Chapter

Relationship between Body Condition Score, Milk Yield, Reproduction, and Biochemical Parameters in Dairy Cows

Wissal Souissi and Rachid Bouraoui

Abstract

Blood indicators are used as a tool to diagnose metabolic disorders. The present review aims to study the relationships between body condition score, milk yield, and reproduction and biochemical parameters in dairy cows. Live weight and body condition are indicators for dairy cow's health, milk productivity, and reproduction. Therefore, many authors investigated the effect of body condition score at calving and of change in body condition score on productive and reproductive performance, on lactation curve parameters, and on postpartum disease occurrence. Moreover, results showed that the cows calving at the highest body condition score lost more subcutaneous fat; condition score change did not exceed 1.05 units. Change in body condition score was positively associated with peak and total milk production. In addition, the decline in dairy reproductive performance may be due to a hampered process of metabolic adaptation. Adaptation to the negative energy balance is a gradual process. The use of risk factors is more appropriate and discussed. Among them are the body condition score and its derivatives, feed intake, the calculated negative energy balance, and metabolic parameters like the plasma concentration of insulin or the triacylglycerol content in the liver. Moreover, factors that play a role in the link between declined reproductive performance and the metabolic situation of the cow during lactating are discussed.

Keywords: dairy cow, body condition score, productivity, reproduction, metabolism

1. Introduction

High-yielding dairy cows are typically in a state of negative energy balance (NEB) during early lactation period because the amount of energy required for the maintenance of body tissue functions and milk production exceeds that the cows can consume [1]. Metabolic processes increase if milk productivity increases. It promotes an increase of metabolic stress. Milk productivity and reproduction traits decrease then. Mobilization of body energy reserves during the early lactation enables the cow to close the gap between the alimentary energy intake and its loss through the milk production [2]. Since the alterations in energy reserves have a considerable influence upon the productivity, health, and reproduction of dairy cows [3, 4], the monitorization of optimal management of energy reserves is obviously needed. Indicators, which characterize dairy cows metabolic processes, are body condition score (BCS) and live weight (LW). It is very important to evaluate the changes of these indicators. Body condition scoring has been widely recommended as a method of evaluating nutritional management of the dairy cows [5]. It is a management tool used to prove if rations meet the animal's need or not. Feeding a cow according to its needs leads to optimal performance. Over conditioned animals (especially at the end of lactation) or under conditioned animals (especially at the beginning of lactation) would have health problems. Klopčič et al. [6] have defined BCS as an indicator of how well the animal maintains energy reserves, reflective of the relationship between nutrition and milk production in a herd. However, there is also more interest in BCS from the breeding side. Generally, BCS shows the decreasing trend during early lactation due to homeorhetic response caused by negative energy balance and partitioning of energy reserves to support milk production. Excessive loss of energy during this period, generally in cows with higher/lower BCS at calving, results in productive, reproductive, and metabolic disorders in dairy cows. Once the cow recovers from negative energy balance, it starts gaining BCS during mid- and late lactation [7].

2. Body condition score

Body condition score (BCS) is a subjective assessment of energy reserves in adipose tissue of a dairy cow and is an important means for managing dairy cows [7]. According to Waltner et al. [8] and Bosio [9], it is an accepted, noninvasive, subjective, quick, and inexpensive method to estimate the degree of fatness in dairy cows. The purpose of condition scoring is to obtain a balance between diet, production, and animal welfare. This technique is mainly used to control dairy cow and pre-calving management; besides, it aims to ensure that cows calve down safely, avoid post-calving diseases (milk fever, hypocalcemia, hypomagnesemia, and ketosis) and metabolic disorders in early lactation (ketosis, fatty cow syndrome), and maximize milk production [6]. In order to determine the BCS, cows were scored on appearance and palpation of back and hindquarters [10]. A variety of scales and scoring criteria are proposed depending on the country or author, making it difficult to share data, comparisons of values, or results [11]. In the United States and Ireland, a 5-point BCS system is used for dairy cows, whereas Australia and New Zealand use 8- and 10-point scales, respectively [11]. In France, the Technical Institute of Cattle Breeding (TICB) has published a 6-point scale established by Bazin [12], where dairy cows are rated from 0 (very lean) to 5 (very fat) [13].

3. Body condition score and milk yield

The milk production of cows correlates with their body condition which is a wide and effective method to evaluate the nutritional management of dairy cows [14]. So, optimal body condition of dairy cow is essential to obtain elite herd and quantity milk production because thin or fat cows may have a greater risk of lower milk yield and higher milk somatic cell count (SCC) [15]. Agenas et al. [16] reported that, at the peak of lactation, the energy needs exceed the energy supply, which generates a negative energy balance (NEB). Then, to correct this deficit, the cow resorts to the mobilization of its body reserve and loses weight. Furthermore, Domecq et al. [17] showed that insufficient energy and protein reserves reduce milk yield. BCS has important effects through critical moment during lactation.

3.1 Body condition score during dry period and at calving

In order to support early lactation, dairy cows have to require enough body reserves. It is evident that over and under reserves have negative results on the animal's performances. Accordingly, over body reserve decreases dry matter intake and prolongs negative energy balance that causes poor production performance (lower peak yield, poor persistency) and reproductive diseases (retention of placenta, calving problems, and metabolic disorder). However, the cow with lower BCS, at calving, mobilizes less body fat, which decreases milk fat without affecting on milk yield, SNF, DMI, or nutrient utilization [7].

During dry period, the optimal body score condition is 3.0–3.25. Cows with BCS are more close to peak milk yield. The passage from BCS = 2 to 3 has a significant progress in milk productivity, but score above 3.5 at calving is deleterious for milk production [7]. According to Roche et al. [18], calving BCS is probably the most influential moment in the cow's lactation calendar, since it affects early-lactation DMI, post-calving BCS loss, milk yield, and cow immunity, and does not directly influence the pregnancy rate (it affects reproduction through nadir BCS and BCS loss). A loss in body condition score during dry period has negative impacts on the animal health, calving, and the amount of fat in ensuing lactation. However, increasing BCS in dry period may improve milk yield especially in the first 120 days [17]. Moreover, amelioration of BCS during parturition increases the milk fat percentage and reduces the anestrous interval after parturition [7]. Roche et al. [19] reported an optimum calving BCS for milk production of 3.5, whereas Berry et al. [20] reported that a total of 305-day milk yield was greatest in cows calving at a BCS of 4.25 units, and cows with 3.25 or 3 BCS units produce a further 50 and 114 kg of less milk, respectively.

3.2 BCS in early lactation

To optimize milk production, it is necessary to maximize milk production in early lactation but not necessarily during late lactation. Cows in early lactation utilize tissue reserves to support milk yield [7]. The high-producing cows cannot have their energy needs through feed intake at early lactation. There is negative energy balance with mobilization of body reserves and a loss of the BCS. Dairy cattle should not lose more than one point in their BCS during early lactation period. BCS at calving would better be around 3.5–3.75 [21]. Besides , Jilek et al. [14] showed that cows with BCS lower than 3.5 in the first month of lactation have the highest milk yield during the first 5 months of lactation. This can be explained by high mobilization of body reserves in high-yielding cows. The body condition level in the last month of drying period influenced its subsequent decrease in the first phase of lactation. Cows with the highest BCS level before parturition retained a high BCS level in the first 5 months of lactation. However, cows with the lowest BCS in the first month of lactation had the lowest BCS in the next 4 months. It is necessary that cows do not lose more than one point of body condition in early lactation: cows with excessive body condition losses will have irregular heats, have longer time to the first ovulation, and may fail to conceive. These cows will also be less persistent in milk production. Cows with a BCS over 6.5 (3.5 in a 5-point scale) at 2 weeks before calving are subject to having depressed intakes, weight loss, fatty liver, ketosis, high nonesterified fatty acid (NEFA) levels, calving, and reproductive problems [6].

3.3 BCS in mid-lactation

Scanes [21] perceived that cows need to realize a positive energy balance, so they have to recognize their BCS through undergoing a proper nutritional program.

Stage	Target body condition score
At calving	3.0
During service period	2.0–2.5
Mid-lactation	2.5–3.0
Drying-off	3.0

Table 1.
Recommended body condition score for Holstein Friesian and Jersey cows [22].

Lactation stage	DMI	BCS goal	BCS min	BCS max
Calving	0	3.5	3.25	3.75
Early lactation	1–30	3.0	2.75	3.25
Peak milk	31–100	2.75	2.5	3
Mid-lactation	101–200	3.00	2.75	3.25
Late lactation	201–300	3.25	3	3.75
Dry-off	>300	3.5	3.25	3.75
Dry	−60 to −1	3.5	3.25	3.75

Table 2.
Suggested body condition score for cows by stage of lactation [23].

BCS between 200 days of lactation and the date of dry-off should be between 2.75 and 3.50. However, the cows should be dried off when they have a BCS of 3.25–3.5. Therefore, the increase in BCS must occur during late lactation. In this period, the nutritional goals are to completely fulfill body fat reserves, without reaching an over-conditioning [7].

3.4 BCS in late lactation

Cows receive a nutritional program to maintain persistency of lactation without gaining excessive weight. Cows are dried off at a BCS of 3.5 [21]. Besides, Scanes [21] noted that nutrition is very important in late lactation and during the dry period. Both at drying-off and at calving, the BCS should be about 3.5.

As a result, Ohnstad and Jones et al. [22, 23] suggested BCS values for different stages of lactation as shown, respectively, in **Tables 1** and **2**.

4. Body condition score and reproduction

As it affects milk production, BCS affects also reproductive performance and fertility, which is negatively associated with milk production [24]. After calving, energy needs exceed energy intake of dry matter intake (DMI), which creates a negative energy balance (NEB). The NEB with some blood metabolites leads to the decline of some reproductive performance [24]. According to Froment [13], the consequences of a loss of BCS on reproduction are more obvious than those of the absolute value of BCS. Froment [13] showed a general tendency toward a deterioration of the reproduction results when this loss after calving increases. As long as this loss remains below 1 point, the influence of weight loss on reproduction remains modest. Conversely, when the loss of state exceeds 1.5 points, the degradation concerns all the reproduction parameters.

5. Negative energy balance and fertility

Negative energy balance (NEB) delays the first ovulation by limiting dominant follicle growth and estradiol production, through decreases in circulating insulin, IGF-1, and LH pulses [25, 26]. The persistence of a negative energy balance (NEB), corroborated by persistent loss of status, has a negative impact on the major sign of estrus: acceptance of overlap [13]. Butler [27] showed that greater NEB/BCS loss during the first 30 days postpartum delays first ovulation (**Figure 1**). The conception rate decreases with increased BCS loss. Cows remaining non-ovulatory after 50 days of lactation will have a higher risk of not becoming pregnant during lactation and, therefore, are more likely to be culled.

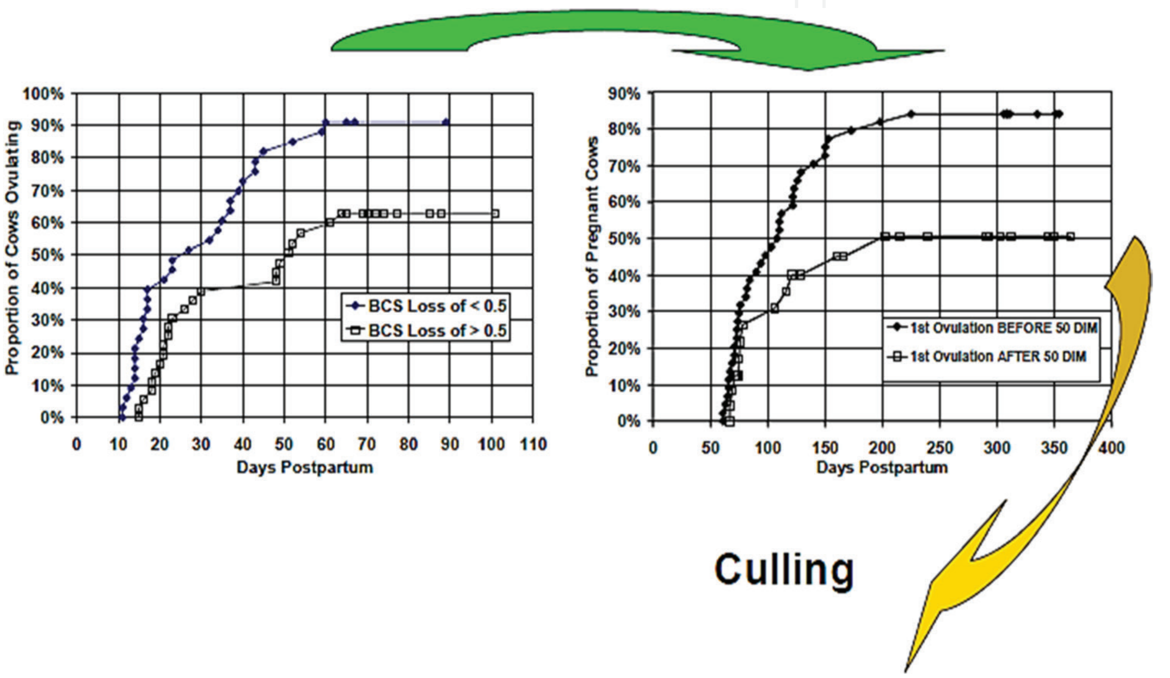

Figure 1.
Early NEB and BCS loss delays the first ovulation and relates to poor fertility/increased risk of culling [27].

6. Body condition score and cyclicity

Delayed recovery of ovarian activity is associated with poor body condition at calving. This situation appears when feed intakes in the last third of gestation are insufficient. For multiparous, practically there is no real effect of BCS at calving on the cyclicity, but a significant effect of the postpartum state loss was determined [13]. According to Freret et al. [28], cows that lost more than 1.5 points of their BCS between 0 and 60 days postpartum are characterized by no cyclicity or prolonged luteal phase.

Females with a high loss of BCS during the first month of lactation have less expression of estrus. Similarly, a loss of body condition greater than 1 point between 0 and 30 days, as well as insufficient BCS at calving, or a postpartum affection increased the average time to onset of the first estrus after calving [13]. Extreme body condition loss in the early lactation can cause irregular heats and longer time to the first ovulation and fail to conceive [29]. Butler [25] related the failure of ovulation of the first wave dominant follicle to high rates of NEFA and ketones in plasma and greater accumulation of triglycerides in the liver during the first 3 weeks of lactation.

7. Effects of BCS on pregnancy rate

López-Gatius et al. [30] reported that low BCS at parturition affects clearly pregnancy rate at the first AI. In their homogenous study, pregnancy rate at the first AI showed a significant neglect of about 10% in cows delivering in low BCS. This decrease of fertility is related to prolonged non-ovulatory intervals especially in thin cows that has a negative impact on the first service conception. In the study of López-Gatius et al. [30], the link between this loss and the success rate at the first AI is low for the category of cows losing little. The relationship becomes more obvious when the loss exceeds one point. In this same study, the loss of body condition has an impact especially on the number of days open (time interval between parturition and conception) especially for cows with a severe loss greater than 1 point. The number of days open of these animals increases by 10.6 days.

According to Hess et al. [31], cows with prolonged negative energy balance prepartum associated with reduced BCS at parturition have extended periods of anestrus [31]. López-Gatius et al. [30] suggested that BCS at parturition and at the first AI might be used as indicators of relationship between the nutritional status of the cow and the number of days open. Animals with good body condition at parturition have the reduced number of days open in comparison with cows having moderate or low body condition. Butler [25] showed that fat mobilization and loss of BCS causing a NEB are strongly associated with the length of the postpartum non-ovulatory period.

8. Body condition score, non-fertilization, early embryonic mortality, dystocia, and metabolism

In the study of Freret et al. [28], the BCS loss between 0 and 60 days postpartum had an effect on the NF-EEM rate: this rate is 41.7% for a loss greater than 1 point, against 29.8% when the loss is less than 1 point. Note that no relationship was observed between calving status score and reproductive performance after artificial insemination. According to Lopez-Gatius et al. [32], the risk of late embryonic mortality is multiplied by 2.4 for each unit of body condition lost during the first month of lactation.

The body condition score is again of interest, the animals in excessive fattening state (status score > 4 on a scale of 0–5) are more at risk of excess fat in the pelvic sector and hence a lower pelvic diameter and a higher risk of dystocia, especially for primiparous.

9. Body conditions score and metabolites

BCS change may have an effect on the biochemical level by changes in concentration of blood metabolites [33]. Malnutrition in dairy cows can influence many biochemical and physiological processes. Therefore, it perturbs the relation between the metabolic capacities of animals and causes metabolic disorders [34]. According to Bernabucci et al. [35] and Samanc et al. [36], dairy cows are exposed to several physiological challenges during the transition period, which might result in greater oxidative stress and metabolic disorders. Joźwik et al. [37] considered this period as the most critical period for dairy cows, with the highest incidence of metabolic diseases and infections caused by NEB. Consequently, during the early lactation, the liver of high-yielding dairy cows aims to correct the negative effect of NEB through undergoing extensive physiological and biochemical changes.

Duchacek et al. [38] showed the changes in milk fat and protein contents as well as the development of the BCS in the post-parturition period (**Figure 2**). The content of milk fat decreased from 4.89% at the beginning of lactation to 3.27% in week 7, and then it increased to 4.06% in weeks 14 and 16 of lactation. The protein content tended to decrease slightly until week 7, and then it increased until the end of the period observed.

Indeed, Duchacek et al. [38] demonstrated (**Figure 3**) the development of the fat to protein ratio used as an indicator of NEB. Cows with a more extensive loss of BCS produced more milk with a higher fat to protein ratio [20]. The maximum value of this ratio (1.62) was observed in the first week of lactation. Later, it decreased to 1.08 in week 7, and then it slightly increased and became stabilized around the value of 1.2.

Fat and labile protein reserves are mobilized during early lactation, but the ability to use body protein is limited in quantity and duration. For instance, estimates have ranged from 10 to 90 kg of fat and up to 24 kg of protein [39]. No further protein mobilization occurred after 5 weeks of lactation, whereas utilization of body fat continued until at least 12 weeks postpartum [40].

Cincovic et al. [41] showed that NEB in early lactation is associated with typical changes such as lower concentrations of glucose, insulin, and IGF-I but with higher concentrations of nonesterified-fatty acid (NEFA) and β-hydroxybutyrate (BHBA) resulted mainly from adipose tissue mobilization.

Furthermore, Van Dorland et al. [42] reported that typical changes during early lactation, associated with negative energy balance, are lower concentrations of glucose, insulin, IGF-I, and higher NEFA and BHBA concentrations. In this period, dairy cows experience several metabolic challenges characterized by the decrease in responsiveness of tissues to insulin [43] and increase in liver gluconeogenesis [44].

Locher et al. [45] recorded that cows with BCS > 3.5 in transition period are exposed to important fat mobilization which leads to elevated plasma NEFA in order to support the energy need. Circulating NEFA can be oxidized in the hepatocytes or exported as constituents of very-low-density lipoproteins (VLDL). Nevertheless, generally postpartum discharge of NEFA exceeds energy requirements and oxidation capabilities of the liver and leads to production of ketone bodies including BHBA and reesterification to triglycerides (TG) [45].

Akbar et al. [46] indicated that these triglycerides are stored in hepatocytes and involve fatty liver development, reduced metabolic function, health status, production and reproductive performance, as well as the incidence and severity

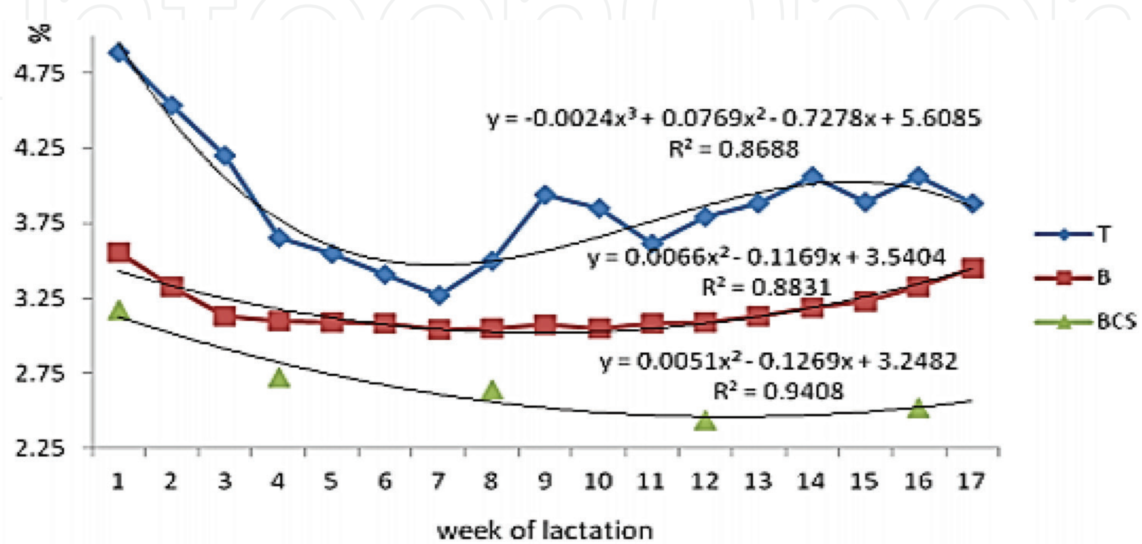

Figure 2.
Development of fat (B) and protein (T) content in milk and the BCS of cows during the first 17 weeks after calving [38].

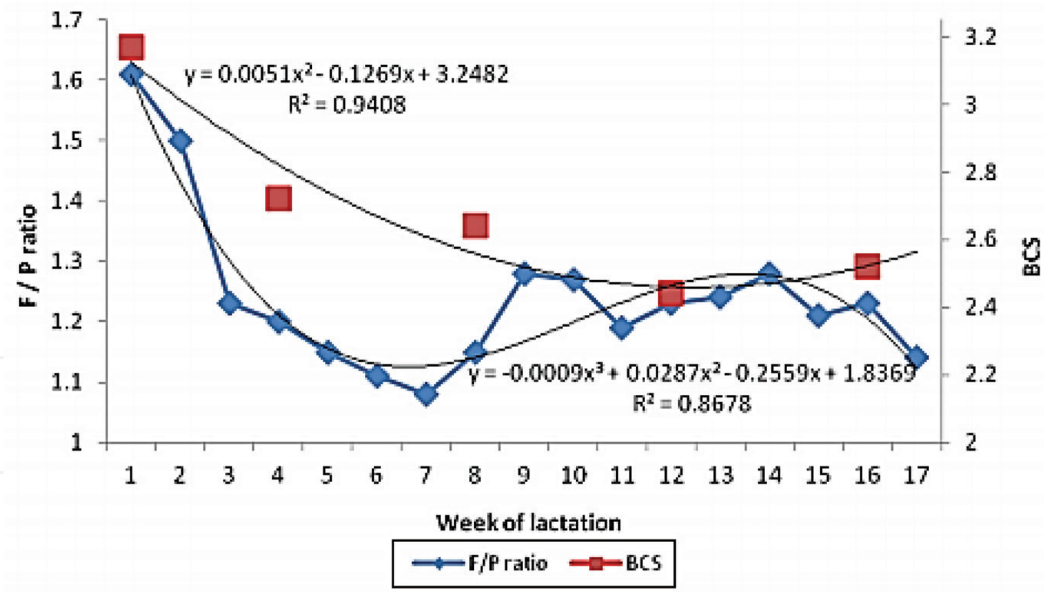

Figure 3.
Development of fat to protein ratio and BCS after calving [38].

of metabolic and infectious disorders. Gillund et al. [5] disclosed that high BCS at calving usually leads to an increased risk of ketosis. Both BCS at calving and BCS in early lactation could be generators of metabolic disorders [18].

10. Conclusions

The body condition scoring (BCS) is a practical and effective tool of management in dairy herds; it affects the productivity, reproduction, and health of the animal. Each stage of lactation has its recommended BCS; thereby, over and under conditioned cows may undergo a verity of risks. BCS has clear effects around calving and early lactation where energy intake exceeds energy needs which leads to NEB. Thus, most of researchers agree about a BCS around 3–3.5 at calving to limit undesirable results on lactation; cows with BCS out of this range are exposed to a decrease in milk production, changes in milk components such as milk fat and proteins, and even a decrease in persistence of lactation.

According to previous studies of BCS, certain complications such as reduced milk yield, increase in metabolic diseases, and delay in the postpartum estrus cycle of thin cows may occur due to a lack of usable body reserves in the early period of lactation. In addition, the risk of dystocia, early embryonic mortality, no cyclicity or prolonged luteal phase, increase in the number of days open, increase in metabolic diseases, and decrease in milk yield of fat cows could occur due to a loss of BCS more than 1 point.

Other studies investigated the effect of changes in BCS and BCS loss on metabolism and showed that NEB in early lactation is associated with typical changes such as lower plasma glucose due to the high demand for this substrate to synthesis lactose and decrease in concentrations of insulin and IGF-I. However, higher concentration of NEFA and BHBA is determined, which are related to body reserve mobilization in order to support early lactation demands.

Acknowledgements

The authors want to thank Dr. Naceur M'Hamdi, for the papers and all documents provided in the preliminary selection of the sections to be used in the chapter.

Conflict of interest

None of the authors of this chapter has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the chapter.

Acronyms and abbreviations

TICB	Technical Institute of Cattle Breeding
NEB	negative energy balance
BCS	body condition score
LW	live weight
SCC	somatic cell count
SNF	solids-not-fat
DMI	dry matter intake
IGF-1	insulin growth factor-1
LH	luteinizing hormone
AI	artificial insemination
NF	non-fertilization
EEM	early embryonic mortality
BHBA	β-hydroxybutyrate
VLDL	very-low-density lipoproteins
TG	triglycerides

Author details

Wissal Souissi[1]* and Rachid Bouraoui[2]

1 Laboratory of Animal and Food Resources, National Agronomic Institute of Tunisia, Tunisia

2 Higher School of Agriculture of Mateur, University of Carthage, Tunisia

*Address all correspondence to: wissal26suissi@yahoo.com

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