Journal of Animal Research: v.7 n.5, p. 801-812. October 2017
DOI: 10.5958/2277-940X.2017.00124.3

Amelioration of Thermal Stress using Modified Roof in Dairy Animals under Tropics: A Review

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Received: 11 July, 2017 **Revised:** 04 Sept., 2017 **Accepted:** 10 Sept., 2017

ABSTRACT

Roof is an integral part of housing systems, which protects animals from solar radiation and rain water. During summer months, heat stress affects animal production adversely. Housing design and shade material play an important role in the microclimate modification and reduction of radiant heat load inside the shed. The most commonly used roofing materials include asbestos sheets, thatch, clay tiles, reinforced cement concrete, galvanized iron sheets, plastic sheets etc., which possess some merits as well as drawbacks. Ideal roof material should have high reflectivity, low conductivity, low under-surface emissivity besides being light, strong, durable, waterproof, good looking, free from tendency to condense moisture inside and economical. Since, animal houses are permanent structure in large organized dairy farms which cannot be changed frequently. Thus, it is worth giving to modify existing roof rather changing the whole structure, which can be achieved by roof modifications such as thermal insulation, polythene shade cloth or Agro-net, mud plastering, thatched asbestos roof, green roofs, roof paints, evaporative roof cooling, solar panels, etc. Effectiveness of roof may further be improved by using techniques of adjustment of roof height, eave length and angle of eave in years to come. A holistic approach which includes animal nutrition as well as animal genetics in addition to shelter management would be more promising in amelioration of heat stress of dairy animals in tropics.

Keywords: Heat stress, Roof materials, Roof modification, Dairy animals

India is an agricultural country as it's more than two third of population live in rural areas and earn their livelihood from agriculture and allied sector. Livestock keeping is an integral part of Indian society, which not only helps in providing nutritional security to rural people, but also opens up employment opportunities to the masses. Climate change, particularly global warming, may strongly affect production performance of farm animals worldwide (Mote *et al.*, 2014). High yielding animals are more sensitive to heat stress (Singh and Upadhyay, 2009). Longer periods of high environmental temperature coupled with high relative humidity compromise the ability of the dairy animals to dissipate excess body heat (Marai *et al.*, 2009). The optimum range of temperature, humidity and Temperature Humidity Index (THI) for better performance of crossbred in subtropical region of India was found to be 19-26 ºC, 52-66 % and 65-68, respectively (Mote *et al.*, 2014).

Some common and effective methods employed to reduce heat stress in dairy animals are obtained through microclimate modifications, such as use of different roof materials, fans, sprinklers, misters, foggers etc. During thermal stress, sprinklers and fans may be used to reduce the heat load in dairy animals (Gaughan *et al.*, 2010). Vijayakumar *et al.* (2009) reported reduced minimum and maximum temperature in buffalo heifers subjected to sprinklers + ceiling fan than non cooled heifers during summer season. Lower overall values of maximum temperature, minimum temperature and THI was reported in buffalo heifers subjected to various cooling systems (cooling jacket, cooling jacket + forced ventilation and sprinklers + forced ventilation) in comparison to non cooled heifers under loose houses during hot humid season (Verma *et al.*, 2015). During hot-dry summer, various heat ameliorating measures like cooling jacket, high speed fan either with sprinklers or cooling jacket may help in reducing thermal stress in Murrah buffalo heifers kept under loose houses (Verma *et al.*, 2016).

Animals gain heat from environment through conduction, convection and radiation that may be either direct solar radiation or reflected radiation from surrounding structures. These solar radiations, both direct as well as indirect, are the major cause of heat stress in animals and by simply providing a shade to the animal exposed to direct solar radiations, cuts the radiant heat load on the animal by about 45% (Blackshaw and Blackshaw, 1994). Most commonly used roofing material includes: thatch, clay tiles, galvanized iron (GI) sheets, asbestos sheets, reinforced cement concrete (RCC) and plastic sheets, which reduces solar radiation on the sheltered animals by different proportions. Due to high capital investment in permanent animal housing structures, frequent replacement of roofing material may neither be technically feasible nor economically viable. Therefore, it would be beneficial to make appropriate roof modifications, such as mud plastering, thermal insulation, solar panels, polythene shed cloth, roof paints etc. to the existing permanent structure rather than changing the whole roof, which is not only economical but also improves the efficiency of existing roof.

ANIMAL HOUSING AND IMPORTANCE OF ROOF

Housing is one of the basic requirements of animals which not only protects them from extreme climatic conditions, but also ensures comfort to its inhabitants. Roof is an integral part of housing, which prevents the access of solar radiations and rain water to the animal body. It has been measured that direct solar radiation energy flow per hour on animal body is 340 kcal/m^2 (Thomas *et al.,* 2012a). Providing shed is an easy and efficient way to mitigate the effects of heat stress on pasture in hot climates (Vanlaer *et al.*, 2014). Thai Brahman heifers under artificial shed or tree shade were better protected than those without shade (Aengwanich *et al.*, 2011). Housing design and the material used for the roof play an important role in the microclimate modification and reduction of radiant heat load inside the shed (Badino, 2007).

A wide variety of roof materials are available: thatch, clay tiles, wood, RCC, galvanized sheets, asbestos sheets, plastic sheets etc. which should have at least one of the following properties: high reflectivity, low conductivity, low under-surface emissivity, correct roof profile (slope) and maximum practical height. Moreover, roof material should be light, strong, durable, waterproof, good looking, free from tendency to condense moisture inside the shed and economical. Type of roofing material determines pitch of roof, which should be 35° for thatched roof; 25° to 30° for tile roof; 12° to 18° for sheet roof, and it should not exceed 45° for any roof material (Thomas *et al.,* 2012b). Thermal conductivity is an important criterion, among others, in selection of roof material; because materials which have lower thermal conductivity allows less heat to pass from within thus, ensuring better microclimate to the inmates during summer season. Although, no single roof material possesses all the properties required to qualify it as an ideal roof material, despite that efforts are always made in selection of roof material to provide maximum comfort to the animals. The modified roof (normal roof fitted with woven polypropylene shade cloth) in comparison to normal roof, provides better microclimate to minimize thermal stress and improves the productive and reproductive performance in Friesian crossbred cows during hot-humid season (Khongdee *et al.*, 2010).

ROOF MATERIALS

Thatch

Thatch is an excellent and cheap material to reduce the heat stress (Yazdani and Gupta, 2000) as it has lower thermal conductivity; but less durability and fire hazard makes it less acceptable at an organized farm. Gawali *et al.* (2004) found that, fully open shelters having thatched roof with bamboo mating and no sidewalls are most economical. It possesses least thermal conductivity (0.05 Kcal/m h ^{o}C) as compared to other conventional roofing materials (Sastry and Thomos, 2012). Under surface temperature of asbestos sheet (41.98 ± 0.73^{o}C) was found significantly higher than that of thatched roof (31.92 ± 0.21^{o}C) during rainy season (Kamal *et al.*, 2013).

Clay tiles

They are mostly used in rural areas in animal shed roofs. Clay tiles roofs are quiet heavy (density is 2000 kg/m^3) thus demanding sufficiently strong frame. Thermal conductivity of clay tiles is higher (2.2 Kcal/m h ^{o}C) than that of thatch material (Sastry and Thomos, 2012). They require frequent maintenance and air passages present between tiles make them prone to moisture penetration during rainy season. It requires a good deal of craftsmanship to construct such roof correctly. Although repair or replacement of broken tiles is fairly easy but they become very slippery during rainy season and it is dangerous to walk on them. Roy and Chatterjee (2010) found that cows kept under tile roofed shed had lesser stress levels than those kept under GI sheet and Polythene sheet roofs.

Galvanized Iron (GI) sheet

It is a good roofing material for preventing rain water entry inside the shed. Moreover it is easy to install, light weight and durable; but higher thermal conductivity (175 Kcal/m h ^{o}C) outweighs its merits (Sastry and Thomos, 2012). Efficiency of metal roof can be improved by making certain modifications like painting rooftops with white and roof underside with black color, sprinkling water over it and placing about 2.5 cm of insulation under the GI sheet (Bucklin *et al.*, 1992).

Asbestos sheets

Asbestos sheets roofs are generally used at organized farms as they are comparatively cheaper than RCC, durable than thatch, and have intermediate value of thermal conductivity (0.4 Kcal/m h ^{o}C) (Sastry and Thomos, 2012). The major demerit of asbestos sheet is its radiation emission property, due to which on getting heated up during peak hours of summer, these sheets start emitting radiations which not only increase the surface temperature of animal but also alter microclimate of the shed. Kamal (2013) recorded higher under surface temperature of asbestos sheet (45.12 ± 2.50 ^{o}C) in comparison to thatched roof (34.30 ± 1.57 ^{o}C) during summer season. Nagpal *et al.* (2005) suggested that heat insulation of asbestos roof can be improved by fastening bamboo mat below the roof and by growing creepers, placement of straw or dung cakes on it. A model of animal house having asbestos sheet roof is depicted in Fig. 1.

Fig. 1: Asbestos sheet roof

Reinforced Cement Concrete (RCC)

RCC roofs are popular in human housing due to their pest (termite) resistance, natural calamity (cyclones) resistance, availability and cost effectiveness of concrete ingredients (Halwatura and Jayasinghe, 2008). RCC roofs are durable and provide favourable microclimate inside the animal shed. Thermal conductivity (0.53-1.50 Kcal/m h ^{o}C) of RCC roof is slightly higher than asbestos sheet, but its greater thickness keeps the shed environment cooler than asbestos sheets. During tropical summers, they tend to exhibit higher soffit temperature which makes them emit long wavelength infrared radiation towards the occupants which continues during night due to the higher heat retaining capacity of the slab (Sadineni *et al.*, 2011).

Polythene sheets

They are generally used in temporary sheds because they can be fixed easily, modifiable as per need and economical and commonly used to make thatch waterproof. Although it has thermal conductivity (0.04-0.05 Kcal/m h ^{o}C) at par with the thatch but its extreme thinness makes it ineffective in protection from solar radiation (Sastry and Thomos, 2012). Its main drawbacks are shorter life and fire prone nature. Roy and Chatterjee (2010) observed that cows kept under polythene sheet roof with mud floor and jute stick wall had higher THI (88.23 ± 0.85) in comparison to tile roof with brick floor and no wall (86.52 ± 0.63) during summer season.

ROOF MODIFICATIONS

Thatched asbestos roof

In this system modified roof is obtained by placing about six inch layer of paddy straw bedding with bamboo structure over asbestos roof (Fig. 2). This prevents excessive heating of asbestos roof during summer months and provides better microclimate to inmates. Patil *et al.* (2014) reported that paddy straw thatched asbestos roof shed was more efficient in maintaining comfortable microenvironment to the crossbred cows for high milk production during summer season in the Konkan region than simple asbestos and white painted asbestos roof.

Fig. 2: Asbestos sheet roof + Thatch

Solar panel/Photovoltaic roof

Solar panels can be fitted over the roof top which not only reduces the heat load of roof but also generates electricity that can be used in farm activities (Fig. 3).

Fig. 3: Asbestos sheet roof + Solar panel

Although fitting solar panel on roof top is capital intensive, but it may make farm self-reliant for electricity particularly in tropical countries. Photovoltaic (PV) roof tiles replace roofing material and are installed directly on to the roof structure (Sharma, 2013). Ceramic tiles or fiber-cement roof slates have crystalline silicon solar cells glued directly on them. Another type of roof-integrated system has a PV element (glass-glass laminate) positioned in a plastic supporting tray anchored to the roof (Bahaj, 2003).

Polythene shade cloth / Agro-net

In this roof modification agro-net or polythene shade cloth, which is commonly used in green houses designed for agricultural purposes is used either alone or over asbestos sheet roof (Fig. 4). Polypropylene fabric or shade cloth which provides 80% shade has become popular as an alternative shade material for animals (Bucklin *et al.*, 1993). Khongdee *et al.* (2010) reported that shade cloth roofing offered a more efficient way to minimize heat stress than that of normal roof. Kamal *et al.* (2014) reported that agro-net shade in open paddock provided favorable micro-climate to crossbred calves in comparison to asbestos sheet shade. Use of agro-net in animal shelter can be proved to be an effective roof modification during summer months as it is comparatively cheaper and modifiable as per need.

Fig. 4: Asbestos sheet roof + Agro-net

Thermal insulation/False ceiling

Insulation acts as a barrier to heat flow, reducing heat gain in summer to keep the house cool and reducing heat loss in winter to keep the house warm. Thermal insulating material like thermocol can be used as false ceiling material by placing it under the asbestos roof (Fig. 5). False ceiling is a common practice to reduce effective area in large buildings or offices in order to minimize expenses on illuminating, cooling and heating devices. Nagpal *et* *al.* (2005) observed that heat insulation can be improved by fastening bamboo mat below the roof. False ceiling in addition to manual and mechanical cooling would facilitate more comfort to cows resulting in higher milk production (Das *et al.*, 2015). As compared to conventional concrete roof, an insulated concrete roof system with an antisolar coating proved better in the tropical climatic conditions of Pakistan (Ahmad, 2010). Lightweight aluminum standing seam roofing systems, modeled and tested on an indoor stadium with a large roof surface area of 51m × 41m, indicated that roof structure with polyurethane insulation and white painted top surface performed better and saved 53.8% of the peak cooling load compared to a dark painted roof with glass wool insulation (Han and Yang, 2009). Polystyrene or polyurethane insulation layers have the capability of reducing the load by more than 50% when compared to an identical building roof without insulation (Sanjay and Prabha Chand, 2008).

Traditionally in human dwellings, insulation material includes mineral wool, expanded polystyrene (EPS), extruded polystyrene (XPS), cellulose, cork, polyurethane (PUR) etc.; while some recently developed building insulations are vacuum insulation panels (VIP), aerogels etc. Future building insulation materials include vacuum insulation materials (VIM), nano insulation materials, dynamic insulation materials (DIM) and NanoCon (Sharma, 2013). All the above insulation materials might be used in modern animal sheds in distant future if they become cost effective and suitable to animal housing.

Fig. 5: Asbestos sheet roof + False ceiling of thermocol

Evaporative roof cooling system

In this system some evaporative cooling techniques like installing sprinklers on roof top, spreading water soaked jute bags on top surface of roof are employed to lower roof temperature during summer season (Fig. 6).

Fig. 6: Asbestos sheet roof + Gunny bags and sprinklers

Bucklin *et al.* (1992) observed that efficiency of metal roof can be improved by sprinkling water over it. Wetted burlap bags are water soaked jute bags that are laid on roof tops to provide evaporative cooling, especially in regions with hot and arid weather which can lower roof temperature by as much as 15°C (Sanjay and Prabha Chand, 2008). These methods are good and effective in reducing heat stress but suffer from non-availability of water.

Mud plastered roof

It is a type of roof modification done in existing structure of thatch or asbestos sheet by application of mud plaster over it, which is made by mixing soil, cow dung and wheat straw in different proportions (Fig. 7).

Fig. 7: Thatch roof + Mud plaster

Mud plastering not only improves the thermal resistance of thatch but also makes them leak proof besides enhancing its life span. In case of asbestos sheet, it reduces emitted radiations by preventing excessive heating of asbestos sheet in summer season. As it increases the weight of roof, a sufficiently strong frame is required to bear the increased weight. Mud plaster requires protection from rain water which may otherwise get washed away. Singh *et al.* (1989) reported that improved (water and fire retardant) thatch (2 inch thick thatch panels made by bamboo structures and mud bitumen plastered on it) created the coolest microenvironment during the summer season as compared to ordinary thatch, corrugated literoof with top surface painted white, literoof as such, corrugated asbestos sheets and tin.

Roof paint / Reflactors

These paints are applied on roof top to reflect solar radiation and thus help in reducing heat load under the roof (Fig. 8). Reflected radiations of white, green and aluminium paints are 75%, 50% and 45%, respectively (Sastry and Thomos, 2012). A compound roof system developed with a combination of radiation reflectors and thermal insulation demonstrated substantial lowering of the heat conducted through a concrete roof (Alvarado *et al.*, 2009).

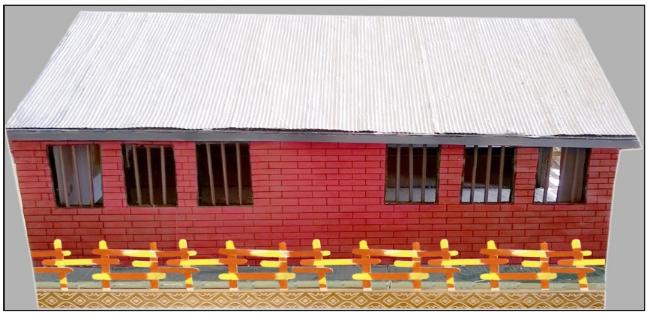

Fig. 8: Asbestos sheet roof + White paint

Green roof

A green roof can be defined as a roof covered by grasses or plants which lie over a waterproof membrane (Jaffal *et al.*, 2012). A green roof is composed of different layers consisting of drainage and barriers for roots plus channels for water (Taleb, 2014). The typical additional load associated with an extensive green roof is about 120–150 kg/m^2 (Castleton *et al.*, 2010). Generally, they are limited to human dwellings as they have been shown to reduce heating and cooling costs. But it may be used in animals housing in distant future. The main disadvantage of green roofs is the higher initial costs of installing and sometimes they can cause structural problems and leakage.

EFFECT OF ROOF MATERIALS ON MICROCLIMATIC VARIABLES

Minimum and maximum temperature

Kamal *et al.* (2014) observed that overall minimum temperature at 9:00 AM was significantly lower ($p<0.05$) in agro-net shading (19.27 ± 0.09°C) as compared to thatch shading roof (23.16 ± 0.1°C), asbestos with canvass shading roof (23.16 ± 0.20°C) and tree shade (23.09 ± 0.25°C) during summer season, whereas at 2:00 PM maximum temperature was more ($p<0.05$) recorded in asbestos with canvass shading roof (34.64 ± 0.20°C) followed by tree shade (34.61 ± 0.30°C) and least in agro-net shading (32.74 ± 0.22°C) followed by thatch shading roof (33.16 ± 0.18°C). Roy and Chatterjee (2010) recorded higher maximum temperature in GI sheet roof (37.72 ± 0.67°C) with brick/mud floor in comparison to tile roof (35.95 ± 1.2°C) with brick floor and brick/jute stick wall during summer season. Lowest dry bulb temperature is observed in shelter having RCC roof when compared to asbestos roof shelters and conventional tree shelters (Kaur and Singh, 2004). The temperature reduction between outside and inside surface of agro-net roof (48.77%) was higher followed by thatched roof (43.58%) and asbestos roof (27.15%) (Kamal *et al.*, 2014).

Temperature and Humidity Index (THI)

Higher ambient temperature coupled with higher relative humidity (RH), contributes greater stress in dairy cattle. THI was lower in cattle shed with tiled roof (86.52 ± 0.63) with brick floor without wall in summer season as compared to polythene sheet roof (88.23 ± 0.85) with mud floor and jute stick wall (Roy and Chatterjee, 2010). Higher THI in loose house covered with asbestos sheet causes thermal stress whereas, lower THI is observed in thatch and mud roof house which creates better microenvironment during rainy season (Jat *et al.*, 2005). Patil *et al.* (2014) observed lower values of THI under modified roof shed (thatch + asbestos) as compared to asbestos shed and painted shed in all periods of trial.

EFFECT OF ROOF MATERIALS ON PHYSIOLOGICAL PARAMETERS

Lower values of Rectal Temperature (RT) in modified roof system having shade cloth (38.56 °C) were obtained as compared to those observed under normal roofing (39.86°C) system in cross-bred animals (Khongdee *et al.*, 2010). Prasanpanich *et al.* (2002) observed that RT of animals placed outdoors (40.4°C) without shade was higher than those lodged indoors (39.0 °C) in an open-sided barn. Murrah buffalo calves (male) under modified roofing (normal roof + Polypropylene shade cloth) had shown lower mean rectal temperature (39.14 ± 0.07°C) than those kept under normal roof (40.00 ± 0.10°C) (Khongdee *et al.*, 2013). Singh *et al.* (2008) reported that the respiration rate was not influenced by providing shed (asbestos, agro-net, and tree). Patil *et al.* (2014) reported that RT (°C), Respiration Rate (RR) per minute and Pulse Rate (PR) per minute of crossbred cows were higher in the asbestos roof shed (38.85 ± 0.09, 43.50 ± 0.17, 64.33 ± 0.08) in comparison to white painted roof shed (38.52 ± 0.011, 39.41 ± 0.18, 61.49 ± 0.09) and thatched asbestos roof shed (38.33 ± 0.010, 37.26 ± 0.19, 60.27 ± 0.05).

EFFECT OF ROOF MATERIALS ON FEED AND WATER INTAKE

Average dry matter (DM) intake of Kankrej cow under RCC shed (12.41 ± 0.17 kg/day) and thatched roof (11.65 ± 0.19 kg/day) were found higher in comparison to tree shelter (10.64 ± 0.14 kg/day) (Chauhan *et al.*, 2011). Conventional barn and mud plaster roof houses were found better for nutrient intake during winter season (Shekhawat and Chaudhary, 2012). Covering of roof with a thatch material resulted in higher body weight gains over tin roofing in Osmanabadi weaned kids (Patil *et al.*, 2008). Crossbred calves reared under thatched roof house consumed higher dry matter/100 kg body weight (3.02 kg) than those reared in loose housing (2.52 kg) system (Yazdani and Gupta, 2000). During summer season, average water intake of Kankrej cow under RCC shed (44.77 ± 0.23 liter/day) were higher in comparison to thatched roof (41.18 ± 0.19 liter/day) and tree shelter (39.77 ± 0.44 liter/day) (Chauhan *et al.*, 2011). The crossbred cows reared under thatched asbestos roof shed (2.92 ± 0.05 kg) consumed more dry matter per 100 kg body weight than those reared in asbestos shed (2.78 ± 0.02 kg) and white painted roof shed (2.86 ± 0.04 kg); whereas asbestos roofed shed (53.83 ± 0.35) cows drank more ($P<0.05$) water (litre/day) than those in thatched asbestos roof shed (45.41 ± 0.34) and white painted roof shed (50.53 ± 0.36) in hot and humid season of Konkan region (Patil *et al.*, 2014).

EFFECT OF ROOF MATERIALS ON MILK PRODUCTION AND COMPOSITION

Berman and Horovitz (2012) stated that availability of shade helps to mitigate the effects of radiation, which may improve animal productivity in warm climates without additional costs. Milk production of animals kept under modified roof system was higher in comparison to cows kept under normal roofing (Khongdee *et al.*, 2010). Milk production was higher in mud plaster roofed house (10.57 ± 0.14 kg) than that of thatch roofed house (9.52 ± 0.08 kg), conventional barn (8.70 ± 0.10) and loose house (8.34 ± 0.11 kg) in cross-bred cows during winter season (Shekhawat and Chaudhary, 2012). The average milk yield (kg/day) was higher in thatched asbestos roof (8.17 ± 0.27) than white painted asbestos roof (7.91 ± 0.28) and asbestos roof (7.52 ± 0.28) shed (Patil *et al.*, 2014). Singh *et al.* (2008) reported that use of paddy straw bedding over the asbestos sheet improved the milk yield of crossbred cows than asbestos roofed shed alone.

The percentage of total solids, solid not fat, fat and protein in milk of crossbred cows was higher ($P<0.05$) in thatched asbestos roof shed (13.71 ± 0.02, 8.89 ± 0.013, 4.87 ± 0.012 and 3.48 ± 0.04) than the asbestos roof (13.04 ± 0.03, 8.41 ± 0.011, 4.45 ± 0.013 and 3.28 ± 0.05) and white painted roof shed (13.31 ± 0.03, 8.62 ± 0.015, 4.64 ± 0.014 and 3.40 ± 0.03) in hot and humid season of Konkan region (Patil *et al.*, 2014).

EFFECT OF ROOF MATERIALS ON GROWTH PERFORMANCE

Calves reared in a cool temperature gained 19 lbs more in three months in comparison to calves raised at a hotter temperature of 10 °C (West 2003). Patil *et al.* (2008) randomly allotted four Osmanabadi weaned kids of similar age and body weights to six housing pattern viz, floor murum with no ventilator + thatch roof (control), floor murum with no ventilator + tin roof, floor murum with one ventilator + tin roof, floor murum with one ventilator + thatch roof, floor murum with two ventilator + tin roof and floor murum with two ventilator + thatch roof. They observed that covering the roof with thatching material proved beneficial and resulted higher body weight gains over tin roofing. Kamal (2013) observed that body weight gain (in kg) is higher in cross-bred calves reared under agro-net shading roof (69.87 ± 1.89) in comparison to calves kept under thatch shading roof (61.86 ± 2.06), asbestos with canvass shading roof (59.53 ± 1.14) and well grown tree (57.79 ± 1.13).

EFFECT OF ROOF MATERIALS ON BLOOD PARAMETERS

Haemoglobin

Lower haemoglobin levels were observed in cows lodged outdoor without shed (10.4 g/100 ml) than those in indoors (13.2 g/100 ml) (Prasanpanich *et al.*, 2002), whereas Singh *et al.* (2008) observed no significant ($P<0.05$) difference in haemoglobin levels of kids kept under asbestos sheet, agro-net, tree shade or kept under open sky. Kamal (2013) also observed no significant difference in haemoglobin values of calves reared under thatch, agro-net, asbestos and tree shade (10.51 ± 0.43, 10.61 ± 0.46, 9.47 ± 0.25 and 10.58 ± 0.36 g/dl, respectively).

Glucose

Bahga *et al.* (2009) reported that lower serum glucose was found in crossbred calves during summer as compared to spring season (38.62 ± 4.81 and 51.69 ± 4.40 mg/100 ml, respectively). Serum glucose levels (mg/dl) found higher in cross-bred calves kept under agro-net (46.44 ± 1.21) than thatch (40.3 ± 1.53), asbestos (39.47 ± 1.62) and tree shade (37.59 ± 1.31) (Kamal, 2013).

Proteins

Variations in serum protein level during heat stress have been reported by several research workers. Scharf *et al.* (2010) found an increased serum protein level at higher environmental temperatures in different *Bos taurus* breeds. High environmental temperature causes increase in total plasma protein of milking cattle (Rasooli *et al.*, 2004). Yousef *et al.* (1997) reported that exposure of summer solar radiation resulted in a significant decrease in plasma concentrations of glucose, total protein and total lipids compared with those exposed to solar radiation in winter.

Enzymes

Nazifi *et al.* (2003) found that serum activity of both SGPT and SGOT increased in fat tailed Iranian sheep during heat stress. Calmari *et al.* (2011) reported a positive correlation between THI and SGOT in dairy cows. Kamal (2013) studied the effect of different roofing materials on serum enzymes i.e. ALP, SGOT and SGPT and found significantly higher overall serum ALP level in calves kept under tree shed (145.39 ± 4.99 IU/L) followed by asbestos and agro-net (137.35 ± 11.8 and 108.87 ± 5.21 IU/L), respectively. Higher serum SGOT level was obtained in calves reared under tree shed (128.27 ± 4.82 IU/L) followed by those under asbestos roof (127.01 ± 5.10 IU/L) in comparison to calves under agro-net (85.33 ± 2.79 IU/L) and thatch (95.80 ± 4.26 IU/L). Kamal (2013) also observed that serum SGPT values did not differ significantly among the above groups i.e. calves under thatch, agro-net, asbestos sheet and tree shade (36.12 ± 1.84, 33.20 ± 2.56, 39.69 ± 4.16 and 40.74 ± 1.84 IU/L), respectively.

Harmones

Cortisol is considered as the representative stress hormone. Higher level of plasma cortisol was found in cross-bred calves kept under asbestos (9.22 ± 0.81) and thatch (9.77 ± 0.63) roof in comparison to those reared under agro-net (7.12 ± 0.58) shed during rainy season (Kamal, 2013). Calves housed in the wooden roof sheds had lower plasma cortisol level in comparison to calves exposed to direct solar radiation (Yousef *et al.*, 1997).

EFFECT OF ROOF MATERIALS ON BEHAVIOURAL PERFORMANCES

Cook *et al.* (2005) reported that behavioural activities of animals may be used as an indicator of animal comfort. Cows preferred shade and spent more time in that shed which blocks maximum solar radiation (Schu¨tz *et al.*, 2009). Dikmen (2013) observed that heat-stressed cattle in hot environment change their standing behaviour. In cows, time spend during standing increased by 10% when thermal load increased by 15% (Tucker *et al.*, 2008). The ruminating behaviour is a major indicator of thermal stress because rumination activity decreases quickly in heat-stressed dairy cows (Soriani *et al.*, 2013). Significant effect ($P<0.05$) of shelter modification was observed on the average time spent in eating during 24 hours in buffalo calves during winter (Jat and Yadav, 2010). Animals kept under modified shed (thatch roof + sand bedding) spent more time in fodder intake as well as on sitting or lying rumination during summer and rainy seasons in cross-bred cows (Madke *et al.*, 2010).

Sharma and Singh (2001) recorded the behaviour of cross-bred animals under different types of housing systems and observed that during summer season, time spent (in minutes) for feeding was higher for loose housing (138.87) as compared to the loose housing with central shed (128.75) and closed housing (113.96). Standing idle, sitting/lying rumination, sitting/lying idle, and frequencies of defecation, urination and drinking water were significantly ($p<0.01$) affected by Shelter system during summer months in cross-bred cows.

Kamal (2013) recorded the behavioural activity – feeding, rumination, drinking – carried out by cross bred calves under various roofing materials and found that calves kept under agro-net spent maximum time (85.48 ± 0.75 minutes) in feeding as compared to calves housed under asbestos roof (75.93 ± 1.34 minutes). However, time spent in drinking water was more in calves reared under asbestos roof (13.67 ± 0.44 minutes) as compared to calves kept under agro-net roof (9.71 ± 0.31 minutes). In this study it was observed that, rumination time was higher in calves reared under ago-net roofing (88.28 ± 0.93 minutes) followed by thatch roof (79.16 ± 1.76 minutes); whereas least ruminating time was observed in calves reared under tree shade (74.32 ± 0.65 minutes) and asbestos roof (74.35 ± 1.55 minutes).

This article reviewed various types of roof materials from heat stress amelioration perspective in dairy bovines. A number of traditional as well as newer roof materials are investigated along with their merits as well as drawbacks; none roof materials possesses all the desired properties. Therefore, improvement in existing roof structure through appropriate modifications, such as thatched asbestos roof, solar panels, polythene shade cloth, thermal insulation, evaporative roof cooling, mud plastering, roof paints etc., is an easy way to create favourable microclimate under the roof rather than changing the whole structure. Effectiveness of roof may further be improved by developing techniques of adjustment of roof height, eave length and angle of eave in years to come. A holistic approach which includes animal nutrition as well as animal genetics in addition to shelter management would be more promising in ameliorating heat stress of dairy animals in tropics.

Possible research issues with roof modification in livestock housing

- Identification and evaluation of new roofing materials to suit different local conditions and the use of locally available resources could be explored.
- Area-specific housing strategies using different kind of roof materials for different animal groups can be adopted for increasing the comfort of animals.
- Scope for future research on the impact of different roof materials on production, reproduction, stress level and behaviour of animals may be studied.
- Inter-relationship of various factors affecting combination of different roof materials needed to be carefully studied.
- Development of techniques related with roof height adjustment, so that roof height can be changed during different seasons.
- Development of adjustable eave length and eave angle techniques could be explored.
- Development of long term strategies of shelter improvement using different roof materials for livestock welfare and comfort.
- There is always a possibility of finding out new, superior and cost-effective roof materials which can better fulfil the demands of an ideal shelter.
- Further investigation regarding economics and life span of different roof materials and their combinations can be carried out.

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