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Heat Stress in Dairy Animals - Its Impact and Remedies: A Review

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ABSTRACT

One of the greatest challenges to production dairy farmers in most part of the tropical country is heat stress and the strain that it causes the lactating dairy cow. Climatic conditions in the most parts of India are such that the warm (or hot) season is relatively long, there is intense radiant energy for an extended period of time and there is generally presence of high relative humidity. Thus heat stress is chronic in nature; there is often little relief from heat during evening hours, and intense bursts of heat and humidity further depress the performance. Thermal stress has a direct effect on feed intake of the cow, which in turn reduces her milk yield. Body weight losses associated with thermal stress may impair her reproductive performance as well. Moreover, the microclimate modifications may also be of significant consequence in regulating the feed intake of the animals as well as in ensuring high efficiency of nutrients conversion which may otherwise be diverted towards maintenance of body temperature. In heat stressed animal, heat tolerance can be attained either by reduction of his normal heat load (i.e., reduced metabolic rate) or by increased heat dissipation to the environment. Improved heat tolerance coupled with high productivity is thus most likely to be attained by increased heat dissipation. The effects of heat stress are costly to the dairy farmers, but there are opportunities to recover some of the losses to hot weather.

Key words: *Heat Stress, THI, DMI, SCC, Milk Yield, Reproduction and Cooling.*

INTRODUCTION

Heat stress is produced by any combination of environmental conditions that cause the effective temperature of the environment to be higher than the animal's thermo neutral zone. Four environmental factors influence effective temperature: 1) air temperature, 2) relative humidity, 3) air movement, and 4) radiation from the sun or other source[15]. The potential for heat stress exists when air temperature rises above the thermo neutral zone of dairy cows, particularly if humidity is also high. The upper critical temperature for lactating cows is in the range of 24 to 27^0C[27]. The temperature humidity index (THI) commonly is used to indicate the degree of stress[10,28]. When the THI exceeds 72, high producing dairy cows are affected adversely.

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Dairy cows respond to heat stress in several ways; reduced feed intake, increased water intake, changed metabolic rate and maintenance requirements, increased evaporative water loss, respiration rate and rectal temperature. High producing and multiparous cows are especially susceptible to heat stress.

The importance of feeding management during lactation period also needs no introduction and has a direct bearing on the level and efficiency of production of the animal. Under feeding during current lactation will result in excessive mobilization of body reserves and impaired productive and reproductive performance. During early lactation, energy intake lags behind milk energy output a situation that is aggravated during summer when feed intake is also depressed by heat stress. Thus this combined effect of these two suppresses the milk production as well as alters the composition of milk. The energy density of the diet therefore would be of critical importance especially in deciding about the feeding management of high yielding animals through early and mid-stages of lactation.

There is no doubt that shading is one of the cheapest ways to modify cow's environment during hot weather. Shed markedly reduces the animals radiant heat load, which is additive to the internal heat load. Unfortunately shed alone will not do the job. Additional cooling in the forms of fans and sprinklers are usually needed. In combination with forced air sprinkling increases the loss of heat over the possible sweating alone. Several studies[9] have demonstrated upper body sprinkling followed by forced air ventilation to be effective means to reduce body temperature and animal performance.

Concept of Microclimate

The microclimate of shed in broad sense is the climate inside shed/ immediate surrounding the animal. The housing environment facilitates normal behaviour, avoids stress and ensures high and stable performance over a longer period[11]. Effective temperature affects the level of heat stress to which animals are exposed[55]. Microclimate of shed and its relation with macroclimate has been reviewed here.

Igono *et al*[38]., reported that five environmental factors influences effective temperature i.e., air temperature, humidity, air movement, solar radiation and perspiration. According to Ansell and Clark[2] when solid concrete walls were removed and replaced by steel piping, the roof raised 1 m and outside paddocks provided with palm thatch shelters, almost no trouble was experienced from climatic stress. They found it necessary to cool the cattle with a sprinkler during hot season, which was effective even with water temperatures of 35°C. Kawanishi and Nagashima[43] compared indoor temperature/ humidity index and out door black globe/ humidity. The index indicated that it was preferable to keep cattle indoor during the day. Central stall being the best because radiant heat load was lower in the center compared to the sides of the barn. Means *et al*[50]., observed that sprinkler and fan cooling systems can provide effective heat stress relief at the lowest water application rate tested, thus, reducing the amount of water consumed and the amount of waste water that must be handled. Turushev *et al*[72]., compared the effect of ventilation system (BSKHI system) over traditional ventilation system on cow shed microclimate. Average monthly temperatures in both sheds were within normal limits, but a much wider variation in temperatures was recorded in shed with traditional system. Higher level of moisture, ammonia and bacteria were also recorded in the air in traditional system of shed. Turner and Chastain[71] observed a drop in temperature of 1-4°C in shed fitted with the high-pressure mist system for cooling a dairy free-stall during the hottest part of the day. Bayhan *et al*[7]., suggested that dairy cows should not be kept in dairy barns with high levels of CO_2, humidity and indoor temperature, and appropriate ventilation system should be installed to minimize stress effects. Gao *et al*[30]., observed that the radiant temperature, black body temperature and tenday mean of air temperature and humidity (THI) for the cowshed in summer season were higher and it had a negative influence on milk production (negative environmental influence coefficients). As the THI increased gradually, the incidence rates of mastitis and uteritis increased, whereas the pregnancy rate decreased.

Importance of Thermal Humidity Index (Thi)

The temperature humidity index is commonly used to denote the degree of stress in dairy cattle. This index is based on the values of ambient temperature and relative humidity. Frazzi[25] concluded that stress was lowest in buildings in which temperature fluctuation was lowest, and that THI is the simplistic measurement of stress assessment. However, the exposure time of animals should also be considered in calculation of effective heat stress factor. Ravagnolo *et al*[55]., reported that the milk yield declined @ 0.2 kg per unit increase in THI when THI exceeded 72. The authors concluded that THI could be used to estimate the effect of heat stress on production. Ping *et al*[53]., investigated the effect of THI on milk yield (MY), pregnancy rate and animal health in 1700 Holstein cows which were fed indoor, DBT and WBT inside and outside were determined from 10th April to 24th May 2001 on Tuesday and Thursday (at 9:00, 14:00 and 20.00). The milk yield decreased with increase in THI. Average THI was significantly negatively correlated with average MY. The most parts of India experience stress between March-September and major production losses occur during July-August. Milk production of crossbreds (Tharparkar X Holstein & Sahiwal X Brown Swiss), Sahiwal and Murrah buffaloes have been related with THI values[74]. The results of these studies indicated that THI had negative effect on milk production and that high producing animals were affected more severely than low producing animals. Moreover, it became evident that in Karnal THI has increased from 71 to 72 over the last three decades. Wiersma and Armstrong[78] of Department of Agriculture Engineering (University of Arizona) quantified heat stress as per following table.

THI	Level of stress
Up to 72	No stress
72-78	Mild stress
78-88	Moderate stress
Above 88	Severe stress even death

Effect of Climatic Variables on Body Temperature, Dmi and Milk Yield Of Cows

The NRC[52] predicts that the DMI for a 600 kg cow producing 40 kg milk will decline from 18.7 kg at 20^0C to 16.7 kg at 35^0C (9%). However, the energy that is consumed during hot weather is used less efficiently for milk production because of greater maintenance costs, which are estimated to be 20% greater when environmental temperature are 35^0C than they were 20^0C[52]. Berman *et al*[9]., suggested that the upper limit of ambient temperatures at which Holstein cattle may maintain a stable body temperature is 25 to 26^0 C, and that above 25^0C practices should be instituted to minimize the rise in body temperature. High environmental temperatures also increase respiration rate and water intake, which consequently reduces DMI due to gut fill[47]. Johonson *et al*[41]., reported that 0.56^0C increase in body temperature above 38.6^0 C resulted into 1.8 and 1.4 kg decrease in milk yield and TDN intake, respectively. Klinedinst *et al*[44]., concluded that the probability of extreme high temperature events (heat waves) would increase as mean temperature increased, and an increasing number of heat waves could significantly effect production, especially on livestock. Umphrey *et al*[73]., reported that the partial correlation between milk yield and rectal temperatures for cows in Albama was 0.135.

The most significant factors affecting milk yield during hot weather in South Carolina were the total numbers of hours when THI exceeded 74 during the preceding four days, and the number of hours exceeding THI 80 on the preceding day[46]. In classical work, Igono *et al*[38]., reported that the critical values for minimum, mean and maximum THI were 64.5, 72 and 76, respectively. Ravagnolo *et* *al*[55]., reported that maximum temperature and minimum relative humidity were the most critical variables to quantify heat stress and both variables can easily be combined into THI. The authors concluded that THI could be used to estimate the effect of heat stress on production. West *et al*[76]., reported that the mean THI two days earlier had the greatest affect on milk yield while DMI was most sensitive to the mean air temperature two days earlier. Milk yield of Holsteins declined 0.88 kg per THI unit increase for the 2 days lag of mean THI, and DMI declined 0.85 kg for each degree (^{0}C) increase in the mean air temperature.

Impact of Various Cooling Systems on Productive Performance of Dairy Cows

Shade Cooling

Although shed reduces heat accumulation from solar radiation there is no effect on air temperature or relative humidity and additional cooling is necessary for lactating dairy cows in a hot and hot-humid climate. A number of cooling options exists for lactating dairy cows based on combinations of the principles of convection, conduction, radiation, and evaporation. Air movement (fans), wetting the cow, evaporation to cool the air, and shed to minimize transfer of solar radiation are used to enhance heat dissipation. Any cooling system that is to be effective must take into consideration the intense solar radiation, high ambient temperature, and the typically high daytime relative humidity, which increases to almost saturation at night. These challenging conditions tax the ability of any cooling system to maintain body temperature of the cow within normal limit.

Various cooling systems have been evaluated. Air conditioning dairy cows for 24 h/d improved 4% FCM yield by 9.6% in Florida[70]. Missouri work showed that air conditioning was not an economical venture[33]. Zone cooled cows (cooled air blown over the head and neck) averaged 19% greater milk yield than controls[58], though other scientists concluded that a well designed shade structure provided greater economic returns than the additional benefits derived from zone cooling[16]. The costs associated with air conditioning and facilities necessary to provide an enclosed environment or ducting for zone cooling have proven cost prohibitive and these types of systems are rare today.

Early work[61] established the benefits of air movement and wetting the cow to air-cooling. The cooling benefits of using fans, wetting the cow and the combination of fans and wetting were compared. Cows tied outside in the sun from noon to 2 p.m. to induce heat stress were moved inside to the respective treatments. Although cows were only sprayed down once during treatment the scientists found that after one hour of exposure to treatments, rectal temperature declined the least for cows with no cooling, was intermediate and similar for cows receiving either sprinkling only or fans only, and the greatest cooling occurred with the combination of fans and wetting the cows. Cows cooled with ducted air and spray for 20 min on, 10 min off, yielded 2 kg/d more milk than shaded controls, maintained rectal temperature near normal (below 39°C), and maintained higher plasma growth hormone compared with shaded controls[39]. They found that when all costs were considered, there was a $0.22 /cow per day profit via improved milk yield. Returns did not consider potential returns from improved maintenance of body weight or reproductive performance. Similarly, Florida workers reported an 11.6% improvement in milk yield when cows were sprayed for 1.5 min of every 15 min of operation[68]. Cooled cows had sharply reduced respiratory rate (57 versus 95 breaths/min), and efficiency of production (kg milk per kg DMI) was improved for cooled cows, probably due to lower energy expenditures for body cooling. Benefits from sprinkling and fans were reported in a temperate, humid climate (Kentucky), where cows yielded 3.6 kg more milk (15.9%) while consuming 9.2% more feed per day than controls[71]. Missouri and Israeli work showed milk yield increases of 0.7 kg/d in moderate temperatures[40] and 2.6 kg increase in warm, humid conditions following sprinkling[35]. Frequency of wetting and duration of cooling was critical to the effectiveness of cooling systems. Wetting cows for 10 s (second) was less effective in cooling cows than wetting for 20 or 30 s, which were similar[24], while cooling for 15, 30, and 45 minutes reduced rectal temperature by 0.6, 0.7, and 1.0°C, respectively. Thus length of time for both wetting and fans had dramatic effects on the amount of cooling achieved.

Large droplets from a low-pressure sprinkler system that completely wet the cow by soaking through the hair coat to the skin were more effective than a misting system[5]. A combination of misters and fans was as effective as sprinklers and fans in Alabama work, where intake and milk yield were similar for the misted cows[45].

Evaporative cooling systems use high pressure, fine mist and large volumes of air to evaporate moisture and cool the air surrounding the cow. Because of the evaporation there is little wastewater to process in this type of cooling system, which is beneficial when developing a water budget for the dairy farm. Evaporative cooling systems improve the environment for lactating dairy cows in arid climates[59], and the reduced air temperature results from the removal of heat energy required to evaporate water. Evaporative cooling can be accomplished by passing air over a water surface, passing air through a wetted pad, or by atomizing or misting water into the air stream. There are questions regarding the effectiveness of evaporative systems in climates with high relative humidity. In Florida work where evaporative cooling pads were used, there was an effective reduction in air temperature of the barn but milk yield was not altered although rectal temperature and respiratory rate were reduced[69]. Similarly, cows in Mississippi that were cooled using evaporative pads had reduced respiratory rate and body temperature and slight increases in DMI with little to no effect on milk yield[13]. Lin *et al*[45]., reported that misters and fans cooled cows as well as a low-pressure sprinkler and fan system. However positioning was important and misters were much more effective when mounted low near the cow and much less effective when mounted higher in the barn. Arcaro *et al*[3]., evaluated three different types of shade for lactating cows in open fields. The tested treatments were: (1) artificial shade using a propylene screen providing 80% direct solar radiation reduction; (2) the same shade structure using a fan of 0.5 HP; and (3) the same shade structure using a fan of 0.5 HP and a fogging system. The parameters analyzed were: milk yield and milk fat content; body temperature, respiration rate, and cardiac rate. The results showed that the best treatment was the shade using forced ventilation associated with a fogging system. Brouk *et al*[12]., concluded that under severe heat stress soaking every 5 minutes with fan cooling and under moderate stress soaking every 10 minutes with fan cooling might be adequate. Frazzi *et al*[26]., reported that the best climatic conditions during the hottest hours of the day were found in the pen with fans and misters (FM). The next best was the section with coolers (CEV), followed by the fans plus sprinklers (FS), and then a control with no cooling (C) pen.

Cooling cattle with evaporative cooled air has been effective in area of low humidity[67]. Even in more humid areas, the daytime humidity often is low enough for beneficial cooling[69]. In mist system, the fine mist particles stay suspended in the air and evaporate before being deposited on the ground, thus cooling the surrounding air; some small droplets may be deposited on the hair coat of cattle. Hahn[32] reported that the presence of these droplets might increase the insulating characteristics of hair coat resulting greater heat build up in the cow. However, as long as the fans provide substantial air movement, properly designed mist systems can effectively improve the environment for dairy cattle[66].

Cooling of holding pens

To improve the holding pen environment overhead sprinklers (not foggers) and large fan were provided and tested in Arizona[78]. Where, 1.2 m diameter fans were mounted overhead at 30^0 angles from vertical so that the air blew down ward and around the cows at approximately 28m^3 per cow. Cow body temperature were 1.7^{0}C lower for the cows cooled in the holding pen than that cows with no holding pen cooling and resulted in milk production that was 0.75 kg/d higher during summer, when daily high temperature were 27 to 46^0 C. Results of research trial in Israel using holding pen cooling five times daily increased milk production 2.4 kg/d over that of non-cooled cows.

Exit lane cooling

To prolong the cooling period at milking time, a system to wet the hair coat of cows automatically as they exit the parlor was developed in Arizona[4]. Fan nozzles and timing of the spray are designed to spray only on to the cow's back and sides. This system would seem to have greatest appeal in operations where cows travel some distance from milking parlor to feed and loafing areas.

Effect of cooling on productive performances of cattle and buffaloes under Indian condition

A study was conducted to evaluate the thermal performance and economic viability of 4 types of dairy shelters with following cooling systems: fan ventilation, spray cooling, and both fan ventilation and spray cooling, and control (no cooling system). The technically efficient and economically viable cooling system for hot and dry climate was the one in which both fan ventilation and spray cooling was provided. Maximum percentage decrease in dry bulb temperature (15.56% w.r.t. ambient and 4.97% w.r.t. control) and temperature-humidity index (6.8% w.r.t. ambient and 2.33% w.r.t. control) was recorded in this cooling system. Maximum increase in milk yield of 12.21% w.r.t. control was observed in dairy shelter with both fan ventilation and spray cooling. The percentage increase in monthly returns was calculated as 9.91% w.r.t. control for the same system[42]. Senthilkumar *et al*[62]., evaluated milk productive performances of crossbred cows under housing in covered shed (T1), housing in covered shed with water spray (T2) and housing in covered shed with electrolyte supplementation (T3). Water spraying and electrolyte supplementation significantly ($P<0.01$) increased feed intake and lowered water intake. Water spraying and electrolyte supplementation had a highly significant ($P<0.01$) incremental effect on the production performance including milk yield (3.15±0.0845 liters and 2.95±0.0841 liters), fat content (4.87±0.0810 and 4.46±0.0704 per cent), SNF content (8.20±0.0572 and 7.79±0.0764 per cent) and total solids content (13.07±0.1253 and 12.25±0.1293 per cent), respectively. Singh and Aggarwal[65] reported higher milk yield in crossbred cows provided with fan and mist (2.12 kg/d) as compared to control in both hot-humid and hot-dry season. But same researchers reported higher milk yield in buffaloes allowed to wallow (7.58 ± 0.12) compared to buffaloes kept under showers (8.60 ± 0.12). In a classical study, Ghosh and Prasad[31] reported that Shed with Evaporative cooling (T2) had lower maximum, minimum temperatures than shed with fans only (T1). Furthermore T2 shed had significantly lower Db and Wb temperature, THI during morning and afternoon hours than that of T1 shed. The T1 cows had higher values of RR, HR, RT and ST. The cows under T2 consumed significantly higher DM, TDN, CP and better milk yield. Nutrient conversion efficiency as well as returns was better in T2 group of cows vis-à-vis T1 cows. Thus the shed with fans alone was not sufficient to eliminate heat stress in high yielding cows particularly in northern part of India and water sprinkling with provision of fans is more effective strategy for managing high yielding crossbred cows in summer.

Cooling Interaction with Feeding

Dietary protein degradability may be particularly critical under heat stress conditions. Diets with low (31.2% of CP) and high (39.2% of CP) RUP feed during hot weather had no effect on DMI; however milk yield increased by 2.4 kg/d and blood area N declined from 17.5 to 13.3 mg/100 ml for the diet containing higher RUP[8]. In addition, cooling the cow may affect the response to different source of protein supplementation. When diets with similar RUP content from high quality (blood, fish and soybean meals) or lower quality (corn gluten meal) proteins were fed to cows housed in shade or shade plus evaporative cooled environments. Cows fed high quality RUP yielded 3.8 and 2.8 kg more milk under evaporative cooling and sheded environments, respectively, than those fed low quality proteins. Flamenbaum *et al*[23]., examined the interactions between dietary manipulation for increased body conditions (3.8 vs. 2.7 on a six point scale) and post partum cooling (summer lactation). Milk production increased 1.9 kg/d with cooling, fat production increased with body condition and cooling, and protein production increased with cooling but not with body condition. Performance was lowest for the non-cooled sub group with low body condition. Among cooled cows, no advantage was attributable with high body condition. An additive effect of high body condition and cooling on milk production in summer was not evident. Chan *et al*[17]., found no interaction between evaporative cooling and fat supplementation in hot summer. Though, evaporative cooling positively affected milk yield, 3.5% FCM and fat yield, suggesting some relief from heat stress.

Quality of Forage and Heat Stress

Environment can alter the partitioning of forage nutrients into productive functions and effect efficiencies of feed utilization. During cold stress animal oxidizes acetogenic substrate for heat production until 'surplus' acetogenic substrate is totally utilized, after which fat mobilization provide an extra source of metabolic fuel. Under thermo-neutral conditions the acetogenic substrate cannot be utilized for synthesis of tissue component when poor quality roughage is fed without proper balancing of nutrients. In such situation, low availability of essential amino acids/glucose, causes acetate to dissipate as heat, and eventually reduces feed intake also[54]. Metabolic heat production, though advantageous during cold weather is liability during hot weather due to difficulty in maintaining heat balance. The most limiting nutrient for lactating dairy cows during summer is usually the energy intake and common approach to increase energy density is to reduce forage and increase concentrate content of ration. High fiber diets many increase heat production, demonstrated by work showing that for diets containing 100, 75 or 50% alfalfa with the remainder being corn and soybean meal, efficiency of conversion of ME to milk was 54, 61, 65%, respectively[18]. Heat production was 699, 647, and 620 Kcal per mega caloric ME for 100, 75 and 50% alfalfa diets, respectively. Cattle were fed pelleted diets of 75% alfalfa and 25% concentrate, or 25% alfalfa and 75% concentrate. The diet containing 75% alfalfa resulted in greater heat production and less retained energy, and the greater O_2 intake by portal drained viscera and liver accounted for 44 and 72% heat increment for low and high alfalfa diets, respectively[56] (Reynolds et al., 1991). Holstein cows were exposed to treatments of thermal comfort and thermal stress environments with *adlib* or restricted (75% of *adlib*) DMI. The objective was to evaluate effects of acute thermal stress, independent of reduced feed intake caused by elevated temperatures, and of reduced feed intake in thermal comfort on plasma concentration of somatotropin, insulin like growth factors I and II, thyroxin and triiodothironine. Overall, effects of nutrition and thermal stress did not markedly alter concentrations of metabolic hormones in lactating dairy cows[49]. West *et al*[75]., demonstrated that DMI decline for diets with a range of NDF concentration from 27 to 35% and was less severe with increasing NDF during hot weather. The total DMI was less during hot weather and suggests that the less severe decline in hot weather was due to lower intake and not higher NDF content.

Heat Stress and Udder Health

Stresses of various types results in increases in SCC. Various form of stress like confinement of animals in hot condition; mammary pathogens and injections of ACTH could also lead to abnormality to high somatic cell counts in milk[77]. Nelson *et al*[51]., reported a positive relationship between high summer environmental temperature and SCC in milk.

The high somatic cell counts observed in hot humid condition due to harsh climatic condition of high humidity and ambient temperature leading to stress condition and increase in susceptibility of infection[36]. Although a Florida study showed a significant increase in SCC in milk from heat-stressed cows, the respective mean SCC from cows (uninfected and infected with *Staphylococcus* spp.) subjected to either heat stress or housed in a thermo-regulated environment were 145,000 and 105,000[21]. A portion of this difference in SCC may be due to the decreased milk yield that is observed under heat stress. It is not unusual to experience 10 to 20% decline in milk yield in dairy cattle experiencing heat stress[63]. Studies at NDRI[64] revealed that the hot humid season (July-August) increase in SCC of milk of dairy animals, mainly due to favorable environment for growth of bacteria. During hot dry season (May-June), SCC is moderate and is low in cold season (December-January) and when the stress on the udder of the cow is minimum. Better cooling strategies (Fan, SCC-2.89 lakhs Vs. Fan and Sprinkler, SCC-2.21 lakhs/ml of milk) improves the udder health status of cow[31].

Effect of Heat Stress on Reproduction

The increase in body temperature caused by heat stress has direct, adverse consequences on cellular function. For instance, elevated temperature reduces the proportion of embryos that can continue in development[19,20]. Heat stress reduces the length[1] and intensity[29] of estrus. Some effects of heat stress may involve ACTH. Heat stress can cause increased cortisol secretion[22], and ACTH has been reported to block estradiol- induced sexual behavior[34]. Some reports indicate that heat stress causes a reduction in peripheral concentrations of estradiol-17b at estrus[79] although this effect has not always been observed[57].

Exposure of cows to heat stress led to reduction in size of the dominant follicles of the first and second follicular wave of estrus cycle[6]. Depression of follicular dominance by heat stress was indicated by: the absence of a decrease in medium sized follicles during the first follicular wave or during the follicular phase of estrus cycle; a large size and slow decrease in size of the second largest follicle; an increase in the number of large follicles during the first follicular wave; and an early emergence of preovulatory follicle[80].

The major strategy to reduce the effects of heat stress on reproduction has been to alter the environment of the cow through the use of shade, fans, or evaporative cooling[14]. However, this approach has not eliminated all problems associated with heat stress. So, additional reproductive strategies are needed to counteract the adverse effects of heat stress. One such strategy might be the use of timed AI (TAI). These protocols involve appropriately timed injections of GnRH (or its agonists) and PGF2a to cause synchronization of ovulation that is precise enough to achieve good pregnancy rates when AI is performed at fixed times[60]. The use of TAI offers advantages for inducing reproductive activity early postpartum, reducing the need for the detection of estrus, and concentrating labor efforts through the use of programmed AI. Timed AI might be particularly effective during heat stress because of the increased problems associated with the detection of estrus. Another possible strategy to enhance reproductive function during heat stress is to provide cows with supplemental antioxidants. There are prospects for development of pharmaceuticals or feedstuffs (nutraceuticals) that regulate heat production and heat loss mechanisms; perhaps fungal culture extracts represent the first example of such preparations[37]. The principal species from which these cultures are derived are strains of *Aspergillus Oryzae* and *Sachharomyces cervisae.* To increase the energy density of the diet, fat may be included in the ration. The added fat alleviates heat stress by providing non fermentive energy[48].

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