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RESEARCH ARTICLE

Using the Appropriate Technology for Disaster Risk Mitigation: The Case of Extreme Heat Events

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ABSTRACT

This research initiative aims at alleviating high temperatures in corrugated iron sheds by coating them with locally available red oxide rust-proof paint and has yielded positive results. Impacted by higher seasonal temperatures due to global warming, Bangladesh faces challenges in cooling these sheds due to rural electric supply scarcity. Elevated temperatures inside the sheds lead to heat stress in poultry, resulting in increased mortality and reduced egg production. The research involves comparing heat transfer in painted and unpainted sheds, demonstrating the iron oxide coating to act as a heat transfer barrier. Field trials have revealed the painted shed to maintain temperatures 2°F-4°F lower throughout the day compared to the unpainted shed and to dissipate heat more gradually during cloud cover. This sustainable technique not only prevents rusting but also regulates temperatures in enclosed spaces, offering potential benefits for animal husbandry and human habitats such as slum housing. The method's simplicity and sustainability make it advantageous for reducing human suffering during extreme weather, suggesting the importance of considering existing solutions rather than developing new ones.

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Climate change is a pressing issue that has impacts on many aspects of life worldwide. One of the consequences of warming involves the noticeable changes in the Earth's climate, leading to unusual weather patterns. Bangladesh ranked seventh in the 2021 Global Climate Risk Index by Germnwatch and is particularly vulnerable to climate related disasters due to its features, despite only contributing 0.56% to global climate change emissions. From 2000-2019 Bangladesh has experienced 185 weather events resulting in a loss of $3.72 billion USD (Climate Reality Project, 2021). The country has also observed a temperature increase of 0.9°F. This is projected to rise up to 2.5°F by 2050 based on a temperature trend analysis (Al-Masum Molla, 2023). Being densely populated with a majority (84%) living in homes with tin roofs, Bangladesh suffers from intense heatwaves that significantly impact living conditions (Anam, 2019). The consequences of warming have negatively affected the wellbeing of both humans and animals putting living standards at risk. Despite being a developing nation where 70% live in rural areas and 40% live below the poverty line (Government of the People's Republic of Bangladesh, 2009), Bangladesh faces limitations that hinder the adoption of advanced mitigation technologies against extreme heat events. Due to energy supply shortages, the country also faces power outages, making existing mitigation measures expensive and inefficient. Therefore, researchers have conducted studies to find technologies that are environmentally friendly, easily accessible, and easily adoptable by local communities. One potential solution that has been suggested is to apply a layer of rust iron-oxide primer on corrugated iron sheets to reduce the indoor temperature.

Literature Review

The effects of global warming in Bangladesh are more vivid than ever showcasing record-breaking temperatures in recent events. Due to urban heat island effects triggered by increased carbon emissions and pollution, the temperature in Bangladesh is increasing at

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an alarming rate while the intensifying heat is becoming more unbearable. An upward trajectory has been discernible in the mean air surface temperature in Bangladesh spanning the years 1901-2022 (World Bank, 2023). Predominantly, instances of extreme heat events have become conspicuous within the last decade, culminating in annual mean temperatures reaching up to 26.6ºC in 2009. While the overall mean air surface temperature has shown an increase of approximately 0.5ºC from 1901-2022, highlighting that the mean temperature differential between the periods 1980-2000 and 2001-2022 amounts to approximately 0.23ºC is imperative (World Bank, 2023). Should the ongoing trend of temperature escalation persist, living conditions are anticipated to become jeopardized. This phenomenon is likely to result in heightened susceptibility to illness among the populace, increased mortality rates among animals, more frequent natural disasters, and a subsequent adverse impact on businesses associated with animal husbandry, potentially leading to their cessation. This discrepancy underscores the alarming escalation in temperatures during the more recent time frame, necessitating careful consideration and mitigation efforts. The air surface temperature should be less than 96.8 F to be in permissible limit, with the permissible indoor air limit lying in the range of 64.4ºF-75.2ºF (Abdul-Wahab et al., 2015; Khovalyg et al., 2020).

Bangladesh faces significant risks from extreme heat events due to its tropical and subtropical climate characterized by high temperatures and humidity. Any further rise in temperature is expected to worsen the impacts of heat-related issues. In 2014, the western region of Bangladesh experienced a higher frequency of days with a maximum temperature (T_{max}) equal to or exceeding 36°C compared to the eastern and coastal areas of the country. Specifically, Rajshahi had 79 days, Mongla had 51 days, and Khulna had 50 days with T_{max} ≥ 36°C in 2014. In comparison, Chuadanga recorded 85 days in 1992, Jessore had 78 days in 2010, Satkhira experienced 72 days in 1986, and Ishurdi had 68 days in 1995 with a T_{max} ≥ 36°C (Karmakar & Das, 2020)the frequencies of days with Tmax≥360C and ≥ 380C have been computed and their trends are investigated to delineate the areas of heat waves in Bangladesh. During the period 1981-2016, Tmax-≥360C is found to prevail annually for 79 days at Rajshahi, 51 days at Mongla, 50 days at Khulna in 2014 whereas it is found to prevail annually for 85 days at Chuadanga in 1992, 78 days at Jessore in 2010, 72 days at Satkhira in 1986 and 68 days at Ishurdi in 1995. In 2014, Tmax≥360C is found to exist annually for many days in western pat of Bangladesh in comparison to the eastern and costal region of the country. That is why year 2014 has been selected to study waves extensively. The study reveals that the monthly, seasonal and annual frequency of Tmax≥360C have increasing trends in Bangladesh except a very few places, having the highest increasing trends over southwestern part of the country with increasing rates of 0.816 day/year and 1.02 day/year, respectively at Mongla. The highest increasing trends over southwestern part may be due to the advection and penetration of higher Tmax due to northwesterly winds and less rainfall over the area. The seasonal and annual frequencies of Tmax≥380C have increasing trends at less than 50% stations in Bangladesh; some of the increasing trends of the seasonal and annual frequency of maximum temperature ≥380C are statistically significant up to 95-99% level of significance. The large-scale synoptic conditions show that heat waves are found to enter Bangladesh from the west/northwest due to the advection of higher Tmax from the west. Heat waves extend from west to east up to about central Bangladesh and a separate area of heat waves develop over the Chittagong Hill Tracts, the reason of which may be due to the diverging pattern of wind flows near the Chittagong Hill Tracts in the year of heat waves. Heat waves are absent along Sandwip-M.Court-Feni-Comilla region. In 2014, heat waves are found to be due to the influence of sub-tropical high over India and its extension over Bangladesh at the surface and at 850 hPa level with strong westerly/northwesterly winds at 850 hPa, influence of anticyclones persisting for many days over the Bay of Bengal at 300 hPa level, absence of upper level westerly troughs over India and Bangladesh \nJournal of Engineering Science 11(1.The Disaster Forum has reported that, since April 2023, approximately 20 individuals in Bangladesh have succumbed to heat stroke (*The Business Standard*, 2023). In April 2023, Bangladesh experienced extreme temperatures, with Dhaka hitting a historic high of 40.6°C on April 15th, marking the highest temperature in decades. Continuous exposure to excessive heat causes serious health conditions such as heat rash, excessive sweating, heat cramps, exhaustion, heatstroke, and even death. A recent study conducted by Rutgers University also found that heat stress may affect more than 1.2 billion people annually by 2100 (Li et al., 2020)agriculture, the economy, and the environment more broadly. Exposure to heat stress is increasing with rising global temperatures. While most studies assessing future heat stress have focused on surface air temperature, compound extremes of heat and humidity are key drivers of heat stress. Here, we use atmospheric reanalysis data and a large initial-condition ensemble of global climate model simulations to evaluate future changes in daily compound heat-humidity extremes as a function of increasing global-mean surface air temperature (GSAT.

The heat waves during April 2023 saw high mortality rate of poultry boiler chickens. The higher temperatures increase the indoor ambient temperature of corrugated iron roof sheds. It was reported that 30 chickens died of heat stroke in Belgacha union of Kurigram Sadar upazila. Similar accounts have been shared by other farmers in Harishwar Kaloa village in Sadar, mentioning that 15 chickens died in one farm due to heatstroke. Farmers highlighted that aside from heatstroke, the intense heat has induced diarrhea in broiler chickens, leading to distressing deaths (*United News of Bangladesh*, 2023.). With scarcity regarding the rural electric supply, air cooling and ventilation systems are not viable. High inside shed temperatures cause heat stress in the poultry, which then leads to higher mortality. Additionally, this also adversely effects egg production. To explore a sustainable remedy, a research initiative has been undertaken. This study involves applying an iron oxide rust-resistant coating to poultry sheds of similar sizes, subsequently comparing the heat transfer performance between the coated and uncoated sheds.

Methodology

The research incorporates a combination of primary and secondary data. Initially, an extensive review of existing heat reduction strategies has been conducted through an analysis of the available literature. Subsequently, field surveys and interviews have been carried out with key personnel in the poultry industry to gather valuable insights. Following this, the study area located in Baupara, Gazipur within Greater Dhaka was chosen. This specific area was selected due to its significance for hosting over 500 farms, thereby serving as a representative location for the study. The roofs of two identically sized poultry sheds on the farm were subjected to different treatments: one had a coating of red iron-oxide paint, while the other served as the control and remained unpainted.

Both poultry sheds exhibit uniform dimensions, measuring 21 meters in length, 6.32 meters in width, and 3.08 meters in height. The corrugated iron sheets comprising the structure of both sheds are constructed from identical materials. These sheds are positioned adjacent to one another and are thereby subjected to identical climatic conditions. Additionally, both structures are equipped with identical ventilation systems. Both structures share a comparable overhead tree cover.

A controlled background experiment was carried out using six pieces of corrugated iron sheets, all having similar dimensions (25’’ x 17’’). Two iron sheets were allocated to each color (i.e., white and iron-oxide red) and two were kept in their manufactured conditions without any paint coating. Two samples of each color were chosen for more precise data and to rule out any anomalous values. Only the colors anticipated to have optimum reflective, heat transfer, and radiative properties in warm climates were chosen, one being white enamel paint and the other being iron-oxide paint. The painted and unpainted sheets were installed on a rooftop at the same angles for sunlight to fall directly on in order to assess their effectiveness at reducing heat.

An infrared thermometer was used to measure the temperature variations, and temperature readings were taken every 30 minutes from the upper surface in direct sunlight to observe the heat reflection or retention. After taking the upper surface reading, another reading was taken after 10 minutes to observe the heat transfer to the lower surface of the corrugated iron sheets. The experiment was conducted under different weather conditions.

This comparative setup aims to observe and analyze indoor temperature variations within the poultry farms. The study employs a hygro-thermometer to measure the ambient temperature variations within the sheds. Temperature measurements were gathered from both the edges and the central area of the poultry sheds, and the average temperature has been reported to ensure reproducibility. Different weather conditions, including hot summer days and monsoon weather, were deliberately chosen to encompass different environmental influences affecting temperature variations on the poultry farm.

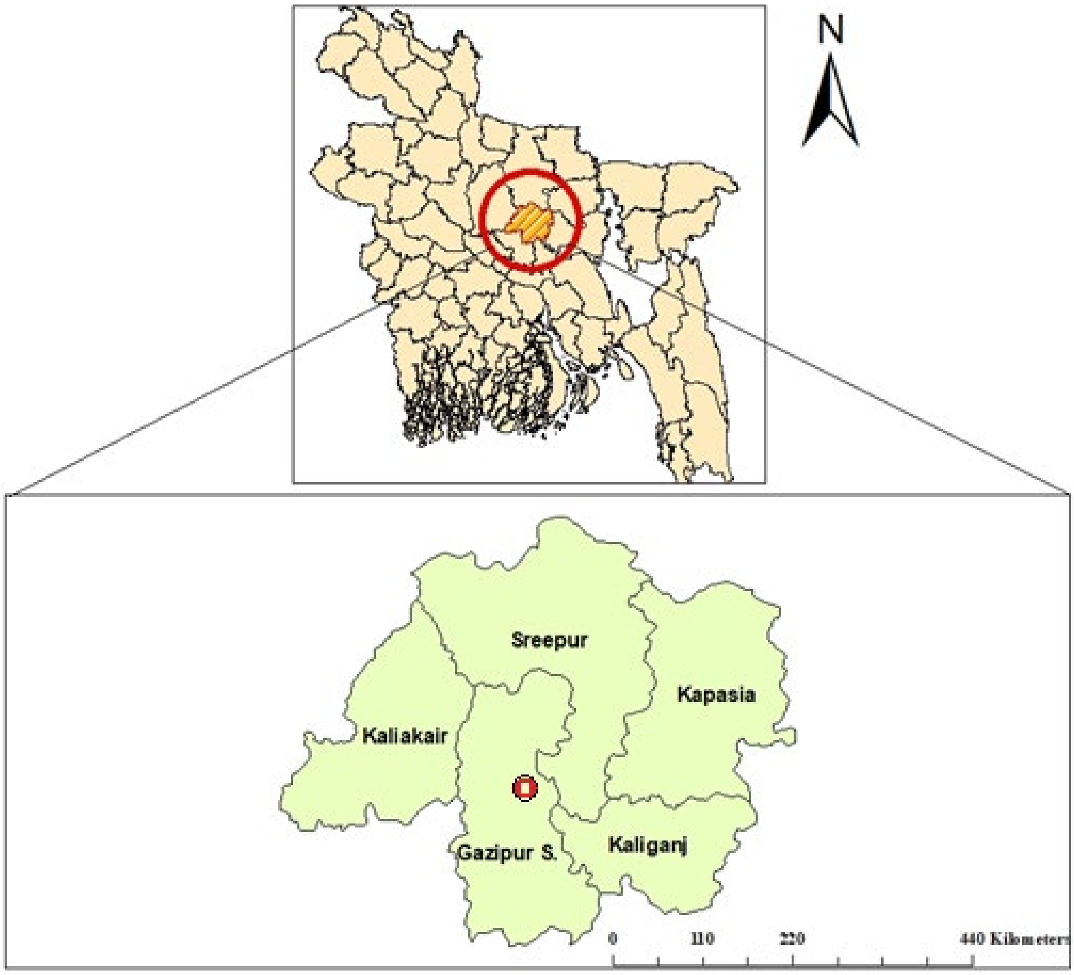

Figure 1. Map of the study area.

Result and Discussions

The red rust-proof oxide paint that was used as a coating is typically composed of iron oxide as its primary constituent. Being a relatively poor conductor of heat, iron oxide serves to mitigate the transfer of heat from the metal surface to its interior. To mitigate and control the indoor temperatures, the roof coatings were applied as done in previous studies (Carrasco-Tenezaca et al., 2021; Peng et al., 2023).

The experiment was systematically replicated over three days (n = 3) during both summer and winter season. Summer trials were specifically carried out in April, as maximum temperatures are observed during this period. Conversely, winter experiments were conducted during the month of December. Temperature data sets were recorded from 10:30 a.m. to 6:30 p.m. in order to comprehensively assess the temperature fluctuations within the sheds.

The indoor ambient temperatures of the coated and uncoated poultry sheds were monitored between 10:30 a.m.-6:30 p.m., revealing a fluctuation in temperature as shown in Figure 2. Analysis indicates an average temperature decrease of roughly 2°F- 4°F during this period.

Even though the poultry shed coated in red rustproof paint had poor ventilation (see Figure 3) due to cloth coverings when compared to the uncoated shed, the overall ambient temperature was lower. The boundary of the chosen poultry sheds are bounded with nets and cloth covers as a method of ventilation and reducing temperature inside the poultry. In addition, ceiling fans are installed at various places inside the poultry sheds to prevent heat stress in poultry.

Thus, the implementation of proper ventilation can cause a further decrease in ambient temperature to be expected to be observed in the red rustproof-coated poultry shed. The ability to store heat for a prolonged period of time would be advantageous during the winter, thus reducing the need for add space heating.

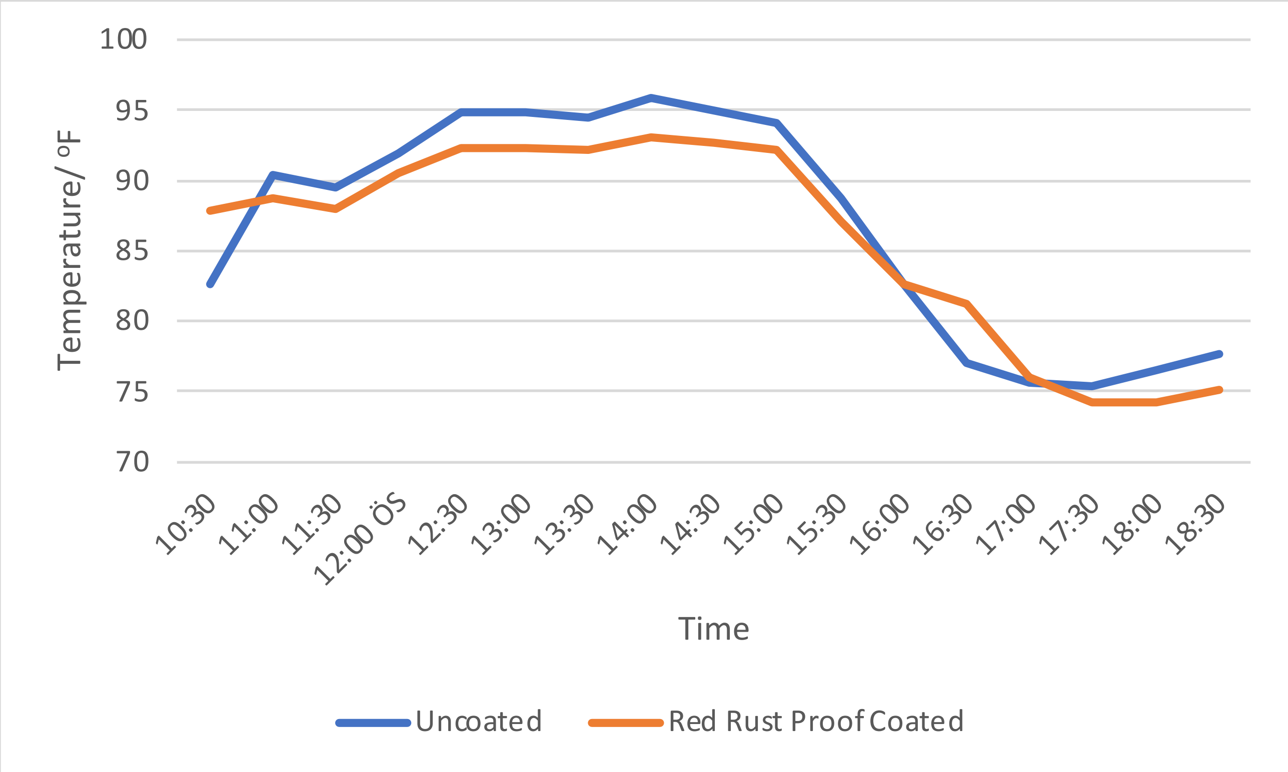

Figure 2. Ambient temperature comparison between uncoated and red rustproof-painted poultry shed.

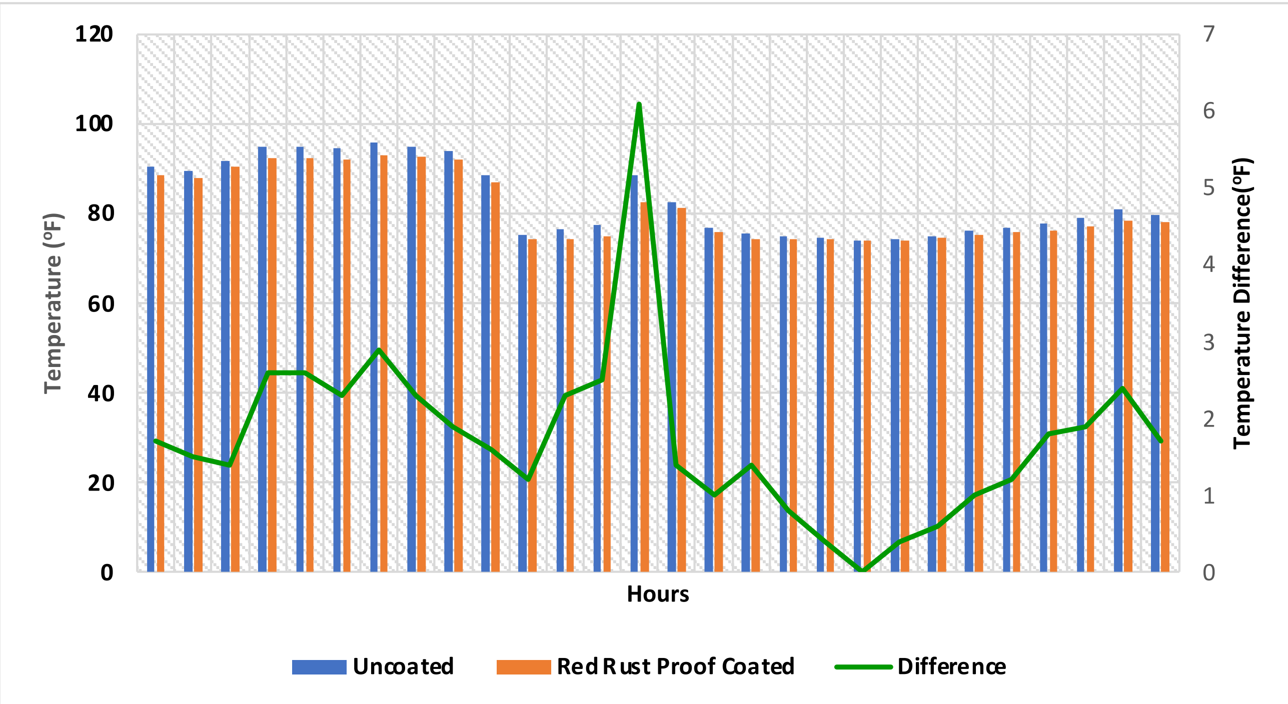

Figure 3. Indoor temperature difference between uncoated and red rustproof-coated poultry shed during summer (Unclouded).

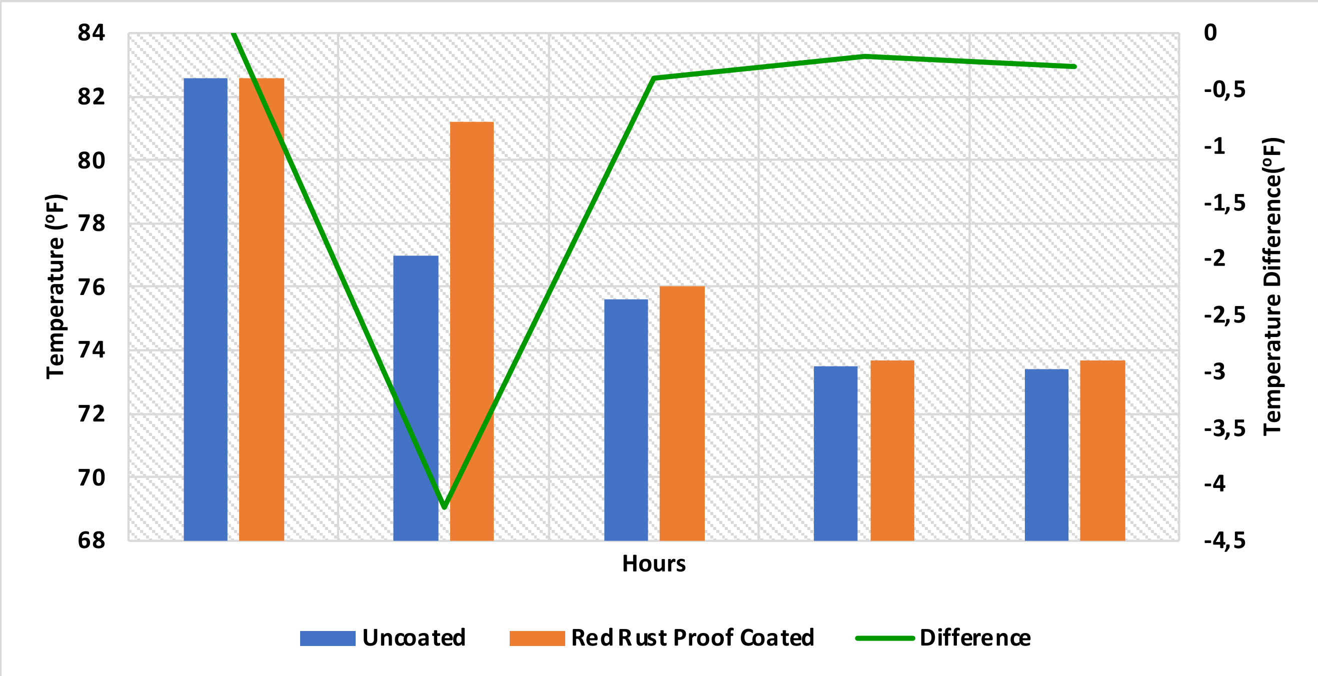

Figure 4. Indoor temperature difference between uncoated and red rustproof-coated poultry shed during summer (Clouded).

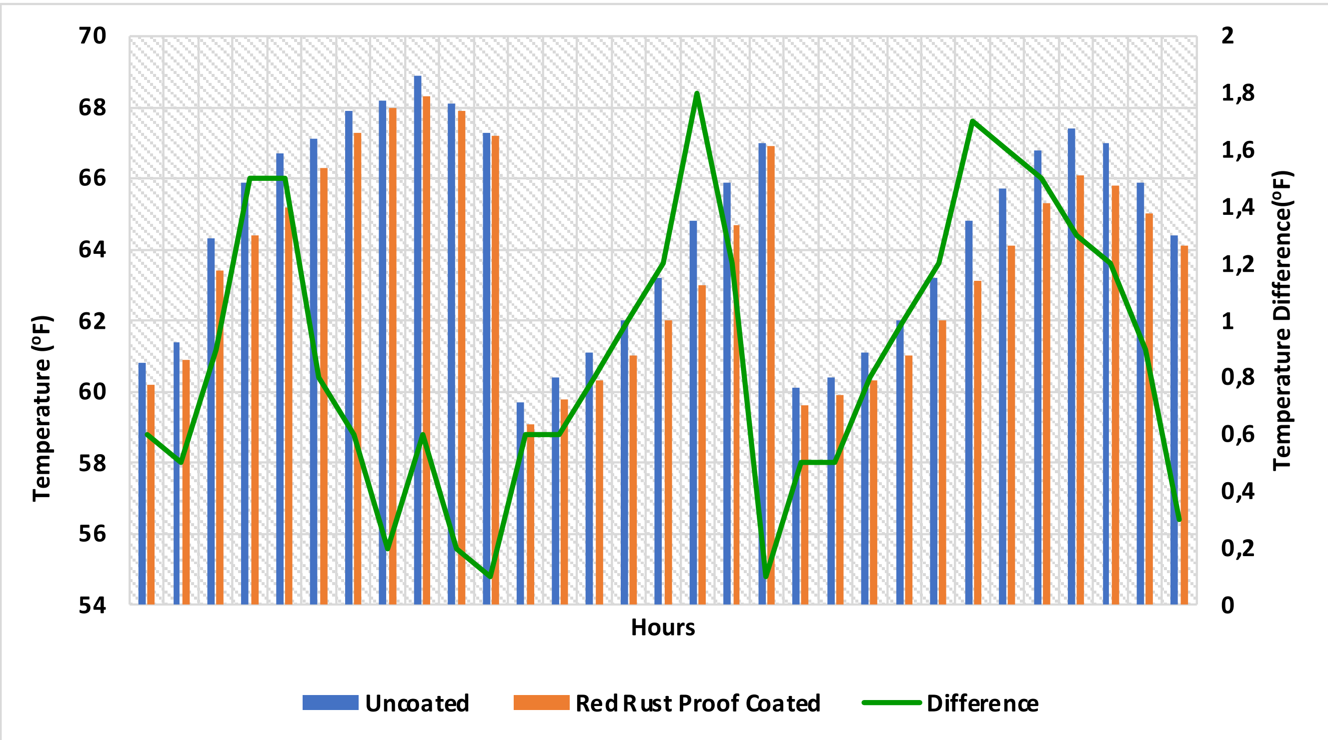

Figure 5. Indoor temperature difference between uncoated and red rustproof-coated poultry shed during winter (Un-clouded).

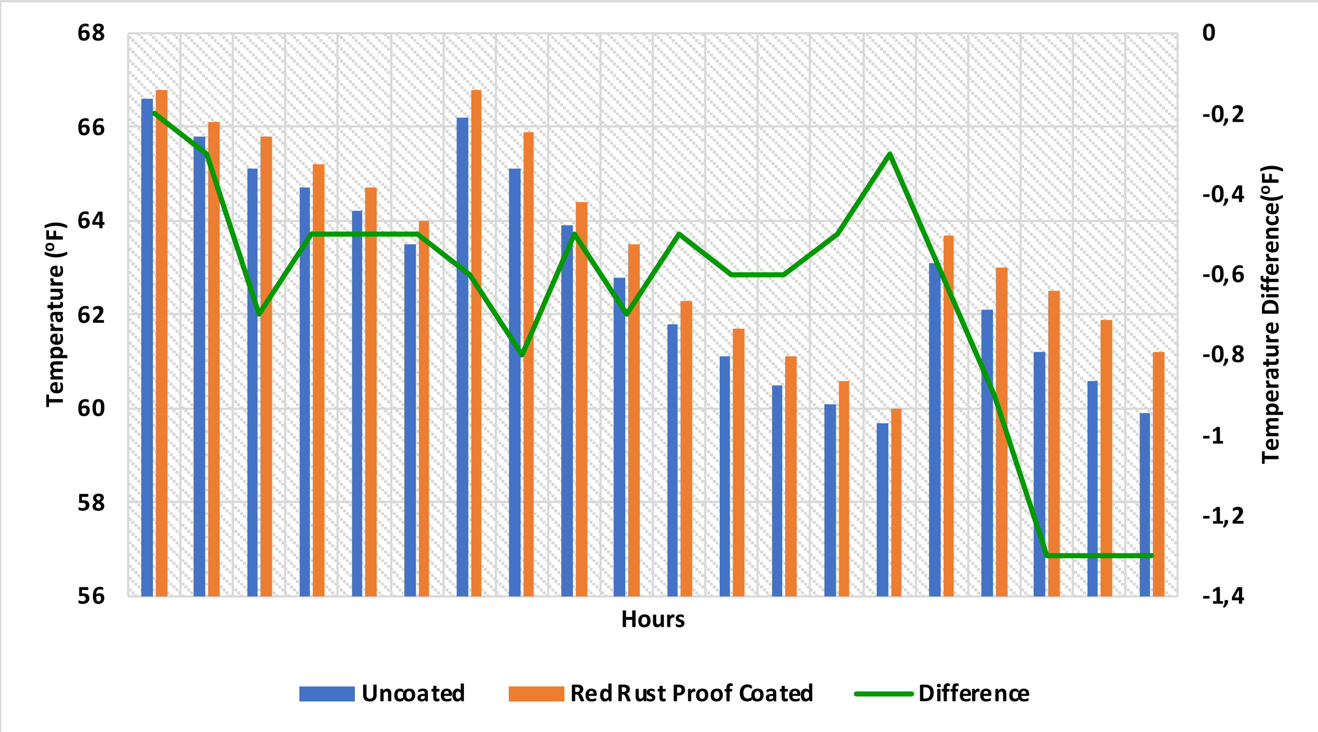

Figure 6. Indoor temperature difference between uncoated and red rustproof-coated poultry shed during winter (Clouded).

The temperature difference between the sheds with and without red rust-proof coating indicates the coating to contribute to controlling indoor air temperature, typically maintaining it within a range of approximately 2°F-4°F lower. The positive temperature variance observed in Figures 3 and 5 implies that, when the sky is clear, the coated shed keeps the ambient indoor temperature lower compared to the uncoated shed. Conversely, Figures 4 and 6 show a negative temperature change, suggesting that during cloudy conditions, the uncoated shed releases heat faster than the coated one, potentially causing abrupt environmental changes for the chickens. Thus, applying red rustproof paint aids in temperature regulation, preventing sudden shocks, especially during cloudy weather. Above 104°F, humans suffer from heat stroke, and this idea helps to cool down the indoor air temperature in order to avoid heat strokes.

Figure 7. Coated with iron oxide primer (A) and uncoated (B).

The poultry industry, in Bangladesh plays a role in providing jobs to around six million people, with women making up 40% of the workforce. With an investment of over 300 billion Taka, this sector contributes 2% to the country's GDP, as reported by the Bangladesh Poultry Industries Central Council (BPICC). Bangladesh is home to an estimated 65,000 to 70,000 poultry farms, and protecting and sustaining this industry from heat events is not only crucial for maintaining employment opportunities and a stable economy but also for ensuring a consistent supply of meat-based food. Additionally, energy shortages have posed challenges for ventilation systems on these farms. Hence, the proposed approach aims to support an area consisting of 500 farms by utilizing available materials that operate independently from energy sources for the effectively regulation of indoor temperatures. Carbon emissions come from the energy used for ventilation. Electric fans are setup inside the farm, which in term uses energy that leads to greenhouse gas emissions.

Increased temperatures have also had an adverse effect on human health, even resulting in deaths. This method can be applied to any housing consisting of tin-roofing to subdue indoor temperatures. In Bangladesh where approximately 84% of the population resides in homes with tin roofs, introducing an economical and sustainable method using locally sourced materials to reduce indoor temperatures in these tin-roofed houses would significantly benefit the people, considering the country's vulnerability to extreme heat events. High temperatures leading to heatwaves and prolonged periods of elevated day and night temperatures impose cumulative physical stress on individuals, worsening major global causes of death (World Health Organization, 2018). This innovative technology diverges from conventional methods that rely on electricity and energy for ventilation and cooling. This shift is particularly significant, as rural communities and slums residing under tin shed roofs encounter energy shortages. This technology can also be implemented in the Rohingya and Geneva refugee camps. Increased indoor temperatures not only trigger public health crises but also bring about socioeconomic challenges such as reduced work capacity, lower labor productivity, restricted mobility, and increased poverty rates. This situation might exacerbate the situation, particularly in major urban centers such as Dhaka, Chittagong, and Rajshahi due to rapid urbanization, thus causing the Urban Heat Island Impact (Dewan et al., 2021). Hence, this mitigation measure of coating a roof with red iron-oxide could be a readily applicable, sustainable mitigation option for resource challenged economies.

Conclusion

The conducted research emphasizes the significance of addressing extreme heat episodes in Bangladesh, particularly in poultry farms, by exploring a sustainable solution for mitigating indoor temperatures in sheds with corrugated iron roofs. The study has highlighted the adverse impacts of elevated temperatures on poultry health, resulting in increased mortality rates and decreased egg production and thereby exacerbating economic losses within the industry. Utilizing a locally available red oxide rustproof paint as a coating on the sheds has demonstrated promising outcomes at reducing indoor temperatures. The coated sheds experienced an average decrease of 2°F-4°F compared to unpainted sheds, showcasing the effectiveness of the iron-oxide coating as a heat transfer barrier. Beyond the poultry industry, this research offers broader implications for improving living conditions, especially for communities residing in tin-roofed houses across Bangladesh. The method's simplicity and sustainability make it a viable option for combating extreme heat events by addressing challenges exacerbated by energy shortages and contributing to alleviating socioeconomic burdens. Moving forward, the application of the iron-oxide primer technique stands as a practical, cost-effective, and eco-friendly solution for regulating indoor temperatures in enclosed spaces. The study's findings emphasize the urgent need to implement such interventions on a larger scale, accompanied by strategic policies and action plans to mitigate the adverse effects of heat stress on human health, livelihoods, and overall well-being in Bangladesh.

Ethical approval

N/A

Authors' contribution

Author Contributions: Conception/Design of study: S.R., A.R.D., M.S.H.A., N.R.K.; Data Acquisition: S.R., A.R.D., M.S.H.A., N.R.K.; Data Analysis/Interpretation: S.R., A.R.D., M.S.H.A., N.R.K.; Drafting Manuscript: S.R., A.R.D., M.S.H.A., N.R.K.; Critical Revision of Manuscript: S.R., A.R.D., M.S.H.A., N.R.K.; Final Approval and Accountability: S.R.,

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