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Factors Associated with Negative Energy Balance and Its Effect on Behavior and Production Performance of Dairy Cows: A Review

Review Article

A.K. Singh[1*], C. Bhakat[1], D.K. Mandal[1], A. Mandal[2], A. Chatterjee[3], M.K. Ghosh[3], T.K. Dutta[3] and M. Karunakaran[4]

[1] Department of Livestock Production Management, ICAR-National Dairy Research Institute, Eastern Regional Station, Kalyani, India
[2] Department of Animal Genetics and Breeding, ICAR-National Dairy Research Institute, Eastern Regional Station, Kalyani, India
[3] Department of Animal Nutrition, ICAR-National Dairy Research Institute, Eastern Regional Station, India
[4] Department of Animal Reproduction, ICAR-National Dairy Research Institute, Eastern Regional Station, India

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*Correspondence E-mail: amitkumarsingh@ndri.res.in

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ABSTRACT

Optimum nutritional condition of dairy cows during the different stages of production is highly recommended. Production of high quality milk is the primary goal of every herdsman. However, improper nutrition of dairy cows leads to different unwanted ailments and disease losses. This becomes a burden for dairy owners. Most commonly, dairy cow undergoes negative energy balance (NEBL) condition due to improper dry matter intake (DMI). DMI in proper amount provides good nutrition for the dairy animals. There is a common trend of depressed DMI during the transition and the initial lactation period of high-producing animals. Following which elevated levels of non-esterified fatty acids (NEFA), beta-hydroxybutyrate (BHBA), blood urea nitrogen (BUN), undesired body condition stages, lowered production performances, poor milk quality, and inferior udder health status of dairy cows are observed. Both over-conditioned and under-conditioned bodies of the dairy animal are more at risk of NEBL thereby posing a negative impact on behavioral and production performance. This review is framed to discuss the effect of negative energy balance on the behavior and production performance of dairy cows.

KEY WORDS behavior, dairy cows, negative energy balance, production performance.

INTRODUCTION

Production of optimum milk quantity and quality, with proper udder health and body condition maintenance of dairy animals, is highly desired at any livestock farm (Kumari *et al.* 2019; Singh *et al.* 2020a; Singh, 2021). Improved milk yield, quality, and health status of dairy animals are beneficial for every dairy owner (Kansal *et al.* 2020; Singh *et al.* 2020b). However, there are many challenges in the successful maintenance of these aspects by the dairy animals (Bhakat *et al.* 2017a). These challenges include the rising cost of feedstuffs, their availability, cost of health care, rapidly increased cost of labor, metabolic disease treatment like mastitis, milk fever, multi-factorial disease as lameness, employed devices for decision making and to combat against odd weather stress and timely insemination facilities (Caja *et al.* 2016) at the farm premise. These challenges permanently adhere to a dairy owner. In order to achieve good results, he has to continuously strive for the best practices (Kumari *et al.* 2020). Studies suggest that adoption of suitable management practices at the farm may help in improving herd health and production performance in terms of both quality and quantity (Kumari *et al.* 2020; Singh *et al.* 2020c). In addition to the above-mentioned challenges, one of the major challenges is to manage NEBL in dairy animals during transition and initial lactation period (Berry *et al.* 2007; Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b).

The transition and initial lactation phase of dairy animals are remarked with pronounced NEBL (Berry *et al.* 2007; Butler, 2009). DMI during these phases is comparatively less than other production phases (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b). There is a dramatic change in the physiological status of dairy animals when they shift from a non-lactating phase (late dry period) to a lactating phase (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b). This physiological shift imposes production stress on the animals when they enter into a production stage (Berry *et al.* 2007; Butler, 2009). Tremendous shifts in the different hormonal levels have been observed in this period (Ospina *et al.* 2010; Chapinal *et al.* 2012). A decrease in DMI implies poor nutrient availability to the animals (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b) which leads to depletion of body reserves of the animals to meet the physiological stress experienced by animals under these phases. Increased NEBL leads to several other productions, reproduction, and health problems (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b). Remarkably increased serum NEFA, BHBA, BUN levels are observed during NEBL in dairy animals (Ospina *et al.* 2010; Chapinal *et al.* 2012). Timely corrective management strategies before the onset of the production stage of animals are studied to have beneficial effects on the animals (Caja *et al.* 2016). A management strategy that encourages a reduction in elevated NEFA, BHBA, BUN levels in serum by improved DMI is highly advisable (Spiers *et al.* 2004; Ospina *et al.* 2010; Chapinal *et al.* 2012; McArt *et al.* 2013).

India and several countries around the world are experiencing a high gap between the availability and demand of certain feedstuffs. Published data reveals that India on average is presently facing a deficit of 35% green fodders and 26% dry fodder residues and 41% deficit of different feed ingredients for concentrate mixture (ICAR-DARE-Annual-Report, 2013). The reason behind this issue may be due to the rapid increase in the population of livestock, reduced land availability for fodder cultivation, increased demand for food items by rising human populations which puts competition for resources. With this constraint also, the nutrients available for animals should be assimilated into their body to meet the requirements for different production and other bodily activities. Recent studies suggest that proper nutritional management condition during the dry period onwards reduces the adverse impact of NEBL to a considerable level (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b). Following this, optimized behavioral and production performance of dairy animals may be achieved (Drackley and Cardoso, 2014; Van Hoeij *et al.* 2018; Singh *et al.* 2020b).

Reviews that summarize knowledge based on the latest findings to reduce negative energy balance for improved behavior and production performances of dairy animals are very scanty. This formed the basis of the framing of this review. This manuscript summarizes the knowledge based on the latest findings to reduce negative energy balance for improved behavior and production performances of dairy animals.

Methodology for this review

A cohesive and rigorous study of the latest and existing literature has been performed for the drafting of this manuscript. Most of the literature referred were not older than 2010 with an upper limit of 2021 for this manuscript. However, some important and older references were also studied and cited in this review. Most of the literature findings were done in the ICAR-National Library in Dairying of National Dairy Research Institute, Karnal. However, several online platforms such as research gate, google scholar, and publishing organizations such as elsevier, springer nature, sage publication, taylor and francis, willey online, Indian journals, etc. were utilized for studying and drafting this manuscript. This manuscript is sub-divided into an in-depth review of factors associated with NEBL and its effect on the behavioral and production performance of dairy animals. We have not focused on other aspects as reproduction, and other health parameters of dairy animals rather we have concentrated our review on factors associated with NEBL and its consequent effect on behavioral and production performance in dairy animals. However, we have indicated suggestions for other management factors such as housing, diet, and husbandry practices which need to be optimized for desired results.

Changes in the metabolic profile of dairy animals during the initial lactation period

Lipolysis rate gets increased than rate of lipogenesis in adipose tissue of animals and the uptake of lipid energy also gets elevated on the onset of lactation. Similarly, the glucose uptake by the animal body exceeds gluconeogenesis in liver of dairy animals. A steady increase in food intake, increased protein mobilization, mineral absorption and mobilization followed by increased capacity and process of digestion occurs in dairy animals. Furthermore, the milk synthesis occurs which causes more utilization of nutrient reserves and blood flow to the mammary system of dairy animals (Ingvartsen and Andersen, 2000; Dann *et al.* 2005; Berry *et al.* 2007; Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b; Singh *et al.* 2020f).

The above-mentioned list of changes in metabolic profile of dairy animals is not exhaustive. Nevertheless, this list represents a major important physiological phenomenon for a dairy animal in its initial lactation period.

Negative energy balance in dairy animals

Late pregnancy to the initial three weeks for dairy animals has been recognized as one of the most important areas of interest for researchers of animal science. The transition period is commonly understood as the period of 3 weeks before and after calving period (Drackley and Cardoso, 2014) in dairy animals. There is a tremendous change in the hormonal control and the nutritional requirement of the animals during this period (Ospina *et al.* 2010; Chapinal *et al.* 2012; McArt *et al.* 2013). However, this period has been observed with a reduction in DMI by 10-30% in dairy animals (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b). During the initial lactation stage, the milk yield and its compositional change occur rapidly for which nutrient requirement by the animals is also elevated (Butler, 2009; Drackley and Cardoso, 2014; Singh *et al.* 2020b). However, due to depressed DMI during this phase there becomes a gap in the supply and demand of available nutrients and energy levels in the dairy animals (Dann *et al.* 2005). This situation is termed as a negative energy balance in dairy animals (Dann *et al.* 2005; Drackley and Cardoso, 2014). NEBL conditions in animals are observed more during the transition and initial 2 months of dairy cows. There is the practical importance of studying negative energy balance of dairy animals to put corrective measures on required time for the animals (Butler, 2009; Drackley and Cardoso, 2014).

During prepartum period, the cutoff values for the NEFA ≥0.3 to 0.5 mEq/L and BHBA ≥0.6 to 0.8 mmol/L were taken to indicate adverse performance effects. However, during postpartum period, on the other hand, the cutoff values for NEFA ≥0.7 to 1.0 mEq/L and BHBA 1.0 to 1.4 mmol/L concentrations reflected negative results in different studies (Wankhade *et al.* 2017). Higher concentrations of both NEFA and BHBA are associated with negative performances in dairy cows. More NEFA concentrations indicate that more body reserves are metabolized in the animals' body.

Higher BHBA levels, on the other hand, reflect more risk of ketosis in dairy cows. Hormones such as insulin-like growth factor (IGF), insulin, oestradiol, growth hormone, cortisol levels were studied by Fenwick *et al.* (2008). Higher levels of insulin mIU/mL (0.22±0.058 *vs.* 0.13±0.019), oestradiol pg/mL (2.2±0.33 *vs.* 1.6±0.24), growth hormone ng/mL (18±8.0 *vs.* 9±0.7), cortisol nmol/L (13±5.7 *vs.* 5±1.6) were observed in cows with mild NEBL than in severe NEBL.

Fenwick *et al.* (2008) found that significantly lower IGF-I ng/mL (11±1.1 *vs.* 51±8.4) and glucose mM (2.7±0.15 *vs.* 4.1±0.13) in severe NEBL than mild NEBL. Whereas, dairy cows suffering from severe NEBL had significantly higher NEFA and BHBA levels. Moreover, the results of this study suggested that increased IGF may suppress embryo development which may lead to high embryonic mortality in dairy cows.

Assessment of energy balance in dairy animals

Different methods of accessing energy status of dairy animals in terms of plasma NEFA, BHBA, glucose, urea, total protein, slaughtered weight, ultrasound techniques, etc. as their concentration changes with change in energy status of dairy animals as proposed by different studies. However, some practical problems exist with these methods. These methods are more applicable for laboratory conditions and can not be easily used in field conditions and they are non-economic as well but they have their respective advantages too. Nevertheless, body condition score (BCS) method can be easily followed and utilized under field conditions (Ospina *et al.* 2010; Chapinal *et al.* 2012; Singh and Kumari, 2019). BCS method predicts the relative body fatness of dairy animals based on fat deposition over specific body parts and it has different scales (Singh *et al.* 2020b).

In recent research, Xu *et al.* (2018) showed that transition period energy balance could be estimated by milk metabolites analysis which may have a role in cell regenerations. They suggested that energy balance estimation may require information on complex net energy consumed from different feed sources, which may be complex and often require a lot of facilities. However, milk constituent estimations may serve for the estimation of energy balance. On other hand, some studies revealed that milk metabolites may be secreted by myo-epithelial cells, damaged SCC, or even from blood (Linzell and Peaker, 1971). Xu *et al.* (2018) remarked from their study that both the milk constituents and milk metabolites may be utilized for the estimation of energy balance of individual cows. In particular, estimation of glycine, choline, carnitine, and fat yield had been identified as the most important parameters. This methodology had 53% to 88% predicting ability. In addition to it, they also indicated that these metabolites may have a relation with cell renewal.

Factors for regulation of DMI in dairy animals

There exists a complex synergism among different factors that control feed intake and so is for DMI by the animals (Butler, 2009; Drackley and Cardoso, 2014). These factors include hormonal changes, metabolites, physiological challenges, internal stimulus, digestive system, and environmental stressors around dairy animals (Ospina *et al.* 2010;

Chapinal *et al.* 2012; McArt *et al.* 2013). The above-mentioned factors have their different importance in the regulation of energy balance of dairy animals.

Role of blood constituents and metabolites

The last two decades have witnessed an increased interest in the study of blood metabolites which reflects energy balance in dairy animals (Seifi *et al.* 2007; Singh *et al.* 2020b; Singh *et al.* 2020f; Singh *et al.* 2020g). These metabolites include particularly NEFA, BHBA, and BUN levels in blood serum or plasma (Chapinal *et al.* 2012). Latest studies suggest that NEFA levels get elevated gradually 2 to 3 weeks before calving till the first month of lactation (Cavestany *et al.* 2005; LeBlanc *et al.* 2005; Ospina *et al.* 2010; Chapinal *et al.* 2012). Max levels of NEFA are seen during or near calving days (Cavestany *et al.* 2005; LeBlanc *et al.* 2005; Ospina *et al.* 2010; Chapinal *et al.* 2012). However, under improper management, this NEBL may prolong up to several months leading to adverse production and health performance in dairy animals (Ospina *et al.* 2010; Chapinal *et al.* 2012; Singh *et al.* 2020b; Singh *et al.* 2020h). Hence, the energy levels during the drying off period in dairy animals form an important management period (Singh, 2019; Singh *et al.* 2020b).

NEFA shows the level of fat mobilization from body reserves as adipose tissues in an attempt to fill the energy gap during NEBL (Ospina *et al.* 2010; Chapinal *et al.* 2012; Singh *et al.* 2020b; Singh *et al.* 2020f). Researches have shown that elevated NEFA levels are also corroborated with increased risk of fatty liver, displaced abomasum, ketosis, poor udder health status, and reproductive problems in dairy animals (Ospina *et al.* 2010; Chapinal *et al.* 2012; Singh *et al.* 2020b; Singh *et al.* 2020i).

A similar trend of elevated levels of BHBA is observed during transition period than other lactation cycle days of dairy animals (Cavestany *et al.* 2005; LeBlanc *et al.* 2005; Ospina *et al.* 2010; Chapinal *et al.* 2012). However, postpartum BHBA levels have been reported higher than prepartum days (Cavestany *et al.* 2005; Seifi *et al.* 2007) which might be due to the more energy demands of dairy animals with the initiation of production period (Seifi *et al.* 2007).

BUN levels are reported to be lower during the dry period than the lactation period (Seifi *et al.* 2007; Singh *et al.* 2020b). The reason behind this phenomenon may be due to increased intake of food by the animals (Cavestany *et al.* 2005; Seifi *et al.* 2007). The highest levels of BUN were observed on near to a month of the initial lactation period (Cavestany *et al.* 2005; Seifi *et al.* 2007). Protein metabolism is increased during initiation of the lactation period which is reflected by elevated BUN levels in dairy animals (Ingvartsen and Andersen, 2000; Buttchereit *et al.* 2010).

Hence elevated DMI will be helpful to express optimum BUN levels in dairy animals (Ingvartsen and Andersen, 2000; Dann *et al.* 2005; Berry *et al.* 2007; Butler, 2009; Buttchereit *et al.* 2010; Drackley and Cardoso, 2014; Singh *et al.* 2020b; Singh *et al.* 2020f).

Glucose is considered the primary metabolic driver in animal organs for growth, production, and reproduction in animals (Cavestany *et al.* 2005; Seifi *et al.* 2007). Serum glucose levels are depressed during NEBL condition as seen particularly 3 weeks before and after parturition (Seifi *et al.* 2007; Ingvartsen and Andersen, 2000; Buttchereit *et al.* 2010).

In addition to above mentioned blood metabolite and constituent levels, some studies (Seifi *et al.* 2007; Nowroozi-Asl *et al.* 2016) shown that during the transition period blood triglyceride, cholesterol, total protein, and albumin levels decrease near calving and again starts elevating with an increase of days in milk. However, aspartate aminotransferase levels increased with progress of days near calving and lactation period in dairy animals.

Hormonal control of DMI

Hormonal control of DMI has been review to the extent of providing basic understanding however, the below-provided list does not highlight reproductive hormones. Stress hormones partially, corticotrophin-releasing hormone is secreted by the paraventricular nuclei of the hypothalamic centers in the brain (Ingvartsen and Andersen, 2000; Buttchereit *et al.* 2010; Nowroozi-Asl *et al.* 2016). This mechanism is found to have a minor mediatory effect on feed intake (Ingvartsen and Andersen, 2000).

Leptin hormone is released mainly from adipose cells and is directly correlated with adipose content in animals' bodies (McCann *et al.* 1992; Maffei *et al.* 1995; Ingvartsen and Andersen, 2000). Leptin levels are found to increase during pregnancy in animals and gradually decrease near calving period (Chien *et al.* 1997; Kawai *et al.* 1997; Ingvartsen and Andersen, 2000; Nowroozi-Asl *et al.* 2016). Leptin has been associated with appetite regulation and also has a role in drawing nutrients from the maternal system to the fetus for growth and development of organs (Yamada *et al.* 2003; Nowroozi-Asl *et al.* 2016). Leptin has a role in body weight regulation and fat deposition in the adipose tissue in animal body (Ingvartsen and Andersen, 2000; Nowroozi-Asl *et al.* 2016).

Ghrelin (GH) hormone has a great influence on the regulation of gastrointestinal activities, regulation of gastric and pancreatic secretion, cell growth; lipid metabolism, cardiovascular activities and immunity levels in animals are also affected by the action of ghrelin (Ingvartsen and Andersen, 2000; DeVriese *et al.* 2008; Börner *et al.* 2013; Nowroozi-Asl *et al.* 2016).

Thyroid hormones have a role in energy metabolism (Ingvartsen and Andersen, 2000; Nowroozi-Asl *et al.* 2016). Increased insulin levels have been shown to decrease feed intake and hence lower DMI (Ingvartsen and Andersen, 2000; Nowroozi-Asl *et al.* 2016) in animals. There has been a positive correlation of insulin levels with DMI in dairy animals (Riedy *et al.* 1995; Ingvartsen and Andersen, 2000; Hosseini *et al.* 2015; Kawashima *et al.* 2016; Nowroozi-Asl *et al.* 2016; Li *et al.* 2017). In nutshell, it may be affirmed that elevated insulin levels may have long-term effect on DMI in dairy animals thereby affecting the whole metabolic and condition of body of animals (Ingvartsen and Andersen, 2000; Nowroozi-Asl *et al.* 2016). Elevated glucagon levels may have an indirect role in the depression of DMI in animals (Meeran *et al.* 1999; Ingvartsen and Andersen, 2000; Habegger *et al.* 2010; Li *et al.* 2017).

Cholecystokinin (CCK) is secreted from the duodenum and jejunum of animal gut region and produces satiety signals in central nervous system in animal's body (Riedy *et al.* 1995; Ingvartsen and Andersen, 2000). However, Somatostatin is released from both brain and gut of animals (Ingvartsen and Andersen, 2000; Stengel and Taché, 2013; Nowroozi-Asl *et al.* 2016). It has similar action of reducing feed intake in animals on elevated levels (Ingvartsen and Andersen, 2000; Nowroozi-Asl *et al.* 2016). An illustration of hormonal control on the regulation of DMI in dairy animals is presented in Figure 1.

Environmental factors associated with DMI

Climatic conditions and housing facilities

Several published data revealed that the earth's mean temperature has increased by 0.2 ˚C per decade (IPCC, 2007) and is expected to rise by 2 to 5 ˚C by the year 2100 (IPCC, 2007; Das *et al.* 2016). Developing countries would be more at risk of increasing temperature as their economy is largely dependent upon agriculture (Silanikove and Koluman, 2015). Thermo-neutral zone for dairy animals has been suggested to be 16 ˚C to 25 ˚C (Das *et al.* 2016) to maintain their proper physiology. When air temperature goes beyond 30 ˚C, a sharp decline in DMI is noticed, and when the temperature raises up to 40 ˚C a depression of 40% DMI is observed (Hooda and Singh, 2010; Hamzaoui *et al.* 2012; Rhoads *et al.* 2013). As a result of which the dairy animals may suffer NEBL and correspondingly the body weight and body condition of animals may go down to unwanted levels (Lacetera *et al.* 1996; Das *et al.* 2016).

In response to such climatic stress, an increase in the maintenance requirement of up to 30% of the animal may be observed (NRC, 2007). Additionally, the milk yield gets sharply lowered as a result of NEBL (Aggarwal and Singh, 2008; Upadhyay *et al.* 2009; Aggarwal and Upadhyay, 2013). Housing facilities that promote a comfortable thermal-humidity index (65-72) in addition to proper ventilation, animal comfort, lower microbial load, etc. should be given preference for dairy animals (Singh *et al.* 2020c). Studies suggest that a temperature humidity index (THI) 78 from THI 68 leads to a reduction in DMI by 21% and consequently milk loss of 9.6% (Bouraoui *et al.* 2002). More severe DMI and milk losses can be observed under higher THI.

Furthermore, the tropical climate offers a harsh environment for dairy animals (Singh *et al.* 2020c) hence housing modifications such as roof thatched or insulated (Sahu *et al.* 2019; Singh *et al.* 2020c) for improved thermal comfort (Sahu *et al.* 2019; Singh *et al.* 2020c), soft bedding such as sand and composted bedding should be adopted to achieve improved results in terms of more DMI, water intake, and milk yield (Singh *et al.* 2020c; Singh *et al.* 2020d; Singh *et al.* 2020e).

Diet regime for dairy cows

Management practice that may lower the blood NEFA near calving would be effective to decrease the risk for production loss and health problems (Ospina *et al.* 2010; Chapinal *et al.* 2011; Janovick *et al.* 2011; Chapinal *et al.* 2012). The suggested cut-off value of NEFA was ≥0.5 mEq/L for predicting a reduction in milk yield and other health problems (Chapinal *et al.* 2011). Dry matter intake and serum NEFA concentrations normally have an inverse relationship (Overton and Waldron, 2004; Drackley *et al.* 2005; Singh *et al.* 2020b).

A dry period diet is one of the critical factors which have far-reaching effects on lactation and other health parameters (Drackley *et al.* 2005; Berry *et al.* 2007; Singh *et al.* 2020b). A feeding regimen that offers high forage diet during far off dry period and a comparatively energy denser diet during close up dry period is suitable feeding management practice to reduce NEBL and consequently improved milk performance, udder health status, and body condition of dairy cows (Drackley *et al.* 2005; Chapinal *et al.* 2011; Chapinal *et al.* 2012; Singh *et al.* 2020b). This type of feeding regime encourages more DMI during the transition period (Beever, 2006; Berry *et al.* 2007; Butler, 2009; Roche *et al.* 2013; Drackley and Cardoso, 2014; Roche *et al.* 2016; Singh *et al.* 2020b).

In an interesting study (Senturk *et al.* 2015), it was found that tannin containing herbal supplementation (Chebracho tannin) during transition period may have protective effects in dairy cows from ketosis and NEBL as showed by lower BHBA levels. In addition, improvement in gut health was observed in a supplemented group in terms of improved stool score and fecal structure without having negative effects on feed intake.

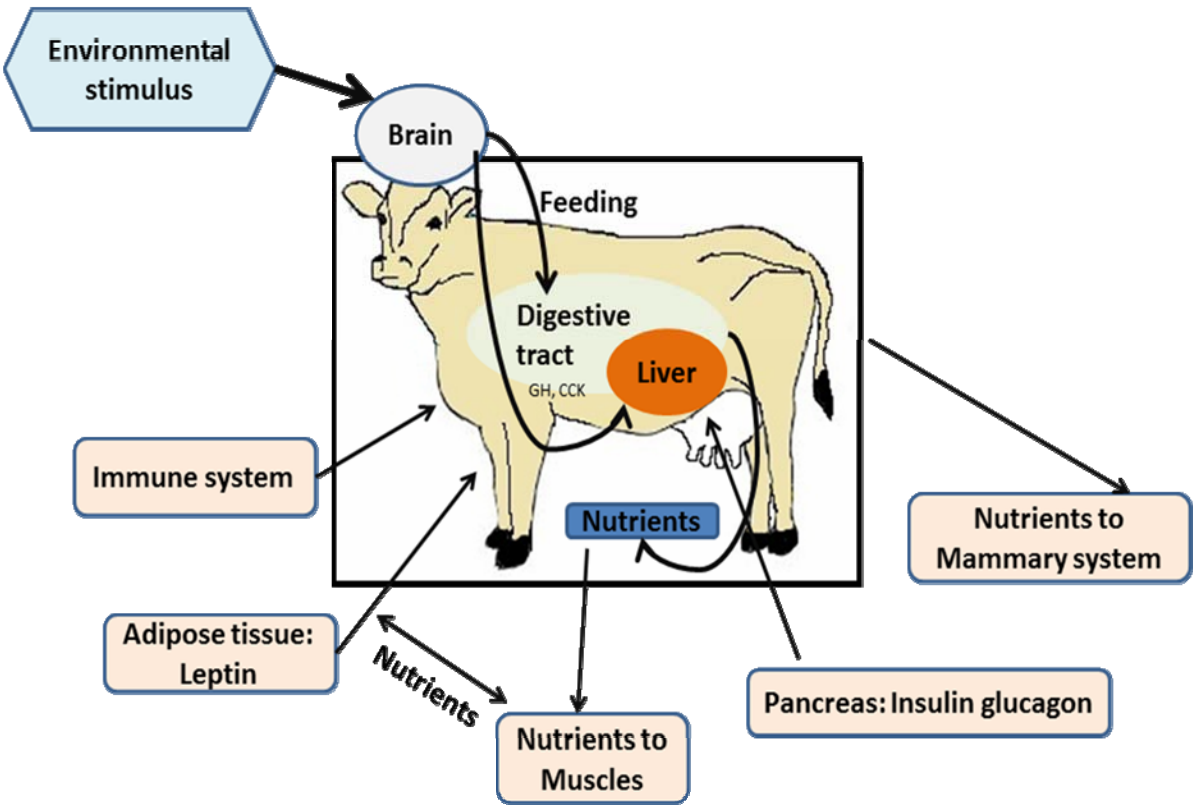

Figure 1 Hormonal control of regulation of DMI in dairy animals

In an investigation (Garcia *et al.* 2011) , it was concluded that 250 g/cow/d protected fatty acid supplementation during the transition period may increase milk yield but it may have adverse effects on BHBA and NEFA levels indicating more NEBL. On the other hand, 300 mL propylene glycol supplementation in another group on an alternate day basis for 30 days postpartum may have Hepato protective effect.

Husbandry practices

A positive emotional state of the animal leads to better animal welfare (Green and Mellor, 2011; Mellor, 2012) whereas prolonged stress conditions in animals may lead to anhedonia (Yalcin *et al.* 2014; Rizvi *et al.* 2016; Lecorps *et al.* 2019). The latter condition has a drastic negative impact on animal health and production performance of dairy animals (Lecorps *et al.* 2019). In order to eliminate such negative emotional problems in dairy animals, expert and gentle handling of animals should be encouraged at the farm for desired results (Novak *et al.* 2016; Lecorps *et al.* 2019). Micro-behavior expressions have practical utility to judge and predict the emotional state of animals (Weary *et al.* 2017). Motivational stimulus which changes the emotional state of animals includes thirst, hunger, drive for energy-dense food, pain, sensations, sleep and body temperature of animals (Denton *et al.* 2009; Mellor, 2012).

However, external stimulus, especially the handling process has a great influence on animal behavior in terms of positive or negative emotion (Green and Mellor, 2011).

Energy balance and production performance of dairy animals

High-producing dairy animals have been developed by a continuous selection of superior germplasm to meet high demand for dairy products (Capper *et al.* 2009; Caja *et al.* 2016). However, the high-producing animals are more prone to NEBL. Several studies (Berry *et al.* 2007; Buttchereit *et al.* 2010; Buttchereit *et al.* 2011; Drackley and Cardoso, 2014; Singh *et al.* 2020b; Singh *et al.* 2020f) explained that DMI has a high influence on energy balance of dairy animals. Improved DMI has shown reduced NEBL in dairy animals (Singh *et al.* 2020b; Singh *et al.* 2020f). However, over and under-conditioned body conditions of dairy animals should be avoided (Heuer *et al.* 2001; Reist *et al.* 2002; Singh *et al.* 2015; Singh *et al.* 2020b) and management practices should be driven to achieve the optimum range of BCS (Paul *et al.* 2018; Singh *et al.* 2020b). Improved energy balance in dairy animals has shown significantly increased milk yield (Roche, 2007; Buttchereit *et al.* 2010; Buttchereit *et al.* 2011; Drackley and Cardoso, 2014; Singh *et al.* 2020b; Singh *et al.* 2020f).

Improved body conditions have shown improved milk flow for dairy animals (Ryan *et al.* 2003; Reis *et al.* 2012; Mohammed *et al.* 2015; Singh *et al.* 2015; Singh *et al.* 2020b).

Transition period is remarked with lowered immunity status of animals and more NEBL elevated the risk of intramammary infections (Reis *et al.* 2012; Bhakat *et al.* 2017a; Singh *et al.* 2020b).

As a result of severe immune-suppression of the mammary system of dairy animals, poor udder health status in terms of increased somatic cell count (SCC), more modified California mastitis test values, elevated pH, and electrical conductivity (EC) in the milk samples of animals are observed (Batavani *et al.* 2007; Buttchereit *et al.* 2011; Gumen *et al.* 2011; Malek dos Reis *et al.* 2011; Bharti *et al.* 2015; Boas *et al.* 2017; Bhakat *et al.* 2017b; Smith *et al.* 2017; Alhussien and Dang, 2018; Singh *et al.* 2020b). Primiparous animals are more at the risk of udder health and reproductive problems as they do not have a fully grown mammary system and proper energy and nutrients are required for the proliferation and maturation of alveolar ducts to make them able to produce quality milk (Bachman and Schairer, 2003; Pezeshki *et al.* 2007). Several studies (Busato *et al.* 2002; Lake *et al.* 2006; Singh *et al.* 2020b) suggest that animals under reduced NEBL showed no changes in milk composition.

Restriction of energy supply to the dairy cows during the transition period leads to lower down the energy balance which is reflected by significantly lower body weight and BCS among other production-related parameters (Janovick *et al.* 2011; Contreras *et al.* 2016; Esposito *et al.* 2020). In a recent study (Esposito *et al.* 2020) it was speculated that the degree of BCS loss may be independent of milk production levels. They found similar DMI among the restricted and non energy restricted diet groups. They proposed that BCS loss is independent of milk production level upon energy intake than DMI. Furthermore, they remarked that intensity and span of lipid mobilization may affect milk fat% in NEBL (Knegsel *et al.* 2007; Mann *et al.* 2015; Esposito *et al.* 2020). Higher fat:protein ratio has been associated with restricted energy supply as revealed by higher NEFA levels than in the case of unrestricted diet (Mann *et al.* 2015; Esposito *et al.* 2020). Cholesterol levels have been suggested to be an indicator for the energy and health status of dairy cows during the transition period (Quiroz-Rocha *et al.* 2009; Esposito *et al.* 2020). In addition, it was suggested that cholesterol concentrations may be a reliable prediction of NEBL and health status of cows (Kim and Suh, 2003; Sepulveda-Varas *et al.* 2015). In their study Esposito *et al.* (2020), a significant and positive correlation between total cholesterol levels and body temperature was observed. From here, it may be assumed that relationship of different body part's temperatures with total cholesterol levels may be explored further for more understanding about management of cows from entering into lower cholesterol levels. Esposito *et al.* (2020) inferred from their study that restricted energy intake during transition cow adversely affects NEFA levels, energy balance, immune response, and poor reproductive health.

Energy balance and behaviors in dairy animals

Under grazing conditions, dairy cows were shown to show lower grazing activities during the first week of initial lactation (Chilibroste *et al.* 2007; Chilibroste *et al.* 2012). Primiparous cows were found to have more difficulty in fulfilling their DMI through grazing during the first 3 months of lactation period. Gilmore *et al.* (2011) found that there was no diet effect on cows for oestrus behaviors that included sniffing, attempting mount on other cows, sexual active group participation by oestrus cows, and also on standing mounting conditions. Itle *et al.* (2015) Investigated that primiparous cows had more standing bouts and shorter average standing bout durations than multiparous cows during the transition period under ketosis conditions. However, cows are found to show more and longer-standing bouts (Jensen, 2012) expressing distress on the day of calving. Moreover, in a review Von Keyserlingk and Weary (2010) stated that standing patterns in dairy animals depend upon the condition of feed, its delivery pattern, and milking. In a recent finding Kaufman *et al.* (2016) investigated that during the transition period, the subclinical ketosis cows showed decreased lying time, increased frequency, and decreased lying bouts expressing discomfort in cows in NEBL. However, Steensels *et al.* (2012) suggested that lying behavior may be influenced by body weight of dairy animals. Kaufman *et al.* (2016) suggested that decreased lying time may also be attributed to more feeding time to cope with production needs. Maltz *et al.* (2013) reported that there was no difference in intake 24 h, eating and lying or standing ruminating time, drinking time, meal duration, and size for dairy animals under different groups in different energy balance during the early lactation period. However, some studies (Gencoglu *et al.* 2010; Singh *et al.* 2020b) found enhanced DMI under treatment group animals during transition period. NEBL cows showed decreased visits and meals, steps, and motion index per day during the transition period (Van Hoeij *et al.* 2018). However, good metabolic profiled cows showed improved DMI during tranition period (Van Hoeij *et al.* 2018; Singh *et al.* 2020b).

Moore and Devries (2020) found that cows shift their feed selecting behavior against induced NEBL and its extent was associated with the intensity of NEBL. They found that long straw (10.2 cm screened) group cows budgeted more time on eating than small straw (2.54 cm screened) group animals. In connection with this, researchers (Beauchemin and Yang, 2005; DeVries *et al.* 2008) found that cows alter their feed selection behavior for small or larger particles in order to maintain their rumen pH and the selection of long fibrous particles help them to cope up with adverse effects of low pH in rumen. DeVries *et al.* (2011) showed that cows may choose to have diet which may help in increasing their nutrient intake in response to NEBL. Azizi *et al.* (2009) remarked that cows with greater yields invested more time in eating, more daily DMI than lower producing cows. Some studies (Miller-Cushon and DeVries, 2017; Grant and Ferraretto, 2018) showed that feed selection and time is taken for eating one meal get improved when dairy cows are offered long fibrous fodder particles. This may help them in combating NEBL. Longer feed particle size, more neutral detergent fiber (NDF) content in fodder, and more roughage inclusion in diet lead to longer eating time in dairy cows (Soita *et al.* 2000; Yang and Beauchemin, 2006; Alamouti *et al.* 2014; Jiang *et al.* 2017).

Furthermore, Jiang *et al.* (2018) remarked that the sorting activity of cows gets reduced concerning reduction in forage particle size. Higher milk fat % has been associated with less sorting against longer dietary particle size (DeVries *et al.* 2011; Fish and DeVries, 2012; Miller-Cushon and DeVries, 2017). Less sorting against small particles resulted in higher reticulo-rumen pH values than another comparable group, finally leading to higher fat %. It may be inferred from the above discussion that selection of fodder particles may be associated with altered feed selection behavior in response with cope with severe NEBL.

CONCLUSION

Different factors are attributed towards NEBL of dairy cows during different stages of animals especially during the transition and initial lactation period and also when the dairy animals are exposed to heat stress. The factors associated with reduced DMI leading to NEBL in dairy animals include hormonal control, diet, housing, husbandry practices. NEBL depresses milk yield and comfort behavior of dairy animals especially during the transition and dry period. Positive emotions of dairy animals during these phases are also anticipated to improve the production and behaviors of dairy animals. Increased forage diet with lower energy diet during far off dry period followed by comparatively denser diet during close up dry period improves metabolic profile thereby improving DMI, production, and behavior of dairy animals. Moreover, studies on the handling of animals during the transition phase on production and behavior in consequent lactation period will add up to the existing knowledge and help in a better understanding biological phenomenon in dairy animals during NEBL.

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