The Pharma Innovation Journal 2022; SP-11(11): 1603-1607

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(11): 1603-1607

www.thepharmajournal.com
Received: 07-09-2022
Accepted: 12-10-2022

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Estimation of body condition score to measure energy reserve in cattle

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Abstract
Cattle is a major livestock species in India contributing about 48% of total milk production. Energy reserves are important for dairy animals as they have tendency to nurture neonates from their tissue reserves. During peripartum period due to less dietary intake, negative energy balance (NEB) occurs in dairy cows resulting in increased lipolysis. Mobilization of tissue reserves helps to meet energy demand following parturition and initiation of lactation. Adipose tissue also helps in fertilization by secreting leptin for postpartum recovery. Therefore, it is important to measure energy reserves. Among several methods, body condition score (BCS) is the most practical, quick and inexpensive method to measure energy reserves. BCS gives an immediate appraisal of the body state of animal or health status of herd and also helps in making decision of optimal management practices. It can be evaluated by body fat reserves and recorded in various scales observing certain skeletal check points at dorsal and caudal regions. Heritability of BCS is moderate and there is negative correlation with milk yield, but positive correlation with milk quality. BCS is strongly correlated with health and fertility traits and can be used as indicator for these traits. That is why it is considered as an optimum intermediate trait fulfilling satisfactory yield but reducing reproductive and metabolic disorder.

Keywords: Adipose tissue, BCS, genetic parameters, tissue reserves

Introduction
Cattle is a major livestock species in India as it comprises of 192.49M population, which is approximately 36% of total livestock population and contributes about half of total milk production of India [1]. The performance of dairy cattle depends on the body state of the animal, which is influenced by their genetic makeup, feeding, stage of lactation, temperament, behaviour and manage mental conditions. The animal utilizes its dietary energy as well as energy reserves for various production, reproduction and physiological functions and these body reserves are indicative of health condition. Dairy cattle experience peripartum period, which is crucial for maintaining their health, lactation and neonates and energy reserves are important to meet energy demand during this period.

Energy Reserves
Cows experience an increased requirement of nutrition for their growth, maintenance and lactation following parturition of about 2 to 4 months. The requirement of energy exceeds the amount of dietary energy. Hence, during peripartum period due to low dietary intake negative energy balance (NEB) occurs in dairy cows. They also have a tendency to nurture neonates from their body tissue reserves. To meet the energy demand following parturition and to initiate lactation tissue mobilization occurs by the activation of hormone sensitive lipases (HSL). Non-Essential Fatty Acids (NEFA) resulted from lipolysis are available to mammary gland for milk fat synthesis (Figure 1) [2, 3].

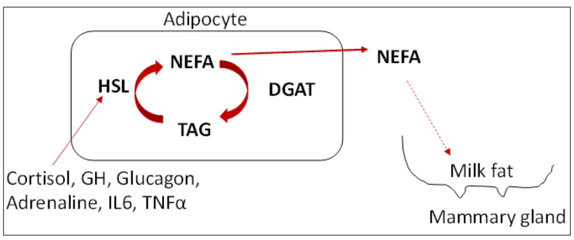

Fig 1: Lipid metabolism in adipocyte and mammary gland

Adipose tissue also affects directly reproduction by secreting leptin hormone which influence hypothalamus to produce GnRH and that affects pituitary to secrete gonadotropins like LH, FSH to help in oocyte maturation. Hence, energy reserves after calving also helps in recovery of postpartum reproductive function. It also helps in reducing disease incidences and maintaining health status of animal. Therefore, it is important to measure energy reserves [5, 6].

Measures of energy reserves

At first, body weight was used to measure tissue reserves, but alone it is not a good indicator as it is affected by so many factors such as; age, parity, gestation, body frame, gastrointestinal contents, weight of vital organs. So, energy reserves may vary up to 40% in animals of similar body weight. [3,5] There are several methods like metabolic and hormonal factors, respiratory calorimeter, body water by dilution with D_2O, estimation of fat cells diameter, ultrasound techniques etc. But these methods are costly, time consuming and need laboratory facilities, machines, skilled technicians and are inapplicable in field conditions. However, Body Condition Score (BCS) is an easier and the most practical method, which is an assessment of thickness of fat cover, prominence of bone of tail and head region (Figure 2).

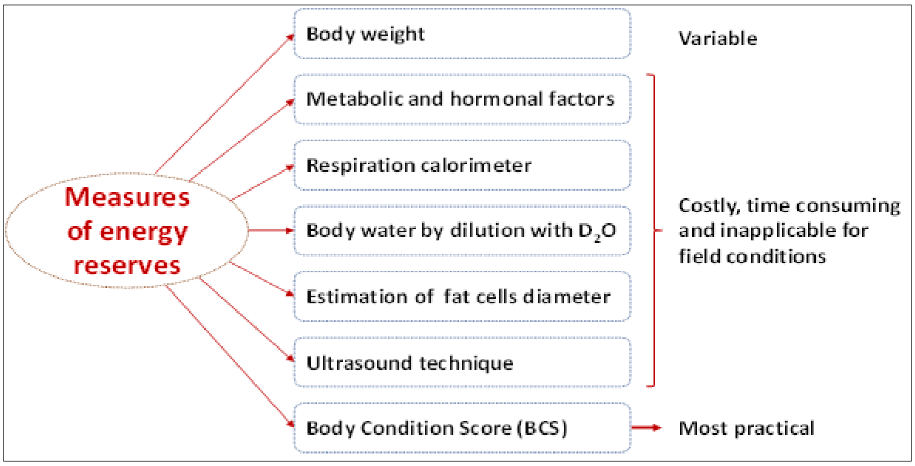

Fig 2: Different measures of energy reserves

Body Condition Score

Murray (1919) described body condition as the ratio of body fat to non-fat components in alive animal. BCS is a subject scoring method to evaluate body fat reserves mainly subcutaneous fat in caudal and dorsal regions [6, 7]. It is universally accepted, non-invasive, quick and inexpensive method to estimate the degree of fatness. Change in BCS overtime is determined by changes in feed intake, utilization of energy for yield, growth and maintenance and in body tissue deposition and mobilization. It also provides a biological relationship between body fat, milk production and reproduction. Changes in BCS changes over time is determined by variation in feed intake, maintenance, growth, production and body fat deposition and mobilization.

Importance of BCS

BCS is important as it gives an immediate appraisal of body state of animal or health status of herd. It also indirectly indicates feed utilization and helps in customizing feeding strategies of different staged animals. It is used as marker for both milk yield and quality. It is also used as indicator for selection of reproductive performances as reproduction is a low heritable trait and difficult to record. As a whole, it helps in making decision of optimum management practices.

Methods of BCS

Scoring is accomplished by visual or tactile observations or both in various scales by farmers, veterinarians, field workers. Manual observations using BCS chart and digital images are used to record BCS once or several times over the lactation [8]. There are certain skeletal check points to evaluate body condition. These are: short ribs, hook bone, pin bone, Thurl, sacral ligament and tail head ligament. After observing each check points, scores are recorded separately and an average body condition score is assigned. There are several BCS charts available with various scales and more commonly adopted chart is from Ferguson *et al.* (1994) [9] and described in Table 1.

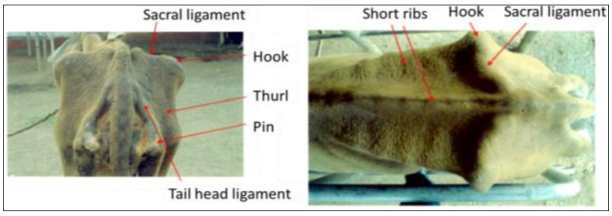

Fig 3: Skeletal check points used to evaluate body condition

Table 1: Body condition score chart adopted from Ferguson *et al.* (1994) [9]

BCS	Tuberosity-fat pad		Thurl	Ligament		Spinous process of short ribs visible
	Ileal (hook)	Ischeal (pin)		Coccygeal	Sacral	
<2.0	Angular-none	Angular-none	V	S	S	Angular >8 cm
2.25	Angular-none	Angular-none	V	S	S	Angular >8 cm
2.5	Angular-none	Angular-fat pad	V	S	S	Angular 6-8 cm
2.75	Angular-fat pad	Rounded-fat pad	V	S	S	Angular 6-8 cm
3.0	Rounded-fat pad	Rounded-fat pad	V	S	S	Angular 6-8 cm
3.25	Rounded-fat pad	Rounded-fat pad	U	S	S	Angular 4-6 cm

3.5	Rounded-fat pad	Rounded-fat pad	U	B	S	Angular 4-6 cm
3.75	Rounded-fat pad	Rounded-fat pad	U	B	B	Rounded 0-2 cm
4.0	Rounded-fat pad	Rounded-fat pad	U	NV	NV	Rounded 0-2 cm
>4.0	Rounded-fat pad	Rounded-fat pad	U	NV	NV	Rounded 0 cm

S-sharp, B- Barely visible, NV-Not visible

Ferguson *et al*. (2006) observed that assessment of BCS in dairy cattle is possible from digital photographs or video taken from rear of a cow rather than anterior and lateral view at 0-20º angle relative to tail head [11]. Bell *et al*. (2018) was also in favor of digital BCS and found that it provides accurate BCS and remove operator error [12]. Both 2D and 3D camera can be used and picture can be analyzed by digital software. Several applications like BCS Cowdition and BCS tracker are available to measure BCS.

Genetic analysis of BCS

Genetic parameters of BCS need to be estimated to assess its economic importance. h^2 of BCS and correlation estimates with other traits also show genetic merit of an animal or of a herd. There are several studies regarding h^2 of BCS and correlation estimates with other traits (Table 2).

Table 2: h^2 of BCS and correlation estimates with various traits

Trait	Model	h^2	Trait	r_g with BCS	r_p with BCS	Reference
BCS loss	Animal	0.01-0.07	Yield traits	0.17-0.50	0.06-0.1	Dechow *et al*., 2002 [13]
	AIREML		Days to first service	0.29-0.68	0.05-0.09	
BCS	Sire	0.22	dairy form	-0.72	-0.44	Dechow *et al*., 2003 [14]
	ASREML		strength	0.69	0.49	
BCS	RPT	0.20	Dairy form	-0.61 to	-0.38 to	Dechow *et al*., 2004 [15]
	RR		P1 to P5	-0.72	-0.46	
	ASREML					
BCS	RPT REML	0.26	NRR	0.04	0.02	Kadarmideen, 2004 [16]
			DFS	-0.35	-0.04	
			SCS	-0.08	-0.02	
			305d MY	-0.50	-0.15	
			Fat yield	-0.43	-0.12	
			Protein yield	-0.39	-0.11	
BCS	Animal REML	0.37	Conformation	-0.3 to 0.45	-	Guliński *et al*., 2004 [17]
			Fat%	0.13	-0.02	
			Protein%	0.16	-	
			305d MY	0.19	0.05	
BCS, at service, at calving	Animal DFREML	0.13	1st postpartum service	-0.21 & -	-	Choi *et al*., 2005 [18]
		0.20	no of services/ conception	-0.08 & -0.02	0.06 & 0.10	
Daily BCS	A-RR Bayesian	0.22 (avg)	Milk Yield	-0.18	-0.28	Loker *et al*., 2012 [19]
			Fat%	0.08	0	
			Protein%	0.2	0.2	
			SCS	0	-0.2	
Daily BCS	A-RR	0.26	Mastitis	-0.73	-	Loker *et al*., 2012[20]
	Bayesian		Metabolic disease	-0.438		
BCS	Animal AIREML	0.3	Milk Yield	-0.34	-0.15	Zink *et al*., 2014 [21]
			Fat Yield	-0.45	-0.08	
			Protein Yield	-0.39	-0.09	
			Fat%	0.14	0.09	
			Protein%	0.22	0.21	
			Fat/Protein	0.05	-0.01	
			SCS	-0.18	-0.03	
BCS	Animal AIREML	0.20	Milk Yield	-0.38	-0.15	Bilal *et al*., 2016 [22]
			DMI	-0.14	-0.02	
			Angularity	-0.65	-0.20	
			BD	-0.06	-0.02	
			Stature	-0.04	0.01	
			Strength	-0.11	-0.01	
			NOBS	-0.03	-0.24	
BCS	Animal MTDFREML	0.20	Milk Yield	-0.41	-0.10	GaliÇ, 2017 [23]
BCS	Animal REML	0.18	Milk Yield	-0.39	-0.15	Frigo *et al*., 2016 [24]
			Protein Yield	-0.17	-0.12	
			Fat Yield	-0.31	-0.11	
BCS	Least Square		SNF	-	0.102	Kumar *et al*., 2018 [25]
			WFCMY		0.116	
BCS	Mixed Animal	0.006	AFC	-0.474	-0.044	Shin *et al*., 2021 [26]

There are several approaches for estimating genetic parameters of BCS i.e., h^2, genetic and phenotypic correlations with other economic traits. Those are: REML, AIREML, DFREML, MTDFREML, Animal, Sire, Mixed, Random Regression, Least Square, Bayesian etc. Genetic analysis for daily BCS, BCS at different stages such as BCS at service and calving, BCS loss can be estimated. For milk yield trait correlation is moderately negative, but for milk composition trait correlation it is positive. In case of conformation or type traits dairy form is negative, but for strength/ capacity correlation is positive. Reproduction traits are related positively with BCS. BCS loss is found to be more with yield and increases with days to first services and it has low h^2. BCS showed highly negative relation with mastitis and other diseases. Disease traits are negatively correlated showing good BCS reduces disease incidences. BCS has strongly negative correlation with Age at first calving (AFC) and calving interval indicating positive correlation with reproduction traits. Body energy change is environmentally and genetically driven and it is a moderately heritable trait. It is the least heritable at the beginning of lactation and the most heritable in mild to late lactation [13]. BCS is highly correlated in first 3 lactations. Hence, several researchers have used first lactation only. Therefore, BCS is considered as an intermediate optimum trait to optimize milk production and the mean while minimizing metabolic and reproductive diseases [27]. Frequency of genotypes with optimal conditions should be increased rather than over fat or underweight genotypes to fulfil satisfactory levels of yield and not over utilizing tissue reserves [23]. Bastin and Gengler (2013) reviewed h^2 as in the range of 0.14 to 0.51 with moderate inheritance [29].

There are only few genome-wide association study (GWAS) of BCS traits in livestock (Table 3).

Table 3: Association study of BCS traits in livestock

Species	h^2 of BCS	Variants	Association	Reference
Roman ewes (1034)	-	48,513 SNPs	QTL associated with body reserve (BR) present on chr 1 LEPR gene for adaptive capacity	Macé *et al*., 2021 [29]
Chicken ecotype: Horro & Jerso (384 & 376)	0.18 & 0.34	-	SNPs on chr 8 for BCS (Horro) LMO4 (chr 8) & LIMK2 (chr 15) genes	Psifidi *et al*., 2016 [30]
Holstein	-	-	DGAT1polymorphism associated with milk production traits, BCS & its changes KK genotype (DGAT1 K232A polymorphism) shows higher fat content in milk, but no significant effect on BCS change	Kadlecova *et al*., 2014 [31]

Approximately 48K SNPs were used to associate body energy reserves in Roman ewes and QTL associated is present in chromosome 1 and linked with LEPR gene (Mace *et al*., 2021) [32]. Psifidi *et al*. (2016) [30] studied BCS in Horro and Jerso chicken ecotypes and found h^2 as 0.18 and 0.34 respectively. SNPs on chromosomes are found to be associated with BCS. Two genes LMO4 and LIMK2 linked.

Conclusions

Body condition score helps in estimating body energy reserves as the most practical, universally accepted, non-invasive, quick and inexpensive method. BCS inherits as a moderately heritable trait. It shows negative correlation with yield traits and dairy form traits and positive relation with milk composition, fertility and with conformation type traits. It is treated as an indicator for health and reproduction trait being highly correlated to them. Hence, BCS group with optimum production, reproduction and growth traits should be chosen. Further, BCS can be utilized for genetic evaluation, genomic selection and for association study to find out good genotypes.

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