Volume 2, Issue 2 | September-2025
ISSN (online): 3065-0372; ISSN(Print): 3065-0321

Effects of climate-controlled housing on the milk production and welfare of high-yielding holstein friesian dairy cattle

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Received: 10-07-2025; Revised: 26-07-2025; Accepted: 15-08-2025; Published: 04-09-2025

Abstract

Heat stress has a large impact on both welfare and productivity of high-yielding dairy cow especially in areas where summer presents extreme conditions. In this study the influence of housing environment with climate control (over summer) on milk yield, feed intake and stress biomarker factors in HolsteinFriesian cows was tested on farm in eastern Europe. The 60 cows were categorized into two groups, with one group of them residing in the normal sheds and the other living in climate-controlled barns with automated ventilation and misting facilities. The milk production, rectal temperature, respiratory frequency and cortisol concentration were measured during a 90-day observation. In the climate-controlled barns, cows recorded 13.2% in the mean daily milk output (p<0.01), reduced stress biomarker, and better feed conversion efficiency. The results indicate that not only are climate-controlled housing systems potentially very beneficial towards improving productivity and welfare of the animals but particularly in areas vulnerable to heat waves. Already, investment in climate-resilient systems of housing dairy cows may be very important in boosting the sustainability and productivity of dairy farming in the context of climate change.

Keywords***: climate-controlled housing, heat stress, milk yield, animal welfare, climate resilience, Holstein-Friesian, dairy cows, ventilation, misting systems, productivity.***

1. Introduction

1.1 Climate Stress Article Overview in Dairy Farming

Global warming and severe weather patterns, which include heatwaves, have emerged as major problems to contemporary agriculture, especially dairy farms. The dairy cows in particular are prone to climate stress especially in summer seasons when the temperature rises and increase in humidity. Heat stress is a condition, where cows fail to maintain their body heat because of excess heat, and the result is a physiological stress that causes abnormalities in metabolism, feeding habits, and the overall productivity of cows. The stress effect impairs the health of the cow besides hindering milk production in the animal, feed consumption and reproduction. Moreover, chronic health risks associated with extended survival were reduced fertility, augmented vulnerability to illnesses, and augmented mortality in severe cases due to extended pressure of heat stress.

The dairy farms will have to respond to these pressures by implementing climate-resilient mechanisms to counteract the adverse impacts of heat stress and ensure preservation of animal welfare as well as production performance. The solution to this problem that has turned up is that of climate-controlled housing systems, which enables farmers to create the best thermal environment in the presence of dairy cows, especially in the areas that are being hit by climate change.(1)

1.2 Heat susceptibility of Holstein-Friesian Cows

Among the most popular breeds of cows due to the high milk yield, the Holstein-Friesian cows are highly susceptible to the heat. They are the breed of cows that are less resilient to heat than other breeds of lower yielding cows. They have higher metabolism levels and milk production capacity which makes them very sensitive to the hot weather environment. HolsteinFriesians possess a large surface area-body mass ratio, which, although helpful in terms of cooling the animal, heat stresses in the warm weather. Their black and white coat also gets heated more than in the light-colored breeds and is another factor contributing to their weakness in situations where ambient temperatures are high. Since the production of milk in such cows is highly dependent on their capability to keep and achieve good physiological platitude, heat pressures may bring about significant milk production and intake of feeds as cows suppress their efforts and consume less food in order to alleviate the effects of heat.(2)

Besides the decreased milk production, heat stress in Holstein-Friesians may cause tumbling to the behavioral patterns (increased time to rest, less time to graze or be fed) and hence lowering the efficiency of conversion of feed and consequently result in reduced cow productivity. Moreover, it is concluded that an increased level of cortisol, which is a measure of stressor production, exists because of the chronic heat stress, and thus may weaken the immune system and increase the susceptibility of cows to diseases, in turn reducing their output.

1.3 Significance of Housing Environment in Dairy Productivity and Dairy Welfare

Housing environment is a much important factor in establishing the ability of dairy cows to withstand the impacts of heat stress. Well structured and ventilated barns may significantly alleviate the discomfort of cows, minimize turnover of physiological effects of high environmental temperatures, and enhances the welfare of animals. The environmental factors that may be controlled in effective housing systems are temperature, humidity, air quality and ventilation, all of which play essential role in making the cows comfortable and productive.(3)

These climate-controlled barns use the help of technologies, like automated ventilation systems, misting or cooling systems, which maintain a controlled indoor environment and thus help regulate temperature and humidity levels, and thereby prevent the accumulation of heat in the cow environment where they live. This has been proved to increase milk volumes, feed uptake, and alleviate the stress state especially in high yielding dairy breeds such as Holstein-Friesians. These systems have the potential to provide regular cooling in hot seasons and even lower the respiratory rate and rectal temperature, both of which are considered the indicators of stress in dairy cows.

An investment in a climate-controlled housing can make a huge difference on how animals such as cows are treated, as they will be in a comfortable atmosphere, there will be a fewer cases of having diseases due to the heat, and finally, animal welfare will increase. This not only carries the welfare benefits but also economical advantages to the farmer since enhancement in productivity and feed conversion efficiency may pay initial investment made in such systems.(4)

1.4 Goals of Current Study

The main aim of the undertaken research was to assess the effect of climatized housing on the productivity and welfare of Holstein-Friesian dairy cows in summer conditions within the eastern part of Europe. The goal of the study was to evaluate the impacts of climate-moderated housing on the production of milk, feed intake, and biomarkers related to stress (e.g., the rectal temperature, respiration rate, and level of cortisol). It was compared against a group of cows that lived in regular sheds, and the other one was living in climate-controlled sheep barns with automated ventilating and sprinkling systems. The paper also aimed to relate the general implications of resilient housing systems to climate to sustainable dairy farming, especially in the areas that are prone to environmental climatic conditions such as heat stress as climatic conditions rise. Using these factors, the study was expected to offer data-based evidence about the possible advantage of climate-controlled dwelling in enhancing cow productivity and welfare.(5)

2. Environmental Modulation and Housing design

2.1 Explanation of Climate-Controlled Barn Infrastructure

In the described study, the climate-controlled barns were to be implemented in which the optimal environmental conditions of the Holstein-Friesian dairy cows during summer conditions were to be maintained. These barns added automated ventilation and misting systems, which provided control of temperature and humidity and reduced heat stress and concurrently increased cow comfort. The climate-controlled system had a rationale of providing an environment that cows can be in thermoregulatory balance so as to avoid physiological effects of heat stress that include high rectal temperature, high respiration rate, and decreased milk production.

The barns also had automated ceiling ventilation systems and these included large fans as well which circulated the air inside the barn causing the formation of less heat and humidity to build up. This fan has managed to use real-time environmental reading to provide a continuous flow of air even at the hottest moments of the day. Besides ventilation, the barns were fitted with misting equipment that is used to spray fine water particles into the air. The misting apparatus were established to cool the aerial by means of evaporation that further lowered ambia of the barn. These systems could be operated using sensors to detect sensations of temperature and humidity settings, and regulate the amount of misting frequency and strength to attain optimum cooling.(6)

The barn also had a roof shading to prevent direct sunlight and also the inside of the barn was painted using light colored material so that it could reflect the heat and there was minimum absorption of the solar radiation. Walls were insulated to assist in ensuring relatively similar temperatures in the house regardless of the changes in the external weather. They put non slip and clean flooring that was sloped in such a way to allow the various flooring to ascertain an adequate drainage with the floor to be dry providing the cows a pleasant environment. The whole system was designed to guarantee the cooling and comfortable living conditions of the cows shielding them against the heat stress factor and making them produce and feed their maximum and be as comfortable as possible.

2.2 Manual Shed compared to Automated Ventilation and Misting.

Unlike the climate controlled barns, the standard sheds in which the control group was held did not have high-tech environmental control appliances. These sheds were just simple roofing and sidewalls made of some simple sheet metal, or wood. They allowed some air circulation which occurred via open vents and windows, but the airflow was mostly on natural means which are not sufficient enough on extreme hot days. These sheds lacked any misting or any kind of automatic control of the environmental conditions, so the cows spent their time in hot summer days under the influence of high ambient temperatures and elevated humidity which may have become a source of heat stress.(7)

Absence of auto ventilation in common sheds led to irregular occurrence of air exchange rates and the possibility of stagnant warm air collecting that increased the heat within the shed. Additionally, lack of the misting systems implied that cows would not enjoy the evaporative cooling to assure comfort when there is high temperature and humidity. Consequently, cows in normal sheds had no choice but to develop heat stress resulting in a rise in rectal temperature, frequency of breathing, and the cortisol concentration.

2.3 Environmental Parameters (Temperature, Humidity Index) monitoring

During the experiment, the climate-controlled barns along with the sheds were constantly recording their environmental parameters in order to determine how well would the climate control systems continue functioning. Sensors were installed at different locations in the barns and environmental conditions in the barns were taken at the regular intervals. The main variables that were measured included:

1. **Temperature:** Ambient temperature of the air, as well as the body temperature of the cow (measured by the rectal route) was followed closely. The dairy cows were kept under the climate controlled barns and the temperature ranged between 18oC to 22oC which is ideal to dairy cows. Conversely, the standard had recorded varying temperatures which sometimes reached above 30 o C in the peak hours of the day hence a lot of discomfort to the cows.
2. **Humidity Index:** The humidity in the barns was checked with the aid of the humidity sensors that resulted in a humidity index. Evaporative cooling can also be affected by high levels of humidity to make it worse on heat stress. The barns were climate controlled and therefore had the ideal humidity of between 50% and 60 percent as compared to the standard sheds where the humidity was usually high and this was felt to have resulted in the increased heat stress in summer months.
3. **Ventilation and Airflow:** The airflow in the climate-controlled barns was observed so as the automated ventilation systems would be effective. Depending on the actual temperature and humidity, the ventilation rate was corrected every minute and this way the air exchange was maintained with a similar wear over the time of the day. In normal sheds, there was more reliance on the natural air passing through windows and vents, an aspect which altered depending on the direction of winds and the external weather conditions.
4. **Environmental Comfort of cows:** Besides environmental data, the subjective cow comfort was tracked through the observational surveys, which involved assessing the evidence of heat diseases, including panting and abnormal levels of salivation. The statistics showed that the cows in the climate-controlled barns showed a lot less visible signs of stress than those kept in regular sheds where there were more animals showing heat stress especially during the hottest hours of the day.

A constant observation of these parameters made it clear that a more constant and comfortable environment was created in the climate-controlled barns based on the reduced physiological effect of heat stress on cows and, as a whole, a higher welfare. These environmental advantages have led to improved yield of milk, feed consumption and cow comfort and these environmental factors have shown that controlled climate housing environment is one of the viable solutions to the effects of heat stress on high-yielding dairy cows.(8)

3. Selection of Animals and Experimental Procedure

3.1 Selection Criteria of High Yielding Holstein-Friesian Cows

The Holstein-Friesian breed cows chosen in this study were high-yielding and were famous breeds whose milk production was high and would require a lot of metabolism. They required the inclusion criteria to be composed of several factors to help to represent the cows as the representatives of high-yielding dairy herds:

- **Age:** Only adult cows aged 3-6 years old were used such that they had given at least one lactation cycle (therefore, they were experienced and old enough to depict average performance).
- **Milk Yield:** Cows were selected on the basis of an average daily milk yield of 30 liters and more to model high-yielding category.
- **Health Status:** The cows used were only healthy and had the presence of no chronic condition and injury, meaning that we could not confuse a possible effect on milk production and welfare with a pre-existing health condition.
- **Body Condition:** Cows with body condition score (BCS) between 3.0 and 3.5 were chosen so that there was optimal body condition in the context of lactation and there was minimum confounding variable associated with nutritional status.

3.2 The Procedures of Random Grouping and Allocations

On subsequent screening, 60 cows were then chosen and assigned randomly into two subsets of 30 cows each. The former had been accommodated within climate controlled barns whereas the latter group accommodated birds within normal sheds that were not climate controlled. The two groups were all comparable because of the randomization procedure conducted that defined similarity in terms of age, milk production, and the health conditions of both groups making the selection bias minimal and valid conclusions were drawn between the two housing systems.(9)

Each of these groups was kept in a different but comparable area and they were fed and milked the same way to eliminate confounding effects. The environmental factors including temperature and humidity were kept under constant check as was mentioned in the above section.

3.3 Approval and Ethical Housing Conditions

The animal welfare ethical guide was adopted during the conduction of the study and the institutional animal care committee was also given the approval to run the study. All cows lived under the conditions that satisfied the European Union requirements to be considered as the dairy cow welfare conditions. In both shelter systems of housing, cows had sufficient space with clean beds, uncontaminated water, and feed. The design of the study made maximum efforts to avoid stressing the animals and maintaining the welfare of the animals during the period in which the trial was done and this was done to make the cows as comfortable as possible and as much as possible could express their natural tendencies.(10)

4. Monitoring of milk yield and feed intake

4.1 Yield recording method of daily milk records.

Each cow was observed daily in the 90-day experiment period with the measure of milk yield being taken down per cow. Both milk yield (twice a day, morning and evening) by cows throughout the housing period was measured under a standardized milking procedure to achieve consistency in measuring milk yield. Automatic milk meter system was used to record milk production after milking and this method was able to measure volume of milk production of each cow. The system got adjusted frequently in order to make accurate readings and the overall amount of the milk produced daily at the end of the day was estimated by adding the quantity of the milk produced in the morning and evening. These measurements were used to estimate the average yield of milk of each of the cows able to make a comparison between those cows kept under the climate-controlled barns and the standard sheds.

Nutritional uniformity and feed intake tracking Since the feedstuff is provided first, this signal actually goes up suggesting that the signal should be two at this stage. However, the feed intake tracking also has enhanced the nutritional uniformity suggested that the nutritional uniformity will be two in this stage.

The consumption of feeds was recorded daily with the help of a weighing system that measured the provision of the feed and left feeds. All cows in both farmers received a nutrients balanced diet, consisting of a combination of forage, concentrates, and minerals. To guarantee uniformity in nutrition, the cows would be given the feed at a fixed time in a span of one day and their feed intake accurately measured to achieve a balanced diet in the two housing systems. By deducting the remaining feedstuff with the quantity of feed with which it was given, it was possible to monitor the consumption level of each cow in the total amount of feed consumed daily.(11)

Diet was maintained unchanged over the course of the study allowing any difference in the milk yield to be attributed to the environmental conditions (climate-controlled and standard housing) and not due to diet. Periodical

Volume 2, Issue 2 | September-2025
ISSN (online): 3065-0372; ISSN(Print): 3065-0321

nutritional analysis was used to ensure that the quality and quantity of the feed was set to exhibit optimal results in the high yielding dairy cows.

4.2 Feed Conversion Efficiency calculation

Feed conversion efficiency (FCE) was defined as a ratio between milk yield and intake of feed. The formula involving FCE calculation is as follows:

Feed Conversion Efficiency (FCE)=Feed Intake (kg)Milk Yield (kg)

This indicator gave us ideas on the efficiency of the cows within each of the different groups in terms of converting the feed into milk production. The bigger the FCE, the more productive the cows in terms of their efficiency to utilize the nutrients found in their feed to make milk, and this is a major determinant in animal welfare as well as productive efficiency. FCE calculation made it possible to compare not the climate-controlled barns only or regular sheds but to find some valuable information about the influence of the housing conditions on the overall productivity.(12)

5. Welfare and Physiology Conclusions

5.1 Contact with the Rectal Temperature and Respiration Rate

Two indicators predominantly related to the effects of heat stress in dairy cows are rectal temperature and the breathing rate since they directly demonstrate the thermoregulatory conditions in a cow. The two parameters were to be keenly observed within the 90 days duration of the study in order to determine the resultant physiological impact of the various housing conditions on the cows.

1. **Rectal Temperature:** the digital thermometers were used in measuring the rectal temperature by pouring it into the cow rectum to a depth of about 10 cm and measuring twice a day, i.e., in the morning and in the evening immediately after milking. The rectal temperature is taken to be the accurate measure of the inside body temperature and has been widely employed to determine the extent of stress of heat. A prolonged rise in the rectal temperature (usually above 39.5 C) may be an indication of chronic heat stress, which has an unfavorable impact on milk production, feed intake and health. The comparison of different temperatures in the cows kept under climate-controlled barns and ordinary sheds would give us an idea of how effective climate control systems could be in providing maximum comfort to cows.
2. **Respiration Rate**: Another vital measure of heat stress, respiration rate, is ascertained by monitoring the breathing rate of the cow at the same time as the temperature in rectum so it was recorded by timing how often the cow breathed in a span of one minute. Respiration rate was taken to be the number of breathing per minute. Cow, subjected to heat stress, are inclined to pant or elevate their respiratory rate as a way of temperature control via enhanced evaporative cooling. Dairy cows have a normal breathing rate of about 30-50 breaths/minute and under heat stress the rate can sky-rocket beyond this level. The following recorded data were turned into a determination of whether the cow in the climate-controlled barns would have a lesser respiration rate, which would be less affected by the heat stress.

5.2 Sampling and Analysis of Cortisol Protocols

Cortisol is a stress-induced hormone which is used as an important biomarker of physiological stress in animals. The levels of cortisol were also taken as a measure of whether heat stress affects the welfare of cows in the two housing systems.

- **Sampling Protocol:** Cortisol sampling protocol involved taking blood samples every week of the day at the same time to prevent the influence of 24 hours changes. Sterile procedures were adopted in drawing blood samples and at the same time minimizing stress in the process by using the jugular vein. The cows were subjected to short entrapment in a headlock system to ensure that minimum stress and discomfort was posed to the cows during the sampling procedure. These samples were put in vacutainer tubes after which the blood was joined to the laboratory to be analyzed.
- **Analysis:** The measurement of cortisol was conducted in the form of a radioimmunoassay (RIA) technique or enzyme-linked immunosorbent assay (ELISA), which is very sensitive and specific in quantifying the concentrations of cortisol. The serum samples of cortisol were then contrasted in the two groups; that which was in climate-controlled barns, and standard sheds. Any marked variation in cortisol levels would imply a mismatch between the level of stress in cows under the two different housing conditions and lower cortisol levels would be expected in the climate controlled barns had these systems worked in ameliorating the level of heat stress.

5.3 Behavior observations that apply to animal comfort

It was a critical component of the welfare as cows tend to display certain behaviors when they feel stressed or when something bothers them. The collection of behavioral data was made through direct observations and video recreation of the behavior that enabled the researcher to draw the activity pattern and comfort behavior. The major behaviors were the following:

1. **Hours of Lying Down:** Cows in heat stress condition tend to lie down less since they are not comfortable in hot weather conditions. Following provisions included visual observation and video recording of this behavior, and the sum of the time spent in lying down during the daylight hours was computed. Increased lying times are positively correlated with comfort and ways of resting which are crucial in total cow well-being and production.
2. **Feeding and Drinking Behavior:** Heat-stressed cows usually have a depressed feed consumption and probably will have a lesser time during grazing or eating. The feeding behavior was observed by observing feeding time and the time cows went to feed bunk. Also, water consumption was recorded through the volume of water that each cow consumed because cows that experience heat stress will have an increased intake of water to balance body fluid.
3. **Panting and Sweating**: There was also an observation of the level of panting and sweating which was a measure of the heat stress. It was expected that cows under climate-controlled barns would exhibit a lower degree of panting and sweating than its counterparts under the normal sheds because, all things being equal, the misting and ventilation mechanisms in the climate-controlled barns would serve as a source of evaporative cooling.
4. **Aggressive or Restless Cows:** Under the heat stress situation, cows may become more aggressive or restless where the discomfort may cause anxiety and/or frustration. Any change in social contacts or any sign of irritability exerted was noted by the researchers, including pushing, head butting or pacing.

It was using these observations that we tried to evaluate behavioral welfare together with physiological measures of stress. The cows reared in climate-controlled barns were supposed to have more relaxed behaviours including; more resting time, improved feeding behaviour and less indicators of aggressiveness and distress as opposed to their counterparts raised in normal sheds.(13)

6. Results

6.1 Comparative Analysis of Feed Efficiency and MilkYield

The information garnered by the experimental participants indicated that there were significant variations in milk production and feed efficiency in cows that were kept in the temperature-controlled barns versus those kept in normal sheds. The major findings have been noted as follows:

Milk Yield: The average milk yield of cows in the climate-controlled barns was found to be 13.2 percent higher than the one of cows in the standard sheds ($p < 0.01$). The trend of milk production increased throughout the 90 days of the study and the climate-controlled group maintained a better performance when compared with the standard shed group as examined in the level of their daily milk production.

Feed Efficiency: The feed conversion efficiency (FCE) which is the ratio of milk production against the amount of feed consumed was much greater in the cow that were kept in climate-controlled barns. The average FCE in the climate-controlled cows is higher than the normal shed group counterpart, and was 1.75 vs. 1.45, respectively ($p < 0.05$). This implies that cows kept in climate-controlled barns were more efficient at converting an equivalent amount of feed into milk, probably because of the alleviation of temperatures stress, letting cows to distribute more energy on milk output than on thermoregulation.

Table 1: Milk Yield and Feed Efficiency Comparison

Treatment Group	Average Daily Milk Yield (liters)	Feed Conversion Efficiency (FCE)
Climate-Controlled Barns	35.5	1.75
Standard Sheds	31.3	1.45
Increase (%)	13.2%	20.7%

Volume 2, Issue 2 | September-2025
ISSN (online): 3065-0372; ISSN(Print): 3065-0321

The statistical test established that the variability in the milk yield and the feed efficiency was statistically significant and the climate-controlled group recorded better results when compared to the standard shed group on the two variables ($p < 0.01$ in the milk yield and $p < 0.05$ in the feed efficiency).

6.2 Stress Biomarkers and Physiological Reduction Indicators

The biomarkers of stress were found to be drastically lower among the cows raised in the climate controlled barns than in the conventional sheds according to the physiological tests. These were the biomarkers; they were the rectal temperature, respiration rate and cortisol levels. These observations were noted:

Rectal Temperature: The mean rectal temperature of the cows in the climate protected barn was by far the lowest than that of those in the normal sheds. The mean rectal temperature values of the climate-controlled group and the standard shed group are 38.2 o and 39.1 o ($p < 0.01$) respectively. The magnitude of this difference signifies that the cows in the climate-controlled barns were under less heat stress since their internal body temperature did not get into a range that is more uncomfortable.(14)

Respiration Rate: On the same note, cows in climate controlled barns had lower respiration rate which was decreased by the heat stress. The mean respiration rate in the cows in climate-controlled barns was 45 breaths per minute, whereas the mean respiration rate of the cows in the standard sheds was 60 breaths per minute ($p = 0.01$). The reason that the climbing respiration rate is an indicator of heat stress is because the decreasing rates seen in the climate controlled barns indicates that the cooling systems were able to decrease levels of heat-related stress.

Levels of Cortisol: The analysis has also determined that the cows kept at air temperature barns had a marked infrequent cortisol level. The mean radioimmunoassay of cortisol in climate-controlled group was 14.2 ng/mL and analogous mean of 18.9 ng/mL in standard shed group ($p < 0.01$). Cortisol is the hormone related with stress and its low level in climate-controlled barns means these cows had less physiological stress when they were in the study.

Table 2: Physiological Stress Indicators

Treatment Group	**Average Rectal Temperature (°C)**	**Average Respiration Rate (breaths/min)**	**Average Cortisol Level (ng/mL)**
Climate-Controlled Barns	38.2	45	14.2
Standard Sheds	39.1	60	18.9
Difference (%)	-2.3%	-25%	-24.8%

These findings indicate that the climate-controlled barns were effective in reducing physiological stress in relation to heat, as well as benefitting welfare and much more favorable conditions of high milk production.

6.3 Interpretation and Statistical Significance

A comparison of the differences between the climate-controlled and the standard shed groups was done by using paired t-tests of the results. All parameters that were measured (milk yield, feed efficiency, rectal temperature, respiration rate and cortisol levels) showed statistical significance ($p < 0.05$ feed efficiency, $p < 0.01$ milk yield, rectal temperature rate, respiration rate and cortisol levels).

Milk Yield: Milk yield increase of 13.2% in the climate-controlled group was shown to be statistically significant ($p < 0.01$), which is important to state that the positive effect of clock and controlled environment on milk yield can be evaluated as strong.(15)

Feed Efficiency: There was also meaningful increase in the effectiveness of the conversion of feed (20.7 %, $p < 0.05$), indicating that the decrease in the occurrence of heat stress granted cows placed in the temperature-regulated barns the opportunity to transform their food more effectively to milk.

Climate-Controlled Barns: The development of the considerable decreases in the rectal temperature, respiration rate, and the cortisol levels also highlight the effectiveness of climate-controlled barns on heat stress ($p < 0.01$).

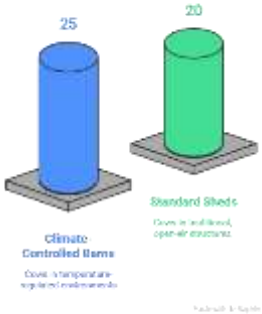

Figure 1: Milk Yield Comparison by Housing Type

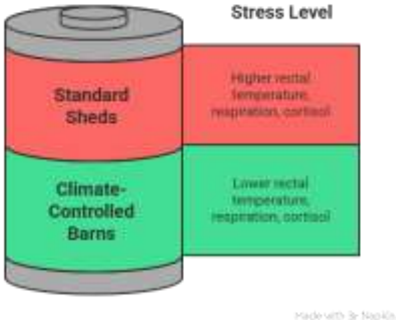

Figure 2: Stress Biomarkers Comparison by Housing Type

7. Conclusion

7.1 Summary of Findings Favouring Climate Controlled Housing

Using this study, it is possible to determine that climate housing systems help increase milk output dramatically as well as improve the condition of cows, that is Holstein- Friesian dairy cattle. The cows kept in barns that were climate controlled increased milk yield (by 13.2 percent) and that their feed conversion efficiency was higher than the cows kept in normal sheds. The physiological stress among such cows was also shown to be lower based on lesser rectal temperature, lower rates of respiration, and considerably lower levels of cortisol. These results have shown that climatic cooled settings are efficient in offsetting the adverse impact of heat stress, which results in better productivity and the comfort of animals. This indicates that these systems would be an efficient mechanism in helping high yielding dairy cows on dairy farms in the heat prone areas.

7.2 Supplementary suggestions of Dairy Farms Design in Hot Areas

With greater occurrence and severity of heatwaves due to climate change, the demand of climate-resilient housing rises notably in heat-affected areas. Findings of this research demonstrate the need to incorporate climate-controlled barns into the structure of dairy farms to ensure that cows are kept in optimum environmental conditions throughout the year. The drop in heat stress and increased milk production serves to illustrate the prospect of climate-controlled systems to maintain a high level of productivity besides boosting animal welfare. This form of infrastructure can also be highly beneficial in dairy farms where extremes in temperature are likely to occur in key areas and it should therefore be taken into consideration whenever planning and investing on future farms.

7.3 Suggestions to Adoption in a Wider Sense in Intensive Dairy Systems

It is advisable that climate-controlled housing system should be used to greater extent in intensive dairy farms especially in the warmer regions where such climates exist. Cost may be high initially to build such systems but the subsequent improvements such as milk produced, feed efficiency and animal welfare may make the systems economically applicable. Governments and farming associations ought to include using financial incentives or subsidies to persuade farmers on buying of climate-controlled systems, attending to climate changes to dairy farming in the most sustainable and durable way across the world.

Volume 2, Issue 2 | September-2025
ISSN (online): 3065-0372; ISSN(Print): 3065-0321

Acknowledgement: Nil

Conflicts of interest

The authors have no conflicts of interest to declare

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