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# Seasonal Influence on Nutrient Requirements of Ruminants: A Review

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## ABSTRACT

There are different agro climatic zones in the tropical countries hence seasonal change is most evident. Adverse climate might lead to environmental stress and changes of physiological and haemato-biochemical parameters in the body. Of the many types of stresses affecting rate and efficiency of animal productivity, most important are the thermal environment and associated factors of humidity, radiation and air movement than factors such as altitude, animal density, confinement *etc*. To reduce this condition, adequate nutrient requirement through diet should be fulfilled basically requirement for maintenance and production purpose. Nutrient requirements have been commonly esthablished in conditions presumed to be relatively free of environmental stress and animals are expected to perform near the genetic potential in the intensive production system. For that reason, such requirements are most relevent during optimum environmental conditions and are less appropriate when animals are exposed to stressful environments. Recently the feeding systems followed in tropical countries are ME and NE for energy feeding and for protein feeding CP along with MP system to meet the nutrient requirement. Here, an effort has been made to review the different modifications of feeding system over the earlier one along with influence of climate and related factors that affect nutrient requirement and utilization. The aim of the present manuscript is to modify the requirement with various climatic variables for augmenting production efficiency and cost effective farming.

**Key words:** Feeding system, Nutrient requirements, Ruminants, Season, Variation.

Climate change is widely considered to be one of the most potentially serious environmental problems ever confronting to the global community and has become an important area of concern to ensure food and nutritional security for growing population. Current climate projection model indicated an increase in temperature by 0.2°C per decade and predicted that the increase in global average surface temperature would be between 1.8°C to 4.0°C by 2100 (IPCC, 2014). The impacts of climate change is global, but tropical countries are more vulnerable as 70% of human population is dependent on agriculture for their livelihood and livestock sector is the integral part of tropical agriculture (Singh and Upadhyay, 2013). IPCC (2014) reported that many of the developing countries tend to be especially vulnerable to extreme climatic events as they largely depend on climate sensitive sectors like agriculture and forestry. Therefore, climate change is one of the most serious long term challenges facing farmers and livestock owners around the world. The variation in climatic variables like temperature, humidity and radiations were recognized as the potential hazards in the growth and production of all domestic livestock species. Climate affects animal production in four ways: the impact of changes in livestock feed-grain availability and price, impacts on livestock pastures and forage crop production and quality, changes in the distribution of livestock diseases and pests, direct effects of weather and extreme events on animal health, nutrient requirement, growth, production and reproduction. Also high ambient temperature accompanied by high air humidity caused an additional discomfort and heightened the stress level which in turn resulted in depression of the physiological and metabolic activities of the animal (Verma *et al*., 2000; Banerjee *et al*., 2014).

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Various feeding standards for feeding various categories and species of animals *i.e.*, National Research Council (NRC), Commonwealth Scientific and Industrial Research Organization (CSIRO), Australian Agricultural and Food Research Council (AFRC) of UK, France protein system (PDI, Institut National de la Recherche Agronomique (INRA), Indian Council of Agricultural Research (ICAR, 2013) *etc.* are followed for feeding various categories and species of animals in temperate and tropical countries. These nutrient requirements have been commonly esthablished in an environment protected from climatic extremes. For that reason, such requirements are most relevent during optimum environmental conditions and are less appropriate when animals are exposed to stressful environments. In tropical condition, because of the small, restricted database, these standards do not reflect requirements for widely different planes of nutrition, quality of feed or individual variation in animal's requirements under climatic stress condition are not cleared (Schiere and Wit, 1993). The ability of the livestock to grow, lactate and breed to their maximum genetic potential and capacity to maintain health is affected by the thermal environment. Colliar and Beede (1985) reviewed the thermal stress and associated factors with nutrient requirements and interrelationships. Climatic stress is the one of the major concerns in the warm region of the world which reduces the intake of nutrients necessary to support maintenance and growth. Nutrient requirements are determined under standardized conditions and applied to an infinite combination of animal, management and environmental conditions. Nutrient demands are increased by thermal stress and few quantitative data exist relating to stress and productive efficiency in ruminant livestock. In this present era of limited resources, it may be necessary to identify the specific nutritional requirements for animals fed under thermal and humidity stress conditions.

## Recent development of energy evaluation system

### Metabolizable energy (ME) system

The metabolisable energy (ME) feeding system, developed by Blaxter (1962), was first proposed for use in UK by Agricultural Research Council (ARC, 1980). The original ME system was later substantially revised by ARC (1980) and further modified by Agricultural and Food Research Council (AFRC 1990) and a new working version was published in 1993 (AFRC, 1993). Metabolizable energy (ME) system of energy evaluation is more accurate than total digestible nutrients (TDN) system because it takes into account the losses through urine and combustible gases. Another advantage of ME system is that efficiency of utilization of energy may be measured in this system. This system can be used either to predict performance of animal from predetermined ration or to formulate ration for specific performance. These modifications were based largely on the extensive work on energy requirements of lactating dairy cows by Moe *et al.*, 1972. Terms were included to allow for energy released from or deposited in body tissues of lactating cows and it also recognized that tissue energy gain was more efficient in the lactating rather than the non-lactating animal (Henrique *et al.*, 2005). Nowadays, ME and NE system is considered over TDN system for energy evaluation and for protein evaluation. Reports regarding utilization of energy using calorimetric studies in ruminants were limited (Tiwari *et al.*, 2000). The ME content of feedstuffs was calculated from their chemical composition, energy digestibility and ME/DE ratio. ME is the gross energy (GE) of the feed minus that of the faeces ($F_E$), urine ($U_E$) and combustible gas (mostly methane, $M_E$) and expressed as Mcal/kg DM or Mcal/d. ARC (1980) defined metabolizability of feed at maintenance ($q_m$) as the proportion of ME in the GE of that feed.

$$q_m = ME/ GE$$

The equations suggested to work out the efficiency of ME utilization for different functions (ARC 1980) were as follows;

$K_{maintenance} = 0.35q_m+0.503$

$K_{growth} = 0.78q_m+0.006$

$K_{lactation} = 0.35q_m+0.420$

Lactating cows $K_g = 0.95\ k_l$

Efficiency for growth of conceptus $K_c = 0.133$

Efficiency for utilization of mobilized body tissue for lactation $K_t = 0.84$

NRC (2001) used following equation to derive ME value from known DE value of feeds.

ME (Mcal/kg) = 1.01×DE (Mcal/kg) -0.45 (NRC 2001).

### Net energy system

The NE requirement for maintenance ($NE_m$) in energy feeding systems presently used in the Europe and North America was derived from calorimetric data. In the UK, energy system, the $NE_m$ was based on fasting metabolism data (fasting heat production (FHP) plus fasting urinary energy output) from beef steers and dry non-pregnant dairy cows after a prolonged period of restricted feeding (usually at maintenance level). Using this approach ARC (1980) reported a curvilinear relationship between fasting metabolism (FM) and live weight (LW) [$FM=0.53^* (LW/1.08)^{0.67}$] from a review of 8 sets of data. This relationship, plus an activity allowance (0.0091* LW) is taken as $NE_m$ for use at present in UK (AFRC, 1993). This approach would suggest a fasting metabolism of around 0.30 (or $NE_m$ of 0.35 if an activity allowance is included) $MJ/kg^{0.75}$ for an adult dairy cow (Corbett and Freer, 2003). The ME requirement for maintenance ($ME_m$) is calculated as $NE_m$ divided by the efficiency of utilization of ME for maintenance ($k_m = 0.35^*ME/GE+0.503$) (AFRC 1993). Alternatively, the $NE_m$ can be estimated by using regression techniques relating ME intake to milk energy output, adjusted to zero energy balance, with dairy cows offered diets at production levels. Using this approach, Moe *et al*. (1972) reported $NE_m$ values of 0.305 and 0.293 $MJ/kg^{0.75}$ respectively from large sets of calorimetric data. The former value is used to form the American NE system, with an activity allowance of proportionately 0.10 being added (NRC, 1981). The latter value is adopted in the European NE systems used in the Netherlands, France, Germany and Switzerland. No activity allowance is adopted in the Netherland, while an activity allowance of proportionately 0.10 is added for loose housed cows in France (INRA, 1989).

The use of fasting metabolism data to determine $NE_m$ may have limitations. It has been suggested that fasting after a long period of restricted nutrition can result in deamination of amino acids from tissue protein for the supply of essential glucose (Chowdhury and Orskov, 1994). This can induce a range of metabolic disorders in the animal, such as hypoglycaemia, hyperlipidaemia, hyperketonaemia and hypoinsulinaemia. However, the maintenance metabolic rate obtained by fasting metabolism (0.30 MJ/kg $^{0.75}$) (ARC 1980) is similar to that derived from regression techniques (0.305 or 0.293 MJ/kg$^{0.75}$) (Moe *et al*., 1972). It thus seems unlikely that the detriment of fasting to animal health influences greatly the heat production. The current NE system remains useful but is empirical and static in nature and thus fails to capture the dynamics of energy utilization by diverse animals as they respond to changing environmental conditions (Ferrell and Oltjen, 2008).

There is no difference in principle between the ME and NE systems, with both systems recognizing that the energy requirement of ruminant as the sum of their energy requirements for maintenance, production (milk and live weight gain) and foetal growth. The only difference between them is where the energetic efficiencies are embodied within the calculation. In the ME system, the energetic efficiencies are used for ration formulation and the prediction of animal performance, while in the NE system the efficiencies are included as part of the energy evaluation of feeds.

**Protein evaluation systems**

A number of new systems have been developed during the last three decades which have attempted to address the deficiencies of the digestible crude protein (DCP) system. Nutritional model for feeding protein to dairy cattle was evolved in UK from the basic crude protein system. The proposals by ARC (1980; 1984) led to the development of the Metabolisable Protein (MP) system (AFRC, 1993) and this is now widely used within the UK for estimating the protein requirements of ruminant livestock and in diet formulation. CP requirement met from different feed sources affected the efficiency of the feed conversion observed by Mehra *et al.* (2006) by supplementation of protein from soybean meal (SBM) showed good response with respect to protein and energy balance, followed by linseed meal and mustard cake (MOC).

In the developing countries like India dietary protein requirements were often based on DCP. This term was a misnomer since it regarded ruminant as monogastric and took no account of the ability of ruminant to utilize rumen degradable N. This was simple and satisfactory for most traditional diets. But it had limitations either with diets rich in degradable N or when formulating diet for high producing animals.

More comprehensive systems based on rumen degradable protein (RDP) and rumen undegradable protein (RUP) and intestinal digestion of RUP was described in NRC (2001). Ruminally degraded feed CP provided a mixture of peptides, free AA and ammonia for microbial growth and synthesis of microbial protein. Ruminally synthesized microbial protein typically supplied most of the AA passing to the small intestine. Ruminally undegraded protein was the second most important source of absorbable AA to the animal. NRC (2001) had assigned estimates of intestinal digestion to the RUP fraction of each feedstuff, but very huge variations were observed in the results of various laboratories.

In NRC (2000), CP of feedstuffs included multiple fractions that differed widely in rates of degradation as per Cornell Net Carbohydrate Protein System (CNCPS) (Sniffen *et al*., 1992). In this model CP was divided into five fractions (A, $B_1$, $B_2$, $B_3$ and C) with different rates of ruminal degradation. Fraction A (NPN) was instantaneously solubilized with an assumed degradation rate (kd) of infinity. Fraction C was determined chemically as the percentage of total CP recovered with ADF (ADIN) and was considered to be undegradable. Fraction C contained proteins associated with lignin and tannins and heat-damaged proteins such as the maillard reaction products. The remaining B fraction represented potentially degradable true protein which was subdivided into fractions $B_1$, $B_2$, $B_3$ based on their extent of degradation in rumen. Fractional rates of degradation for the three B fractions were reported within the range $B_1$ (120-400%/h), $B_2$ (3-16%/h) and $B_3$ (0.06-0.55%/h). Different equations were provided in NRC (2001) for computing RDP and RUP values for feedstuffs from the above fractions. Output of the CNCPS model supplies information on rumen conditions, assisting with diet formulation (Lanzas *et al*., 2007).

It is user friendly and allowing easy adjustments of input data. Published tests show that the model works well with dairy cows and predicts first limiting amino acids for beef cattle (CNCP, 2003).

**Metabolizable protein (MP) system**

The concept of metabolizable protein (MP) was first proposed by Burroughs *et al.* (1974) in the USA. This concept was then developed into systems to replace DCP, in UK by ARC (1984) and in France by INRA, later in Scandinavian countries (Madsen, 1985) and USA. Several systems (Madsen, 1985; NRC, 2001; AFRC, 1993) used MP as a measure of protein quality. MP is the true protein that is absorbed in the ruminant's intestine that includes estimates of available microbial and dietary escape protein and is potentially more accurate than other protein systems (Fig 1). The goals of ruminant protein nutrition is to provide adequate amounts of rumen degradable protein (RDP) for optimal ruminal efficiency and to obtain the desired animal productivity with a minimum amount of dietary CP. Selection of complementary feed protein and non protein nitrogen (NPN) supplements provide the types and amounts of RDP that would meet, but not exceed, the N needs of ruminal microorganisms for maximal synthesis of MCP and digestible RUP that would optimize the profile and amounts of absorbed amino acid. Knowledge of the kinetics of ruminal degradation of feed proteins was fundamental to formulate diets for adequate amounts of RDP (Brito *et al*., 2006) for rumen microorganisms and adequate amounts of RUP for the host animal. Microbial protein synthesis in the rumen was often the main component of metabolizable protein supply in ruminants (Moorby *et al.,* 2006) and supplied 70 to 80% of the required amino acids to ruminants (Chumpawadee *et al*., 2006). Bacterial crude protein (BCP) could supply from 50% (NRC, 2000) to essentially all the MP required by beef cattle, depending on the UIP (undegradable intake protein) content of the diet. Efficiency of synthesis of BCP is critical to meet the protein requirements of beef cattle economically; therefore, prediction of BCP synthesis is an important component of the MP system. In most cases, natural diets contained sufficient DIP (degradable intake protein) to meet microbial needs for amino acids, peptides, or branched chain amino acids. Deficiencies have not been reported in practical feeding situations.

In CNCP system MP could be predicted if the CP and total carbohydrate content, intake of CP and carbohydrate, fractional degradation rate and passage rate of different carbohydrate and protein fractions of a feed or TMR are known. NRC (2001) considered TDN (Total Digestible Nutrients) value of a feed in estimating the microbial crude protein (MCP) yield and further the MP availability. The MCP yield was assumed 130 g/kg of TDN intake and the requirement for RDP was 1.18×MCP yields. Therefore, yield of MCP was calculated as 0.130×TDN when RDP intake exceeded 1.18×MCP yields. When RDP intake was less than 1.18×TDN predicted MCP, then MCP yield was calculated as 0.85×RDP intake.

In AFRC (1993) key protein parameters *i.e.* quickly degradable protein (QDP), slowly degradable protein (SDP) and rumen undegradable protein (UDP) were derived from measurements of the rates of protein degradation (dg) in the rumen. The fractional rumen outflow rates per hour (r) varied from 0.02 to 0.08, depending on the level of feeding. Effective rumen degradable protein (ERDP) was a measure of the total N supply that appeared to be actually captured and utilized by the rumen microbes for their growth and synthesis purposes and digestible undegradable protein (UDP) was that part of UDP of feed which was digested in lower tract/ intestine of animal. The level of feeding (L) also influenced the ERDP and RUP values of feed. Microbial protein synthesis was assumed to depend on several factors *viz.* energy and nitrogen supply to the microbes, level of feeding to the animals whereas energy supply was assumed the first limiting factor. For estimation of rumen microbial crude protein (MCP) yields (y), fermentable metabolizable energy (FME, Mcal/d or Mcal/kg DM) was used (AFRC, 1993). When nitrogen supply to rumen microbes was limiting for microbial protein synthesis, MP system increased the amounts of ERDP required to match the amount of FME supplied by the diet.

The NRC (2001) proposed 80% digestibility of the microbial true protein vs 85% proposed by AFRC (1993). Microbial true protein was set from MCP less nucleic acid content which was considered to be 20% by NRC (2001) vs 25% by AFRC (1993). Thus the percentage of MCP that truly contributed to MP was 64, comparable to the value suggested by AFRC (63.75). Zhao and Lebzien (2002) stated that the prediction of the total crude protein supply at the duodenum was more accurate and simpler than the separate prediction of the rumen microbial crude protein (MCP) and the rumen undegraded dietary crude protein (UDP) and thus gave the concept of utilizable crude protein (uCP). They found uCP determination is more practical and accurate than separate determination of UDP and MCP in evaluating dietary protein value for ruminants. Zhao and Lebzien (2000) developed an *in vitro* incubation technique for estimating uCP of feedstuffs for ruminants. Different systems used different constants and methods to estimate the absorbed protein from the duodenum as depicted in Table 1.

## Effect of seasonal climatic variation on nutrient requirement

Thermal environment imparts a series of physiological and metabolic changes in the body which are necessary for adaptability and survivability and maintenance of body homeostasis. Birkelo *et al.* (1991) reported that maintenance requirement during high ambient temperature increases due to increase energy requirement to dissipate body heat generated during heat increment. Recently, Talukdar (2016)

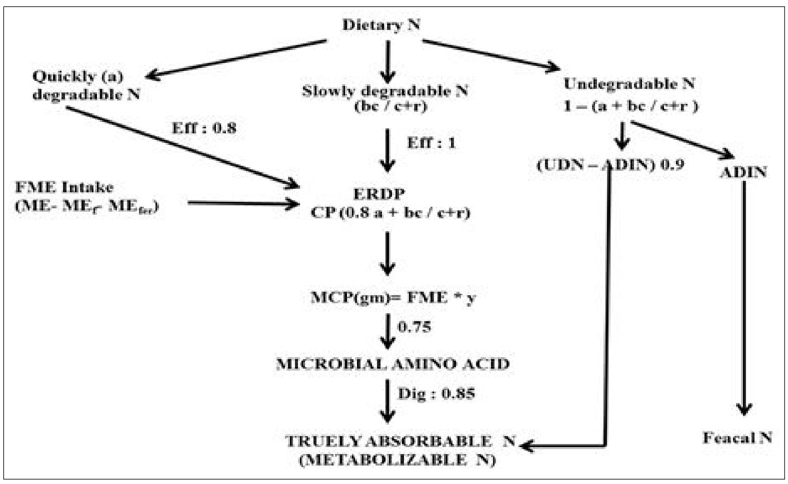


**Fig 1:** Flow diagram of MP system (AFRC, 1993).

reported that metabolizable energy requirements for maintenance ($ME_m$) is higher during high thermal humidity index (THI) summer period in tropical condition as the level of stress is higher during summer period indicated by high plasma cortisol level. Kundu *et al.* (2010) summarized the effect of different THI on tropical ruminants. It is recommended that increase in dietary energy supply by 10-15% through a highly digestible feed ameliorates heat stress. Thermal stress in livestock production results in increased demand for net energy for maintenance and subsequent reduction in energy for tissue growth and production (Ames *et al.*, 1994). Salah *et al.* (2015) reported that small ruminants and cattle of warm and tropical climate appeared to have higher $ME_m$ relative to live weight (LW) compared with temperate climate ones. Moreover from large data set of meta-analysis study found that there is higher energy and protein requirements of tropical and warm-area ruminants compared with those proposed in the existing international feed system standards (NRC; ARC; INRA and AFRC) tables assessed from a study based on feeding and digestive trials including a large diversity of diets and animal genotypes representative of tropical and warm areas intended to update the values for maintenance and growth requirements. Kurihara (1996) reported that the $ME_m$ increased by 10% at 32°C was due to the heat increment which acted as a promoter of heat stress from the inner part of the body. The high environmental temperature increased results energy required to dissipate the extra heat increased. At 1°C below lower critical temperature (LCT) ruminant animal energy requirement (TDN) increases 1% (NRC, 1981). Cattle's maintenance energy requirements increase by 1 to 1.5% for each degree below the LCT (Nienaber and Hahn, 2007). The maintenance requirements of livestock also increase at temperature below the thermo neutral zone (cold stress) (Todini, 2007). As ambient temperatures below the lower limit of thermoneutral zone, animals convert more energy to heat (Shazer *et al.*, 2009) and digest their feed less efficiently. Unless additional energy is provided to compensate for increase in energy demand for cold environment, the availability of ME for productive processes would be limited (Mc Bride and Christopherson, 1984). Environmental changes evoke predictable responses in the nervous, circulatory and endocrine system (Niyas *et al.*, 2015; Habibu *et al.*, 2017).

While assessing the energy requirements of ruminants in cold season heat of warming (HW) of feed and water appears to be relevant as reported by Upadhyaya *et al.* (2003). Adjustments to $NE_m$ (net energy for maintenance) for metabolic acclimatization of 0.0007 Mcal/°C that average monthly temperature is above or below 20°C are recommended by NRC (1981). Additional adjustments to $NE_m$ for cold stress are recommended by NRC (1981) if cattle are exposed to temperatures below their lower critical temperature (LCT). Total insulation is a function of tissue insulation (hide thickness and subcutaneous fat) and external insulation (hair coat plus layer of air surrounding the body). Mud, wind and precipitation influence the effectiveness of external insulation.

## Effect of seasonal variation on rumen function and nutrient utilization pattern

The thermo-neutral zone of dairy cattle is about 5 to 20°C reported by ICAR (2013), but it varies among individual animals. Dry bulb temperature and humidity are the two major components in a given area that determine the extent of heat stress in animals. LPHSI (1990) quantified heat stress as a temperature humidity index (THI) > 72 is considered to indicate the heat stress in tropical dairy animal. Thus, the animal shall have no stress if THI is below 72, shall have mild stress if it is between 72-79, medium stress between 80 -88 and severe stress, if it is above 90. Young (1983) stated that ruminants adapt to chronic cold stress conditions, by increasing thermal insulation, basal metabolic intensity and DMI, besides increasing the rumination activity, reticulo-rumen motility and rate of passage of digesta. However, during extreme cold, DMI does not increase at the same rate as metabolism. Hence the animals could remain in a negative energy balance and the energy use shifts from productive purposes to heat production. Various hormones are also involved in thermal adaptations include, prolactin, growth hormone, thyroxine, glucocorticoids, mineralocorticoids, catecholamines and antidiuretic hormone etc involved with nutrient partitioning and for homeostatic regulation, augmented by thermal stressor

**Table 1:** Constants and methods used to estimate the absorbed protein from the duodenum in different systems.

| | Nordic AAT | France PDI | UK (ARC, 1984) | UK (AFRC, 1992) |
|---|---|---|---|---|
| Rumen passage rate | 0.05 | 0.06 | 0.08 | 0.02-0.08 |
| Effective rumen degradable protein | CP[1-{a+bc/c+k}] | CP*1.11[1-{a+bc/c+k}] | CP[1-{a+bc/c+k}] | CP[1-{a+bc/c+k}] |
| Efficiency of microbial crude protein synthesis | 179g/ kg digestible carbohydrate | 145g/ kg fermentable OM | 8.34g/ MJ ME | 9-11g/ MJ FME |
| **Proportion of amino acid- N** | | | | |
| Microbial N | 0.70 | 0.8 | 0.85 | 0.75 |
| Undegradaed feed N | 0.65-0.85 | 1.0 | 1.0 | 1.0 |
| **Absorption** | | | | |
| Microbial protein | 0.85 | 0.80 | 0.85 | 0.85 |
| Undegraded feed protein | 0.82 | 0.55-0.95 | 0.85 | 0.90 |

(Farooq *et al*., 2010; Lakhani *et al*., 2018). These also effect energy, water, electrolyte metabolism, dry matter intake, digestibility etc in tropical livestock. Following are the parameters highly affected by climatic alteration in tropical livestock.

## Nutrient intake

### Effect of environmental variables on DMI

Temperature humidity index (THI) based on temperatures below or above the thermo neutral range, alters DMI and metabolic activity. Under high ambient temperatures, livestock are expected to decrease dry matter intake (DMI) to reduce their metabolic heat production (Hill and Wall, 2017). This was mostly evident at 40°C exposure of thermal temperature in tropical environment (Yadav *et al*., 2016). During high THI period cattle reduced feed intake and with severe heat stress, DMI can decrease by up to 30%. High producing cows are the animals most sensitive to high environmental temperature because of their high feed intake. Dry matter intake starts to drop (8-12%) and milk production losses of 20-30% during high ambient temperature in tropical condition. While during cold stress, there is increase in feed intake by 20-40% to compensate for heat loss (Nisa *et al*., 1999). Chauhan *et al*. (1999) studied the effect of extreme cold on voluntary dry matter intake and nutrient utilization in growing buffalo calves and inferred that protection of winter results in saving of about 1-1.5 kg digestible organic matter. A short-term, sharp decline in DMI may be observed more often in the extreme cold than in the summer due to the effects of winter storms (NRC, 1981).

### Rumen physiological function

Seasonal changes cause a rhythmic alteration in the gut motility, rumination, ruminal contractions, rumination time and rumen pH. Increased environmental temperature during summer season in tropical condition reduces all the rumen physiological function (Soriani *et al.,* 2013) results in depression of appetite (Dikmen *et al*., 2012) by having direct negative effect on appetite center of hypothalamus. There is higher concentration of lactic acid and lower ruminal pH in summer stressed ruminant (Mishra *et al*., 1970) due to reduced rumen motility during high ambient temperature. But limited study has been done on the effect of environmental temperature on rumen function.

### Rumen microbial activity

Seasonal changes lead to changes in the rumen bacterial community due to the change in nutritive composition of the pasture irrespective of the season as did the production phase of the animals (Noel *et al*., 2017). The change in microbiota due to thermal exposure may change fermentation pattern in rumen resulting in variation in digestibility of different feed components and also composition of fermentation products. Other than alteration of bacterial activity, different responses in digestibility in ewes exposed to thermal exposure for different times might be related to changes of ruminal and intestinal absorption of nutrients (Christopherson and Kennedy, 1983).

### Rumen fermentation pattern and volatile fatty acid (VFA) production

High environmental temperature reduced total volatile fatty acid production and the ratio of acetic acid to propionic acid was decreasing with the increase in temperature (Tajima *et al*., 2007). Season had variable significant effect on rumen fermentation pattern of small ruminant and in spring and winter seasons, it had better rumen fermentation efficiency than in autumn and summer (Saber *et al*., 2016). There was significant decrease in total VFAs, lactic and butyric acids in summer in Sheep. Effects of ruminal temperature on a dual-flow, continuous-culture system on *in-vitro* fermentation characteristics was investigated and found that high ruminal temperature decreased total VFA concentration as compared with normal ruminal temperature (Salles *et al.,* 2010). Decrease in molar concentration of volatile fatty acid during high environmental temperature was mainly attributed to decrease in roughage intake and variation in fermentation pattern due to changes in microbial population (Uyeno *et al*., 2010).

### Nutrient digestibility

There was a significant change in the nutrient digestibility when ruminant livestock are exposed to rhythmic variation of seasonal environmental temperature and was reported as higher during high THI summer season than the winter season (Talukdar *et al*. 2017; Egea *et al*., 2019). This increase in the digestibility may be due to slower passage rate and longer mean retention time of digesta in dairy cows and heifers maintained under hot environment (Nonaka *et al*., 2012). Also during high environmental temperature dilution of rumen content due to higher water intake, reduction of rumen bacteria activity, decline in rumen motility and reduction of saliva production may be responsible for digestibility changes (Bernabucci *et al*., 2009). Digestibility pattern at different thermal exposures was investigated and it has been reported that digestibility at 25 and 30°C did not change whereas digestibility increased at 35°C and then decreased at 40°C thermal exposure (Yadav *et al*., 2012). Higher concentrations of lactic acid and lower ruminal pH were observed in heat-stressed cattle, which may imply that a high lactic acid concentration and lower ruminal pH might be involved in inhibiting rumen motility during high environmental temperature (Mishra *et al*., 1970). Report on effect of cold environmental temperature on digestibility of nutrients is limited. At 10°C below LCT digestibility of the nutrients was decreased by 1% (NRC, 1981).

## CONCLUSION

Efficient use of feed resources and precise nutrient requirement standard is recognized as important component of livestock management and economic necessity in intensively managed ruminant livestock. The above factors are important in feeding system and should therefore be incorporated in future revision of feeding system. Among the stressors, high environmental temperature has a substantial impact on maintenance requirement in tropical climatic condition, so, while deriving nutrient requirement, it will be helpful to reduce stress by adjustment in feeding system nutrient (energy, protein) requirements besides climate resilient livestock production. Also the alteration of environmental temperature due to seasonal effect there are changes in the microbial and physiological function as a result altered rumen function needs further study.

**Conflict of interest**

No potential conflict of interest was reported by the authors.

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