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Saving the Poultry Industry in Bangladesh: Appropriate Technology for Controlling the Ambient Temperature of Poultry Sheds with Corrugated-Iron Roof by Paint Coating

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Abstract: Bangladesh experienced a significant rise in temperature over the past years which has affected a 3 billion USD poultry industry due to an increased mortality rate of poultry. Global warming has resulted in increasing indoor temperature of the poultry sheds throughout the day as the sheds are made of corrugated iron sheets that absorb infrared radiation that exacerbates ambient shed temperature. An experimental program was conducted that looked at painting the corrugated iron sheets to limit the sunlight-inferred energy transferred, thus, decreasing the temperature in the poultry sheds. Sets of corrugated iron sheets were chosen: unpainted as a reference, red rust proof, and white enamel paint coating, with identical dimensions and thickness. The experiment was conducted under sunlight and the top and bottom surface temperatures of the corrugated iron sheets were recorded using an inferred sensor at predetermined intervals. Multiple runs were for more accurate and precise results. Heat accumulation was significantly reduced by coating corrugated-iron sheets with red rust-proofing (corrugated-iron sheet bottom surface temperatures; red rust proof 83.5 ± 3.6 < White 85.4 ± 4.6 < unpainted 88.3 ± 4.9). The combined effect would be that the internal temperature of the poultry sheds would be reduced by painting the corrugated-iron roofs red rust-proof coating. Painting the poultry sheds with red rust-proof paint could be a viable mitigation measure to sustain the poultry farms in Bangladesh amidst warming temperatures - an appropriate technology solution bolstered by the local supply chain.

Keywords: global warming, poultry industry, thermal mitigation, red rust-proof painting

Introduction

The detrimental effects of global change are now more vivid in Bangladesh than ever, exhibiting a non-uniform change in temperature. Between 1976 and 2019 Bangladesh experienced an average 32.9°F (0.5°C) increase in temperature across all its regions. Furthermore, it is anticipated that Bangladesh will experience an increase in temperature of about 34.7°F (1.5°C) by the year 2050 (The World Bank, 2021). In Bangladesh, 70% of people live in rural areas, and 40% of people live below the poverty line (MoEF, 2009). Ensuring proper nutritional intake involves meeting the protein demand of the country, thus, immense growth in poultry industries is observed making it the country's second-largest livestock after fisheries (BARC, 2011). Considering the current circumstances, it has proven to be a serious impediment to the expansion and production of poultry. Additionally, insufficient power supply all around the country has led to the liquidation of many poultry farms. It was estimated that more than BDT 150 thousand million was invested in poultry farms across Bangladesh and the collapse of this industry would not only result in a fall in the country's GDP and an increase in the unemployment rate in rural areas but also a deprive people of their meat based protein demand (M.A. Hamid et al, 2017). Considering the expensive mitigation measures to tackle the escalating temperature and lack of resources in rural areas, the poultry industries are at risk of going out of business due to depreciating, and in some cases marginal profits which might result in a scarcity of meat-based protein throughout the country.

Fig. 1

Poultries gathering below ceiling fans due to extreme heat

It has been observed that the corrugated iron sheets used in poultry sheds absorb heat, accumulate it over time, and emit it inside the shed. Thus, the indoor ambient temperatures in the poultry shed exceed the comfort zone of livestock, such as chickens. Consequently, there is a decreased production of eggs and weight in chickens as they start to consume less feed when the temperature surpasses their bearable temperature. During prolonged periods of high temperature, poultry experience heat strokes, and the mortality rate of poultry increases. Poultry farmers installed ceiling fans as a measure to cool down the chickens. Unfortunately, that too has proven to be ineffective due to frequent power outages. This has led to many poultry farms going out of business due to marginal to no profit.

The study aims to provide an economically viable and easy solution to mitigate the adverse impacts of heat on Poultry Farming by utilizing an interdisciplinary approach combining scientific analysis, data estimation, economic evaluation, and farmers' engagement to provide solutions and assessing the potential relationship between the corrugated iron roof and paints to mitigate the effect of heat on poultry farming. The overall objective of this study is to contribute to the development of functional strategies and guidance for helping Poultry Farmers and policymakers adapt to changing climate and escalating heat waves while promoting sustainable and economically viable Poultry farming in small-scale farms within rural communities.

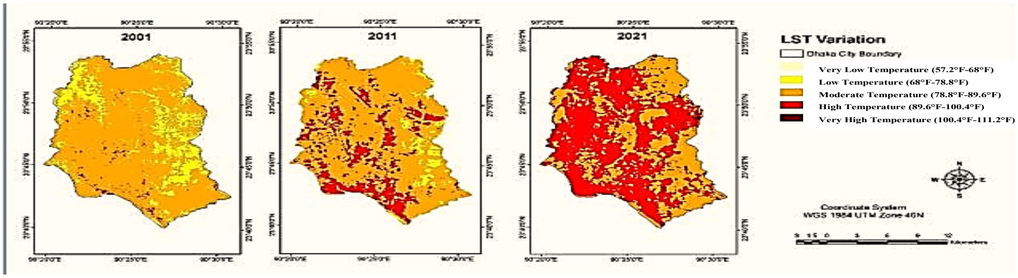
Data and Methods

A mixed method has been applied for this project. For a more reliable and accurate result, a number of methods were carried out in this study. Considering only one type of analysis (i.e. qualitative research) might not be sufficient to completely depict the issue.

Bangladesh is known for its six different season variations. Due to climate change summers in Bangladesh are getting hotter and longer, now lasting from February to October. Similarly, the monsoon season is extending from February until October, along with reduced rainfall during the peak monsoon period in some regions. Winters are also becoming warmer. In recent years Bangladesh has experienced a noticeable trend of rising temperature, with Dhaka recording a historic maximum temperature of 105.08 °F (40.6°C) on April 15th 2023, the highest in decades.

Fig. 2

Land Surface temperature map of Dhaka City (Mou & Ishmam, 2021).



These rising temperatures are consistent with the current climate, which has warmed by 34.16 °F (1.2°C) since pre-industrial times due to human activities (TBS Report, 2023). The increasing temperatures pose significant challenges for Bangladesh, affecting daily life, the environment, and the economy in various ways. The effects of rising temperature in Bangladesh lead to increased heatwaves. These heatwaves not only effecting people but also have detrimental effects on agriculture and livestock. Livestock is one of the fastest-growing industries in Bangladesh, contributing about 2% to the country's GDP and more than 16% to the agriculture sector in the Fiscal Year 2021-22 (Hossain, 2023).

Poultry such as chickens is homoeothermic, meaning they maintain a constant body temperature being unaffected by any changes in their surrounding environment. The effects on poultry due to a range of temperatures are explained in the table below.

Table 1

Effects on poultry in different temperature zone (Amit, 2023).

Temperature Range	Effects on Poultry
55° to 75°F	The thermal neutral zone refers to the specific temperature range within which chickens can maintain their body temperature without the need to adjust their basic metabolic rate
65° to 75°F	Ideal temperature range
75° to 85°F	At this zone, a slight reduction in feed consumption is expected, but with adequate nutrient intake, production efficiency remains high. However, there may be potential effects such as reduced egg size and compromised shell quality.
85° to 90°F	Weight gains are lower. Egg size and shell quality deteriorate. Egg production usually suffers.
90° to 95°F	Feed consumption continues to decrease. There is some danger of heat prostration among layers, especially the heavier birds and those in full production.
95° to 100°F	Heat prostration is probable. Emergency measures may be needed. Egg production and feed consumption are severely reduced. Water consumption is very high.
Over 100°F	At these temperatures, the primary concern is the survival of the birds.

The ideal temperature range for optimal poultry production is usually between 65°F-75°F (Rakesh Kumar, 2016).

When the ambient temperature exceeds this range the birds are susceptible to heat stresses. Heat stresses occur when a bird is struggling to find the equilibrium between body heat production and body heat loss. On average, during the summer the temperature of Dhaka and its peripheries range from 80^{o}F-90^{o}F. When the ambient temperature exceeds the body temperature of the poultry, the birds cannot carry out non-evaporative cooling. Consequently, birds are compelled to control their body temperature by means of panting which takes up a lot of energy. This can lead to reduced intake of feed and weight loss of poultry. An increase in evaporative cooling reduces the poultry's ability to retain water inside the body even if they are fed more water or electrolytes. Further symptoms of heat stress are poor eggshell quality, reduced hunger, and even death.

In this study, a questionnaire survey of Poultry farmers was conducted to gather information on their existing practices and challenges regarding increasing heat. In addition to that, an economic analysis was done to evaluate the potential cost-effectiveness of different heat mitigation measures. The survey questionnaire was designed to acquire relevant knowledge about farmers' current infrastructure, ventilation system, existing heat mitigation measures, ongoing maintenance cost, and business profit.

Fig. 3

Questionnaire session with a Poultry Farmer

In light of the current climatic conditions and resource strapped economy, an approach of paint coating the corrugated iron sheets was taken to abate the indoor shed temperature. The color chosen for this study is White Enamel paint and Red Rust-Proof paint. Both of these colors have diverse properties due to the differences in their reflective, absorptive, and radiation characteristics. These properties influence how colors interact with light and heat.

To investigate the impact of different colors on corrugated iron sheets on temperature levels, several experiments were conducted. The experiments were carried out using six pieces of corrugated iron sheets, all having similar dimensions (25'' x 17''). Two iron sheets were allocated to each color and two were kept in their manufactured conditions without any paint coating. Two samples of each color were chosen for more precision of data and to rule out any anomalous values. Only the colors anticipated to have optimum reflective, heat retardation, and radiation properties in warm climates were chosen, one being white enamel paint, while the other being red rust-proof paint. The painted and unpainted sheets were installed on a rooftop at the same angles where sunlight directly falls to assess their effectiveness in reducing heat.

Fig. 4

Sample of coated and uncoated corrugated iron sheets in sunlight.

In order to measure the temperature variations, an infrared thermometer was used. To ensure consistency in the data collection process, temperature readings were taken at regular intervals at specific locations on the corrugated iron sheets to maintain consistency across the experiments. Temperature readings were taken every 30 minutes of the upper surface that directly contacts sunlight to observe the heat reflection or retention. Before taking the upper surface reading, another reading was taken after 10 minutes to observe the heat transfer on the lower surface of the corrugated iron sheets. Temperature readings were recorded from morning until evening to evaluate fluctuations in temperature during periods of maximum sunlight exposure.

Fig. 5

Recording temperature reading using an infrared thermometer.

These different weather conditions were chosen to capture a range of environmental factors that could affect temperature levels within the poultry farm.

The color that yielded the most favorable outcomes was applied within a poultry farm. The ambient temperature of the poultry farm was recorded using a Hygrothermometer from morning till afternoon during summer. The Poultry farm worked on with is situated in Baupara, Ward no 22, Gazipur, Dhaka. There are more than 500 farms in this area with the same climatic conditions and topography, thus, the heat mitigation measure can be applicable to all the farms.

The existring condition of the poultry farm was observed to assess the severity of the situation and to evaluate proper implication of mitigation measure. The boundary of the poultry farm chosen is bounded with nets and cloth covers as a method of ventilation and reducing temperature inside the poultry. In addition to that, ceiling fans are installed in different places inside the poultry farm to prevent heat stress in poultry. The poultries are also fed saline through a water distribution system during periods of high temperature. While visiting the farm it was observed that some chickens died due to extreme heat.

Fig. 6

Broiler chicken dying due to heat stress.

The white paint used in this experiment is enamel paint. Enamel paints contain petroleum spirit, white lead, oil, and resinous materials (Sreekanth & Asmatulu, 2013). Light-colored paints, such as white have high reflectivity, meaning they reflect a significant portion of the incoming sunlight. This helps to prevent the absorption of solar energy and reduces heat buildup on surfaces coated. The enamel paint can also absorb some of the heat that is transferred to the surface of the metal, preventing some of the heat from reaching the interior.

Red rust-proof oxide paint is typically formulated with iron oxide as the primary ingredient, which gives it a characteristic red color. Iron oxide is a relatively poor conductor of heat, so it can limit the amount of heat that is transferred from the metal surface to the interior of the metal.

In addition, red oxide primer can absorb most of the sunlight that hits the metal surface. The absorption of light by paint colors determines the amount of energy they capture and convert into heat. Darker colors such as red have higher absorption rates, meaning they absorb a larger portion of the light spectrum, including the more energetic wavelengths like ultraviolet (UV) and visible light. Additionally, emissivity refers to a material's ability to radiate heat. Paint colors with higher emissivity can efficiently release absorbed heat back into the environment. In general, darker colors tend to have higher emissivity, making them better at dissipating heat compared to lighter colors, which have lower emissivity and may retain more heat.

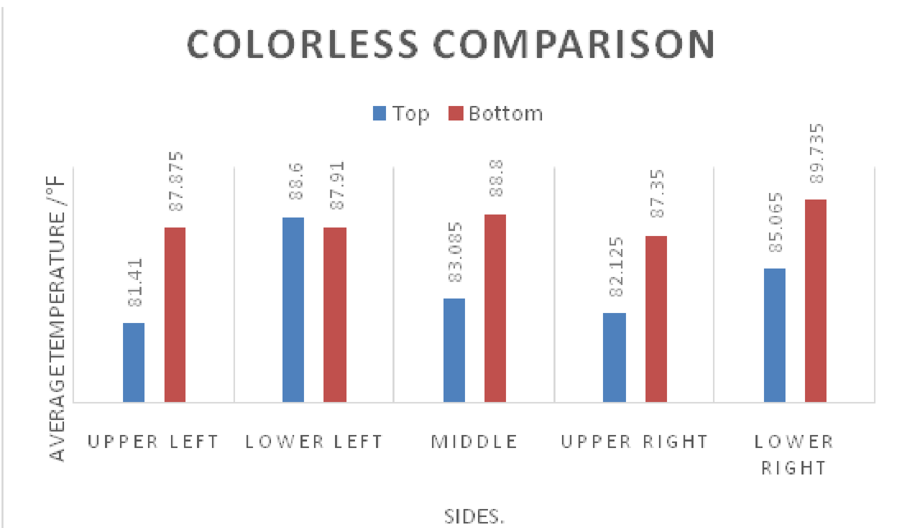
Results and Discussion

The aim of this study is to decrease the indoor ambient temperature in poultry farms to an endurable level. Thus, the main focus would be on the amount of heat transferred from the top surface of the corrugated iron sheets to the bottom surface, which is responsible for increasing the ambient temperature inside the poultry. Prior to implementing on real life scale, the experiment was done on several small samples with several data points recorded on 5 different sides of each corrugated iron sheets to assess the distribution of heat and for a more comprehensive understanding of the impacts of the coatings on the corrugated iron sheets.

It was observed that throughout time as the uncoated iron sheets were kept under sunlight, they were getting hotter, increasing the temperature of both the upper and the lower surface. Even though the shiny upper surface reflected some sunlight, most of the heat was absorbed and was accumulated throughout the day.

Fig. 7

Comparison of average temperatures on five sides for both surfaces

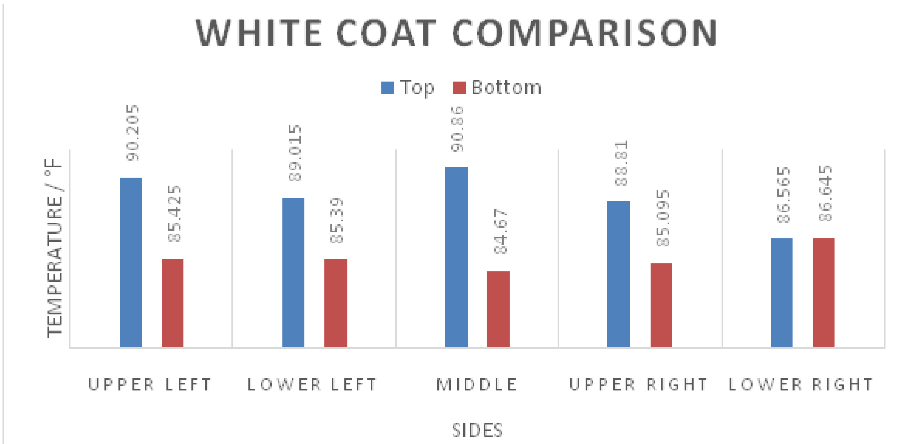


The bar graph depicts that the bottom surface was warmer than the top surface because of the reflectamce by the top surface and absorption of a significant portion of the heat and conducting it all throughout the surface. Additionally, the lack of insulation in the uncoated corrugated iron sheets allows more heat to be transferred to the bottom surface where it is accumulated. As a result, the overall ambient temperature is expected to rise throughout the day if corrugated iron sheets are installed.

As a measure to reduce the ambient temperature inside the poultry farms, the corrugated iron sheets were coated in white enamel paint. A significant drop in temperature was observed on the bottom surface as the white paint reflected back more sunlight and absorbed less heat.

Fig. 8

White Coat Comparison of average temperatures on five sides for both surfaces

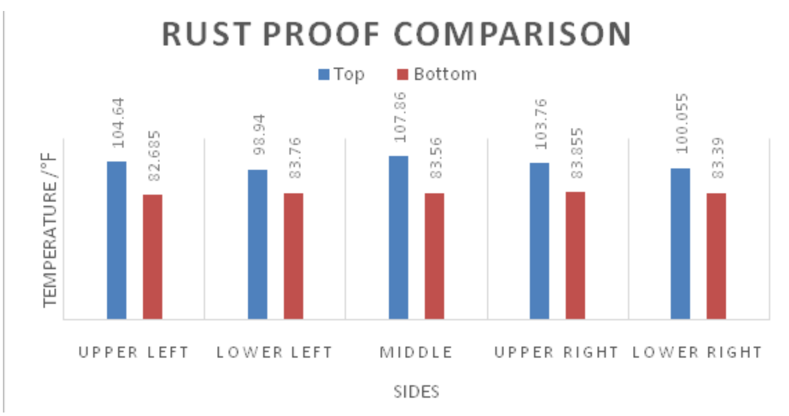


The bar raph shows that a higher temperature was recorded on the top surfaces compared to the shiny colorless corrugated iron sheets. On the contrary, the temperature on the bottom surface was significantly less, meaning the heat transfer was lower than that of colorless iron sheets. The application of white-coated iron sheets is more likely to reduce the ambient temperature than installing uncoated corrugated iron sheets.

Red Rust-proof paint contains iron oxide which protects iron sheets from rust and corrosion. The red of this paint is darker in color and possesses properties like emissivity and radiation. When painted red rust-proof it was observed that there is a significant amount of drop in ambient temperature.

Fig. 9

Red Rust Proof coat comparison of average temperatures on five sides for both surfaces

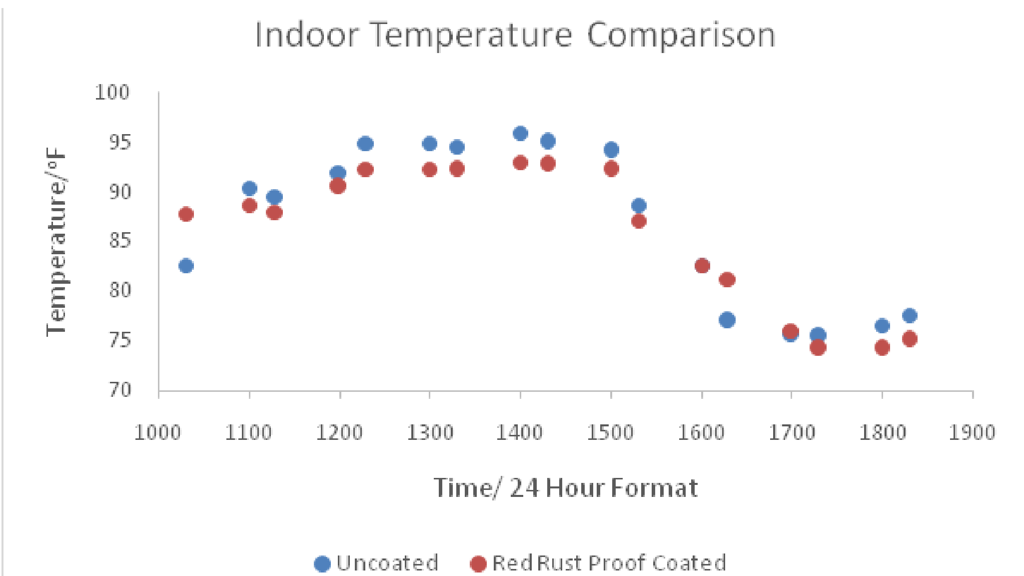


The bar graph demonstrates that the upper surface of the red rust-proof coated iron sheet exhibits a higher temperature compared to the white paint iron sheet or uncoated one. However, the temperature of the bottom surface remains relatively lower than both the uncoated and white coated corrugated iron sheets. The graph indicates that a significant amount of sunlight heat is absorbed by the red rust-proof paint. This can be attributed to the presence of iron oxide in the paint, which acts as a poor conductor of heat, limiting the transfer of heat from the metal surface to the interior. Moreover, the red oxide primer absorbs a significant portion of the sunlight that strikes the metal surface, further reducing the amount of heat transferred to the metal. Due to the higher emissivity of the darker sheet, such as the red rust-proof painted corrugated iron sheet, heat is effectively radiated away from its surface, resulting in a cooler temperature at the bottom surface of the iron sheet.

As established before the corrugated iron sheets coated in red rust-proof paint transferred the the least amount of heat when compared to uncoated and white-coated corrugated iron sheets. Thus, it is expected that applying red rust-proof paint on corrugated iron sheets will reduce the ambient temperature of the poultry the most. Following the experimentation on small samples, the effectiveness of this method is examined on poultry. Two poultry sheds of similar dimensions were chosen. One shed was unaltered to observe the existing condition inside the poultry, while the other shed was coated with red rust-proof paint to distinguish the temperature variation.

Fig. 10

Ambient temperature comparison between uncoated and Red rust proof painted Poultry Shed



During the morning, the temperature difference between the two sheds was insignificant. Throughout the day, the ambient indoor temperature inside the uncoated poultry shed ascended more quickly than the one in the red rust-proof coating.

Fig. 11
Red Rust-Proof Painted Shed

Fig. 12
Coated and Uncoated poultry shed.

An average temperature difference of 2°F- 4° F was observed between the two sheds from noon to evening. Both heat transfer and emission were less in the coated shed when compared to the uncoated shed. During rain not oly the uncoated shed cooled down rapidly but also gained back heat rapidly once the rain stopped which can lead to life-threatening shocks. On the other hand, the temperature loss and gain in the rust-proof coated iron sheet were more gradual and remained consistent.

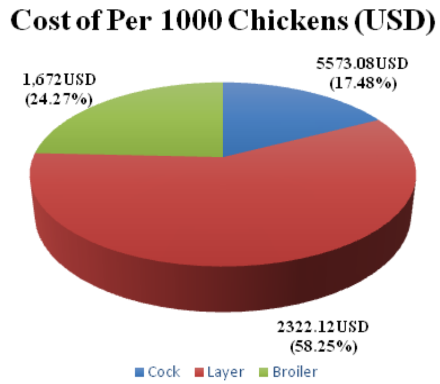
It is observed that the uncoated shed experienced temperatures exceeding 95 °F with a wet bulb temperature of 83.96 °F which is on the verge of being a health hazard as wet bulb temperature beyond 87 °F and humidity of 50% or above requires immediate cooling treatment as such conditions can be life-threatening as stated by Penn State. On the other hand, the rust-proof coated shed experienced temperatures upto 92 °F with a wet bulb temperature of 82.1 °F, thus, reducing the risk of heat stresses. From the survey with the local poultry owners, it was acquired that 7-8 chickens die daily during summer or spells of heatwaves. Adapting to this mitigation measure will surely cut down the death toll of poultry.

From the graph, it can be observed that the only time the ambient temperature of the uncoated iron sheet was less than the red rust-proof coated iron sheet was during the period when it rained. Even though the poultry shed coated in red rust proof paint had poor ventilation due to cloth coverings when compared to the uncoated shed, the overall ambient temperature was less. Thus, it can be expected that with the implementation of proper ventilation, a further decrease in ambient temperature can be observed in the red rust-proof coated poultry shed.

Over the years due to meat-based protein demand, the poultry meat production cost has experienced a 9.3 cents (10BDT) rise. Additionally, per kg of broiler chicken is sold at USD 2.23-2.32 (BDT 240-250). While eggs sell at a price of US cents 12-15 (13-16BDT) a piece that is higher now than ever. Even after a good market value small-scale poultry farmers are going out of business. The poultry industry, still recovering from the impacts of the COVID-19 pandemic, is now facing additional challenges due to prolonged power outages and the adverse consequences of a significant increase in fuel prices. An estimated 8-10 hours of power outages occur regularly in rural areas. Thus, diesel-run generators are used in poultries adding up to the cost of maintenance. Due to inefficient ventilation within the poultry, poultry farmers are compelled to breed less number of chickens during summer to prevent heat stress. To add to that transportation costs surged by 25-30 %. The production of chicks drops to 25-30% due to breeding costs ascending by US cents 2.3-2.6 (2.5-2.75 BDT) per chick.

Fig. 13

Value of different types of chickens per 1000 in USD



The pie chart depicts that it costs more to purchase broiler and layer chickens. These two types of chickens also need a proper cooling system to survive in the hot and humid weather of Bangladesh. Poultry farmers installed ceiling fans in the sheds where these two types of chickens are being bred. They use locally produced feed for chickens which costs 50kg bag 28.42 USD (BDT 3060). Also, the transport fare has now increased to USD232.21-USD250.79 (BDT25,000-BDT27,000) per pickup van (Ali, 2022).

Table 2

Cost of Broiler Production in small scale poultry farm (Source: Kawser Poultry Farm)

Cost Item	Cost in USD
Housing cost	577.30
Broiler Equipment cost	406.23
Feed cost	2319.07
Total labour cost	182.63
Utility cost	278.65
Veterinary	122.61
Litter cost	31.09
Transportation cost	232.21
Total cost	4149.79

With the maintenance cost already bring very high the increased mortality rate of poultry due to heat stress makes the business difficult to run for small-scale poultry owners considering that the market value is always fluctuating and at times they do not make significant profit. The proposed measure would not only save more poultry and bring in more profit, it will also save around 200 USD per month worth of fuels required for generators for extended cooling in poultry sheds.

Conclusion

Bangladesh is one of the countries that is most vulnerable to climate change and the temperature is increasing at an alarming rate. The weather is being altered due to the influences of climate change making summer longer and hotter. Additionally, Bangladesh is an overpopulated developing country going through an industrialization phase, meaning there is a high demand for energy. Due to the shift from agriculture to industrialization, more power consumption is taking place. Unfortunately, Bangladesh cannot produce the required amount of electricity for its people and industries which can be seen by the frequent power outages taking place all over the country. The increase in overall temperature along with changes in weather patterns and frequent power outages has taken a massive hit in poultry industries. Poultry industries play a significant role in meeting the meat-based protein demand across the country and creating employment in rural areas for both men and women. Due to the aforementioned reasons, poultry owners are going out of business due to marginal to no profit, mainly because of birds experiencing heat stresses and dying. In 2022, 800 chickens died due to heat stresses as the poultry owners were unable to operate their cooling systems because of frequent power outages (Dhaka Post, 2022). The mitigation measure focused on in this paper was proposed considering its availability, feasibility, and how economically viable it is. The poultry sheds were coated in red rust-proof paint which reduced the ambient temperature of the environment where poultry is maintained. The reduction of temperature can lead to a decreased mortality rate of poultry. Consequently, poultry owners can profit more by implementing this mitigation measure. The red rust-proof paint can also enhance the longevity of the corrugated iron sheets making them last longer. It's important to note that other factors, such as ambient temperature, air circulation, and insulation, can also influence the overall heat transfer in a given system. The color of the corrugated iron sheet alone is not the sole determinant of heat transfer, but it can play a role in combination with other factors.

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Appendix

Values for Fig 11

Time	Uncoated Corrugated Iron Sheet	Rust Proof Painted sheet
1030	82.6	87.8
1100	90.4	88.7
1130	89.5	88
1200	91.9	90.5
1230	94.9	92.3
1300	94.9	92.3
1330	94.5	92.2
1400	95.9	93
1430	95	92.7
1500	94.1	92.2
1530	88.7	87.1
1600	82.6	82.6
1630	77	81.2
1700	75.6	76
1730	75.4	74.2
1800	76.5	74.2
1830	77.6	75.1