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MANAGEMENT OF DAIRY ANIMALS FOR IMPROVED HEALTH AND PRODUCTION DURING CIRCADIAN PATTERN: A REVIEW

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A circadian rhythm is a roughly 24-hour cycle in the biochemical, physiological, or behavioral processes of living entities, The term "circadian" comes from the Latin circa, "around", and diem or dies, "day", meaning literally "approximately one day." The nature of the rhythms is endogenous and innate and driven by an endogenous clock. Such self sustained oscillations with a period of about one day are called "circadian rhythms" A variety of biological variables including behavior, physiological function and biochemical factor oscillate in organisms. Rhythmicity in physiological parameters is an important process both as convenient and reliable markers of operation of the biological clock and as an indicator of general health of an animal. One of the most dramatic features of the world in which we live is the cycle of day and night. Correspondingly, almost all the species exhibit daily changes in their behavior and or physiology. These daily rhythms are not simply a response to the 24-hour changes. Thermal environment exert a profound influence on various physiological responses and ultimately the productivity of animals. Excessive hot exposure affects the animals at cellular level and is reflected in production and accumulation of the damaging molecules i.e. free radicals. In this part of review, pertinent information on the effect of circadian variations on physiological responses, oxygen consumption, heat production, and heat loss by dairy animals has been emphasized.

CIRCADIAN RHYTHMS

All domestic livestock are homeotherms, that is, they maintain relatively constant internal body temperatures usually within a narrow range, on an environment of which the temperature may change over a wide range. Homeotherms have optimal temperature zones within which no additional energy above maintenance is expended to heat or cool the body as they maintains equilibrium between heat production and heat loss. Thermoregulation involves a number of physiological and biochemical adjustments which vary in intensity with duration of environmental stress and also in relation to genetic makeup. Failure of adaptation to extreme climatic conditions lead to decreased growth and production. In India, crossbred cattle plays an important role in economy with respect to milk production, but their heat dissipation ability is poor due to low density of sweat glands. Because of the larger body size, high basal metabolic rate (BMR) and poor heat dissipation, heat stress further increases the heat storage in crossbred cattle. Under conditions of high environmental temperature, the physiological reactions, viz. respiration rate, pulse rate, rectal temperature, skin temperature increase which intern enhance the extra heat load and disturbs heat dissipation mechanisms. Thermoregulatory adjustments excited by the animal are expressed as changes in rectal temperature, skin temperature, respiration rate and pulse rate.

Table 1: Frequency range in Biological Rhythms. (Piccione and Caola, 2002)

Domain	Range
Ultradian	t<20 h
Circadian	20h≤ t≤ 28h
Infradian	t>28h
Circaseptam	t=7± 3days
Circadiseptan	t=14± 3days
Circaviginatan	t=21± 3days
Circatriginatan	t=30± 3days
Circannual	t=1year±3months

ANATOMICAL ORGANIZATION OF THE CIRCADIAN CLOCK

Studies of unicellular organisms depict the cellular nature of the system generating circadian rhythms. In higher organisms the circadian pacemaker is located in cells of specific structures of the organism. These structures are present in certain regions of the brain (i.e., the optic and cerebral lobes) in insects; the eyes in certain invertebrates and vertebrates; and the pineal gland in non mammalian vertebrates. In mammals, the circadian clock resides in two clusters of nerve cells called the suprachiasmatic nucleus (SCN), which are located at the anterior hypothalamus. The landmark discovery in the early 1970s demonstrated that the SCN is the site of primary regulation of circadian rhythmicity in mammals gave researchers a focal point for their research. By damaging (i.e., lesioning) the SCN in rats, researchers could disrupt and abolish endocrine and behavioral circadian rhythms (Klein et al., 1991). Furthermore, by transplanting the SCN from other animals into the animals with the lesioned SCN, researchers could restore some of the circadian rhythms. Finally the SCN's role as a master pacemaker regulating other rhythmic systems was revealed by similar studies in hamsters, which demonstrated that the restored rhythms exhibited the clock properties (i.e., the period, or phase, of the rhythm) of the donor rather than of the host (Ralph etal., 1990).

Circadian rhythms could persist in isolated lungs, livers, and other tissues grown in culture dishes (i.e., in vitro) that were not under the control of the SCN (Yamazaki et al., 2000). These findings indicate that most of the cells and tissues of the body can modulate their activity on a circadian basis. These observations do not suppress the central role played by the SCN as the master circadian pacemaker. SCN somehow regulates the entire 24 hour temporal organization of cells, tissues, and the whole organism through neural or neurohormonal signals. However, the characteristics of the circadian signal in which the SCN communicated with the rest of the body remain unknown (Stokkan et al., 2001).

EFFECT OF SCN ON SLEEP-WAKE CYCLE

The effects of SCN lesions on numerous rhythms have been elucidated, their effects on sleep are less clear. SCN lesions clearly disrupt the consolidation and pattern of sleep in rats but have only minimal effects on the animals' amount of sleep or sleep need (Mistlberger et al., 1987). Sleep is subjected to two essentially independent control mechanisms: (1) the circadian clock that modulates the propensity for sleep and (2) a homeostatic control that reflects the duration of prior waking (i.e., "sleep debt"). Recent studies suggest that SCN lesions can affect the amount of sleep in squirrel and monkeys. Moreover, sleep studies in mice which carry mutations in two of the genes influencing circadian cycles (i.e., the DBP and Clock genes) indicated that these mutations resulted in changes in sleep regulation (Franken et al., 2000). These observations raise the intriguing possibility that the homeostatic and circadian controls may be more interrelated with each other.

CHARACTERISTIC FEATURES OF CIRCADIAN RHYTHMS

According to De Mairan's observations, the circadian rhythm is self-sustained in nature. Thus, almost all diurnal rhythms that occur under natural conditions continue to cycle under laboratory conditions devoid of any external time giving cues from the physical environment. Circadian rhythms that are expressed in the absence of any 24-hour signals from the external environment are called free running rhythms: meaning that the rhythm is not synchronized by any cyclic change in the physical environment. A diurnal rhythm should not be called circadian until it has been shown to persist under constant environmental conditions and thereby can be distinguished from those rhythms that are simply a response to 24-hour environmental changes. However, almost all diurnal rhythms are found to be circadian.

The organism's response to light (i.e., whether a cycle advances, is delayed, or remains unchanged) differs depending on the phase in the cycle at which it is presented (Pittendrigh, 1960). Thus, exposure to light during the early part of the individual's "normal" dark period generally results in a phase delay, whereas exposure to light during the late part of the individual's normal dark period generally results in a phase advance. The existence of a phase-response curve also predicts that entrainment is achieved by discrete resetting events rather than changes in the rate of cycling. Addition to the duration of the light exposure, the light intensity can also affect cycling periods when organisms are left in constant source of light. The effect of exposure to brighter light intensities varies from species to species. In some species it can lengthen and in other species it can shorten this period.

LIGHT ENTRAINED CIRCADIAN RHYTHMS

Although involvement of the circadian rhythm is related to the light/dark cycle of the solar day, it also persist in constant conditions (e.g. constant light).The rhythm period can be reset by exposure to a light or dark pulse, and if there is change in lighting conditions, the animal can gradually adjust to the new pattern provided it does not deviate too much from the species norm. Animals that are kept in total darkness for a long period of time start to display "free running" rhythms (Thomas and Armstrong, 1988). Animal species differ dramatically in their sensitivity to light. For every species there is an intensity of light or limit of sensitivity, below which the animal shows no physiological response to light. (Lawson and Kennedy, 2001) revealed that the threshold in cattle was quite low. The lowest light intensity tested (50 Lux) caused a drop in night time plasma melatonin level in the heifers. Information about day length travels from the SCN to the pineal gland. In response to this information, the pineal gland secrets the hormone melatonin. The secretion reaches peak at night and wanes during the day (Zucker et al., 1983). Chesworth et al., (1987) reported that continuous light treatment induces suppression of circadian rhythmicity of locomotor activity in rats.

Rusak and Zucker, (1979) stated that the environmental cues that entrain the circadian rhythms are called Zeitgebers or circadian synchronizers. These include water and feed intake, motor activity, sleep wake rhythm, corticosterone release, activity of pineal N acetyl transferase enzyme and body temperature. Dahl et al., (2000) has indicated that 6-8 hours of darkness is important for dairy cows in order to ensure the continuation of natural circadian rhythms. Cassone and Stephan. (2002) also stated that the circadian oscillator, entrained by the light-day cycle via the retinohypothalamic tract, can impose circadian patterns on a wide array of physiological and behavioral processes. Dunlap et al,. (2004), reported that the circadian clock can act as an instrument for estimating the day length or night length thus, seasonal phenomena which respond to changing of day length can be regulated appropriately.

CIRCADIAN RHYTHM AND ANIMAL BEHAVIOUR

The physiological processes of an organism are regulated by a circadian rhythm, the length of which is approximately 24 hours. This rhythm was first described in the movement of plant leaves by the French scientist Jean Jacques d'Ortous de marian (Meijer and Rietveld, 1989). Klein et al., (1991) stated that circadian rhythms affects animals sleeping and feeding pattern, brain wave activity, hormone production and other biological activities related to the daily cycle. In the retina of eye light is transformed into nerve impulses that are conveyed to the hypothalamic nuclei of the central nervous system. Hypothalamic suprachiasmatic nuclei (SCNs) are the principal generators of circadian rhythms and the part of entrainment system that synchronizes the animal with its environment, especially with lighting conditions. The circadian system is regulated by the wavelength, intensity, timing and duration of the lighting stimulus (Cardinali et al.,1972). These endogenous biological rhythms allow us to anticipate periodic changes in the environment and are thus important for adaptive behavior. (Van der Veen et al., 2006) stated that in most mammals, daily rhythms in physiology are driven by a circadian timing system composed of a master pacemaker in the suprachiasmatic nucleus (SCN).

CIRCADIAN RHYTHM AND PHYSIOLOGICAL RESPONSES

Domestic animals exhibited a diurnal rhythm in body temperature, which depends mainly on the climatic conditions. There are small circadian or nychthermal (24Hrs) fluctuations in core body temperature of cattle in both the natural environment and in steady temperature environments. (Vaidya, 2009). It has been widely reported that seasonal changes in ambient temperature can affect the body temperature in cows, for example, the mean body temperature and the amplitude of the body temperature rhythm are higher in the summer than in spring or winter (Berman and Morag, 1971). Body temperature is also affected by physiological state as the body temperature of lactating cows appear to be more influenced by elevated ambient temperature than in non-lactating pregnant cows (Zhang et al., 1994: Mader et al., 1999). Animals exposed to a natural and fluctuating environment will show diurnal variations of rectal temperature less than 1oc (Robertshaw, 1985). The diurnal variation of rectal temperature was significantly higher during open environment as compared to under shade, irrespective of the season. Knowledge of the relationship between the circadian change in body temperature and environmental thermal conditions is needed to increase our understanding of maintenance requirements and limitations to productivity performance (Araki et al., 1984). Likewise, such information is essential for the evaluation of the benefits of any environmental modifications (Igono and Johnson, 1990). Also Zhang et al., (1994) demonstrated circadian rhythm in beef calves exposed to hot and cold stress conditions when core body temperature was measured continuously for 10 days animals exposed to cold (10C), thermoneutral (210C) and hot (320C) conditions in controlled environmental chambers (relative humidity 50%) lights remained on from 0800 to 2100 h and animals were fed at 0800 to 2000 h. Daily fluctuations in temperature of 10C were noted for each environmental condition. Furthermore, the time at which the highest and lowest core temperature occurs differed between environmental conditions Animals under cold conditions reached a maximum core temperature between 1600 and 2100 h compared to thermoneutral 0300 to 0500 h and hot 1800 to 1900 h. Das et al., (1999) also reported a diurnal variation in skin temperature of different body parts in response to heat stress in male buffalo calves.

CIRCADIAN RHYTHM WITH OXYGEN CONSUMPTION, HEAT PRODUCTION AND HEAT LOSS

Heat production in animals has been shown to vary with environmental temperature (Brody, 1945). The magnitude of response, however, depends upon the physiological makeup of animals and extent of exposure to the stress. During winter and summer the oxygen consumption (VO2) in Murrah buffaloes adults ranged between 1.37± 0.05 l/m at 2 pm and 1.8 ± 0.2 l/m at 2 am and.35 ± 0.09 l/m at 2 pm and 1.24 ± 0.5 l/m respectively during 24 hours (Vaidya, 2009). Mean volume of oxygen consumed in dairy cattle has been reported to be between 100 – 150 litres / hr at a temperature of 60°F. Normal oxygen consumption in calves (0-6 months) has been reported to be 130 (110 – 135) litres/hr In Ayrshire oxen, normal values of O2 consumption were found to be 0.66 litres/min (Hales and Findlay, 1968). Normal oxygen consumption in calves has been reported to be 130 (110-153) lit/ hr (Mullick, 1960). In Ayershire oxen, normal values were found to be 0.66 lit/ min (Hales and Findlay, 1968) and in adult buffaloes, mean VO2 has been reported to be 94 lit/ hr (Mullick,1960). Chikamune (1986) observed that annual average oxygen consumption was 1.96 0.17 lit/ minutes in adult Holstein cows. Dang (1990) observed in buffaloes that VO2 increased from the resting value of 2.71 lit/ min to 7.00 lit/ min after exercise. Zerbini et al., (1992) observed that oxygen uptake (VO2) increase to 2-3 litres/min in crossbred dairy cows under field conditions.

CIRCADIAN RHYTHM IMPORTANT FOR ANIMALS

Circadian rhythmicity is present in the sleeping and feeding patterns of animals, including human beings. There are also clear patterns of core body temperature, brain wave activity, hormone production, cell regeneration and other biological activities. In addition, photoperiodism, the physiological reaction of organisms to the length of day or night, is vital to both plants and animals, and the circadian system plays a role in the measurement and interpretation of day length. Timely prediction of seasonal periods of weather conditions, food availability or predator activity is crucial for survival of many species. Although not the only parameter, the changing length of the photoperiod ('daylength') is the most predictive environmental cue for the seasonal timing of physiology and behaviour, most notably for timing of migration, hibernation and reproduction. Body temperature in cattle exhibits a profound circadian rhythm with a minimum in the morning and maximum in the afternoon.

CONCLUSION

The circadian body temperature rhythm in dairy cows is dynamic and is affected by both the physiological status of the animal and environmental stressors. (Vaidya, 2009) found that there was a disruption in the circadian body temperature rhythm in cattle and buffaloes indicating that growing cattle and buffaloes may be under more physiological stress than adult cattle and buffaloes at this time. Circadian rhythmic variations during different seasons help in regulating physiological functions and oxygen consumption in order to maintain the thermal balance. Extending the study of rhythmicity of physiological parameters to farm animals is important from an economic perspective because knowledge of this process can lead to improvements in stress and disease management through better knowledge of animals rhythmic behavior and extent of its reaction to a set of environmental variables in its micro environment.

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