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Efficacy of Paddy Straw as Roof Heat Insulator in Cow Shed: Its Impact on Productive Performance and Economic Consideration

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Abstract—*Roof thermal insulation is an important technique to modify physical environment of dairy barn that can limit the adverse effects of high environmental temperature in tropical countries. Different materials are used in animal shed for heat insulations, but this is an expensive solution and their situation specific usefulness has not been confirmed. The objective of the present study was to find out the usefulness of cheaply available paddy straw as heat insulator in cow-shed, its influence on altering micro-environment of the shed, impacts on physiological and production performance of crossbred Jersey cows under loose housing system. Two types of housing were compared- (i) Modified shed (T_1)- thatch ceiling under asbestos roof and partial replacement of concrete floor with sand bed and (ii) existing shed (T_0) having asbestos roof and concrete floor. Twenty crossbred Jersey cows were divided into two groups, ten in each and housed in two respective sheds. Under-roof insulation by paddy straw efficiently reduced the ceiling surface temperature at covered area of modified shed (T_1). During day time surface temperature beneath the roof of T1 shed lowered by 1.44 to 9.15 °C in summer (March-April) and 0.24 to 7.86 °C in winter months (December-February). Floor surface temperature of covered area of modified shed was also less. Altered environment through thermo-protection in covered area and soft flooring by sand bed in open area reduced stress on animals as was evident from cardinal physiological indices of cows and enhanced milk yield per day. Quality of milk was also better because of lesser somatic cell counts. The expenditure incurred for under-roof insulation by paddy straw was Rs 15500 and sand bed Rs 7000 as per fair market price in February 2016. Expenditure incurred was compensated by enhanced milk yield with additional profits. It was concluded that paddy straw can be effectively used in roof insulation of cow shed for favourable alteration of thermal micro-environment; it is cheap, economic and profitable in long run.*

Keywords*: Paddy straw, Sand floor, thatch roof, insulation, temperature, crossbred cow milk.*

1. INTRODUCTION:

Roof is a very important structure in animal house. It protects animals from direct sun, rain, dew, mist, hailstorm, thermal radiation etc. In tropical countries radiative heat transmitted from underside of roof is one of the major sources for heat loads in animals. Thus quality of roofing material is an important consideration for livestock house construction. Basic characteristics of roofing materials for livestock shed should be strong, durable, lightweight, hygienic, thermo-protective, fire resistance, no-hygroscopic etc. [1,13]. Depending upon the availability, accessibility and affordability livestock houses are constructed by farmers / organizations and use tin, asbestos, tiles, thatch and reinforced cement concrete (RCC) etc. as roofing structures. Once the shed is constructed, it becomes very difficult and expensive to do major alterations, except some minor modifications. Tin / asbestos is the most commonly used roofing materials adopted by farmers in Indian subcontinent. Thermal conductivity of GI sheet, tin and asbestos are quite high, radiate much heat and make the micro-environment of animal shed warmer. In this study, efforts have been made for easier and cheaper way to combat heat stress in cow shed by designing suitable frame to use paddy straw as heat insulator. The major objective was to study the efficacy of paddy straw as heat insulator in cow-shed, its impact on animal welfare, behaviour, productivity and its economic proposition.

2. MATERIALS AND METHODS:

2.1 Location of the experiment

The experiment was conducted at ICAR-National Dairy Research Institute (ICAR-NDRI), Eastern Regional Station (ERS), Kalyani, West Bengal, India. The weather is mostly hot and humid; the maximum ambient temperature in summer goes up to 39^{o}C and minimum temperature in winter comes down to about 8^{o}C. The average annual rainfall is 1000-2000 mm, most of which is received from early June to September.

2.2 Experimental design

Twenty lactating crossbred Jersey cows were divided into two groups (10 in each). The best possible uniformity on their average age, parity, stage of lactation and milk yield were kept between the groups. Cows in control group (T_0) were kept in

existing loose housing condition i.e. concrete floor and asbestos sheet as roof material. Treatment group (T_1) cows were kept in modified shed. Shed modification was done by roof thermal insulation and flooring comfort. Flooring comfort was given by 4-6 inches depth sand bed (616 ft^2 area), which was nearly 38% of total pen area.

2.3 Roof thermal insulation

Roof thermal insulation was done by use of paddy straw (thatch) under the asbestos roof. Area of insulated part was 12.5 ft X 28 ft. About 12 inches below the asbestos roof one MS pipe frame was fabricated. A pad of 3-4 inches thick paddy straw supported by bamboo splits was prepared over the frame for heat insulation. Side gaps were also covered by straw pads. Air space of 8-9 inches remained trapped between paddy straw and ceiling of asbestos roof.

2.4 Housing and management of experimental cows

All the cows were kept under loose housing system. Three sides of the paddock were half walled (3.5 ft high) enclosure made up of brick-cement and rest one side was guarded by outer wall of manger. There was a drain (12 inches wide) in between covered and open space with adequate slope. Water trough was provided in one corner of the paddock with 24 hours availability of water. This system of housing facilitated free movement and sufficient exercise to the animals. All the feeding management practices and the feed ingredients were same for both the groups as per requirement of whole lactating herd. Concentrates, *ad libitum* seasonal green fodder and paddy straw were provided to complete the nutrient requirement of all the lactating animals.

2.5 Milking Practices

Machine milking was done twice a day during morning from 6.00 to 8.00 AM and evening from 2.30 to 4.30 PM. The milk was weighed and recorded in kilogram for individual animal. Before milking the animals were groomed and washed. Towels soaked with antiseptic solution were used for wiping of the udder and teats just before attaching the teat cups of milking machine. Teat dipping was done after completion of milking.

2.6 Recording of parameters

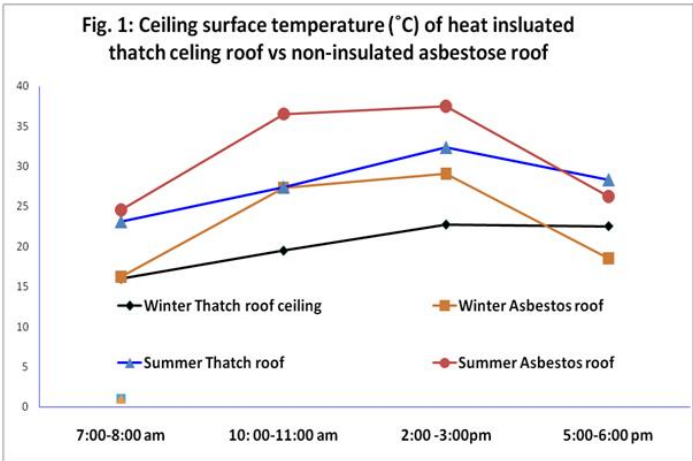
Both floor and inside roof surface temperatures of shed materials were measured by an infrared digital thermometer (-32°C to 320°C) of Metrix+TM, MT 2A. The surface temperatures were taken from a constant distance of 10 inches from the objects by attaching a fixed scale. Surface temperatures in different locations were recorded 4 times in a day at 7:00-8:00 am, 10:00-11:00 am, 2:00-3:00 pm and 5:00-6:00pm. The study period (December to April) was divided into 2 season viz. winter (December-February) and summer (March- April). Rectal temperature, heart rate and breathing rates of cows were recorded at weekly intervals at 8.00-9:00 AM and 2:00-300 PM. Rectal temperature was recorded by using a clinical thermometer. Pulse rate was taken from middle coccygeal artery without disturbing the animal and expressed as counts per minute. Respiration rate was counted from a distance by observing flank movements and expressed as counts per minute. Daily milk yield of twenty lactating animals were recorded.

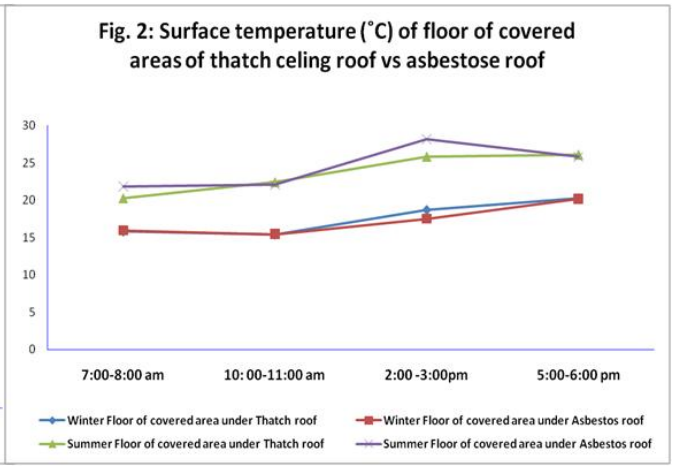
2.7 Statistical analysis

The data were analyzed by using statistical software [17]. The statistical methods used to analyze the data were one way **ANOVA** and **General Linear Model.**

3. RESULTS AND DISCUSSION:

The surface temperatures of ceiling of roof and covered area of modified insulated shed (T1) vis á vis non-insulated shed (T0) have been depicted through Fig. 1 and 2, respectively. Underside of asbestos roof insulation by paddy straw pads altered the micro-environment of cow-shed.





In summer season, due to thatch roof insulation, the ceiling surface temperature of T1 shed compared to T0 was significantly reduced by 1.44, 9.15, and 5.16 ^{o}C at 7-00 am, 10 am and 2 pm, respectively. In winter season, the corresponding values were 0.24, 7.86 and 6.34, respectively. However, at 5-00 pm the trend was reversed i.e. temperature at T1 was 2.11 and 4.04 ^{o}C higher than T0 in summer and rainy seasons. At floor surface of covered area of T1 shed temperature in summer season was 1.55 and 2.40 ^{o}C lower than T0 during 7-00 am and 2-00 pm, respectively, however, difference were not statistically significant. Results indicated that insulation of ceiling by paddy straw changed the micro-environment of modified shed (T1) in favourable direction and improved cow-shed comfort.

The effects of modification of thermal and physical environment of cow shed were observed on their body physiological indices, production parameters, behaviour, performance in terms of milk yield and quality etc. Here, in this present experiment, changes in cardinal physiological responses of crossbred Jersey cows and other production performances became evident due to combined effects of roof thermal protection and flooring comfort subjected by soft sand bed. Cows of T1 shed showed significantly lower deviations in their body vital parameters such as temperature, pulse and respiration rate compared to that of T0 both during morning and afternoons.

In the present study, overall influence of roof thermal insulation and floor comfort assistance given by sand bed was observed on cows' following physiological and productive performances (Table 1). The impacts on animals that was found in the present investigation was combined effects of heat insulation by paddy straw and flooring comfort by sand bed, whereas changes in thermal environment of cow-shed was due to beneath-roof heat insulation.

Table 1: Impact of shed modification (T1) on overall performance of Jersey crossbred cows compared to T0 shed

Sl No	Particulars	Direction of shift in T0
1.	Rise from normal cardinal physiological response (Rectal temperature, Pulse and Respiration rate/ minute)	Less deviation (Response is +ve and significant)
2.	Milk yield /day /cow	Enhanced (+ve and significant): 380 g /day/cow
3.	Milk composition	No significant change
4.	Milk quality (MCMT score and somatic cell count in milk)	Less score & less somatic cell count (+ve and significant)
5.	Blood biochemical parameters	Alterations show no significant differences
6.	Resting period / lying behaviour (comfort)	Increased significantly. Animals preferred sand bed to spent most of the time
7.	Feed intake	No significant change

The severity of heat stress is an important issue on profitable dairy production as global warming progresses. To combat the stressful situations, many techniques of environmental management including fans, misters, sprinklers, and cooled waterbeds, are used to attenuate the effects of thermal stress on cow health, production, and reproduction [4]. Solar radiation is a major factor responsible for heat stress [2] and causes deterioration in performance of animals and their welfare indices. There was reduction in milk production and animal welfare due to the stress, climatic condition and improper housing comfort reported earlier [3,5-6,9-11,18].

As the thermal conductivity of straw is very less (0.05 K cal/through meter, °C; [13]) it takes more time to be heated up and also release heat slowly. Because of this reason T1 shed was little warmer during evening (5-00 to 6-00 pm) as compared T0. In loose housing system, as there is enough cross ventilation, this transient heat load due to insulation get diluted with evening cooling. Thus, insulation provides protection during warmer parts of the day from radiated heat transmitted from ceiling to inner side of cow-shed.

Like present study, beneficial effects of thermal insulation, stress reduction in different modules have been reported with varying results in different climatic conditions [3,5-6,14,16]. Cement sheets recorded the highest temperature (26.71±1.13°C) and THI (77.23±1.76) at 8.00 am, whereas the lowest temperature (24.83±1.17°C) and THI (74.54±1.72) were recorded in the thatched shed [16]. Influence of different types of roofing materials on micro-climate in animal loose housing system was studied [5-6,14-15] and reported lower roof inside surface temperature (°C) in thatch roof. Both thatch and agro-net shade material helped in better relieving the thermal stress in crossbred cattle. An investigation was carried out on Jersey x local crossbred cows [3,12] by creating three different type of shelters viz. asbestos roof, paddy straw thatched roof and white painted asbestos roof. Thatched roof shed effectively reduced environmental temperature, humidity and THI and milk yield was significantly higher ($P<0.05$) in thatched roof shed in comparison with white painted roof shed and asbestos roofed shed in the Konkan region of India. In crossbred cows, paddy straw bedding over the asbestos sheet significantly ($P< 0.05$) improved the milk yield in comparison to cows kept under asbestos roofed shed had also been reported [15].

3.1 Economic considerations:

Economic analysis of paddy straw insulation plus soft flooring by sand bed was also done (Table 2). Manufacturing works got done departmentally after purchase of materials during February 2016 and hence, a fair market value for works of the then period was taken for cost calculation in the present study. Shelter modification can help altering microclimate towards improvement in production and livestock welfare; however, animal productivity benefits should be reflected from the costs of improving the animal's environment [1].

Table 2: Income and expenditure statement for construction of paddy straw (thatch) insulation and sand bed in cow-shed

S. No	Particulars	Price(Rs)
	Expenditure:	
1.	Roof ceiling insulation by thatch	
a)	Frame made up of Iron pipe (Square) ¾ inches width 16 Gauze: 340 ft @Rs 24 /ft	8160
b)	Flat Iron Bar ¾ inches width X 12 mm thick: 60 kg @ Rs 48/ kg	2880
c)	Welding stick & other miscellaneous items	460
d)	Paddy straw & Bamboo split	1500
e)	Manufacturing cost of Iron frame*	1500
f)	Manufacturing cost of Paddy straw insulation*	1000
2.	Construction of sand bed in open area	
a)	Bricks, cement and Sand for sand bed boundary	3500
b)	Filling sand (≈300 c.ft)	2500
c)	Construction cost of sand bed*	1000
3.	Total Expenditure (1+2):	22500
	Income:	
4.	Increase in milk yield: @380 gm/cow/day	
	Additional yield from 10 cows in 300 days of lactation= 300 x 0.38 X 10 =1140 kg (say ≈ 1100 kg)	
	Sale price of milk* @ Rs 30/- kg= 1100 x 30=Rs 33000	
5.	Income Generated:	33000
6.	Profit (4-3):	9500

*Price taken as fare market value in the year 2016

The estimated profit in the first year became less because for expenditure incurred on fixed costs like construction of insulated ceiling and sand bed. From second years onwards and up to 4th year income will be more because of expenditure will occur only on sand filling and maintenance of sand bed. Durability of thatch ceiling would be 4-5 years and recurring expenditure on this head could be considered at every 4 years interval. Thus, second year / lactation onwards estimated additional income would be more. Thus present interventions of shed micro-environment modification through heat insulation by paddy straw and soft flooring by sand bed was economical and profitable. Moreover, cows remained comfortable, which is one of most important concern in present day's context of ethical animal production.

4. CONCLUSION:

Under-roof insulation by paddy straw efficiently reduced the ceiling surface temperature and favourably altered the cow-shed micro-environment. Floor surface temperature of covered area of modified shed was also less. Shed modification through false ceiling by paddy straw and soft flooring by sand bed reduced stress on Jersey crossbred cows and increased milk yield per day. Quality of milk was better because of lesser somatic cell counts. Paddy straw can be effectively used in roof insulation for favourable alteration of thermal micro-environment of cow shed; it is cheap, economic and profitable in long run.

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