 2011). Animals calving at high BCS (BCS >4) showed a significant decrease in the number of days open (5.8 or 11.7) than animals with an intermediate (BCS 3) or low body condition (<2), respectively.

### Body Condition Score and Physical Characteristics

Yan et al. (2009) found that the correlation coefficient (r) was highest (0.62 to 0.88) with heart girth, followed by belly girth (0.52 to 0.88) and length (0.51 to 0.83) and lowest (0.35 to 0.69) with height at wither. Heart girth was, therefore, selected as the primary indicator for prediction of body weight and energy balance. There exists a highly significant relationship of condition score with body weight and heart girth (Nielsen et al., 2002; Gallo et al., 2001) and between body weight and BCS (Toshniwal et al., 2008). Jong (2005) reported phenotypic correlation of BCS with angularity and chest width as 0.51 and 0.55, respectively. Similarly, the genotypic correlation was -0.75 and 0.71, respectively. There exists a positive relationship between the body condition and the legs, (between r=0.19 and r=0.31) (Miko et al., 2014). Bigger animals have poorer fertility and an unfavourable correlation between production and growth rate (Wall et al., 2007).

### Body Condition Score and Health

Low BCS cows were prone to reproductive compromise whereas, obese cows had lower superoxide dismutase and were more sensitive to oxidative stress and metabolic diseases (Roche et al., 2013; Bernabucci et al., 2005). Pregnancy rate at first AI significantly decreased by 10% in cows calving in poor condition (BCS <2) (Gatiusa et al., 2003). However, Mullniks et al. (2012) reported that body condition score had no effect on pregnancy rate. Cows loosing ≥1 unit BCS after calving had a prolonged interval to luteal activity restoration (Shrestha et al., 2005; Tamadon et al., 2011). Animals calving at high BCS (BCS >4) showed a significant decrease in the number of days open (5.8 or 11.7) than animals with an intermediate (BCS 3) or low body condition (<2), respectively.

### Table 4: Correlation coefficient between BCS and production traits (Manzoor et al., 2017)

| Characteristic | BCS | Daily milk yield (kg/day) | Peak milk yield (kg) | Days to attain peak milk yield (days) | Dry period (days) | Days to first service (days) |
|---------------|-----|--------------------------|---------------------|--------------------------------------|------------------|-----------------------------|
| BCS | 1 | | | | | |
| Daily milk yield (kg/day) | 0.343* | 1 | | | | |
| Peak milk yield (kg) | 0.662** | 0.372 | 1 | | | |
| Days to attain Peak milk yield | -0.072 | -0.751** | -0.080 | 1 | | |
| Dry period (days) | -0.330* | -0.426** | -0.065 | 0.354* | 1 | |
| Days to first service (days) | -0.768** | -0.262 | -0.462** | 0.051 | 0.284 | 1 |

* Significance at p<0.05, ** Significance at p<0.01
stein and crossbred cows during the lactation were more vulnerable to mastitis. (Loker et al., 2012). Animals in 4–5th month of lactation were more susceptible (59.49%) to mastitis with hind quarters more affected (56.52%) than forequarters (43.47%) (Joshi and Gokhale, 2006). There exists a significant associations exists between mastitis infection rates and BCS, frequency of concentrate feeding and amount of roughage at drying off and dry period in dairy cows, depicting that feeding practices affects risk of mastitis (Valde et al., 2007). Harpothn et al. (2014) reported that irrespective of BCS at dry off in Holstein–Friesian dairy cows, low energy diet fed were comparatively healthier with little risk of developing metabolic disorders in early lactation than cows fed with the high-energy diet. Correlation between dairy character (DC) and BCS was -0.61 and incidence of diseases other than mastitis in Danish Holstein was 0.43, and between DC and mastitis was 0.27 (Lassen et al., 2003).

**Body Condition Score and Biochemicals**

Propionate production in dairy cows with low dry matter intake doesn’t suffice glucose demand during the early postpartum period resulting immobilization of body reserves (Drackley et al., 2001). Fatter dairy cows undergo extensive mobilization of body fat before calving while, thinner cows mobilize fat, amino acids from the diet or from the skeletal muscle breakdown as well as glycerol resulting in more glucose production and this continued during the first weeks of lactation (Kokkonen et al., 2005; Reynolds et al., 2003). High-BCS cows had the lowermost postpartum energy balance and the highest plasma concentrations of leptin prepartum, none sterified fatty acids postpartum energy balance and the highest plasma concentration related to this review article.

**EPILOGUE**

Body condition scoring provides a yardstick for determining the condition of cow without aid of any high technology and investment. It gives an instant evaluation of the body state of the animal and is readily incorporated in operational decision making. Physiological stage affects BCS. BCS fluctuation affects production profile of milk yield, peak milk yield, days to attain peak yield, daily milk yield, persistency and the milk constituents; also affects reproductive traits of oestrus, ovulation, conception rate, pregnancy rate, parturition ease, days open, calving interval, dry period of 60 days is sufficient for optimum production and reproductive profile. BCS affects body weight; and heart girth in turn affects body weight. Obese cows are more prone to metabolic disorders while thinner cows are immuno compromised and shows mastitis. As calving and lactation advances, mobilization of body tissues cause increase in blood glucose, fatty acids, urea and total protein affecting production, reproductive and health traits. Ideal body condition during each stage of lactation is that which enhances milk production, curtails reproductive and health disorders, and maximizes economic returns.

**ACKNOWLEDGEMENTS**

Authors are highly thankful to dean faculty of veterinary science, Shuhama, SKUAST–Kashmir.

**CONFLICT OF INTEREST**

There is no conflict of interest among authors.

**AUTHORS CONTRIBUTION**

The Authors worked cooperatively while collection of information related to this review article.

**REFERENCES**

- Abeni F, Calamari L, Stefaniini L, Pirlo G (2000). Effects of daily gain in pre and post-pubertal replacement dairy heifers on body condition score, body size, metabolic profile, and future milk production. J. Dairy Sci. 83: 1468-147. https://doi.org/10.3168/jds.S0022-0302(00)75019-3
- Al-Anbari NN, Petrus TY, Al-Jashaami SM (2012). The effect of body condition score and its changes score on some productive traits of Local Jenubi cows. Euphrates J. Agric. Sci. 4: 1-7.
- Ashaq Manzoor, Patoo RA, Khaliq T, Nazir T, Adil S, Mehraj M, Najar M (2017). Effect of body condition score on serum biochemical profile and body morphometry in crossbred dairy cattle. Appl. Biol. Res. 19(1): 100-104 https://doi.org/10.5958/0974-4517.2017.00014.3
- Bernabucci U, Ronchi B, Laceterna N, Nardone A (2005). Influence of body condition score on relationships between metabolic status and oxidative stress in periparturient dairy cows. J. Dairy Sci. 88: 2017-2026. https://doi.org/10.3168/jds.S0022-0302(05)72878-2
- Berry DP, Veerkamp RF, Dillon P (2006). Phenotypic profiles for body weight, body condition score, energy intake, and energy balance across different parities and concentrate feeding levels. Livest. Sci. 104:10-12.
- Bewley JM, Schutz MM (2008). Review: An interdisciplinary review of body condition scoring for dairy cattle. Profess.
Butler WR (2000). Nutritional interactions with reproductive performance in dairy cattle. Anim. Reprod. Sci. 2: 449-457. https://doi.org/10.1016/S0378-4320(00)00076-2.

Drackley JK, Overtor TR, Douglas GN (2001). Adaptations of glucose and long-chain fatty acid metabolism in liver of dairy cows during the periparturient period. J. Dairy Sci. 84: 100-112. https://doi.org/10.3168/jds.S0022-0302(01)70204-4.

Earle DF (1976). A guide to scoring dairy cow condition. J. Agric. 74: 228-231.

Friggens NC, Andersen JB, Larsen T, Aaes O, Dewhurst RJ (2004). Priming the dairy cow for lactation: a review of dry cow feeding strategies. Anim. Res. 53: 453-473. https://doi.org/10.1051/animo:2004035.

Gallo L, Carnier P, Cassandro M, Zotto RD, Bittante G (2001). Glucose and long-chain fatty acid metabolism in liver of dairy cows during the periparturient period. J. Dairy Sci. 84: 100-112. https://doi.org/10.3168/jds.S0022-0302(01)70204-4.

Kuhn MT, Hutchison JL, Norman HD (2006). Body condition score at parturition and postpartum supplemental fat effects on cow and calf performance. J. Anim. Sci. 84: 2908-2917. https://doi.org/10.2527/2005.83122908x.

Lassen J, Hansen M, Sorensen MK, Aamand GP, Christensen LG, Madsen P (2003). Genetic relationship between body condition score, dairy character, mastitis, and diseases other than mastitis in first-parity Danish Holstein cows. J. Dairy Sci. 86: 3730-3735. https://doi.org/10.3168/jds.S0022-0302(03)73979-4.

Loker S, Miglior F, Koeck A, Neuenschwander TF, Bastin J, Jamrozik L, Schaeffer R (2012). Relationship between body condition score and health traits in first-lactation Canadian Holsteins. J. Dairy Sci. 95: 6770-6780. https://doi.org/10.3168/jds.2011-4497.

Lowman BG, Scott NA, Sommerville SH (1976). Condition scoring of cattle. East Scot. Coll. Agric. 6: 14-17.

Manzoor A, Patoo RA, Khan HM, Nazir T, Khursheed A, Najar M, Ahmad P, Shah AA (2017). Dynamics of body condition score and its effect on performance traits of crossbred cattle. Indian J. Dairy Sci. 70(4):439-442.

McNamara JP (2011). Body condition, measurement, techniques and data processing. Encyclopedia of Dairy Sciences. 2nd Edition: 457-466. https://doi.org/10.1016/B978-0-12-374407-4.00055-8.

Miko E, Szabo A, Graff M (2014). Relationship between the body condition and the main judgement characteristics of holstein-friesian cows. Rev. Agric. Rural Develop. 3: 2063-4803.

Mishra S, Kumari K, Dubey A (2016). Body Condition Scoring of Dairy Cattle: A Review. Research & Reviews: J. Vet. Sci. 2: 58-65.

Mouffok CE, Semara L, Madani T, Debeche H, Belkasmi F (2013). Impact of pre and post-calving body condition score change on reproduction traits of monthbeld cows in Algerian semi-arid area. J. Anim. Plant Sci. 23: 1253-1263.

Mulligan F, Garey L, Rice D, Doberly M (2006). Production diseases of the transition cow: body condition score and energy balance. Irish Vet. J. 59: 505-10.

Mulliniks JT, Cox SH, Kemp ME, Endecott RL, Waterman RC, Vanleeuwen DM, Petersen MK (2012). Relationship between body condition score at calving and reproductive performance in young postpartum cows grazing native pastures. J. Anim. Sci. 90: 675-682. https://doi.org/10.2527/jas.2011-4497.

September 2018 | Volume 6 | Issue 3 | Page 84
Muneer S, Rao SK, Raju SKG (2013). Serum biochemical analyses of pregnant crossbred cows. J. Anim. Sci. 90: 2811-2817. https://doi.org/10.2527/jas.2011-4189

• Munee S, Rao SK, Raju SKG (2013). Serum biochemical profiles and body condition score in crossbred cows affected with postpartum anestrus. Theriogenology Insight. 3: 21-24.

• Mustafa A, Qureshi MS, Khan S, Habib G, Swati ZA, Rahman SU (2012). Body condition score as a marker of milk yield and composition in dairy animals. J. Anim. Plant Sci. 22: 169-173.

• Nielsen HM, Friggens NC, Lovendahla P, Jensena J, Ingvartsen KL (2002). Influence of breed, parity, and stage of lactation on lactational performance and relationship between body fatness and live weight. Livestock Prod. Sci. 79: 119-133. https://doi.org/10.1016/S0301-6226(02)00146-X

• Ostergaard S, Sorensen JT, Houe (2003). A stochastic model simulating milk fever in a dairy herd. Vet. Med. 58: 125-143. https://doi.org/10.1016/S0167-5877(03)00049-7.

• Pires JAA, Delavaud C, Faulconnier Y, Pomies D, Chilliard Y (2013). Effects of body condition score at calving on indicators of fat and protein mobilization of parturient Holstein-Friesian cows. J. Dairy Sci. 96(10): 6423-6439. https://doi.org/10.3168/jds.2013-6801

• Pramanik PS (2000). Studies on temperament and body condition score and their relationship with milking behavioral traits and dam-calf interactions in dairy buffaloes. Ph.D. thesis submitted to Indian Veterinary Research Institute (Deemed University), Izatnagar, India.

• Prasad S (1994). Studies on Body Condition Scoring and Feeding Management in Relation to Production Performance of Crossbred Dairy Cattle. Ph.D. thesis, National Dairy Research Institute (Deemed University), Karnal, India.

• Pryce JE, Coffey MP, Simm G (2001). The relationship between body condition score and reproductive performance. J. Dairy Sci. 84: 1508-1515. https://doi.org/10.3168/jds.S0022-0302(01)70184-1

• Pushpakumara PGA, Gardnerb NH, Reynolds CB, Beeverb DC (2003). Relationships between transition period diet, metabolic parameters and fertility in lactating dairy cows. Theriogenology. 60: 1165-1185. https://doi.org/10.1016/S0093-691X(03)00119-5

• Rao KS, Moorthy PRS (2002). Effect of parturium body condition score of dairy cow on quality and quantity of milk production. J. Dairy Biosci. 13: 86-99.

• Reynolds CK, Aikman PC, Lupoli B, Humphries DJ, Beever DE (2003). Splanchnic metabolism of dairy cows during the transition from late gestation through early lactation. J. Dairy Sci. 86: 1201-1217. https://doi.org/10.3168/jds.S0022-0302(03)73704-7

• Roche JR, Lee JM, Macdonald KA, Berry DP (2007b). Relationships among body condition score, body weight, and milk production variables in pasture-based dairy cows. J. Dairy Sci. 90: 3802-3815. https://doi.org/10.3168/jds.2006-740

• Roche JR, Macdonald KA, Schutz KE, Matthews LR, Verkerk GA, Meier S, Loor JJ, Rogers AR, McGowan J, Morgan SR, Taukir S, Webster JR (2013). Calving body condition score affects indicators of health in grazing dairy cows. J. Dairy Sci. 96: 5811-5825. https://doi.org/10.3168/jds.2013-6600

• Schutz KE, Cox NR, Macdonald KA, Roche JR, Verkerk GA, Rogers AR, Tucker CB, Matthews LR, Meier S, Webster JR (2013). Behavioral and physiological effects of a short-term feed restriction in lactating dairy cattle with different body condition scores at calving. Dairy Sci. 96: 4465-447. https://doi.org/10.3168/jds.2012-6507

• Shrestha HK, Nakao T, Suzuki T, Akita M, Higaki T (2005). Relationships between body condition score, body weight, and some nutritional parameters in plasma and resumption of ovarian cyclicity postpartum during pre-service period in high-producing dairy cows in a subtropical region in Japan. Theriogenology. 64: 855-866. https://doi.org/10.1016/j.theriogenology.2004.12.007

• Singh R, Randhawa SN, Randhawa CS (2015). Body condition score and its correlation with ultra-sonographic back fat thickness in transition crossbred cows. Vet. World. 8: 290-294. https://doi.org/10.14202/vetworld.2015.290-294

• Singh RR, Dutt T, Mandal AB, Joshi HC, Pandey HN, Singh M (2009). Effect of body condition score on blood metabolite and production performance in crossbred dairy cattle Indian J. Anim. Sci. 79: 629-635.

• Straten MV, Shipigel NY, Friger M (2009). Associations among patterns in daily body weight, body condition scoring, and reproductive performance in high-producing dairy cows. J. Dairy Sci. 92: 4375-4385. https://doi.org/10.3168/jds.2008-1956

• Tamadon A, Kafi M, Saeb M, Ghavami M (2011). Association of milk yield and body condition score indices with the commencement of luteal activity after parturition in high producing dairy cows. Iranian J. Vet. Res. 12: 3-36.

• Theurer ML, McGuire MA, Higgins JT (2003). Relationships between body condition score and peak milk. J. Dairy Sci. 86: 282.

• Tiezzi F, Maltrecca C, Ceccinato A, Penasa M, Bittante G (2013). Thin and Fat cows and the nonlinear genetic relationship between body condition score and fertility. J. Dairy Sci. 96: 6730-6741. https://doi.org/10.3168/jds.2013-6863

• Toshniwal JK, Dechow CD, Cassell BG, Appuhamy JADRNN, Varga GA (2008). Heritability of electronically recorded daily body weight and correlation with yield, dry matter intake, and body condition score in Holstein dairy cows. J. Dairy Sci. 91: 3201-3210. https://doi.org/10.3168/jds.2007-0627.

• Valde JP, Lystad ML, Simensen E, Osturis O (2007). Comparison of feeding management and body condition of dairy cows in herds with low and high mastitis rates. J. Dairy Sci. 90: 4317-4324. https://doi.org/10.3168/jds.2007-0129

• Wall E, Coffey MP, Brotherstone S (2007). The relationship between body energy traits and production and fitness traits in first-lactation dairy cows. J. Dairy Sci. 90: 1527-1537. https://doi.org/10.3168/jds.S0022-0302(07)71638-7

• Yan T, Mayn CS, Patterson DC, Agnew RE (2009). Prediction of body weight and empty body composition using body size measurements in lactating dairy cows. Livest. Sci. 124: 233-241. https://doi.org/10.1016/j.livsci.2009.02.003