Impact of Temperature-Humidity Index and heat reducing management practices on Milk Production at some selected areas of Bangladesh

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Impact of Temperature-Humidity Index and heat reducing management practices on Milk Production at some selected areas of Bangladesh

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Abstract

The very essence of ensuring wholesomeness and availability of milk is a matter of the consumers' health and food safety in Bangladesh. This research examines the impact of Temperature Humidity Index (THI) on milk production in some chosen farms in the area of Patiya Upazila, Chattogram, Bangladesh in the months of January, February, March, and April of 2024. The major findings were to see the impact of the Temperature Humidity Index on the milk yield in HF crossbreed cows and to compare the sensitivity of different farms to THI with some management practices. Information was obtained through structured interviews and assessed with key information. The statistical tests applied include Pearson's correlation test, the linear regression test, and the use of graphs using R (4.4.0). Nine farms were involved in the study, out of which only Farm A had provisions for heat stress management. It was observed that THI was high in April and lowest in January and the milk yield has depicted a decreasing trend for Farms B to I but constant in Farm A. Pooled Pearson 'r' values revealed the moderate negative relationship between THI and milk production in one of the farms (Farm A) and a very large negative correlation in other farms (Farms B to I). Therefore, it was found that high THI levels have a negative influence (r values close to -1) on the mean milk production in the study and the potential ways of ameliorating heat stress in dairy animals include regular showering, provision of fans, and air movement. Some of these practices were of great use in the fight against heat stress and steadiness of milk production. Thus, the realization of such practices is indicated to promote dependable milk production due to the effects of global warming. This study helps to each of the environmental factors affecting dairy farming most of all, the adverse consequences of high THI on the production as well as stressing the necessity for appropriate preventive measures like mechanical cooling. It is suggested to continue with the experimental trials to identify the efficacy of these strategies as separate steps and as combined measures to make dairy farming sustainable.

Keywords: THI, Heat Stress, Milk Production, Global Warming, Management

Chapter I

INTRODUCTION

The constant and fundamental need of the population and its uninterrupted quality supply of milk and other types of food products is one of the most important needs in supporting the health of a nation and ensuring food safety. It is possible to state that raising the productivity of quality livestock products specially milk and various dairy products is one of the prominent objectives for the development of animal farming globally, which acquires crucial significance with the growth of the population on our planet, particularly in our country (Gorelik, 2021). There are a total of 4323.79 (lakh in number) livestock population in Bangladesh among them 247 (lakh in number) are cattle population and the milk production is 130.74 lakh metric ton (*Livestock Economy at a Glance*, n.d.). However, the efficient production of animals is all about their health and a conducive environment where an animal is expected to live satisfying its physical requirements and behavior (Imrich, 2021). Thus, every species, breed, or type of animal has an optimum or comfort zone, where the metabolism, heat production of the animal, and its heat dissipation are all constant and independent of the ambient temperature. In this area, the animal suffers stress to achieve the state of homeothermy. This puts an extra load on how the body can regulate its temperature hence reducing the energy that should go into the actual manufacturing processes (Bianca, 1976). This changes the feeding behaviors, physiological and metabolism activities, and the pattern and productivity of the animal's production.

Today in the world, climate change is evident and research proving this is on the increase in pace. Increasing trends in global temperatures, changes in the regime of precipitation, and higher intensities of hazardous climatic events are some identified manifestations of climatic change. Dairy cattle are even more sensitive to high temperatures than other ruminants for the reason of high basal metabolism and the ineffective sweating mechanism, especially in the kidney and gastrointestinal regions (Bernabucci, 2010).

Heat stress may be incurred when the temperature of the surrounding environment crosses the temperature level of a cow's body and it can down production by as much as 50% of cow's milk (Salem & Bouraoui, 2011). Dairy cattle are most comfortable at a certain environmental temperature ranging between 5 to 25 degrees Celsius which is referred to as the thermo neutral zone (McDowell, 1976). Any encroachment with the ideal conditions is detrimental to their health and well-being and consequently to the quantity and quality of milk (Reyad, 2016).

One practical weather parameter that has been widely adopted in extrapolating the influence of weather on dairy cows because of its ease of determination is the THI (Hubbard, 1999) since it combines the impact of temperature as well as relative humidity altogether in one index. The crucial level of THI is between 70 and 72, in which production of dairy cows is affected, for which cooling is necessary. The milk production is significantly reduced at the range of THI of 72-78. At the THI level of 78-82, considered to be in the dangerous category, the production is significantly compromised and it is required to cool down the animals (Du Preez, 1990). The negative impacts of the dangerous category are altogether apparent at THI values of 82 and above in emergency conditions with increased vulnerability to death where it's very necessary to cool down the animals (Armstrong, 1994). (Nienaber, 2003) stated the emergence THI value as 84 initially. Based on the reviewed work by (Johnson, 1987), it was found that at 72 mean THI, the milk yield potential begins to decrease and the changes in THI are significantly associated with the losses in the milk yield potential. Significant declines are observed when the mean THI ranges from 76 to 78. A drop in production is when there will be a diminution of the daily production of milk which is 0.26 kg per day for one unit of THI escalation. According to the energy conservation and extension of the model heat balance, suggested by (Berman, 2004), the influence of body weight, uncovered body surface, milk yield, animal's coat, thermal radiation, airflow rate, humidity, and temperature are counted (Novak, 2009).

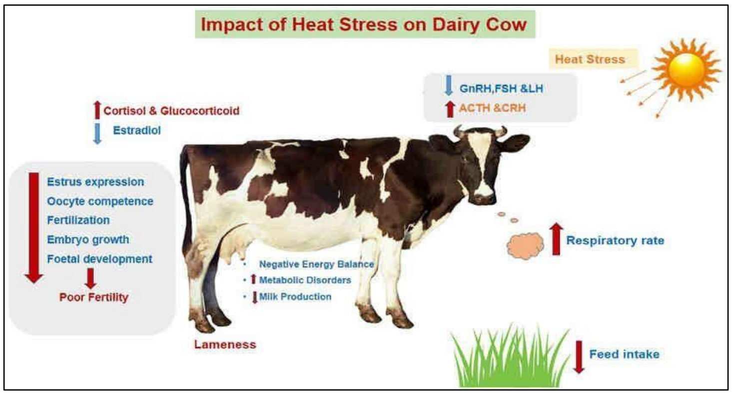

Figure 1: Impact of heat stress (Mondal & Reddy, 2018)

This sector is having increased challenges because of the various complications between environmental conditions and the efficiency of milk production, the impacts of the environment on dairy farms must be well understood to ensure the sustainability and profitability of dairy farming. Thus, the result from this current study could play a pivotal role in reducing the hardship of high temperature on milk production to some extent which in turn would contribute to the national economic fund as well as the general enhancements of the health of the people of this country. The primary goals of this study are:

- Identify the influence of THI on milk production of HF cross-breed cows.
- Assess the reduction that could be achieved from selected farm management practices on the influence of THI on milk production with that of non-adaptive farms.
- Compare the influence of THI on milk production in a farm implementing specific management practices against farms without such practices.

Chapter II

LITERATURE REVIEW

Heat stress, as indexed by the Temperature-Humidity Index (THI), poses a significant challenge to dairy production, particularly in regions with hot and humid climates. This phenomenon has been extensively studied for its detrimental effects on animal welfare, physiology, and productivity. The present review delves into the existing literature to elucidate the relationship between THI and milk production in dairy cattle, with a specific focus on the role of management practices in mitigating its adverse impact.

2.1 Impact of THI on Milk Production

Several previous studies confirm the physiological basis for the inverse relationship between THI and milk production in dairy cows (Ekine-Dzivenu, 2020), (M'Hamdi, 2021), (Nasr & El-Tarabany, 2017), (Soriani, 2013). Daily milk yield was affected significantly by heat stress. Indeed, the increase in THI led to a significant decrease ($P<0.001$) in milk production (M'Hamdi, 2021). According to (Cowley, 2015) who reported that, if the THI levels are below or above the thermal comfort zone, the dairy cows are subjected to heat stress and this will culminate in a decline in milk yield. (Ravagnolo, 2000) and (Dunn, 2014) found smaller decreases in milk yield of around 0.2 kg per day per point rise in THI. (Gantner, 2011) and (Bouraoui et al., 2002) stated that for every point rise in the value of THI to a level above 68, the yield was found to reduce by 0.41 kg/cow/day under the Mediterranean climate. Besides, (Bernabucci, 2010) reported an improvement in LP, when cows returned to the thermal comfort zone ($68<THI<72$), milk production increased by 0.27 kg of milk per change of one unit of THI. According to (Bouraoui, 2002) a negative association existed between daily THI and milk yield as elevating the THI value from 68 to 78, results in a 9.6% reduction in DMI coupled with a 21% reduction in milk production. (Spiers, 2004) reported that milk yield decreases by 0.41 kg/cow/day for each THI unit increase of above 69, feed intake decreased within a day after initiation of heat stress, while milk yield decreased after 2 days of heat stress. (Gaafar, 2011) reported that with increases in THI from 59.82 in the winter to 78.53 in the summer, heat stress reduced the total

(305 days) and daily milk yield by 31.40 and 29.84%, respectively. There is evidence that heat stress has an impact on various parameters of milk production, particularly in terms of reduced milk production (Galán, 2018), (Polsky & Von Keyserlingk, 2017), (Zimbelman, n.d.) and (Nienaber, 1999).

2.2 Farm Management Practices and Heat Stress Mitigation

Concerning this negative impact, different management practices have been implemented on to the dairy farms to counter effects of heat stress. The ventilation system must create a good microclimate in the cowshed at all times of the year: hot and cold. The task here is rather crucial in the sense to develop a thermostable state in the remainder of the body of an animal; it should be in a state where by it can effectively and adequately transfer heat energy between and animal and the environment. In animals, convection, radiation and conduction heat which is in excess in animals is released. Thus, the processes of heat exchange are regulated and an ideal heat exchange with the surrounding is established ideal for an animal. The heat in this case has to be constant and this is what leads to thermal comfort being provided for the animals. Limiting factors of thermal comfort (lower and upper critical temperature of the environment) are critical for the animal body, where the regulation of the temperature of the cow's body occurs effectively, and its efficiency is maximum. Hence, proper working of influent ventilation systems is highly recommended in construction of cowsheds. The ventilation system has to be able to eliminate heat and moisture, toxic gases, and prevent the formation of condensation. Ventilation can be used to cool the cowshed as well as water sprays on the floor as well as walls. This sort of a barn cooling is hence a good guard against thermal stress. In the cowshed, where the air humidification–cooling system is installed, the air temperature during heat is lower than the average in the field of 2.61 ± 0.74°C. Although the relative humidity in the cowshed is on average 16.29 ± 4.12% wetter than in the open air, the THI in the barn is lower than in the open air. Therefore, the cooling intensity in the cowshed is efficient, and cows can experience only mild thermal stress when the THI increases by more than 72. In this cowshed the air temperature decreases by 3.17 ± 0.86°C compared to cowsheds without an air humidification–cooling system. The air humidification–cooling system creates good conditions to reduce the conditions for cows to experience thermal stress (Bleizgys, 2022). Similarly, efficient cooling methods like sprinkling, ventilation, and provision of shades have revealed the ability of cooling the animals and thereby extending the comfort zone. Ventilation also plays a role in the alleviation of heat stress inasmuch as it concerns convective and evaporative cooling. In case circulation air supplied by natural or mechanical ventilation is inadequate, increased circulation fans can be added in the barns (Renaudeau, 2012). A combination of fans (to increase convective heat loss) and either sprinklers or foggers/misters (to promote evaporative cooling) has been shown to be the most effective way to cool dairy cows other than using air conditioning (JW Worley, 2006). In fact, the addition of fans inside existing buildings to recirculate the air successfully reduced heat stress by decreasing body temperatures (-0.5°C) and respiration rates (-11 breaths min^{-1}), and enhanced milk production (+1.0 $kg \cdot day^{-1}$). The levels of improvement of physiological responses by fans alone were near to those reached through evaporative cooling systems (-0.6°C, -17 breaths min-1, and +2.0 kg day^{-1}) (Fournel, 2017).

Though a fair amount of work done globally regarding THI and milk production, there is a lack of enough research on this in the Patiya, Chattogram. The high sensitivity of cows to the climate characteristics and the particular management practices used in the area of interest to the current research make it important to conduct studies to quantify the effect of THI on milk yield and the effectiveness of the implemented cooldown strategies in the region only. This study intends to fulfil this gap in knowledge by presenting original data regarding the association between THI and milk yield in the context of the Study Area. Thus, in the research objectives, the study adds on to the knowledge and literature of heat stress solutions in dairy cattle and offers a regional perspective for dairy farmers.

Chapter III

MATERIALS AND METHODS

3.1 Study Area and Period

The study was conducted in Patiya Upazila under the Chattogram district of Bangladesh. These are the areas that have a density of dairy population and this type of study has not been carried out before in this place, which is why it has been chosen for this study. The data for this study was collected between January to April in the year 2024 in the study area.

3.2 Study Population

A total of 9 different dairy farms were studied.

3.3 Study Design

This study employed a comparative, observational design to look into the impact of THI on milk production in dairy farms.

Selection of Farms:

- A total of nine dairy farms were included in the study.
- One farm (Farm A) was identified as implementing specific management procedures aimed at mitigating heat stress in cows.
- The remaining 8 farms (Farms B-I) were not implementing such procedures.

3.4 Farm Location

In Figure, the details of the location of each farm were provided. Farm population is not fixed farm by farm rather it depends on the capacity, experiences, and willingness of the farmers, profit, and other factors related to farming. Farm both in rural and urban areas were studied for this research.

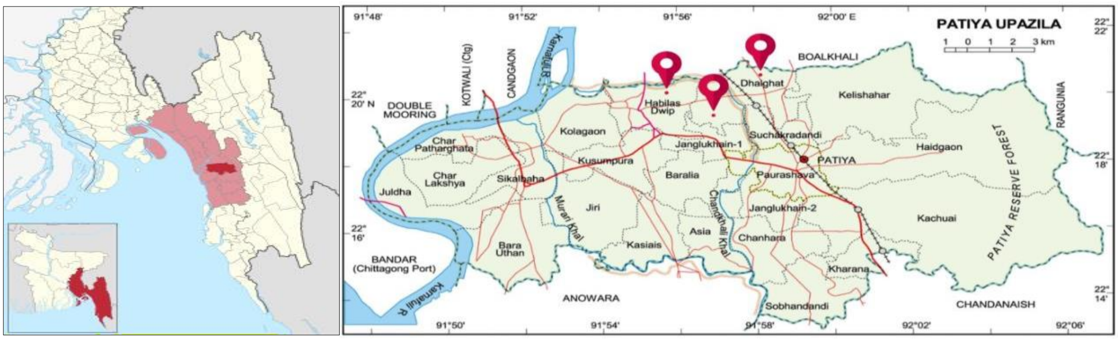

Figure 2: Geographical location of the Study Area

3.5 Data Collection

For the present study, total data were collected randomly from 9 farms. A questionnaire was developed bearing highlights of the objectives. As according to the information linked to the prepared study, the following questionnaire has been constructed. Information was obtained from the respondents mainly through the administration of face-to-face questionnaires. When constructing the questionnaire, issues to do with managerial aspects in the farms were given priority in most of the questions. Daily milk production from the individual farms was also gathered over a period of time. The data on temperature and relative humidity for the same period was obtained from a reliable data source. (https://www.visualcrossing.com/weather-data)

3.5.1 Management practices

Table 1: Management Factors

Factors	**Farm Id**								
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*
Frequency of showering (per day)	4	1	2	2	2	1	1	2	2
No. of fans (per animal)	1 fan / 3	0	1 fan / 9	0	0	1 fan / 8	1 fan / 6	0	0
Ventilation status	+++	+	++	++	+	++	+	++	+

"+++" indicates excellent ventilation; "++" indicates good ventilation; "+" indicates adequate / minimum ventilation.

3.5.2 Milk production & THI

The cows were milked two times a day, one was in the morning between 6.00 and 7.00 am and another one was during the afternoon between 5.00 to 6.00 pm.

Gathered information entailed mean temperature, minimum and maximum temperature for each month as well as relative humidity, from which the THI index was calculated by applying the formula provided below:

$THI = 1.8 \times Ta - (1\text{-}HR) \times (Ta – 14.3) + 32$ (Kibler, 1964).

Here, Ta stands for Mean ambient temperature at 0°C, and HR stands for Mean Relative Humidity based on the unit value. The estimated values of THI were used to quantify its impact on milk production.

3.6 Statistical analysis

3.6.1 Data Preparation:

The data on daily milk yield and THI for each farm was compiled into a Microsoft Excel spreadsheet. Data cleaning and formatting were performed in R (4.4.0) to ensure accuracy and suitability for analysis. Comparative descriptive analysis was performed for milk production at the farm level.

3.6.2 Correlation Analysis:

Pearson's correlation coefficient (r) was calculated to assess the strength and direction of the linear relationship between THI and milk yield for each farm. The significance level (p-value) was determined to evaluate the statistical significance of the correlation coefficients.

3.6.3 Linear Regression Analysis:

Linear regression models were constructed for each farm group (Farm A and Farms B-I) to quantify the association between THI and milk yield. The models took the following general form:

$$\text{Milk Yield} = \beta_0 + \beta_1 * \text{THI} + \varepsilon$$

Where:

- Milk Yield is the dependent variable (per day average milk yield)
- The independent variable is THI
- β_0 is y-intercept (predicted milk yield when THI is 0)
- β_1 is the regression coefficient (the slope), indicating the change in milk yield related to a unit increase in THI
- ε is the error term (represents unexplained variability)

p-value which indicates the probability of observing the observed association by chance. A low p-value (<0.05) indicates a meaningful correlation between THI and milk yield. By comparing the results from Farm A and Farms B-I, the analysis aimed to determine if the implemented management procedures at Farm A moderated the effect of THI on milk yield.

Chapter IV

RESULTS

4.1 Impact of THI on milk production across farms

Here, **Figure 3** shows the mean THI values for four months (Jan to April) which reflects that the mean value of THI was highest in April and it was lowest in January and there is a clear increasing trend in THI from January to April.

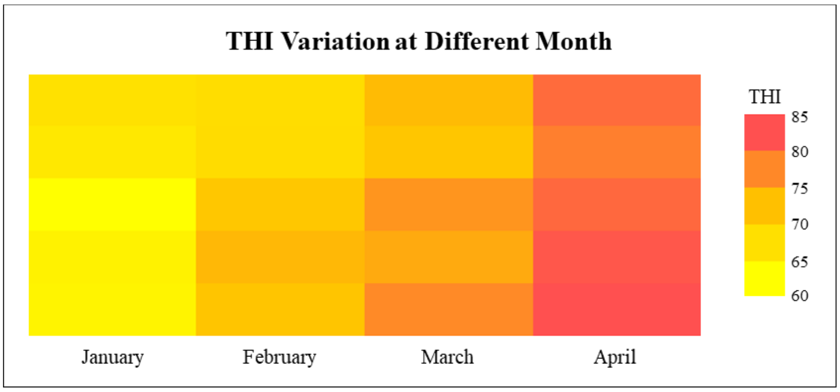

Figure 3. Heat map of THI (Temperature humidity index) from January to April 2024 at Patiya Upazila in Bangladesh.

Figure 4 represents the variation of average milk yield/cow/day across farms A to I from January to April. It indicates the decline of average milk yield/cow/day from farm B to I from January to April where it was somewhat consistent in the case of farm A.

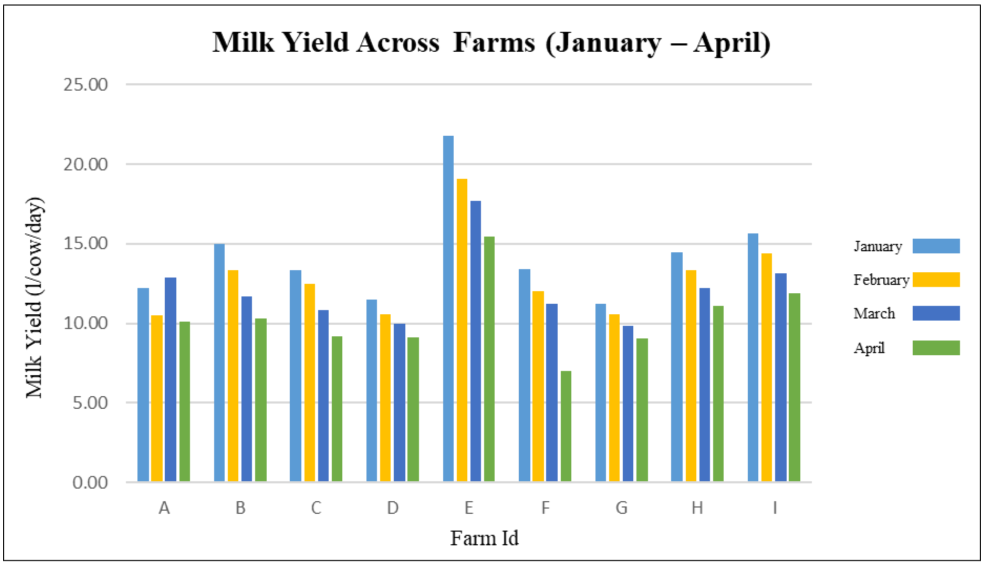

Figure 4: Average Milk Production/cow/day of Farm A to I from January to April

Table 2: Correlation Coefficients between THI and Milk Production

Farm Id	Correlation coefficient (r)	p-value
A	*-0.446*	*0.555*
B	-0.989	0.011
C	-0.992	0.008
D	-0.997	0.003
E	-0.990	0.010
F	-0.995	0.005
G	-0.998	0.002
H	-0.995	0.005
I	-0.967	0.033

Pearson correlation coefficients were calculated to assess the strength and direction of the linear relationship between THI and milk production for each farm.

The results are summarized in **Table 2**. It shows that all farms exhibit that milk production and THI are negatively correlated, as indicated by the negative values of the correlation coefficients (r). This implies that as THI increases, milk production tends to decrease. The strength of the negative correlation varies across farms. While most farms show a strong negative correlation (r values close to -1), Farm A has a weaker negative correlation (r = -0.446). The degree of the relationship stated by the correlation coefficient is tested by the P-values associated with these coefficients.

Table 3: Univariable linear regression between THI and Milk Production (l/cow/day)

Farm Id	Intercept(β_0)	Slope(β_1)	R-squared(R^2)	p-value
A	*17.274*	*-0.081*	*0.199*	*0.555*
B	32.246	-0.271	0.978	0.011
C	29.432	-0.248	0.984	0.008
D	19.973	-0.133	0.993	0.003
E	44.403	-0.356	0.980	0.010
F	29.520	-0.217	0.990	0.005
G	19.275	-0.125	0.997	0.002
H	26.774	-0.193	0.990	0.005
I	37.123	-0.361	0.935	0.033
Avg	**28.447**	**-0.221**	**0.894**	**0.070**

Simple linear regression models were fitted to each farm to achieve the estimation of the dependent variable of milk yield (L/cow/day) by the independent variable of THI. The regression coefficients (β_0 and β_1) and their corresponding p-values for each farm model are presented in **Table 3**.

All farms exhibited that THI and milk production are negatively correlated, indicated by negative values of the slope (β_1). This means that as THI increases, milk yield decreases for all farms. The magnitude of the negative impact of THI on milk yield varied across farms, as evidenced by the different values of the slope. Based on the R-squared values, it is clear that the models account for a considerable level of variation in the milk yield in most of the farms, with values ranging from 0.935 to 0.997. It shows that milk production is negatively correlated to THI weakly in farm A whereas it's the almost opposite in the case of the other farms (B to I) due to having a moderate negative correlation. The p-value associated with β_1 indicates the statistical significance of the slope. However, the magnitude of this impact varies considerably between farms, suggesting potential differences in management practices. The largest decrease in milk yield per unit increase in THI was observed in Farm E (-0.356 L/cow/day), while the smallest decrease was observed in Farm A (-0.081 L/cow/day). The average decrease in milk yield per unit increase in THI across all farms is -0.221 L/cow/day (**Table 3**).

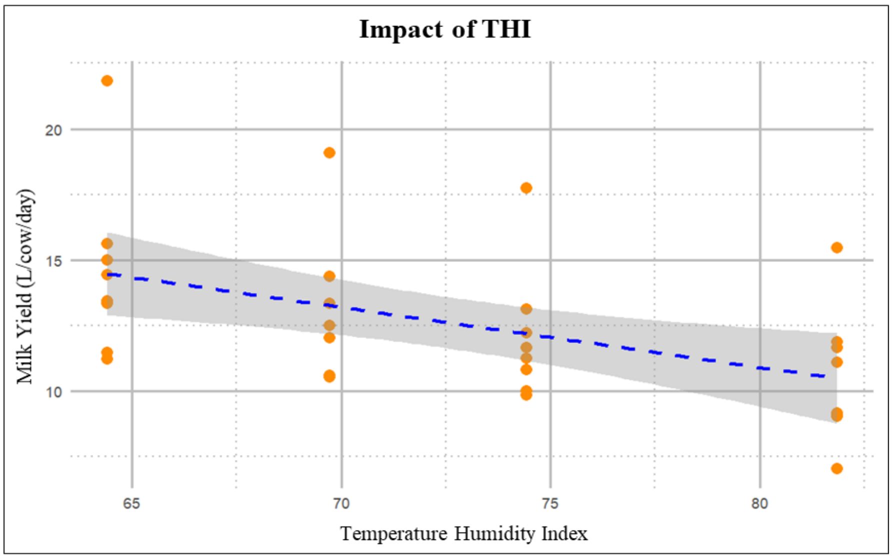

Figure 5. Relationship between THI and Milk Production during January to April

Negative relationships between THI and Milk yield is demonstrated in **Figure 5**, which indicates that when THI increases, milk yield decreases and vice versa.

4.2 Comparison between Farms:

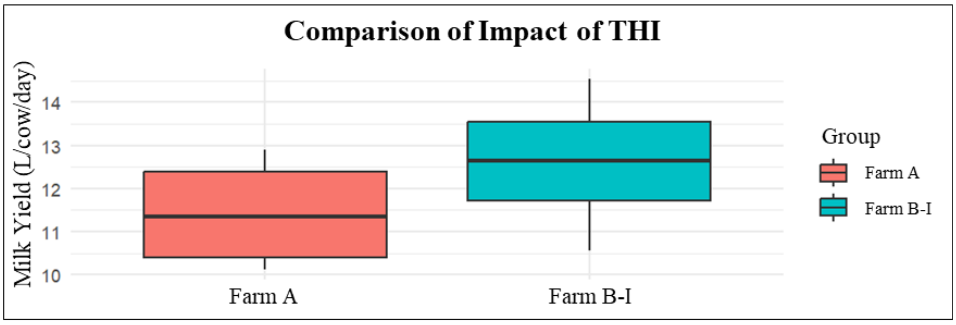

Figure 6 Comparison of the impact of THI on Milk Production between Farm A and Farm (B to I).

Figure 6 represents the differences in the impact of THI between farm A and farm (B to I) which strongly support the results of correlation analysis and linear regression analysis. The figure shows a boxplot comparing the average milk production (liters/cow/day) between Farm A and the combined Farms B-I (Farm B to Farm I) for the four months (January to April). The boxplot reveals several key features regarding milk production and potential management effects:

The center line within each box represents the median milk yield. In this case, the median milk yield for Farms (B-I) is positioned higher than the median for Farm A. This indicates that Farms (B-I), as a group, generally produced more milk per cow per day compared to Farm A across the four months.

The box represents the interquartile range (IQR), which captures the middle 50% of the data. The IQR for Farms (B-I) is wider than the IQR for Farm A. This suggests greater variability in milk yield among Farms (B-I) compared to Farm A.

The combined findings of median milk yield and IQR could be interpreted in the context of farm management practices. Farm A's potentially lower median milk yield, coupled with less variation in yield, might indicate management strategies influencing a more stable milk production level across the months, even under varying THI conditions. Farms (B-I), on the other hand, while showing a higher median milk yield, also exhibit greater variability, which could be due to management practices that are more susceptible to fluctuations in THI.

Chapter V

DISCUSSION

The aim of the present study was to establish the impact of the Temperature Humidity Index (THI) on milk production across the different farms, and more precisely how some of the management practices in farm A influenced this effect. The results of correlation and linear regression analyses provided the evidence for the primary hypothesis, showing that THI has a negative influence on the milk production in the farms that did not implement particular management strategies (B to I) compared to the farm A, while THI didn't have a noticeable influence on the milk production in the farm A.

Impact of THI on Milk Production

The negative correlation of THI with the production of milk in dairy cows has physiological evidence substantiated in several past studies (Ekine-Dzivenu, 2020), (M'Hamdi, 2021), (Nasr & El-Tarabany, 2017), (Soriani, 2013). It was observed that heat stress from weather conditions reduced the amount of milk yield per day. Enhancement of THI resulted in a sharp decline in milk yield (M'Hamdi, 2021). (Bouraoui, 2002) stated that daily THI level was demonstrated to have a negative relationship with milk yield. When it raised 78 from 68, the reduction of milk yield and DMI (Dry Matter Intake) was 21% and 9.6% respectively. Milk production decreased by 0.41 kg/cow/day for each increment in THI values crossing 69. The implications taken together, ambient temperature and relative humidity work conjointly as a regulator of the core body temperature in slashing DMI. Reduction in the rate of metabolism as well as rumen fermentation help to accomplish this (Moody, 1971). The nutrients that are accessible to be used to synthesize milk are reduced when the DMI lowers. The rate of milk production decreases and a majority of lactation indices are changed as well (W. Smith, 1993). Dairy cows are known to decrease feed consumption across the stages of heat stress, and this may increase with rising temperatures. One of the factors that have been pointed out as responsible for the decrease in milk synthesis is the reduced intake of various nutrients because the latter is related to a negative energy balance condition (Wheelock, 2010). Thus, with this study it is clearly established that THI affects milk yield negatively, that is, milk yield reduces as THI increases. It has been observed that heat stress affects many aspects of lactation known to be associated with a decrease in overall milk yield (Galán, 2018), (Nienaber, 1999) and (Polsky & Von Keyserlingk, 2017).

Management Practices and THI Mitigation

As mentioned in the Results section, the correlation coefficients and regression slopes indicated higher values of Farm A, and Farm B to I which represented that farms that shower 3-4 times/day, have fans, maintain adequate ventilation, or incorporate some management practices had a weaken negative correlation and less regression slope suggested that farms' production reduced with THI but not significantly. On the other hand, Farms without such practices (Farms B to I) have a slight negative correlation and a much steeper slope suggesting the significant extent of reduction in milk yield due to increased THI level.

The above-observed difference is in harmony with the outlined hypothesis that some management practices are capable of eradicating the influence of THI on milk yield. Management activities that are believed to improve cow comfort and thus improve physiological well-being are; showering the cows (3-4 times a day), adequate aeration, and use of fans particularly during hot seasons. It can be argued that these practices probably help the cows to cope with the thermal stress better implying that the farms with such measures may stand to lose less of their milk yield than such farms lacking such practices.

Effectiveness of Management in Farm A

To mitigate the impact of THI on milk production Farm A follows some managemental practices which aren't followed by other farms (Farm B to I). The practices are cooling strategies like showering the cows for more times, providing adequate ventilation & shady areas, rendering more fans, and increasing the frequency of feeding and awarding more nutritional feed.

Ventilation is also effective in cooling the cowshed as well as floor and water sprays is also effective. Such a cooling of the barn is thus a good defense against thermal stress. Speaking of the effects of the air humidification and cooling system in a cowshed where it was installed the temperature of the air during the heat is lower by

2.61 ± 0.74°C as to the average in the field. Averagely the relative humidity in the cowshed is about 16.29 ± 4.12% higher as compared to that of the open air but the THI is less in the cowshed than in the open air. Thus, the cooling intensity in the cowshed is effective, and cows are going to be affected by a slight thermal stress only if the THI rises by more than 72. For this reason, the air temperature in this cowshed is 3.17±0.86°C lower than in the cowsheds that do not have an air humidification–cooling system. Air humidification–cooling system forms a suitable environment as far as the occurrence of thermal stress in cows is concerned (Bleizgys, 2002). In the same way, efficient ways of cooling such as sprinkling, ventilation, and provision of shades have shown the way to cool the animals and thereby, extend their comfort zone. Convective as well as evaporative cooling is part of ventilation in relation to heat stress moderation. If the circulation air provided by natural or mechanical means is insufficient, the circulation fans can be stepped up in the barns (Renaudeau, 2012). The researchers, therefore, recommended that the most effective way of cooling dairy cows apart from air conditioning, is by using a combination of fans which enhance the convectional heat loss, and sprinklers or foggers/misters which promote evaporative cool (Worley, 2006).

In fact, many of the existing structures were fitted with electric fans to recirculate the air and this was effective in minimizing heat stress as reflected by the decrease in body temperatures by -0.5°C, reduction in respiratory rates by 11 breaths per minute, and increase in milk production by 1 kg per day. The increase in the improvement of the physiological responses achieved only by the fans was close to the evaporative cooling system of (-0.6°C, -17 breaths min^{-1}, and +2.0 $kg.day^{-1}$) (Fournel, 2017).

Cooling strategies can be divided into two approaches direct cooling and indirect cooling. Indirect cooling is thus a method of lowering the environmental temperature around the animal with the purpose of maintaining a thermal differential and facilitating heat transfer. The first and compulsory measure is to provide sheds in the area of housing. Wind enhances the evaporative cooling of the skin by compressing through the body coat thus decreasing the efficacy of thermal resistance of the coat (Berman, 2004). Thus, it was observed that with an increase in airflow rate over the cow from about 0.2 – 0.9 m/s, the sweating rate is increased resulting in reduced rectal temperature. Another means to indirectly cool down the cow to enhance its heat balance is the application of forceful ventilation. For instance, the technology of high-volume, low-speed fans (HVLS), as well as low-volume high-speed fans (LVHS) (J. R. Smith & Harner, 2012), has been adopted into the shed. Another type of free stall built is low profile cross-ventilated (LPCV) which allows a noticeable control of the environment around the cow and helps the animal maintain a stable internal body temperature (Smith, 2008).

Direct evaporative cooling through wetting the cow with water and then evaporating the water through fans was included (Flamenbaum, 1984) and was noted to be very useful in the reduction of thermal stress by high-yielding cows (Flamenbaum & Galon, 2010). Evaporative cooling when used in hot and dry climates can reduce air temperature by 15°C, although the process is limited to the relative humidity range of 70-75% (Berman, 2009). According to (Smith & Harner, 2012), heat stress in dairy cows can be controlled by managing them and their environment through the following practices; increased water delivery, cooled holding pen, proper ventilation in the holding pen, and the cow barn, proper ventilation in the free stall areas. In other words, when these priorities are acted upon, we should be able to make gradual accommodations in the production of milk (everything else being held constant) and reduce the impact which heat stress has in the longer term.

The independent use of fans and sprinklers was evidenced since reports dating back to the 1940's (Seath & Miller, 1948) whereby it was observed that while fan and sprinkler lessened rectal temperature and respiratory rate, their combined use enhanced the overall effectiveness. Another benefit of using sprinklers along with fans was the decrease of diurnal fluctuation of core temperature. Most of the cooling response is attributed to the enhancement of. From this research, it is evident that while milk production was affected by high values of THI, utilization of specific management protocol (cooling methods) can help to moderate the impact.

LIMITATIONS AND FURTHER RESEARCH

This specific study employs the total farm production approach of data collection, thus limiting the comparison to liters of milk per cow. This was because individual cow data would be likely to provide a much better understanding of the variation problems that could be anticipated. Further, there are limitations to the current study as it is correlational only, which implies that this study does not directly associate specific management practices with heat stress and the methods to overcome it. Further research is needed to:

- Various practices adopted on Farm A and the effectiveness of each of them, consecutively or jointly.
- Carry out experimental investigations to assess the level to which the several management strategies impact heat stress tolerance and milk production separately.

CHAPTER VI

CONCLUSIONS

This study shows that the degree of THI causes a significant reduction in milk production. It also offers an initial indication that the farm management practice may also be useful in alleviating the consequences of heat stress on milk production. Farms with probably better management such as Farm A had a lower sensitivity to THI variation. This is very evident when comparing Farm A with Farms B to I, where such practices can be applied to provide comfort to cows, reduce heat stress, and, therefore, sustain milk production during high THI. More studies are necessary to learn and encourage the use of those practices for better stability of dairy farm operations under conditions of global warming and to guarantee the sustainability of milk production.

CHAPTER VII
RECOMMENDATIONS

1. **Prioritization of Heat Stress Management:** Due to the severe effect of THI on milk yield, dairy farmers should pay considerable focus to heat stress mitigation programs. It should include activities such as showering the cow 3-4 times a day or the use of cooling systems like showering, improved ventilation and provision of enough fans, provision of adequate shade, and clean water.

2. **Tailored Management Approaches:** Given the variability of the environment in dairy farms, it is important that dairy farms undertake an evaluation of the heat stress factors so as to establish measures that will effectively deal with this problem in their specific farms. This approach will advance the ability and assurance of a good adaptation to particular environmental and herd conditions.

3. **Continued Research and Development:** In order to further the knowledge of heat stress and its application to milk production, there are several avenues of research that need to be explored. These are the sustainability of costs of heat stress management strategies, comparisons of the effectiveness of various cooling systems across various geographical climates, and the effects of diet and breeding for improved thermo tolerance.

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BIOGRAPHY

I am Hasibur Rahman Sakib, now for further description of my family background, I am the son of Mahbubor Rahman and Fatema Begum. I passed my SSC in the year 2015 from Chattogram Collegiate School securing a CGPA. 5.00. Next, I passed my HSC from Chattogram College in the year of 2017 securing a CGPA. 5.00 also. At this stage, I am serving as an Intern Veterinarian at Chattogram Veterinary and Animal Sciences University under the Faculty of Veterinary Medicine.

My ambition is to develop into an accomplished veterinary surgeon with a special focus on the dairy industry. I have a strong desire to pursue more knowledge in this area and would like to participate in research work in the near future.

APPENDIX-I

A questionnaire to assess the impact of heat stress on milk production and management practices in dairy farms of Patiya Upazila, Chattogram, Bangladesh

General Information of the farm

- Name of the farm:
- Location:
- Contact details:
  - Name & Position:
  - Contact number:
- Number of years in operation:
- Farm size: Large / Medium / Small scale farm

General information of animal

- Number of cows:
- Number of pregnant cows:
- Number of cows in 1st parity:
- Number of cows in 2nd parity:
- Number of cows in 3rd parity:
- Number of cows in lactating period:
- Number of cows in dry period:
- Milk yield of a cow per day:
- Avg milk yield of the farm (Daily):

Biosecurity Practices

- Away from locality……. Y / N
- Designated entry / exit point for vehicles…….Y / N
- Protocol for new animal introduction…….Y / N
- Frequency of disinfection for equipment, vehicle, and facilities….. D/ W/ M/ Other
- Isolation facilities for sick animals…….Y / N
- Proper boundary & fencing…….Y / N
- Pest control programme…….Y / N

Husbandry Practices

- Avg Herd size / Stocking density………………………………………….
- How are animal housed? Loose house / Stantion barn (Face in / Face out) [Single / Double Row]
- Floor type? Concrete / Soil / Cement
- Footbath…….Y / N
- Ventilation status? Poor / Moderate / Good / Nothing
- Drainage system? Poor / Moderate / Good / Nothing
- Frequency of house cleaning ….D / W / M / Other
- Animal Health check….D / W / M / Other
- Vaccination protocols…Regular / Not regular / Never
- Deworming protocols…Regular / Not regular / Never
- Water source?...............
- Type of milking practice? Hand / Machine
- Washing of udder before milking? …….. Y / N
- Washing of udder after milking? …………. Y / N
- Providing roughage after milking? ……….. Y / N
- Record Keeping…….Y / N
- Records: a)Tag no b)Birth date c)Vaccination date d)Parity e)Deworming date f)Heat period g)Pregnancy date h)Last hit date i)Other……………
- Visitor access? Restricted / Not restricted
- Feed management:
    - Roughage:
    - Concentrate:
    - Supplementary diet:
- Feeding for lactating cow…………………………………………………………………
- Feeding for dry cow………………………………………………………………………
- Advanced technology? …… UMS / UTS / UMMB
- Maintenance of residual period? ….. Y / N

Interviewee

Owner/Manager/Employee

Interviewer

Hasibur Rahman Sakib








Statistical analysis with R (V 4.4.0)

Performing Pearson's Corelation:

```
> C1 = cor.test(adata$THI, adata$MilkProd)
> print(C1)

        Pearson's product-moment correlation

data:  adata$THI and adata$MilkProd
t = -0.70844, df = 2, p-value = 0.5551
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9849808  0.9010755
sample estimates:
       cor
-0.4458877
```

```
> C2 = cor.test(bdata$THI, bdata$MilkProd)
> print(C2)

        Pearson's product-moment correlation

data:  bdata$THI and bdata$MilkProd
t = -9.3361, df = 2, p-value = 0.01128
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9997749 -0.5554176
sample estimates:
       cor
-0.9887209
```

```
> C3 = cor.test(cdata$THI, cdata$MilkProd)
> print(C3)

        Pearson's product-moment correlation

data:  cdata$THI and cdata$MilkProd
t = -10.724, df = 2, p-value = 0.008584
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9998289 -0.6430611
sample estimates:
       cor
-0.9915158
```

```
> C4 = cor.test(ddata$THI, ddata$MilkProd)
> print(C4)

        Pearson's product-moment correlation

data:  ddata$THI and ddata$MilkProd
t = -17.493, df = 2, p-value = 0.003252
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9999354 -0.8482893
sample estimates:
       cor
-0.9967479
```

```
> C5 = cor.test(edata$THI, edata$MilkProd)
> print(C5)

        Pearson's product-moment correlation

data:  edata$THI and edata$MilkProd
t = -10.216, df = 2, p-value = 0.010446
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9998117 -0.6140104
sample estimates:
       cor
-0.9905542
```

```
> C6 = cor.test(idata$THI, idata$MilkProd)
> print(C6)

        Pearson's product-moment correlation

data:  fdata$THI and fdata$MilkProd
t = -14.031, df = 2, p-value = 0.005041
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9998997 -0.7740790
sample estimates:
      cor
-0.994959
```

```
> C7 = cor.test(gdata$THI, gdata$MilkProd)
> print(C7)

        Pearson's product-moment correlation

data:  gdata$THI and gdata$MilkProd
t = -24.201, df = 2, p-value = 0.001703
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9999662 -0.9176346
sample estimates:
       cor
-0.9982969
```

```
> C8 = cor.test(hdata$THI, hdata$MilkProd)
> print(C8)

        Pearson's product-moment correlation

data:  hdata$THI and hdata$MilkProd
t = -14.031, df = 2, p-value = 0.005041
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.9998997 -0.7740790
sample estimates:
      cor
-0.994959
```

```
> C9 = cor.test(fdata$THI, fdata$MilkProd)
> print(C9)

        Pearson's product-moment correlation

data:  idata$THI and idata$MilkProd
t = -5.3585, df = 2, p-value = 0.03311
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.99933224 -0.08208283
sample estimates:
       cor
-0.9678929
```

Performing Linear Regression:

```
> L1 = lm(MilkProd ~ THI)
> summary(L1)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
      1       2       3       4 
 0.1251 -1.1691  1.6068 -0.5629 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 17.27482    8.33607   2.077    0.173
THI         -0.08101    0.11435  -0.708    0.555

Residual standard error: 1.463 on 2 degrees of freedom
Multiple R-squared:  0.2006,	Adjusted R-squared:  -0.1991 
F-statistic: 0.5019 on 1 and 2 DF,  p-value: 0.5551
```

```
> L2 = lm(MilkProd ~ THI)
> summary(L2)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
       1        2        3        4 
 0.19223 -0.01911 -0.42108  0.24797 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept) 32.24605    2.11704  15.243  0.00428 **
THI         -0.27113    0.02904  -9.336  0.01128 * 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3716 on 2 degrees of freedom
Multiple R-squared:  0.9776,	Adjusted R-squared:  0.9664 
F-statistic: 87.16 on 1 and 2 DF,  p-value: 0.01128
```

```
> L3 = lm(MilkProd ~ THI)
> summary(L3)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
        1         2         3         4 
-0.160606  0.342091 -0.178520 -0.002965 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept)  29.4318     1.6840   17.49  0.00325 **
THI          -0.2477     0.0231  -10.72  0.00858 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.2955 on 2 degrees of freedom
Multiple R-squared:  0.9829,	Adjusted R-squared:  0.9745 
F-statistic:   115 on 1 and 2 DF,  p-value: 0.008584
```

```
> L5 = lm(MilkProd ~ THI)
> summary(L5)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
      1       2       3       4 
 0.3674 -0.4419 -0.1454  0.2200 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept) 44.40256    2.54749   17.45  0.00327 **
THI         -0.35601    0.03495  -10.22  0.01045 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.4471 on 2 degrees of freedom
Multiple R-squared:  0.9812,	Adjusted R-squared:  0.9718 
F-statistic: 104.4 on 1 and 2 DF,  p-value: 0.010446
```

```
> L7 = lm(MilkProd ~ THI)
> summary(L7)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
       1        2        3        4 
 0.02190  0.01746 -0.07991  0.04055 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept) 19.285917   0.378243   50.99 0.000384 ***
THI         -0.125568   0.005189  -24.20 0.001703 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.06639 on 2 degrees of freedom
Multiple R-squared:  0.9966,	Adjusted R-squared:  0.9949 
F-statistic: 585.7 on 1 and 2 DF,  p-value: 0.001703
```

```
> L9 = lm(MilkProd ~ THI)
> summary(L9)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
      1       2       3       4 
-0.4606  0.0717  0.9669 -0.5780 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)  
(Intercept) 37.12321    4.91150   7.565   0.0170 *
THI         -0.36102    0.06737  -5.358   0.0331 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.862 on 2 degrees of freedom
Multiple R-squared:  0.9349,	Adjusted R-squared:  0.9023 
F-statistic: 28.71 on 1 and 2 DF,  p-value: 0.03311
```

```
> L4 = lm(MilkProd ~ THI)
> summary(L4)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
       1        2        3        4 
 0.07953 -0.08239 -0.05308  0.05595 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept) 19.97341    0.55623   35.93 0.000774 ***
THI         -0.13347    0.00763  -17.49 0.003252 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.09762 on 2 degrees of freedom
Multiple R-squared:  0.9935,	Adjusted R-squared:  0.9903 
F-statistic:   306 on 1 and 2 DF,  p-value: 0.003252
```

```
> L6 = lm(MilkProd ~ THI)
> summary(L6)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
       1        2        3        4 
 0.09102  0.01042 -0.23104  0.12960 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept) 29.52013    1.12928   26.16  0.00146 **
THI         -0.21736    0.01549  -14.03  0.00504 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.1982 on 2 degrees of freedom
Multiple R-squared:  0.9899,	Adjusted R-squared:  0.9849 
F-statistic: 196.9 on 1 and 2 DF,  p-value: 0.005041
```

```
> L8 = lm(MilkProd ~ THI)
> summary(L8)

Call:
lm(formula = MilkProd ~ THI)

Residuals:
        1         2         3         4 
 0.080825  0.009249 -0.205159  0.115085 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)   
(Intercept) 26.74430    1.00280   26.72  0.00140 **
THI         -0.19302    0.01376  -14.03  0.00504 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.176 on 2 degrees of freedom
Multiple R-squared:  0.9899,	Adjusted R-squared:  0.9849 
F-statistic: 196.9 on 1 and 2 DF,  p-value: 0.005041
```