DESIGN OF A SMART AUTOMATION SYSTEM FOR DETECTION OF TEMPERATURE AND HUMIDITY THROUGH A DEVELOPED SENSOR SYSTEM OF POULTRY VENTILATION PROCESS

A thesis submitted to the Department of Electronics and Communication Engineering, Hajee Mohammad Danesh Science and Technology University in partial fulfillment of the requirements for the degree of Master of Science in Electronics and Communication Engineering abbreviated as M.Sc. (Engineering) in ECE

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
FACULTY OF POST GRADUATE STUDIES

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY,

DINAJPUR-5200, BANGLADESH

CERTIFICATE

This is to certify that the work entitled as **"Design of a Smart Automation System for Detection of Temperature and Humidity through a Developed Sensor System of Poultry Ventilation Process"** by Md. Kaimujjaman has been carried out under our supervision. To the best of our knowledge this work is an original one and was not submitted anywhere for a diploma or a degree.

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DECLARATION

The work entitled **"Design of a Smart Automation System for Detection of Temperature and Humidity through a Developed Sensor System of Poultry Ventilation Process"** has been carried out in the Department of Electronics and Communication Engineering, at Hajee Mohammad Danesh Science and Technology University is original and conforms the regulations of this University. We understand the University's policy on plagiarism and declare that neither this project nor any part of this project has been used or submitted elsewhere for any kind of degree or awards.

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Session: 2020-2021

The thesis titled **"Design of a Smart Automation System for Detection of Temperature and Humidity through a Developed Sensor System of Poultry Ventilation Process"** submitted by Md. Kaimujjaman, Student ID: 2005110 and Session 'January-June' 2022, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of M.Sc. (Engineering) in ECE.

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Abstract

Agriculture and poultry must be addressed as the economic background of any country. Furthermore, agricultural progress and economic prosperity are inextricably linked. Technology advancements and new technical developments have ushered in a new era of real-time animal health monitoring. Although commercial poultry management still has to establish actual implementation. This study focuses on a sensor-based solution for minimal- cost, capital-saving, value-oriented, and productive chicken farm management in order to increase the value of the broiler farm economy index (BFEI). The goal of this research was to see if an Intelligent System based on an Embedded Framework could be utilized to monitor chicken farms and adjust environmental conditions using smart devices and technology. This study also looked into how different temperature (ranges from 25°C to 33°C) affected broiler performance efficiency factor (BPEF), livability, and feed efficiency (FCR). It was discovered that the group reared at higher temperatures had greater broiler performance efficiency factor, livability, and lower feed efficiency.

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Chapter 1

Introduction

In the introduction chapter, motivation for the research is briefly discussed, which is followed by the thesis topic and problem backdrop. The objective of the research is then presented along with the possible solutions. The goal was to relate the scientific work with research topic and go into further detail in subsequent chapters.

1.1 Background

Chickens are the most popular poultry species farmed in big quantities. One of the most active segments of the livestock industry is the poultry business. There are currently around 850 million dollars invested in the poultry industry. Over the past five years, this industry has grown at an amazing rate of 8 to 10 percent annually. Small farmers in underdeveloped nations rely heavily on the sale of poultry as a source of income. It is essential for meeting the daily protein needs of people by consuming meat and eggs. To provide food, including meat and eggs, over 0.05 trillion chickens are produced every year. Poultry contributes greatly to poverty reduction and improved food security in developing nations as a source of high-quality protein.

For many poor and middle-class families, chicken products constitute their sole affordable source of animal nutrition. Under five-year-old who are sick and undernourished, eggs provide a convenient source of high-quality protein [1]. According to the United States Department of Agriculture (USDA) [2], [3], Bangladesh's poultry business employs one million enterprises and eight million people, producing 10.22 billion eggs and 1.46 million tons of poultry meat yearly. The poultry business provides 36% of the total protein we consume in the form of meat and eggs. In Bangladesh, 95 eggs are consumed annually per capita, whereas 6.5 kg of chicken are consumed annually [4].

Chickens are influenced by high ambient temperatures in poultry farming, especially when there is a high relative humidity and a sluggish air speed above the birds [5],[6]. Severe heat stress reduces production efficiency and raises flock death rates. It reduces growth rates, egg output, meat quality, and egg quality, such as smaller eggs and thinner shells, all of which can lower their commercial value, resulting in considerable yield and economic losses [7], [8].

The current poultry farming chicken cages automation equipment has entered the rapidly developing chicken breeding industry upgrading by mechanization, automation, intelligent system to complete the equipment, and complete sets of equipment application technology bottleneck is the main issue of laying hens that plagues most scale enterprises, and the solution has emerged in recent years with the advancement of environmental policies across the farming also face new challenges.

1.2 Problems of Existing Poultry Farming Systems

Climate anomalies, such as unexpected temperature and humidity increases, have become more common in recent years. It has harmed not just the proper growth of chickens, but also the quality of their meat and the size of their eggs [9], [10]. The damaged eggs fetch a low market price and are occasionally discarded during processing. Poultry owners suffer significant financial losses as a result of this. For bringing a solution, technological structures known as control sheds are used in large scale commercial farms, which are very expensing in construction [11]-[13]. Moreover, running and maintaining the control sheds extensively increased the cost. With up to 70% of the overall production cost being made up of input costs, feed is by far the largest component. [14]-[17]. In addition, chickens came into market from control sheds have less immunity than open sheds. To balance the harsh summer conditions and losses, electrolytes, carbonated water, supplementing drinking water with vitamins are excessively used by poultry owners to tackle the mortality in chickens [18], [19]. However, these preventions may make a health concern in human body after consuming poultry meats and eggs. Therefore, development of alternative techniques is getting attention for the remedy of poultry owner's anxiety over higher mortality rate in heat stressed condition in summer season.

The issues brought on by climate change are now an international issue, and the poultry industry is not exempt from climate changing. Particularly in open-sided poultry houses in tropical locations, the rise in ambient temperature and relative humidity is seriously disrupting the poultry sector. Commercial broiler chicks are especially vulnerable to these climatic extremes because of their rapid growth. Heat Stress is a situation that elicits the biological stress mechanisms of an animal. The negative impacts of heat stress on poultry have been reported [20]-[24]. The concept of heat stress or the exposure to high ambient temperature can be broadly categorized into two: The acute heat, which refers to exposure to stress with a very high temperature during short period. Its main effect on broiler chickens is an increase in mortality, often by suffocation; The chronic heat, which refers to the exposure of an animal to a prolonged high temperature for several weeks. The resultant consequence of this is a decrease in performance of the birds. The responses of birds to high ambient temperature includes high body temperature; lower feed intake, higher feed efficiency, lesser live weight and growth and performance [25]. Thus, it is highly suggested to employ modern poultry farming techniques with embedded technology to reduce these consequences while keeping cost in mind for all types of poultry growers.

1.3 Purpose of the Research

The main purpose of this study is to developed a micro-controller based embedded automation system that provides a suitable environment to the poultry house for the betterment of the living conditions of the poultries. Another goal of this research is to periodically monitor the environment's temperature and humidity levels as well as that of the smart intelligent system. This study also aims to investigate the new system performance to that of more traditional methods of rearing poultries in terms of mortality rate, live weight gain, feed efficiency and a measure of the profitability of broiler farms.

1.4 Possible Ways of Implementing New Farming Techniques

The traditional method of managing chicken farms has a number of drawbacks, including excessive power consumption and poor energy efficiency. The smart control system has several advantages, including high energy efficiency and the ability to increase and acquire a 10 times greater illumination range than a typical farm. The poultry farm uses one of six different types of smart control systems. These are-Wireless Sensor Network (WSN), Internet based control systems, Integrated solution using WSN and GPRS, Smart Sensing technologies, Raspberry PI and Arduino based control systems. These systems will be discussed in detail in Chapter 2.

Incorporation of intelligent sensor technology in the poultry sheds for continuous monitoring of temperature and relative humidity and turn-on the automated ventilation system at threshold conditions would be a promising solution for the reduction of heat stress of the poultry. In this study, it has been suggested that an intelligent system can be designed and implemented that can track and manipulate environmental factors like temperature and humidity. The sensors carry out the monitoring, and the data is kept in a digital storage unit. The automated system compares these data against threshold values suitable for broiler chicks' growing conditions. The system uses relay switches that autonomously alter the environment factors if it is unfavorable for the poultry.

1.5 Outline of the Research

The thesis is sectioned into different parts as follows: Chapter 1, discusses about the research background and purpose of the study. Chapter 2 describes relevant works and best environmental factors. The proposed design principles, block diagram of working process, system working flowcharts are discussed in Chapter 3. Chapter 4 describes the details methodology of how the Automation system is developed. Finally, chapter 5 depict the outcomes, and conclusive comments on the performance of the system.

Chapter 2

Literature Review

In this chapter, relevant works are briefly discussed, environmental states in poultry farms and selection of the environmental parameters are given.

2.1 Related Work

In order to collect numerous climate restrictions, Roham et al. [26] created and maintained a smart system that connected to a Beagle Bone Controller and a network of wireless sensors in greenhouses. This device is gathering the climatic parameters and grouping them into the web server's database. Applications for smartphones and the web resolve parameters and anticipate the surroundings.

The innovative system of the mobile network with the wireless sensor network to visually monitor the farm's environmental conditions was presented by Sravanth Goud et al. [27]. The user can operate the system by sending a message from their mobile device to the network, and they can also read and monitor the temperature and humidity on their mobile device. In the absence of a human command, the system can respond automatically by running a saved program. For the user who leaves his farm for a while, this strategy was quite helpful.

Rupesh Muttha et al. [28] developed the GPRS-based network with wireless sensors for monitoring chicken farms. The control system transmitted signals to the farmer about all parameters anywhere and at any time via GPRS while also keeping an eye on the farm's humidity, temperature, and food supply levels.

A wireless monitoring system was developed by Gerard Corkery et al. [3] to record the ambient conditions across the chicken farm. The sensors will keep track of light, NH_3 and CO_2 concentrations, humidity, temperature, and air velocity inside the farm.

To achieve the ideal settings for the birds, the system may compare environmental factors with crucial relevant conditions.

To administer the bird farm, Siwakorn Jindarat et al. [29] created an intellectual structure utilizing a smartphone. By adjusting the fan speed to meet the needs of the birds and recording the relative humidity of the farm and the filter fan system, they programmed the Arduino and Raspberry PI. They came to the conclusion that the system was easy for farmers to use and that it could be altered whenever necessary to provide crucial measurements of farm conditions in accordance with seasonal requirements.

2.2 Environmental States in Poultry Farms

Poultry growers from temperate climates countries such as Bangladesh facing the difficulty of high ambient temperatures during summer which has a major impact on production performance of commercial poultry. If balance between body heat loss and body heat production are not achieved birds are 'heat stressed'. It is associated with all types of poultry at all ages. As a result, an intelligent system can offer an environment that is appropriately regulated and controlled to avoid limiting bird performance. The most fundamental technique of regulating the poultry environment, according to Mutai et al. [30], is to maintain optimal temperatures in these facilities by altering circulation and warming rates. A relative humidity (RH) of more than 70% is unfavorable and should be avoided by using ventilation in buildings [31]. RH levels below 50% because more dust and airborne microorganisms to be produced, but this is not a regular occurrence. High RH paired with high temperatures might cause discomfort in birds during the summer months [32].

Birds eat more feed to maintain a normal body temperature when exposed to cooler temperatures. Feed is not turned to meat when it is utilized for heating [33]. When temperatures rise too high, energy is squandered as birds struggle to cool down. In these circumstances, ascites (a metabolic illness that causes performance decline) and mortality in broilers will be more common. According to a recent study, when two separate temperature ranges (26^{o}C and 32^{o}C) were applied to different groups of broilers during growth, the group exposed to the higher temperature performed better and used less feed [34].

The conventional systems for controlling chicken farms have a number of drawbacks, including low energy efficiency and high-power usage. In today's poultry farming, smart control technologies like Zigbee, Arduino, Raspberry Pi, and the integration of wireless sensors, GPRS and MIMO systems have been adopted [35]-[40].

2.3 Best Selection of Environmental Parameters for Broilers

After surveying different reports on broiler chicken or bird farming, selection of threshold conditions for poultry farm environment parameters are made below in Table I [41], [42]. It has been seen that during the brooding period of broiler chickens (age < 7 days) 30^oC-33^oC temperature is required for best production. Due to extreme temperatures, broilers older than 21 days may experience heat stress. As a result, the temperature of poultry farm decreases by $2^oC/3^oC$ in every week as the chickens grow older. If broiler fecal matter is not changed in every two weeks, relative humidity (RH) in the poultry environment might reach 70 percent, which is not ideal for the best farming.

Table 1. Parameter Selection.

Age (Days)	Temperature	Humidity
0-6	30^oC -33^oC	50%-60%
7-14	28^oC -31^oC	50%-65%
15-21	26^oC -29^oC	60%-75%
>21	25^oC -28^oC	65%-80%

Chapter 3

System Design & Descriptions

In this chapter block diagram and circuit diagram of the designed system are given. The sensors and accessories placement plan on the poultry house are also depict here. This chapter also describes how the embedded system works for monitoring and controlling environment parameters using flow diagram and finally the hardware and sensors tools used to design the system are also discussed with pictorial representation.

3.1 Block Diagram of Proposed System

Microcontroller (MC) is the heart of our proposed system. The MC collects data from the temperature and humidity (TH) sensors, stores data through Micro SD Card module, analyzes the data and on/off relay switches according to TH sensor values. The MC also keeps track with time through Real Time Clock Module and displays the system actions through Liquid Crystal Display to provide interaction between human and machine world.

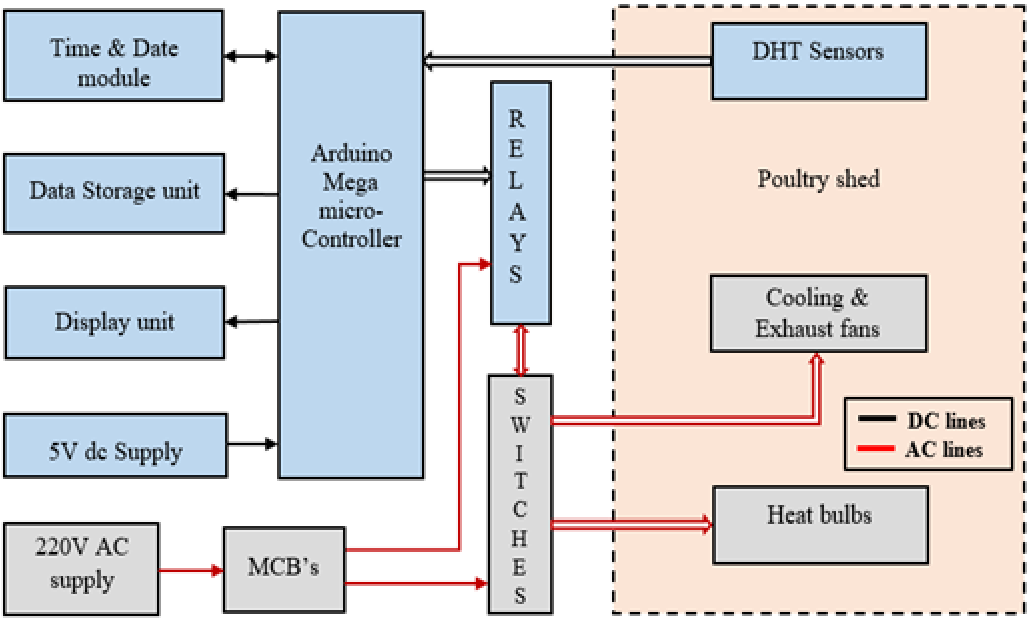

Fig. 1. Block diagram of proposed system.

3.2 Sensors and Accessories Placement Plan

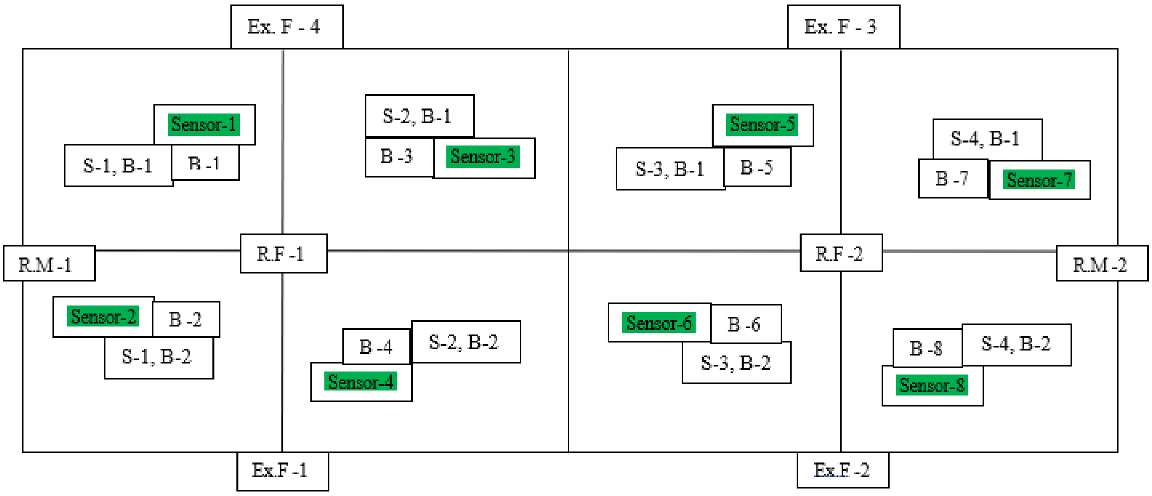

Fig. 2. Sensors, heaters & Coolers placement plan

LEGENDS

S-X, B-X = Shade –X, Branch-X

R.F-X = Roof Fan-X
Ex. F = Exhaust Fan-X
B-X = Bulb-X
R.M-X = Room Light-

3.3 System Flowchart

The flowchart represents the main functionality of the program in Arduino microcontroller. The system reads environment temperature and relative humidity from DHT sensors and stores them into micro-SD card by microcontroller. The system also checks the threshold values of different parameters and takes it action by switching heat bulbs, cooling and exhaust fans ON/OFF at regular intervals.

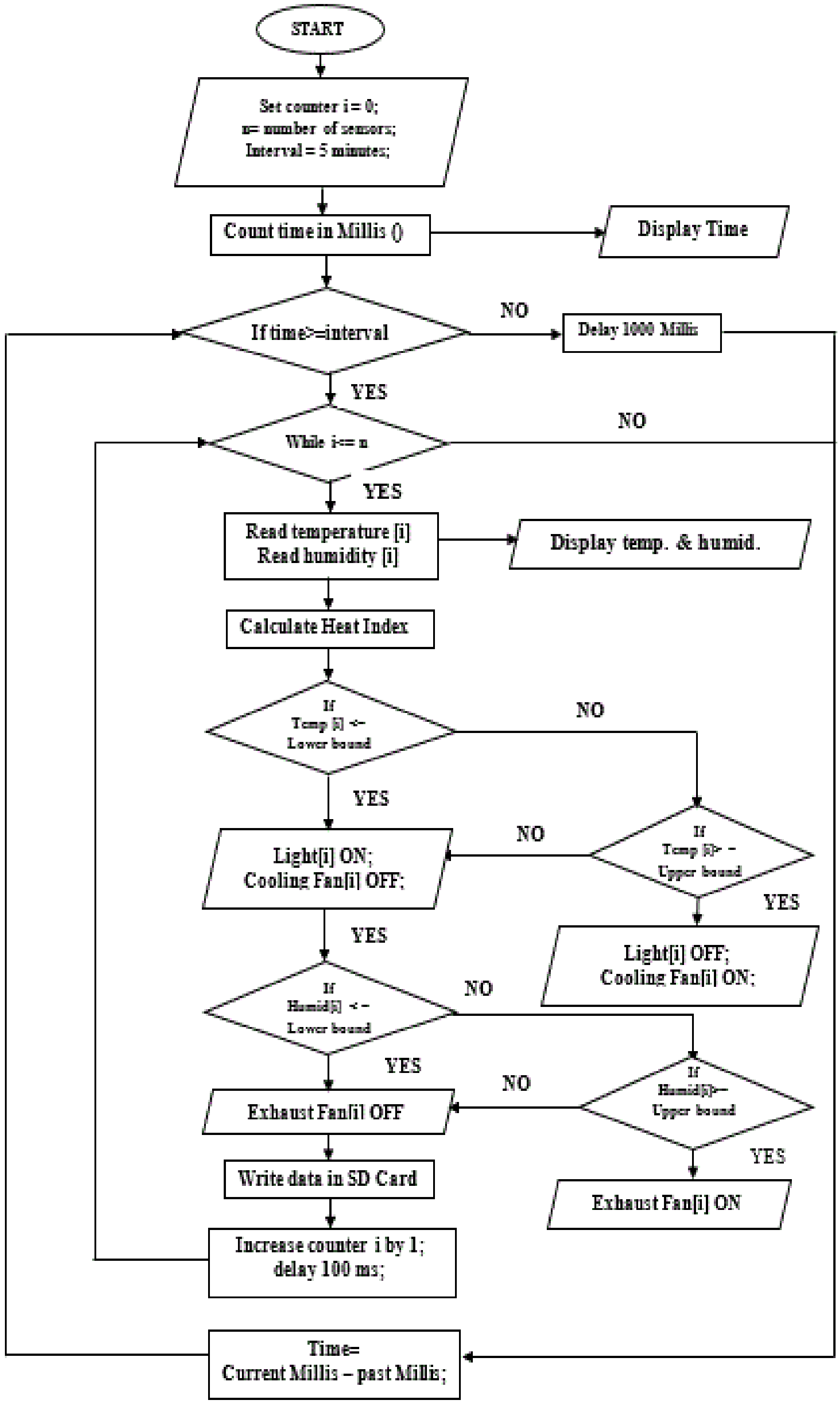

Fig. 3. Flowchart representation of programming

3.4 Circuit Diagram of the Proposed System

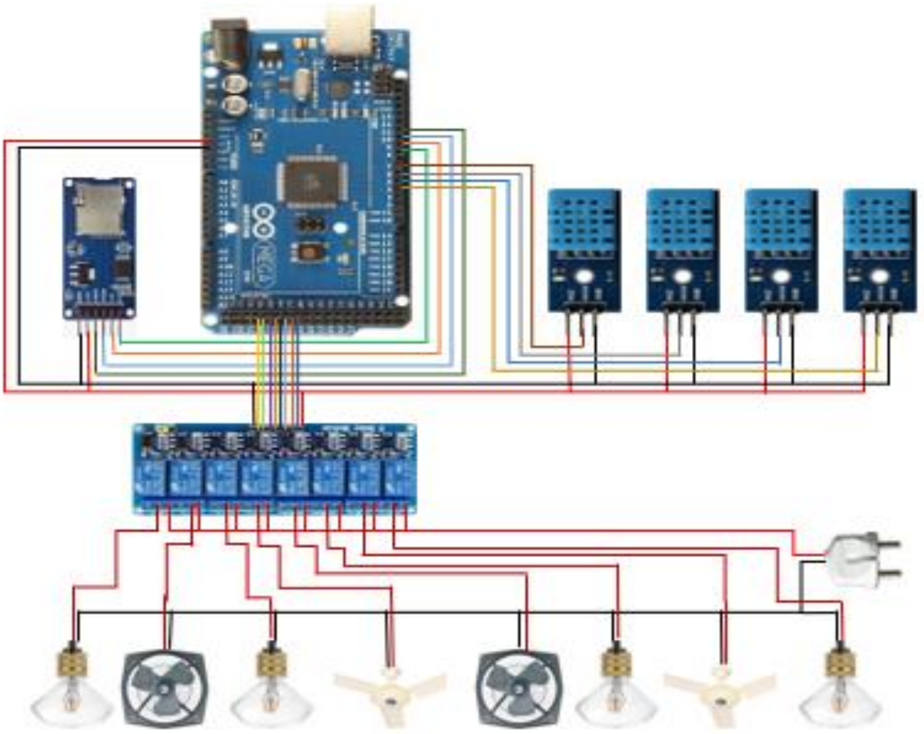

Fig. 4. Partial circuit diagram of the proposed System

3.5 Hardware Descriptions

A. Arduino MEGA Development Board: In this project, we used Arduino Mega development board (country origin: China) based on ATmega2560. The features of this development board are given below:

- **ATmega2560**-The high Performance, low power AVR® 8-bit microcontroller.
- **EEPROM**-The ATmega2560 features 4kb (4096 bytes) of EEPROM, a memory which is not erased when powered off.
- **Digital and Analog Pins**- The Mega 2560 has 54 digital pins, whereas 15 supports PWM (Pulse Width Modulation), and 16 analog input pins, the most of any Arduino board.
- **Serial Ports**- Connect to several devices through the 4x hardware serial ports (UARTs).

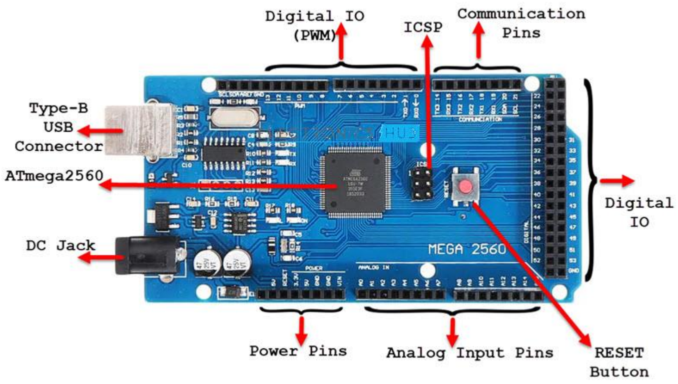

Fig. 5. Arduino MEGA development board

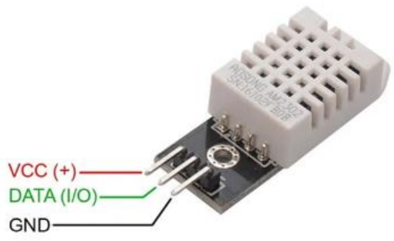

Fig. 6. Digital temperature & humidity sensor

B. Digital Temperature & Humidity (DHT22) Sensor: The DHT22 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds, so when using our library, sensor readings can be up to 2 seconds old.

C. Micro-SD Card Reader Module: The operating voltage of a typical microSD card is 3.3 V. Because of this, we are unable to directly link it to circuits that require 5V logic; in fact, any voltages higher than 3.6V run the risk of irreversibly damaging the microSD card. For this reason, the module has an internal ultra-low dropout voltage regulator that can control voltage up to 3.3V.

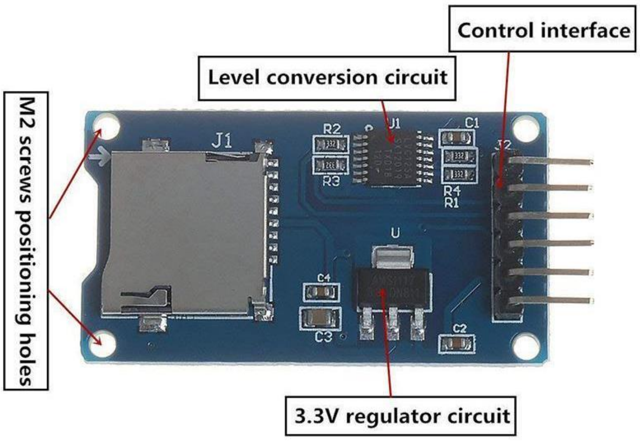

Fig. 7. Micro sd-card reader module

D. Liquid Crystal Display (16*2 LCD): A 16-pin gadget called an LCD 16x2 has two rows with room for 16 characters each. We can use the LCD 16x2 in either 4-bit or 8-bit mode. Additionally, it is possible to make original characters. It contains 3 control lines that can be utilized for control in addition to the 8 data lines.

E. Relay Switches: Relays are electrical switches that can be programmed, and Arduino or any other micro-controller can control them. It is used to automatically turn on and off equipment that uses high voltage and/or current. It serves as a link between high voltage devices and Arduino.

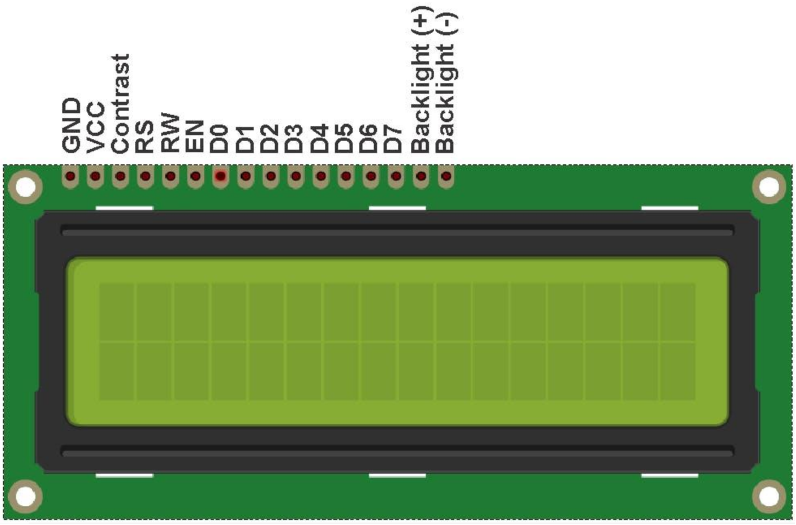

Fig. 8. Liquid crystal display (16*2)

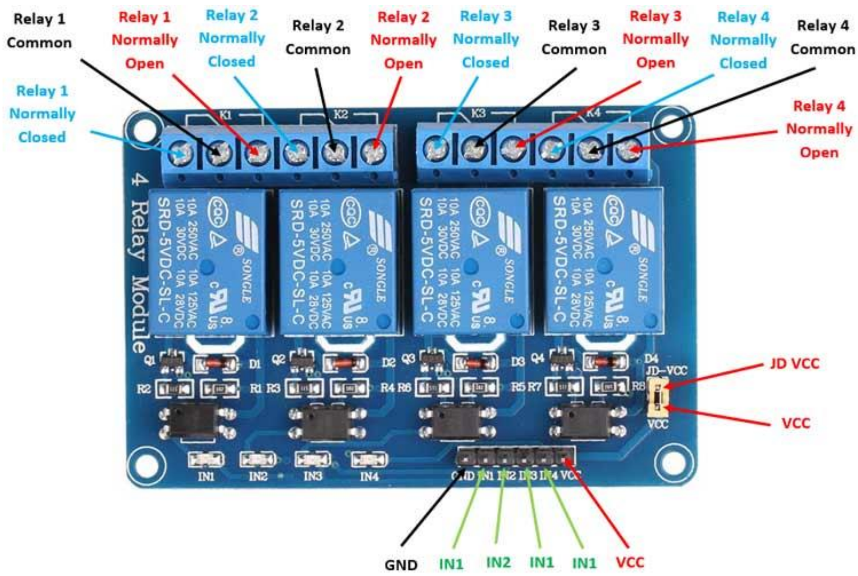

Fig. 9. Four-channel relay module

Chapter **4**

Methodology

This chapter describes the detail procedure of implementing the system into a poultry house. The step-by-step interfacing techniques, the protocols used by the sensor technology and data acquisition method are also discussed in detail here.

4.1 Interfacing Temperature and Humidity Sensor with Arduino Microcontroller

The DHT22 (Digital Humidity and Temperature Sensor V.22) is a digital output temperature and relative humidity sensor. It uses a thermistor to measure temperature and a capacitive humidity sensor to measure humidity from surrounding air. It contains 4 pins (VCC, GND, NC and DATA). The NC pin is connected to VCC with a 1K pull-up resistor. Usually, DHT sensors are placed far away from microcontroller board. Therefore, the NC pin doesn't require any connection. DHT sensors uses one wire single protocol for transferring data. In this project a total of seven DHT22 sensors are installed.

4.2 Interfacing Micro SD Card Reader Module with Microcontroller

Storing data is an important task for many projects. There might be several ways for storing data but SD cards and micro-SD Cards are one of the most popular and easiest way to store data. The SD card modules allows us to read from and write on to it. It uses SPI protocol for data communication. Although micro-SD card module supports 16GB memory card at highest level. It has 6 pins (VCC, GND, MISO, MOSI, SCK and CS).

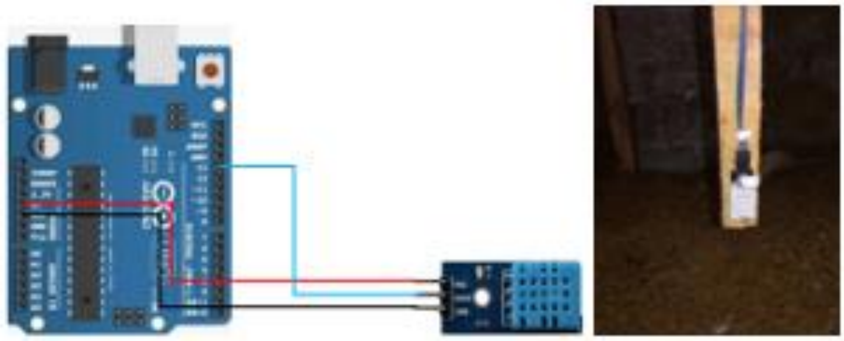

Fig. 10. Interfacing DHT22 sensor with Arduino

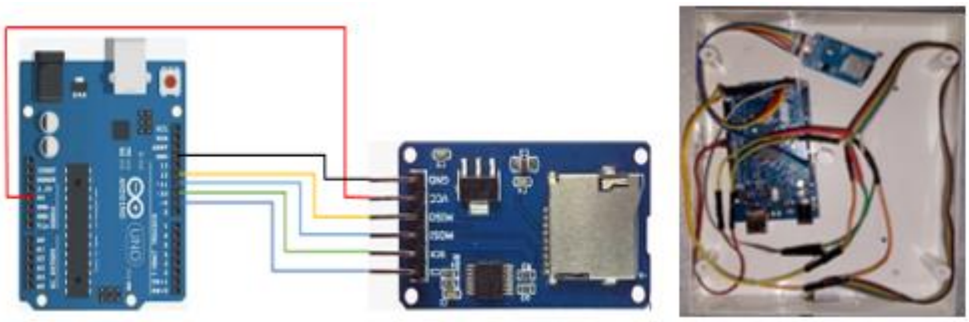

Fig. 11. Interfacing SD Card reader module with Arduino

4.3 Interfacing DS-3231 real time clock(rtc) module with arduino

The DS-3231 is a real time clock which keeps track with current time and date. It is integrated in every electronic device now a days which needs to keep track with time. It uses I2C communication protocol. The RTC module has 6 pins, off them 4 pins (VCC, GND, SDA, SCL) are connected with microcontroller. It contains a lithium battery of 3.3V. For the first time use of this module, it requires to set time and date. Once it set, if the module sustains from power, it keeps track with time with the help of on-board battery.

Arduino can calculate time in the unit of mills() from the last time when it turned ON. For example, it calculates (3000) as 3 seconds since it turns on. Whenever it truns off, it cannot track the time. That's why for a specific time on everday a real-time clock (rtc) module can provide exact time and date to the arduino. A rtc module is always on with its external battery supply. But before we using it, intially we need to set the present time and date through arduino ide.

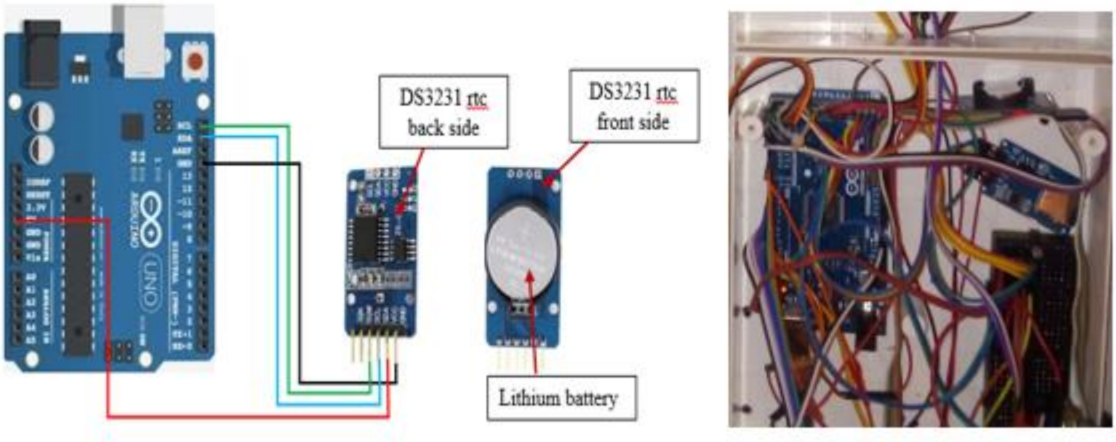

Fig. 12. Interfacing DS-3231 real time clock(rtc) module with arduino

4.4 Interfacing lcd 16×2 lcd display with Arduino

Display units provides an important role to establish better communication between human world and machine world. In modern world they are an important part of embedded systems. The 16x2 LCD will have 32 characters in total, 16in 1st line and another 16 in 2nd line. The connections which are done for LCD are given below:

- PIN1 or VSS to ground
- PIN2 or VDD or VCC to +5v power
- PIN3 or VEE to ground (gives maximum contrast best for a beginner)
- PIN4 or RS (Register Selection) to PIN7 of ARDUINO
- PIN5 or RW (Read/Write) to ground (puts LCD in read mode eases the communication for user)
- PIN6 or E (Enable) to PIN6 of ARDUINO
- PIN11 or D4 to Digital PIN of ARDUINO
- PIN12 or D5 to Digital PIN of ARDUINO
- PIN13 or D6 to Digital PIN of ARDUINO
- PIN14 or D7 to Digital PIN of ARDUINO
- PIN15 or VDD to 5V of ARDUINO
- PIN16 or GND to GND of ARDUINO

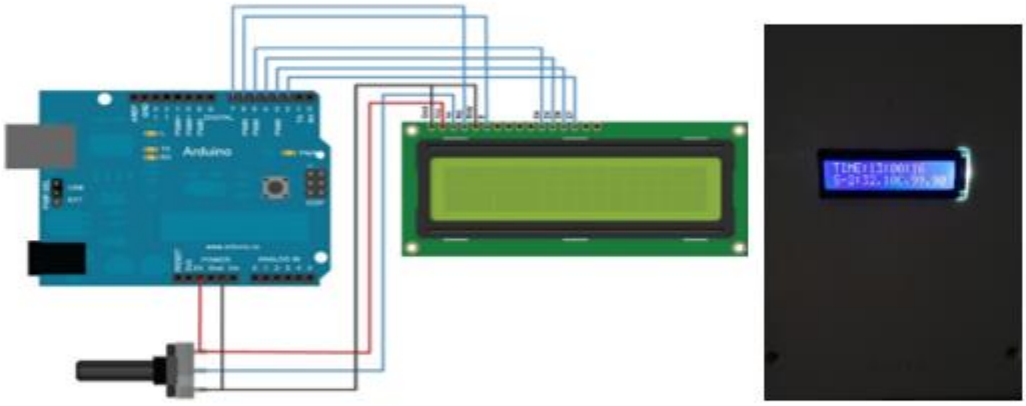

Fig. 13. Interfacing lcd 16×2 display with arduino

B100K potentiometer is used for controlling the lcd brightness. Lcd display can show everday date and time and other informations like sensor values or relay on/off conditions. In this project the lcd display visualize time, sensor values and SD card conditons.

4.5 Interfacing relay switches with microcontroller

Relay switch can be named magical switch as it works only with 5V DC supply but can control 230V, 450V or 1000V AC appliances. The principal on which its work is electromagnetism. When the coil of relay is energized it acts like a magnet and changes the position of a switch. The circuit which powers the relay is completely isolated from the part which turns ON/OFF switches. This provides electrical isolation.

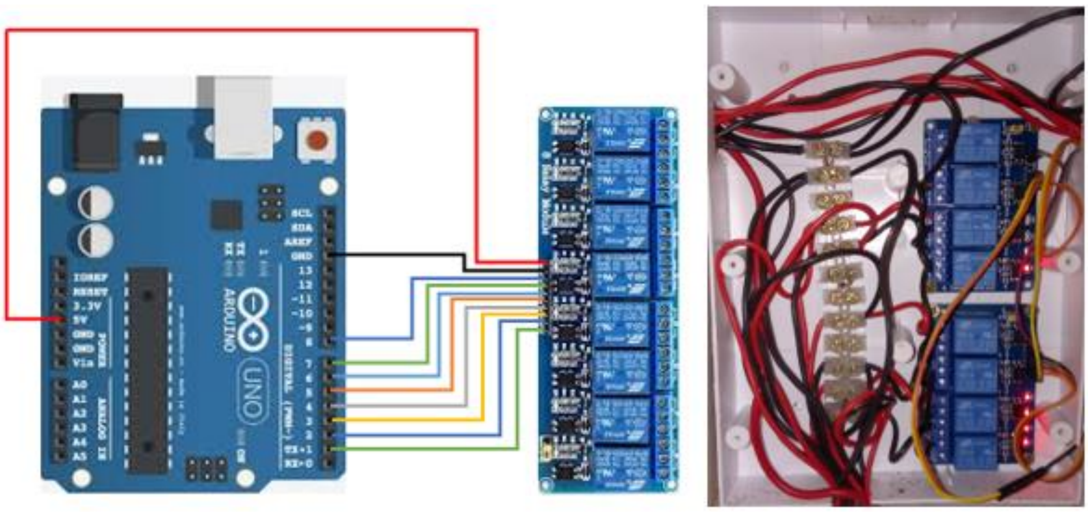

Fig. 14. Interfacing relay modules with Arduino

Fig. 15. Installation of fans & light holders

4.6 Installation of Light holders and Fans

We have set 5 exhaust fans, which will pass the hot air and 2 Celling fans for cooling purpose of the poultry room. Also, we have set 6 light holders for 6 chicken shade, which provides heat if temperature is below the margin line.

4.7 Installation of Complete Hardware System and Poultry House

In this project 5 exhaust fans, 2 celling fans, 6 light holders, 1 room light are set and therefore in total of 14 AC appliances are set. Now we have to put 14 switches on electrical boards. For doing this, two electrical boards are required, one for fans and another for lights. All of the peripheral's modules such as sensing unit, data storage unit and control units are interfaced with Arduino microcontroller. The sensing unit consists of DHT sensors by which temperature and RH are recorded. Each broiler cells exactly holds one DHT sensor, 2-3 heat bulbs and one exhaust fan. The data storage unit collects data from sensors and stores them on micro-SD-card through SD-card module. Control unit consists of relays, analog switches, heat bulbs, cooling fans, exhaust fans and most importantly the microcontroller. This way the hardware setup is finalized.

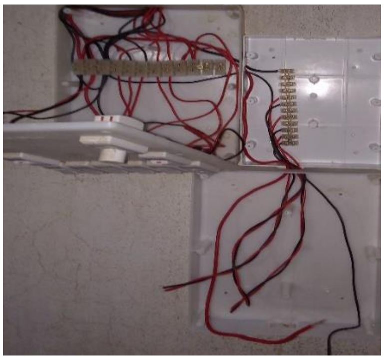

Fig. 16. Installation of Analog switches.

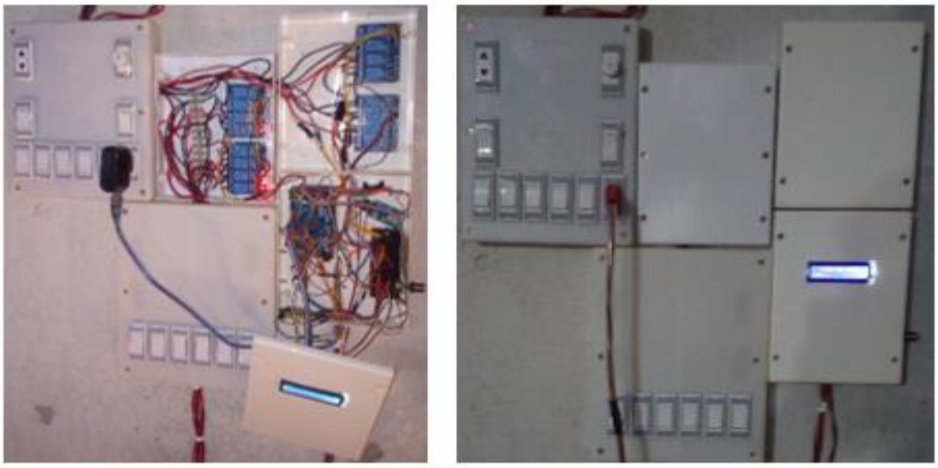

Fig. 17. Complete circuit without and with cover

Fig. 18. Before & after covering with plastic

Fig. 19. Door opened and closed of poultry room

4.8 Protocols (OWSP, I2C, SPI)

One wire single protocol (OWSP) is used by DHT sensors for transferring data. DHT sensors have 4 pins (VCC, GND, NC and DATA). The NC pin is connected to VCC with a 1K pull-up resistor. Usually, DHT sensors are placed far away from microcontroller board. Therefore, the NC pin doesn’t require any connection. Micro-SD card module uses Serial programming Interface (SPI) protocol for data communication. It has 6 pins (VCC, GND, MISO, MOSI, SCK and CS). Although it supports 16GB memory card at highest level. The RTC module has 6 pins, off them 4 pins (VCC, GND, SDA, SCL) are connected with microcontroller. It uses Inter-Integrated Circuit (I2C) communication protocol. A RTC module is always on with its external battery supply. But before we using it, initially we need to set the present time and date through Arduino ide.

4.9 Software Setup

Now the software setup is achieved by uploading the software program to Arduino’s processor. The flowchart of the program is represented in section V. Once the upload has done, the microcontroller automatically gathers the values of DHT sensors in regular intervals, matches values with environmental parameters which are requires according to the age of broilers, and performs action through relay switches for achieving a healthy environment for production farm.

4.10 Data Acquisition

The monitoring period over broiler chickens took place from September 2020 to January 2021. During these periods two yards of broilers are produced, one in summer and another in winter conditions. Each yard requires 28-35 days for growing broilers on a commercial manner. The sensors were enclosed by cells and placed at chicken level (approximately 0.4-0.6m above ground level). Temperature and RH was measured using DHT sensors, Analog temperature meter and hygrometer. Data was measured at 5 minutes time interval for all DHT sensors. Data acquisition also contains average body weight and amount of feed consumed on each week. Data was downloaded from micro-SD Card via USB connection to origin software for analyzing.

Chapter 5

Result & Discussion

In this chapter, smart system outcomes are depicted for both winter and summer seasons. The temperature and humidity levels differences between smart and conventional system are also provide here. The effect of broiler performance in both systems such as mortality rate, feed efficiency, efficiency factor and farm economy index outcomes are also discussed.

The smart system features six TH sensors (DHT 1 through DHT 6) in contrast to the conventional system's one TH sensor (DHT 7). The data is recorded on an SD card by the microcontroller, which records the temperatures and humidity levels at regular intervals of 5 minutes. The accuracy of the temperature and humidity readings from the TH sensors is additionally checked using a thermometer and a hygrometer. In order to construct temperature and humidity graphs, data is then transferred into data analysis software and Excel spreadsheets. These graphs are then used to evaluate the performance of the chosen smart system.

5.1 Smart System Responses on Winter Season

Here, a random day from each week is chosen, and the temperature and humidity graphs of the day are presented to make things clear for the reader.

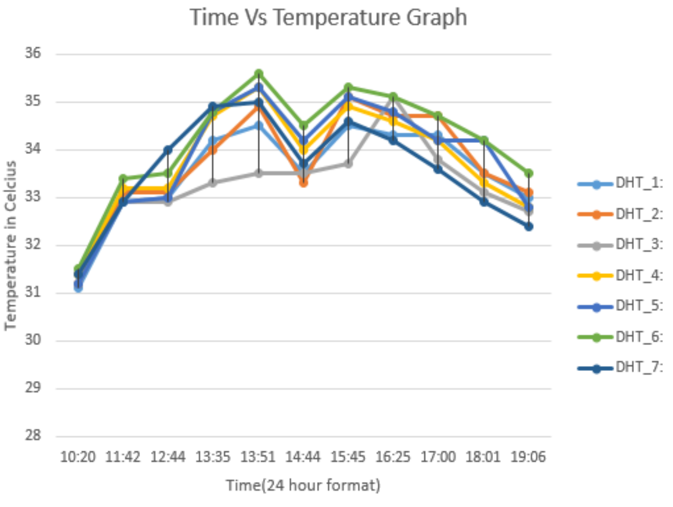

Fig. 20. Thermal states of one day in 1st week of cages within smart system

A. Temperature and Humidity Graphs of a Day in Week-1

In Day -1 controlling system of AC appliances is enabled. Plastic cover of poultry room is puts off. That's why in day -1 system records-controlled temperature and relative humidity. From the above data tables and graphs we observed that,

Highest temperature = 35.6°C recorded by DHT Sensor 6,

Lowest temperature = 31.1°C recorded by DHT sensor 1,

Highest humidity = 98.9% recorded by DHT Sensor 6,

Lowest humidity = 76.2% recorded by DHT Sensor 1

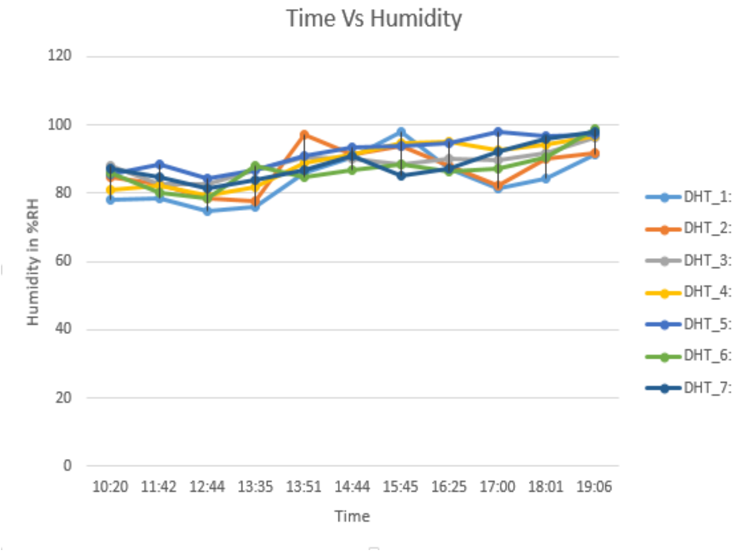

Fig. 21. Humidity states of one day in 1st week of cages within smart system

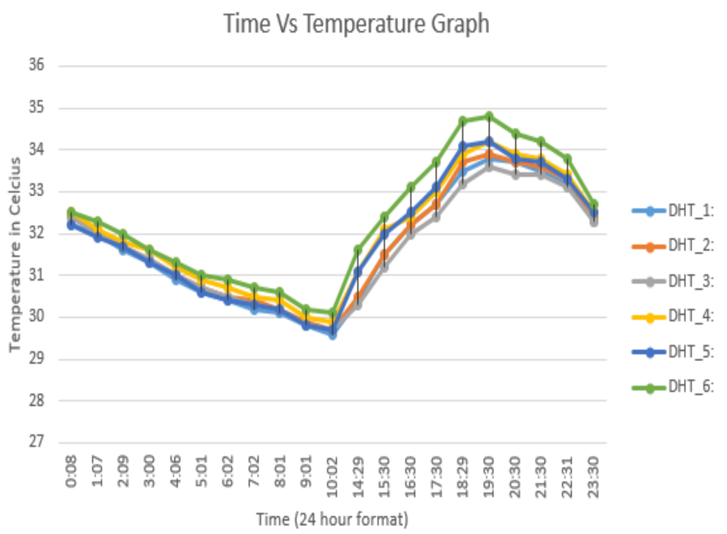

Fig. 22. Thermal states of one day in 2st week of cages within smart system

B. Temperature and Humidity Graphs of a Day in Week-2

In Day -2 controlling system of AC appliances is enabled. Plastic cover of poultry room is puts off. That's why in day -2 system records-controlled temperature and relative humidity. From the above data tables and graphs we observed that,

Highest temperature = 34.4°C recorded by DHT Sensor 6,

Lowest temperature = 29.6°C recorded by DHT sensor 1,

Highest humidity = 91.9% recorded by DHT Sensor 3,

Lowest humidity = 70.5% recorded by DHT Sensor 1.

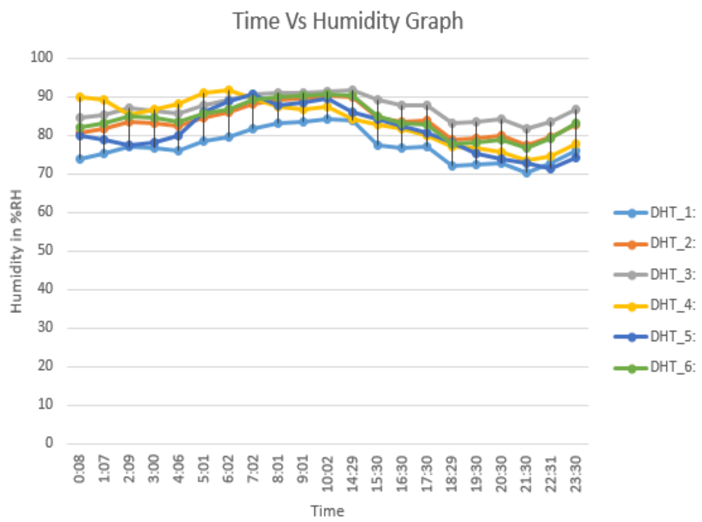

Fig. 23. Humidity states of one day in 2st week of cages within smart system

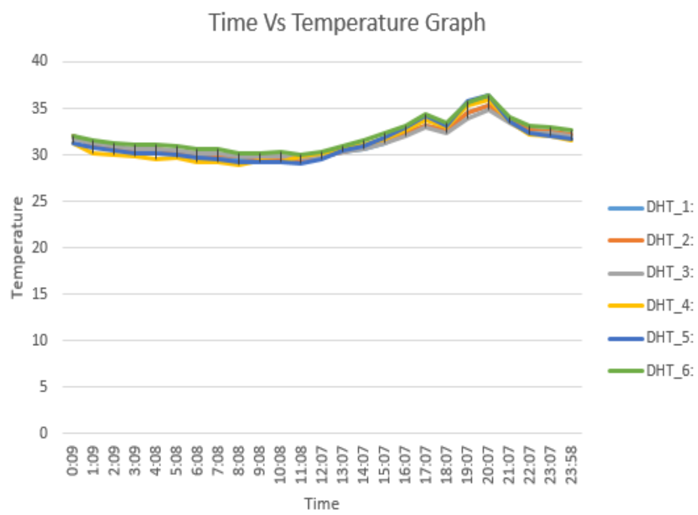

Fig. 24. Thermal states of one day in 3st week of cages within smart system

C. Temperature and Humidity Graphs of a Day in Week-3

In Day -3 controlling system of AC appliances is disabled. Plastic cover of poultry room is puts off. That's why in day -3 system records natural temperature and relative humidity. From the above data tables and graphs we observed that,

Highest temperature = 35.8°C recorded by DHT Sensor 6,

Lowest temperature = 29.2°C recorded by DHT sensor 4 and 5,

Highest humidity = 99.9% recorded by DHT Sensor 5,

Lowest humidity = 72.3% recorded by DHT Sensor 1.

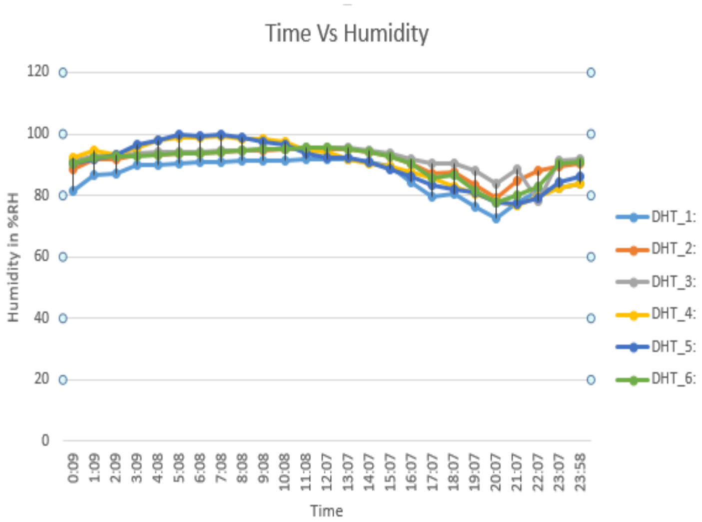

Fig. 25. Humidity states of one day in 3st week of cages within smart system

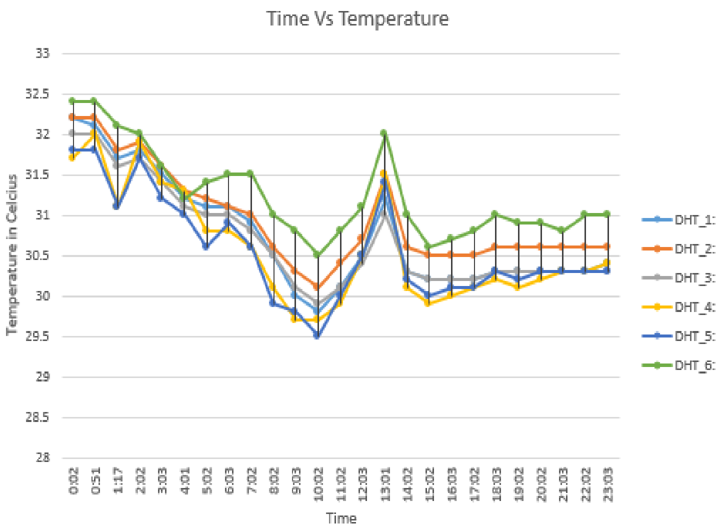

Fig. 26. Thermal states of one day in 4st week of cages within smart system

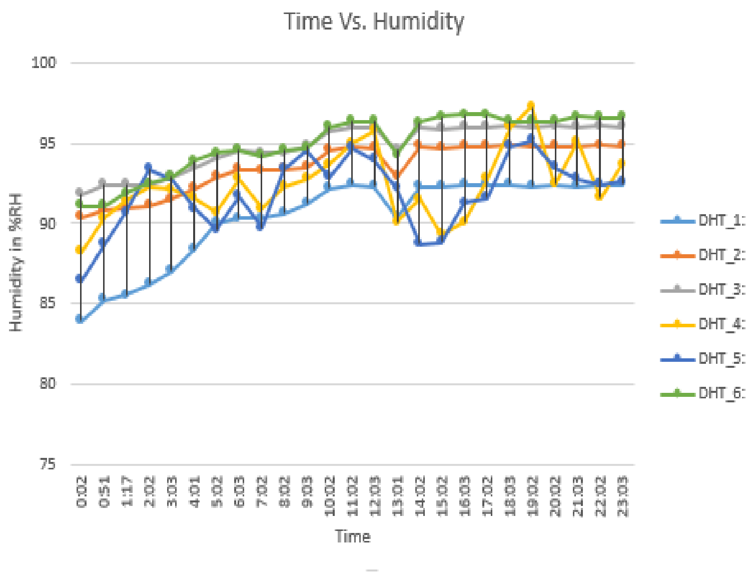

Fig. 27. Humidity states of one day in 4st week of cages within smart system

D. Temperature and Humidity Graphs of a Day in Week-1

In Day -4 controlling system of AC appliances is enabled. Plastic cover of poultry room is puts on. That's why in day -4 system records-controlled temperature and relative humidity. From the above data tables and graphs we observed that,

Highest temperature = 32.4ºC recorded by DHT Sensor 6,

Lowest temperature = 29.5ºC recorded by DHT sensor 5,

Highest humidity = 97.3% recorded by DHT Sensor 4,

Lowest humidity = 83.9% recorded by DHT Sensor 1.

In day -4 it is observed that, temperature is not rise above 32.4ºC and not down below 29.5ºC. It's because controlling system of AC appliances is enabled. Whenever any area rises its temperature above 32.0ºC, fans start for cooling that particular area and whenever any area goes below 30.0ºC, light start for heating that particular area. Thus, we can conclude smart system doing its job properly.

5.2 Mean Body Weight Bar Diagrams of The Broilers from Winter Shed

After every seven days, the broilers' body weight is physically recorded. The broilers were fed five different types of feed namely (Nourish, Sun, A1, Aman and ACI) to determine how the smart system (SS) influences the weight gains. The blue bars represent the weight gains of the broilers grown within smart system. The orange and ash bars represent the weight gains of those broilers grown within conventional system. It is clear from the bar diagrams below that broilers grown using smart systems gain more weight than broilers grown using conventional systems.

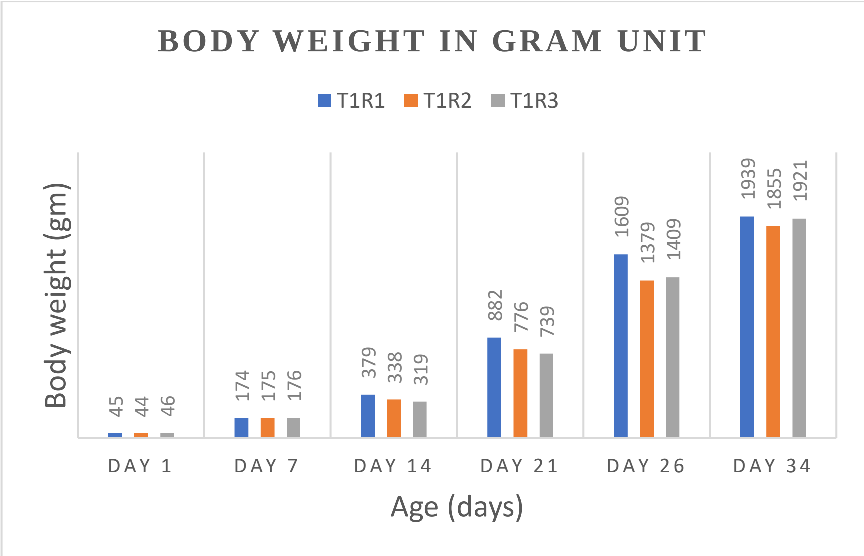

Fig. 28. Average weight bar diagram of the broilers taking A1 feed

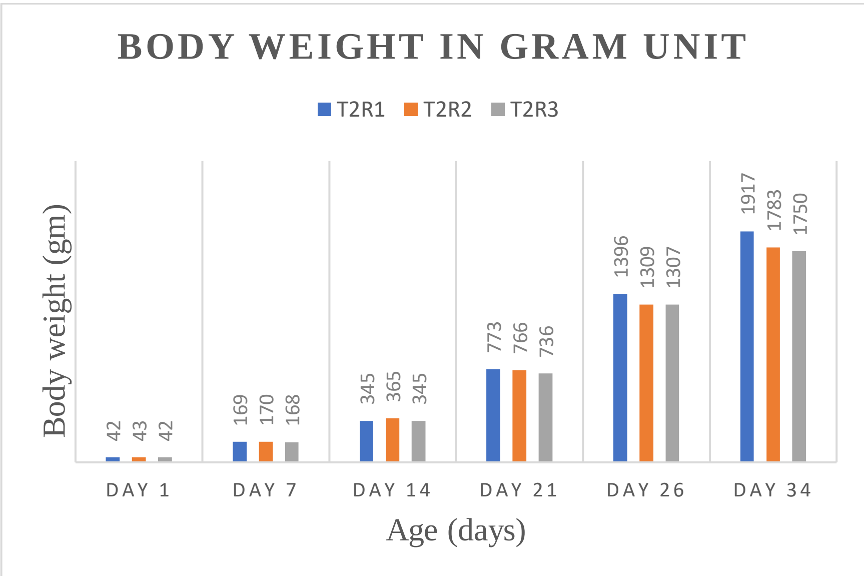

Fig. 29. Average weight bar diagram of the broilers taking SUN feed

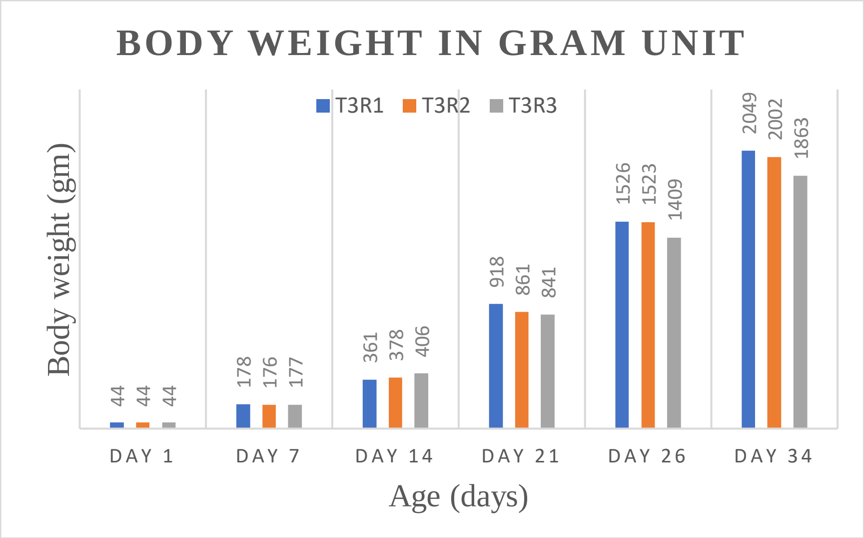

Fig. 30. Average weight bar diagram of the broilers taking AMAN feed

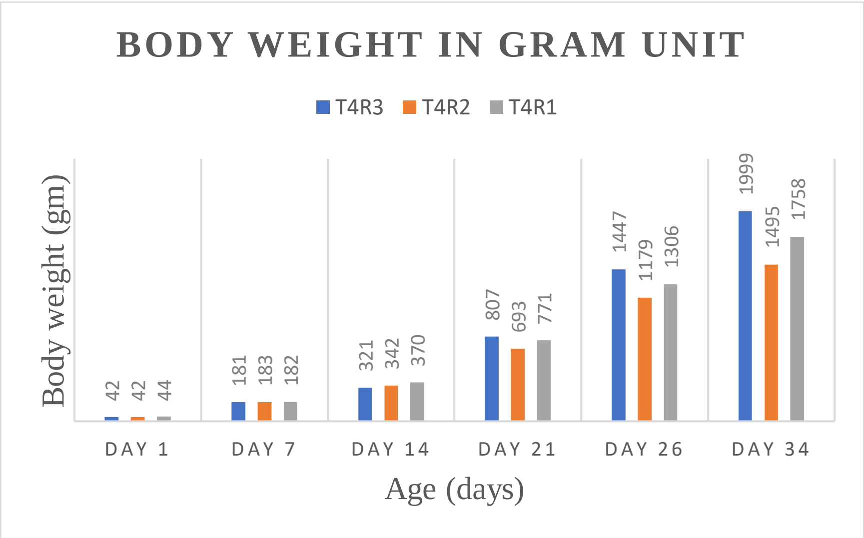

Fig. 31. Average weight bar diagram of the broilers taking NOURISH feed

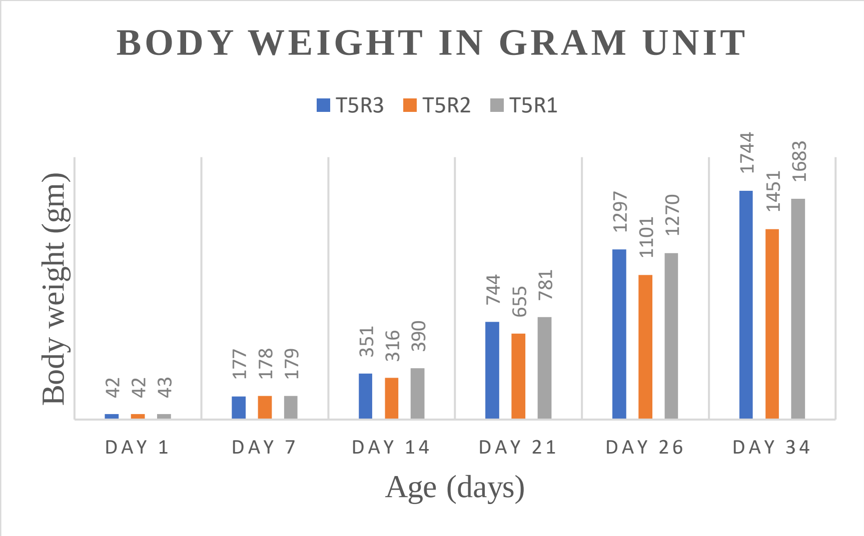

Fig. 32. Average weight bar diagram of the broilers taking ACI feed

These state space bar diagrams show the broilers' average weight growth from (Fig. 28 to Fig. 32). In order to determine how the smart system affected the broilers' growth, five different types of chicken feed were supplied to the animals. When the broilers were 34 days old, the blue bar's values were found to be at their highest. It should be emphasized that the blue bar shows the weight gain of the broilers grown using smart controls, whereas the other two bars show the weight gain of those broilers grown using conventional controls. Thus, it is clear that the production of the poultry house is impacted by the smart managed system.

5.3 Smart System and Conventional System Responses on Summer Seasons

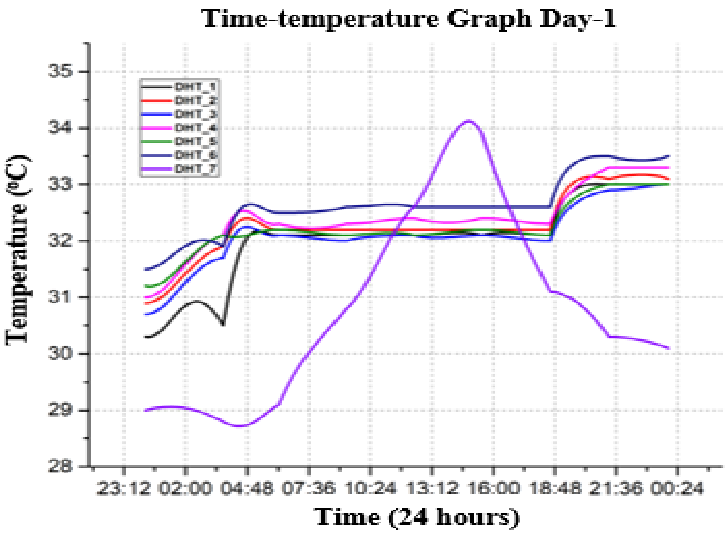

Fig. 33. Temperatures in cages in a day in the 1st Week

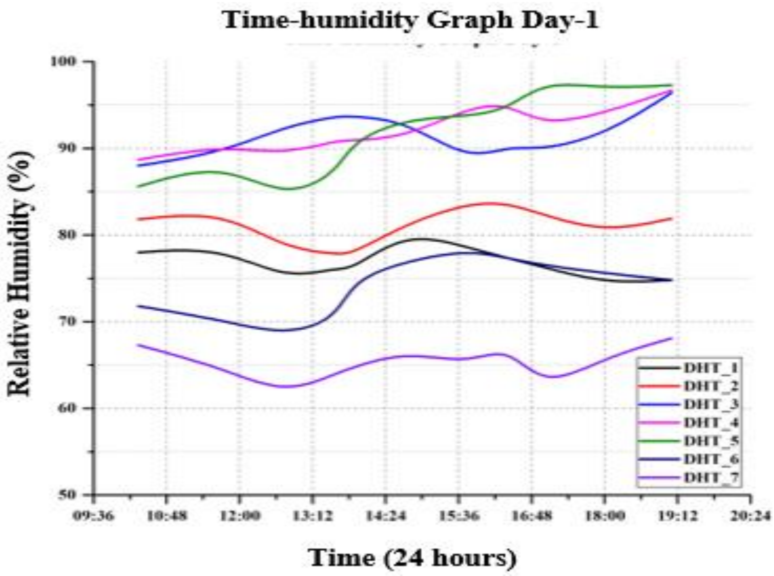

Fig. 34. Humidity's in cages in a day in the 1st Week

A. Temperature and Humidity Graphs of a Day in Week-1

The most crucial period for chicken farming is the first week, which lasts up to 7 days for broiler chicks. In the husbandry of poultry, this period is often referred to as the brooding phase. The majority of chicken deaths occur at this stage as a result of unsuitable conditions. At this point, the ideal temperature range for chicken farms is between 30°C and 33°C, with a relative humidity range of 50-60%. It has been observed from Fig. 33, the controlled shed temperature under the designed smart system lies between 30°C and 33.5°C whereas the temperature of the conventional controlled shed fluctuates between 28.6°C and 34.6°C. From (Fig. 34) Relative humidity in conventional system fluctuates between 62% and 68% and Relative humidity in smart controlled systems (cell 1, 2 and 6) lies between 69% and 83% that is permissible. Although a higher relative humidity is observed from cell 3, 4 and 5 in smart system. Rising of the RH above 90% at cell no. 4, 5, and 6 is not the indication of humidity rather than indication of high air pollutants NH_3 level. [43], [44].

B. Temperature and Humidity Graphs of a Day in Week-2

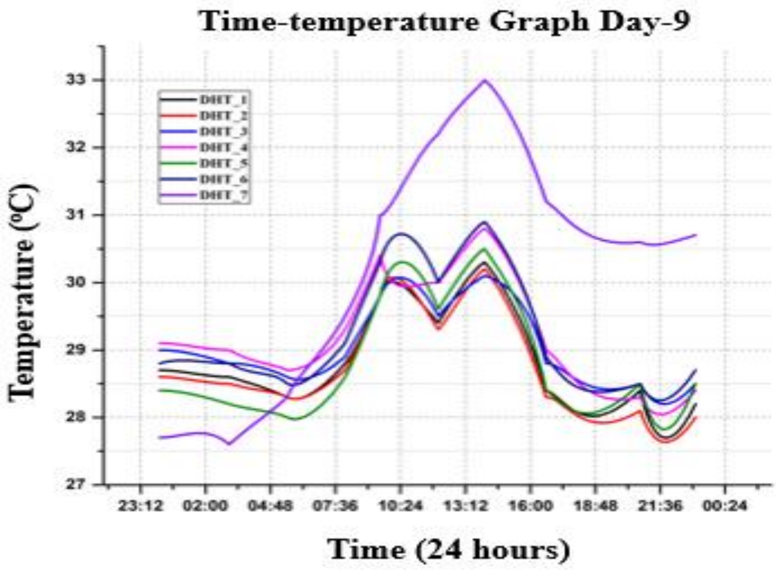

Fig. 35. Temperatures in cages in a day in the 2nd Week

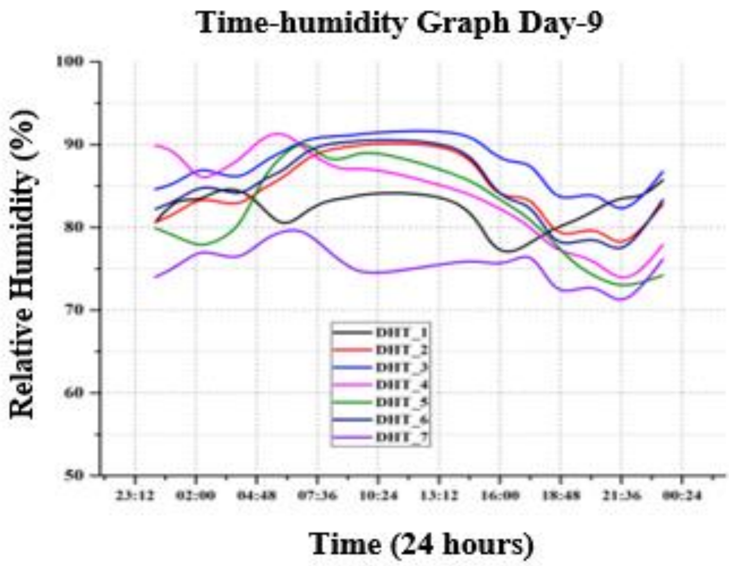

Fig. 36. Humidity's in cages in a day in the 2nd Week

In the 2nd week, at the age of (8-14) day's broiler chickens, environmental temperature requires modification. For that reason, upper and lower thresholds of temperature is decreased by 2°C. Now the temperature range is set from 28°C to 31°C, and the RH thresholds are kept same as the 1st week. From Fig. 35. it is seen that; smart system temperature lies between 28°Cand 31°C. On this day environment temperature is maximum which is near 33^{o}C at mid of the day. From Fig. 36. RH is between 70-80% in conventional subsystem and 80-90% in smart subsystem.

C. Temperature and Humidity Graphs of a Day in Week-3

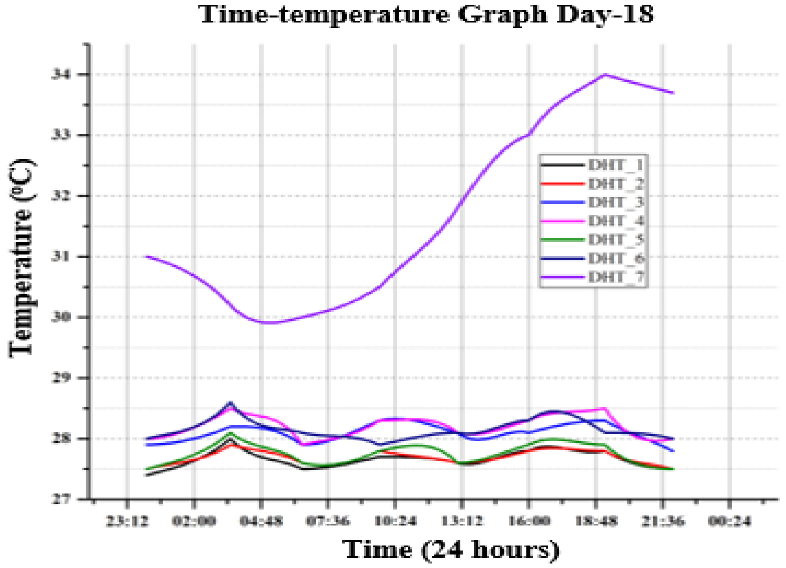

Fig. 37. Temperatures in cages in a day in the 3rd Week

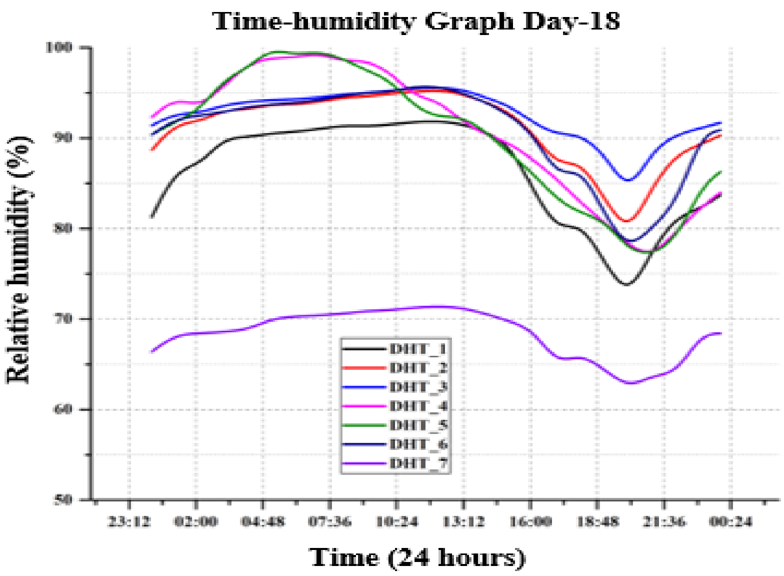

Fig. 38. Temperatures in cages in a day in the 3rd Week

In week-3, up to age of 21 day's broiler chickens, conditions for upper and lower thresholds of temperature are again decreased by 2^{o}C. Now the temperature range is set from 26ºC to 29ºC, and the RH thresholds set between 60-75%. From Fig. 37. it is seen that, temperature lies between 27.4ºC to 28.6ºC on day 9 whereas environment temperature fluctuates between 29.8ºC to 34ºC. From Fig. 38. RH is between 63-73% in environment and 80-90% in smart subsystem.

D. Temperature and Humidity Graphs of a Day in Week-4

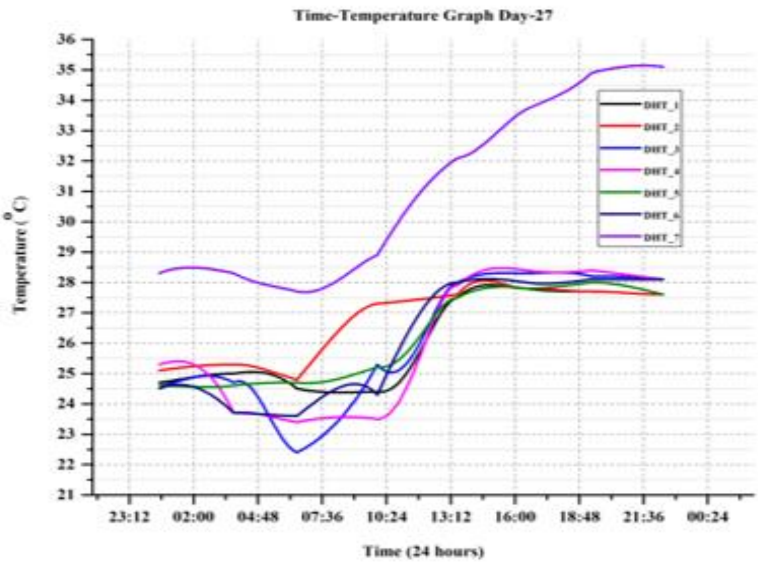

Fig. 39. Temperatures in cages in a day in the 4th Week

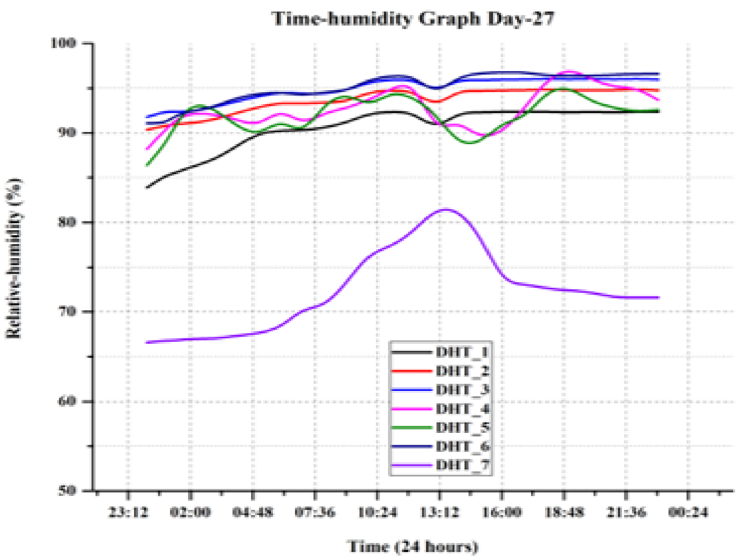

Fig. 40. Temperatures in cages in a day in the 4th Week

For week-4, broiler age above 21 days conditions for temperature range is set between 24^{o}C to 27^{o}C and RH range is (65%-80%). From Fig. 39. temperatures from sensor 1 to 6 reflects same temperature line as selected range whereas ambient temperature is uprising and reached to 35^{o}C. Thus, broiler growing under conventional environmental conditions may suffer heat stress and leads to death of broilers. Although a higher value of RH near 95% from sensor 1 to 6 are observed from Fig. 40. This is because the increasing amount of broilers fecal matters in cells.

It has been observed from all the observation weeks that temperature in cells could be controlled by the proposed smart system whereas the relative humidity could be controlled somewhat small degree. The significant controlling of the RH controlling can be achieved by regular changing of fecal matters from broilers sheds in every two weeks. Thus, we can conclude smart system doing its job properly by controlling optimum environmental parameters for chicken farming.

5.4 Measurement of the Performance Efficiency of Broilers in both systems

5.4.1 Livability

One of the most significant aspects is the broilers livability, which is described as the ratio of the end broilers population to the preliminary quantity of broilers [45], [46].

$$\text{Livability} = \frac{(\text{Numbers of broilers sold} \times 100)}{\text{Number of broilers at the beginning}}$$

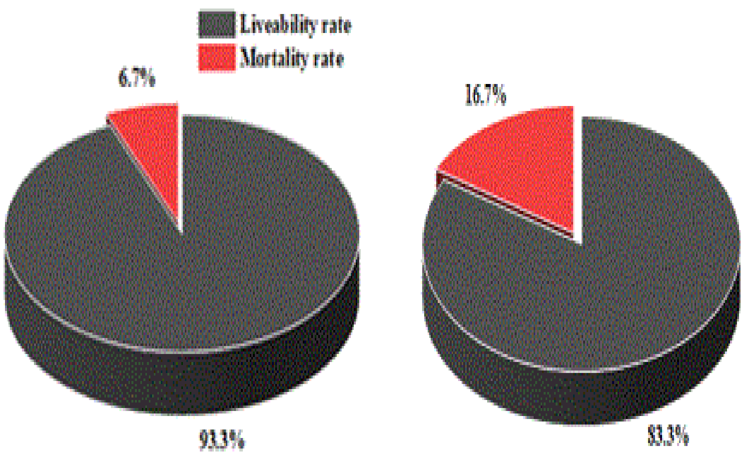

Fig. 41. Livability vs. mortality pie diagram for broilers in smart and conventional systems

The average life expectancy of a modern broiler is nearly seven weeks. Chicken flocks have a mortality rate of nearly 5-6 percent on average. It can rise to 20% if broilers are not properly maintained. A higher mortality rate is a major hindrance to commercial broiler chicken expansion. During broiler production in smart and conventional systems, it has been observed that livability rate is 93.3% in smart system and 83.3% in conventional system. Figure 41 indicates that the smart system has a 10% higher livability rate than conventional system. Alternatively, we can say smart system has lower mortality rate than the conventional system.

5.4.2 Feed Efficiency or Feed Conversion ratio

$$\text{FCR} = \frac{\text{Total quantity of feed consumed per broiler (kg)}}{\text{Mean body weight gain (kg)}}$$

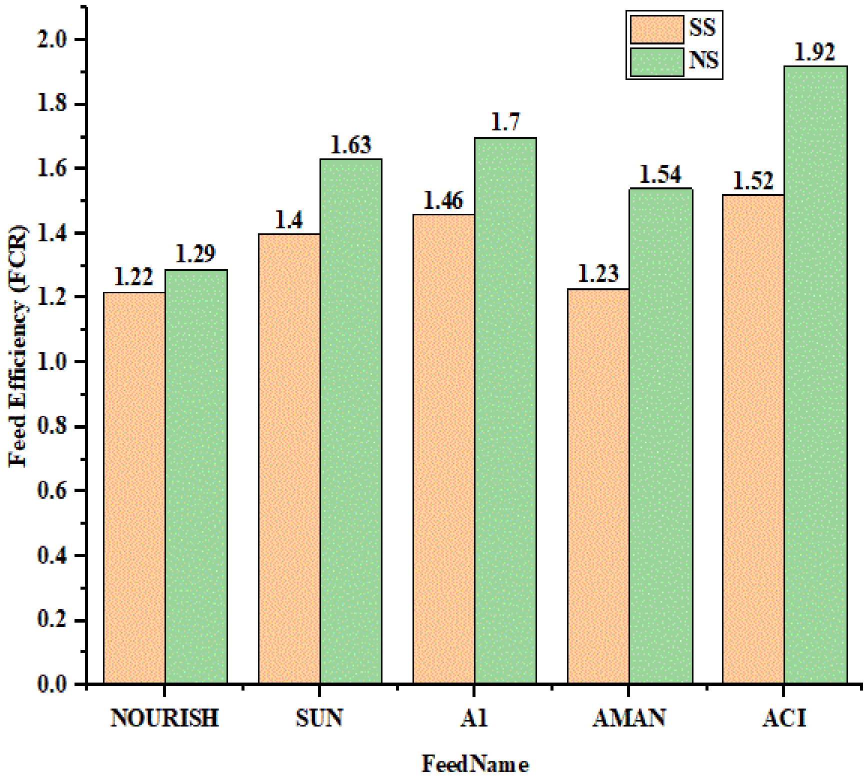

Fig. 42. Feed conversion ratio bar diagram for broilers.

Comparing broiler production to other livestock, it is thought to be feed efficient. Feed conversion ratio (FCR), which denotes the proportion between feed consumption and body weight, is a straightforward way to express feed efficiency [47]. Feed conversation ratio is the net amount of feed used to produce one (kg) of broiler. The lower the FCR, the more efficient the animal is in converting feed to meat.

For poultry farming the conventional FCR is ranges from 1.7 to 2.0. To investigate how smart system (SS) affects the FCR, five different types of feed were given to the broilers namely (Nourish, Sun, A1, Aman and ACI). These feeds were also given to the broilers those are grown into conventional system (NS). From Fig. 42, FCR values in smart system (SS) ranges from 1.22 to 1.52 for different feeds whereas FCR in conventional system (NS) ranges from 1.29 to 1.92, which is an indication of better FCR in smart system. This can reduce overall cost for poultry production. As in poultry feed cost is around 70% from overall cost. Thus, smart system is becoming more environmentally friendly and sustainable because of the outstanding feed efficiency capabilities of today's mercantile broiler chicken traits.

5.4.3 Broiler Performance Efficiency Factor

A practical and exhaustive indicator to evaluate the performance of broilers is the broiler performance efficiency factor (BPEF). It has a direct relationship with the FCR. The lower the FCR value, the higher the BPEF. The BPEF value should be at least 100. The BPEF will be better if the value is higher.

$$\mathrm{BPEF} = \frac{\text{Live weight (kg)} \times 100}{\mathrm{FCR}}$$

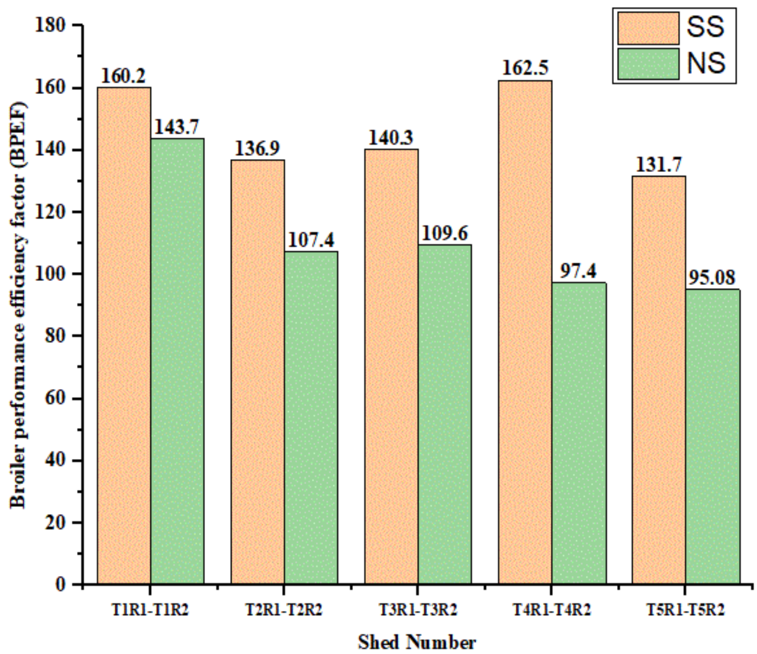

Fig. 43. Broiler performance efficiency factor bar diagram in smart and conventional systems

From Fig. 43. It is evident that broilers maintained in smart system (SS) have a performance factor of over 130 in all cells, which is above the minimum value of BPEF. We observe from cell-T4R2 and cell-T5R2 have BPEF value less than 100. These cells were enclosed in conventional system (NS). Therefore, broilers maintained in a conventional system have failed to achieve the desired broiler performance efficiency factor.

5.4.4 Broiler Farm Economy Index (BFEI)

The ultimate or terminal live weight is the goal for producers, who also want to maximize the broilers' livability and reduce the amount of nutrient used to get there. The BFEI includes each of these distinct biological elements to make it easier to compare the performance of live birds among chicks, growers, or in reference to breed standards and global benchmarks. The BEFI calculation formula is as follows:

$$\text{BFEI} = \frac{\text{Average live weight (kg)} \times \text{livability \%}}{\text{FCR} \times \text{growing period (days)}}$$

Table 2. Broiler Farm Economy Index Calculation

<table>
<tr><th colspan="3">Smart System</th><th colspan="3">Conventional System</th></tr>
<tr><th>Shed No</th><th>BFEI</th><th>Mean BFEI</th><th>Shed No</th><th>BFEI</th><th>Mean BFEI</th></tr>
<tr><td>T_1R_1</td><td>4.08</td><td rowspan="5">3.89</td><td>T_1R_2</td><td>3.52</td><td rowspan="5">2.52</td></tr>
<tr><td>T_2R_1</td><td>3.52</td><td>T_2R_2</td><td>2.54</td></tr>
<tr><td>T_3R_1</td><td>3.72</td><td>T_3R_2</td><td>2.50</td></tr>
<tr><td>T_4R_1</td><td>4.64</td><td>T_4R_2</td><td>2.33</td></tr>
<tr><td>T_5R_1</td><td>3.50</td><td>T_5R_2</td><td>1.72</td></tr>
</table>

A BFEI score of 2.0 or higher suggests superior farm management and optimal broiler performance, whereas a reading of less than 1.3 denotes inadequate performance. From Table II. mean broiler farm economy index for smart system is 3.89 and the mean value of BFEI in conventional system is 2.52, which is a clear indication of better broiler farm management in smart automated system.

Advantages

- One of the most significant advantages of this smart system is the ability to control heat bulbs, cooling, and exhaust fans atomically.
- This system requires less labor for monitoring the broilers.
- A cost-effective system for domestic and commercial poultry farm management.

Conclusions

Temperatures, humidity, light intensities, and ammonia (NH_3) levels in poultry sheds have been found to be the most essential elements in poultry production. The goal of this project is to create a smart system for controlling environmental elements that affect chicken or broiler farming. The system maintained minimum and maximum threshold conditions based on the age of broiler chickens in order to offer a favorable environment for broiler chickens during their growing period. The temperature threshold is between 25^{o}C and 33^{o}C, while the relative humidity is between 50% and 85%. Ventilators were activated when the temperature raised over the maximum value, and heat bulbs or heaters were activated when the temperature fell below the minimum value. Similarly, Exhaust fans turned on and off as accordingly the RH fluctuation between maximum and minimum levels. The health of the poetry is very important for keeping a good farm production and minimizing the total power required by the smart control system in order to reduce the overall production cost of poultry farms. Poultry farming with modern technologies and embedded systems, where climate parameters are continuously monitored and controlled by the system, can provide a lower mortality rate, a lower feed efficiency, a higher efficiency factor, and a higher farm economy index than traditional poultry farming management.

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Appendix I

Source code of the System

```
#include <SD.h>
#include<SPI.h>
#include<Wire.h>
#include<LiquidCrystal.h>
#include<DS3231.h>
#include "DHT.h"

const int CSpin = 53;
#define DHTTYPE DHT22   // DHT 22  (AM2302), AM2321

#define DHTPIN1 8     // Digital pin connected to the DHT sensor
#define DHTPIN2 9     // Digital pin connected to the DHT sensor
#define DHTPIN3 10     // Digital pin connected to the DHT sensor
#define DHTPIN4 11     // Digital pin connected to the DHT sensor
#define DHTPIN5 12     // Digital pin connected to the DHT sensor
#define DHTPIN6 15    // Digital pin connected to the DHT sensor
#define DHTPIN7 16    // Digital pin connected to the DHT sensor

DHT dht1(DHTPIN1, DHTTYPE);
DHT dht2(DHTPIN2, DHTTYPE);
DHT dht3(DHTPIN3, DHTTYPE);
DHT dht4(DHTPIN4, DHTTYPE);
DHT dht5(DHTPIN5, DHTTYPE);
DHT dht6(DHTPIN6, DHTTYPE);
DHT dht7(DHTPIN7, DHTTYPE);
LiquidCrystal lcd(7,6,5,4,3,2);
DS3231 rtc(SDA,SCL);
long previousMillis = 0;
long lcdpreviousMillis = 0;
const long interval= 120000;
//Declaring msg strings
char line2[17] = "                ";
char msg1[] = "Sdcard failed..";
char msg2[] = "Initializing Data Card..";
char msg3[] = "Sensors Working Well..";
char msg4[] = "Data Written into SdCard..";
char msg5[] = "Failed to Write in SdCard..";
char msg6[] = "Collecting Information.";
char msg7[] = "Sensor 1 failed to read..";
char msg8[] = "Sensor 2 failed to read..";
char msg9[] = "Sensor 3 failed to read..";
char msg10[] = "Sensor 4 failed to read..";
char msg11[] = "Sensor 5 failed to read..";
char msg12[] = "Sensor 6 failed to read..";
char msg13[] = "Sensor 7 failed to read..";
//declaring relay pins
int ExF1=41;
int ExF2=43;
int ExF3=45;
int ExF4=47;
int ExF5=33;
```

```
int CellF1=35;
int CellF2=37;
int Bulb1=28;
int Bulb2=26;
int Bulb3=24;
int Bulb4=22;
int Bulb5=27;
int Bulb6=29;

void setup() {
  Serial.begin(9600);
  dht1.begin();
  dht2.begin();
  dht3.begin();
  dht4.begin();
  dht5.begin();
  dht6.begin();
  dht7.begin();
  lcd.begin(16,2);
  rtc.begin();
// The following lines can be uncommented to set the date and time
//  rtc.setDOW(TUESDAY);     // Set Day-of-Week to SUNDAY
//  rtc.setTime(14, 20, 0);     // Set the time to 12:00:00 (24hr format)
//  rtc.setDate(8, 12, 2020);   // Set the date to January 1st, 2014
//  while(!Serial){
//    //waitng for serial port to connect. for native USB port only
//  }
  pinMode(Bulb1,OUTPUT);
  pinMode(Bulb2,OUTPUT);
  pinMode(Bulb3,OUTPUT);
  pinMode(Bulb4,OUTPUT);
  pinMode(Bulb5,OUTPUT);
  pinMode(Bulb6,OUTPUT);
  pinMode(CellF1,OUTPUT);
  pinMode(CellF2,OUTPUT);
  pinMode(ExF1,OUTPUT);
  pinMode(ExF2,OUTPUT);
  pinMode(ExF3,OUTPUT);
  pinMode(ExF4,OUTPUT);
  pinMode(ExF5,OUTPUT);
  //Set the relays high
  digitalWrite(ExF1,HIGH);
  digitalWrite(ExF2,HIGH);
  digitalWrite(ExF3,HIGH);
  digitalWrite(ExF4,HIGH);
  digitalWrite(ExF5,HIGH);
  digitalWrite(CellF1,HIGH);
  digitalWrite(CellF2,HIGH);
  digitalWrite(Bulb1,HIGH);
  digitalWrite(Bulb2,HIGH);
  digitalWrite(Bulb3,HIGH);
  digitalWrite(Bulb4,HIGH);
  digitalWrite(Bulb5,HIGH);
  digitalWrite(Bulb6,HIGH);
```

```
  Serial.println("initializing SD card....");
  if(!SD.begin(CSpin)){
    Serial.println("SD card failed to initialize...");
    for (int i = 0 ; i <= strlen(msg1)+16; i++) { // loop through the string
        update_lcd_buffer(msg1[i]); // update lcd with each character
        delay(500);
     }
    for(int i=0; i<=16; i++){
    line2[i]=" ";
    }
   // while(1);
  }else{
    Serial.println("SdCard Started..");
    for (int i = 0 ; i <= strlen(msg2)+16; i++) { // loop through the string
        update_lcd_buffer(msg2[i]); // update lcd with each character
        delay(500);
    }
    for(int i=0; i<=16; i++){
    line2[i]=" ";
    }
  }
  //Serial.println(F("DHT22 test!"));
}

void loop() {
  lcd.setCursor(2,0);
  lcd.print("TIME:");
  lcd.print(rtc.getTimeStr());

  long currentMillis = millis();
  if(currentMillis - previousMillis >= interval){ // Reading temperature or humidity takes about 120000
milliseconds!
    previousMillis=currentMillis;
    // Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)
    //sensor One readings
    float h1 = dht1.readHumidity();
    float t1 = dht1.readTemperature();// Read temperature as Celsius (the default)
    float f1 = dht1.readTemperature(true);// Read temperature as Fahrenheit (isFahrenheit = true)
    //sensor Two readings
    float h2 = dht2.readHumidity();
    float t2 = dht2.readTemperature();
    float f2 = dht2.readTemperature(true);
    //sensor 3 readings
    float h3 = dht3.readHumidity();
    float t3 = dht3.readTemperature();
    float f3 = dht3.readTemperature(true);
    //sensor 4 readings
    float h4 = dht4.readHumidity();
    float t4 = dht4.readTemperature();
    float f4 = dht4.readTemperature(true);
    //sensor 5 readings
    float h5 = dht5.readHumidity();
    float t5 = dht5.readTemperature();
    float f5 = dht5.readTemperature(true);
    //sensor 6 readings
```

```
float h6 = dht6.readHumidity();
float t6 = dht6.readTemperature();
float f6 = dht6.readTemperature(true);
//sensor 7 readings
float h7 = dht7.readHumidity();
float t7 = dht7.readTemperature();
float f7 = dht7.readTemperature(true);

delay(100);
// Check if any reads failed and exit early (to try again).
if (isnan(h1) || isnan(t1) || isnan(f1)) {
  Serial.println(F("Failed to read from DHT sensor1!"));
  for (int i = 0 ; i <= strlen(msg7)+16; i++) { // loop through the string
      update_lcd_buffer(msg7[i]); // update lcd with each character
      delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
}
if (isnan(h2) || isnan(t2) || isnan(f2)) {
    Serial.println(F("Failed to read from DHT sensor2!"));
    for (int i = 0 ; i <= strlen(msg8)+16; i++) { // loop through the string
      update_lcd_buffer(msg8[i]); // update lcd with each character
      delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
}
if (isnan(h3) || isnan(t3) || isnan(f3)) {
    Serial.println(F("Failed to read from DHT sensor3!"));
    for (int i = 0 ; i <= strlen(msg9)+16; i++) { // loop through the string
      update_lcd_buffer(msg9[i]); // update lcd with each character
      delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
}
if (isnan(h4) || isnan(t4) || isnan(f4)) {
    Serial.println(F("Failed to read from DHT sensor4!"));
    for (int i = 0 ; i <= strlen(msg10)+16; i++) { // loop through the string
      update_lcd_buffer(msg10[i]); // update lcd with each character
      delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
}
if (isnan(h5) || isnan(t5) || isnan(f5)) {
    Serial.println(F("Failed to read from DHT sensor5!"));
    for (int i = 0 ; i <= strlen(msg11)+16; i++) { // loop through the string
      update_lcd_buffer(msg11[i]); // update lcd with each character
      delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
 }
```

```
  if (isnan(h6) || isnan(t6) || isnan(f6)) {
    Serial.println(F("Failed to read from DHT sensor6!"));
    for (int i = 0 ; i <= strlen(msg12)+16; i++) { // loop through the string
        update_lcd_buffer(msg12[i]); // update lcd with each character
        delay(500);
          }for(int i=0; i<=16; i++){
          line2[i]=" ";
          }
  }
  if (isnan(h7) || isnan(t7) || isnan(f7)) {
    Serial.println(F("Failed to read from DHT sensor7!"));
    for (int i = 0 ; i <= strlen(msg13)+16; i++) { // loop through the string
        update_lcd_buffer(msg13[i]); // update lcd with each character
        delay(500);
          }for(int i=0; i<=16; i++){
          line2[i]=" ";
          }
   }else{
    Serial.println("All sensors working properly");
    for (int i = 0 ; i <= strlen(msg3)+16; i++) { // loop through the string
        update_lcd_buffer(msg3[i]); // update lcd with each character
        delay(500);
          }for(int i=0; i<=16; i++){
          line2[i]=" ";
          }
  }
// Compute heat index in Fahrenheit (the default)
float hif1 = dht1.computeHeatIndex(f1, h1);
float hic1 = dht1.computeHeatIndex(t1, h1, false);

float hif2 = dht2.computeHeatIndex(f2, h2);
float hic2 = dht2.computeHeatIndex(t2, h2, false);

float hif3 = dht3.computeHeatIndex(f3, h3);
float hic3 = dht3.computeHeatIndex(t3, h3, false);

float hif4 = dht4.computeHeatIndex(f4, h4);
float hic4 = dht4.computeHeatIndex(t4, h4, false);

float hif5 = dht5.computeHeatIndex(f5, h5);
float hic5 = dht5.computeHeatIndex(t5, h5, false);

float hif6 = dht6.computeHeatIndex(f6, h6);
float hic6 = dht6.computeHeatIndex(t6, h6, false);

float hif7 = dht7.computeHeatIndex(f7, h7);
float hic7 = dht7.computeHeatIndex(t7, h7, false);

//opening file in sdcard
File sdcardfile = SD.open("Data.txt", FILE_WRITE);
//Condition for celling fan 2
if(t1<=26.00 || t2<=26.00 || t6<=26.00){
  digitalWrite(CellF2,HIGH); // celling fan turn off
  sdcardfile.print(rtc.getDateStr());
  sdcardfile.print(" -- ");
```

```
  sdcardfile.print(rtc.getTimeStr());
  sdcardfile.print(" -- ");
  sdcardfile.println("Celling Fan-2 turn off");
  Serial.println("Fan 2 is off");
  }else if(t1>=28.00 || t2>=28.00 || t6>=28.00){
    digitalWrite(CellF2,LOW); // celling fan turn on
    sdcardfile.print(rtc.getDateStr());
    sdcardfile.print(" -- ");
    sdcardfile.print(rtc.getTimeStr());
    sdcardfile.print(" -- ");
    sdcardfile.println("Celling Fan-2 turn on");
    Serial.println("Fan 2 is on");
    }

//Condition for celling fan 1
if(t3<=26.00 || t4<=26.00 || t5<=26.00){
  digitalWrite(CellF1,HIGH); // celling fan turn off
  sdcardfile.print(rtc.getDateStr());
  sdcardfile.print(" -- ");
  sdcardfile.print(rtc.getTimeStr());
  sdcardfile.print(" -- ");
  sdcardfile.println("Celling Fan-1 turn off");
  Serial.println("Fan 1 is off");
  }else if(t3>=28.00 || t4>=28.00 || t5>=28.00){
    digitalWrite(CellF1,LOW); // celling fan turn on
    sdcardfile.print(rtc.getDateStr());
    sdcardfile.print(" -- ");
    sdcardfile.print(rtc.getTimeStr());
    sdcardfile.print(" -- ");
    sdcardfile.println("Celling Fan-1 turn on");
    Serial.println("Fan 1 is on");
    }
//writing to serial monitor
  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_1:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h1);
  Serial.print(F("%  Temperature: "));
  Serial.print(t1);
  Serial.println(F("°C "));

  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_2:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h2);
  Serial.print(F("%  Temperature: "));
  Serial.print(t2);
  Serial.println(F("°C "));
```

```
  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_3:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h3);
  Serial.print(F("%  Temperature: "));
  Serial.print(t3);
  Serial.println(F("°C "));

  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_4:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h4);
  Serial.print(F("%  Temperature: "));
  Serial.print(t4);
  Serial.println(F("°C "));

  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_5:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h5);
  Serial.print(F("%  Temperature: "));
  Serial.print(t5);
  Serial.println(F("°C "));

  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_6:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h6);
  Serial.print(F("%  Temperature: "));
  Serial.print(t6);
  Serial.println(F("°C "));

  Serial.print(rtc.getDateStr());
  Serial.print(" -- ");
  Serial.print(rtc.getTimeStr());
  Serial.print(" -- ");
  Serial.print(F("DHT_7:   "));
  Serial.print(F("Humidity: "));
  Serial.print(h7);
  Serial.print(F("%  Temperature: "));
  Serial.print(t7);
  Serial.println(F("°C "));
//displaying temperature, humidity on lcd screen and actions on bulbs according to condition
```

```
for(int j=1; j<8; j++){
    if(j==1){
      lcd.setCursor(0,1);
      lcd.print("S1:");
      lcd.print(t1);
      lcd.print("C,");
      lcd.print(h1);
      lcd.print("%");
          sdcardfile.print(rtc.getDateStr());
          sdcardfile.print(" -- ");
          sdcardfile.print(rtc.getTimeStr());
          sdcardfile.print(" -- ");
          sdcardfile.println("Bulb 1 is on, Exhaust Fan 1 is off");
          Serial.println("Bulb 1 is on, Exhaust Fan 1 is off");
          }else if(t1>=28.00){
          digitalWrite(Bulb1, HIGH);  //bulb 1 st to off
          digitalWrite(ExF1, LOW);
          sdcardfile.print(rtc.getDateStr());
          sdcardfile.print(" -- ");
          sdcardfile.print(rtc.getTimeStr());
          sdcardfile.print(" -- ");
          sdcardfile.println("Bulb 1 is off, Exhaust Fan 1 is on");
          Serial.println("Bulb 1 is off, exhaust 1 is on");
          }
      }else if(j==2){
        lcd.setCursor(0,1);
        lcd.print("S2:");
        lcd.print(t2);
        lcd.print("C,");
        lcd.print(h2);
        lcd.print("%");
        if(t2<=27.00){
          digitalWrite(Bulb2, LOW); //bulb 1 set to on
          Serial.println("Bulb 2 is on");
          sdcardfile.print(rtc.getDateStr());
          sdcardfile.print(" -- ");
          sdcardfile.print(rtc.getTimeStr());
          sdcardfile.print(" -- ");
          sdcardfile.println("Bulb 2 is on");
          }else if(t2>=28.00){
          digitalWrite(Bulb2, HIGH);  //bulb 1 st to off
          Serial.println("Bulb 2 is off");
          sdcardfile.print(rtc.getDateStr());
          sdcardfile.print(" -- ");
          sdcardfile.print(rtc.getTimeStr());
          sdcardfile.print(" -- ");
          sdcardfile.println("Bulb 1 is off");
          }
        else if(j==3){
          lcd.setCursor(0,1);
          lcd.print("S3:");
          lcd.print(t3);
          lcd.print("C,");
          lcd.print(h3);
          lcd.print("%");
```

```
if(t3<=27.00){
   digitalWrite(Bulb3, LOW); //bulb 1 set to on
   digitalWrite(ExF5, HIGH);
   sdcardfile.print(rtc.getDateStr());
   sdcardfile.print(" -- ");
   sdcardfile.print(rtc.getTimeStr());
   sdcardfile.print(" -- ");
   sdcardfile.println("Bulb 3 is on, Exhaust Fan 5 is off");
   Serial.println("Bulb 3 is on, exhaust 5 is off");
   }else if(t3>=28.00){
   digitalWrite(Bulb3, HIGH);  //bulb 1 st to off
   digitalWrite(ExF5, LOW);
   sdcardfile.print(rtc.getDateStr());
   sdcardfile.print(" -- ");
   sdcardfile.print(rtc.getTimeStr());
   sdcardfile.print(" -- ");
   sdcardfile.println("Bulb 3 is off, Exhaust Fan 5 is on");
   Serial.println("Bulb 3 is off, exhaust 5 is on");
   }
 else if(j==4){
   lcd.setCursor(0,1);
   lcd.print("S4:");
   lcd.print(t4);
   lcd.print("C,");
   lcd.print(h4);
   lcd.print("%");
   if(t4<=27.00){
     digitalWrite(Bulb4, LOW); //bulb 1 set to on
     digitalWrite(ExF4, HIGH);
     sdcardfile.print(rtc.getDateStr());
     sdcardfile.print(" -- ");
     sdcardfile.print(rtc.getTimeStr());
     sdcardfile.print(" -- ");
     sdcardfile.println("Bulb 4 is on, Exhaust Fan 4 is off");
     Serial.println("Bulb 4 is on, exhaust 4 is off");
     }else if(t4>=28.00){
     digitalWrite(Bulb4, HIGH);  //bulb 1 st to off
     digitalWrite(ExF4, LOW);
     sdcardfile.print(rtc.getDateStr());
     sdcardfile.print(" -- ");
     sdcardfile.print(rtc.getTimeStr());
     sdcardfile.print(" -- ");
     sdcardfile.println("Bulb 4 is off, Exhaust Fan 4 is on");
     Serial.println("Bulb 4 is off, exhaust 4 is on");
     }
    else if(j==5){
       lcd.setCursor(0,1);
       lcd.print("S5:");
       lcd.print(t5);
       lcd.print("C,");
       lcd.print(h5);
       lcd.print("%");
       if(t5<=27.00){
         digitalWrite(Bulb5, LOW); //bulb 1 set to on
         digitalWrite(ExF3, HIGH);
```

```
              sdcardfile.print(rtc.getDateStr());
              sdcardfile.print(" -- ");
              sdcardfile.print(rtc.getTimeStr());
              sdcardfile.print(" -- ");
              sdcardfile.println("Bulb 5 is on, Exhaust Fan 3 is off");
              Serial.println("Bulb 5 is on, exhaust 3 is off");
              }else if(t5>=28.00){
              digitalWrite(Bulb5, HIGH);  //bulb 1 st to off
              digitalWrite(ExF3, LOW);
              sdcardfile.print(rtc.getDateStr());
              sdcardfile.print(" -- ");
              sdcardfile.print(rtc.getTimeStr());
              sdcardfile.print(" -- ");
              sdcardfile.println("Bulb 5 is off, Exhaust Fan 3 is on");
              Serial.println("Bulb 5 is off, exhaust 3 is on");
              }
             else if(j==6){
               lcd.setCursor(0,1);
               lcd.print("S6:");
               lcd.print(t6);
               lcd.print("C,");
               lcd.print(h6);
               lcd.print("%");
               if(t6<=27.00){
                 digitalWrite(Bulb6, LOW); //bulb 1 set to on
                 digitalWrite(ExF2, HIGH);
                 sdcardfile.print(rtc.getDateStr());
                 sdcardfile.print(" -- ");
                 sdcardfile.print(rtc.getTimeStr());
                 sdcardfile.print(" -- ");
                 sdcardfile.println("Bulb 6 is on, Exhaust Fan 2 is off");
                 Serial.println("Bulb 6 is on, exhaust 2 is off");
                 }else if(t6>=28.00){
                 digitalWrite(Bulb6, HIGH);  //bulb 1 st to off
                 digitalWrite(ExF2, LOW);
                 sdcardfile.print(rtc.getDateStr());
                 sdcardfile.print(" -- ");
                 sdcardfile.print(rtc.getTimeStr());
                 sdcardfile.print(" -- ");
                 sdcardfile.println("Bulb 6 is off, Exhaust Fan 2 is on");
                 Serial.println("Bulb 6 is off, exhaust 2 is on");
                 }
                }else if(j==7){
                  lcd.setCursor(0,1);
                  lcd.print("S7:");
                  lcd.print(t7);
                  lcd.print("C,");
                  lcd.print(h7);
                  lcd.print("%");
                  }
  delay(6000);
}
//writing data to SD Card
if(sdcardfile){
  //for dht sensor 1
```

```
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
sdcardfile.print(F("DHT_1:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h1);
sdcardfile.print(F("%  Temperature: "));
sdcardfile.print(t1);
sdcardfile.print(F("°C "));
sdcardfile.print(f1);
sdcardfile.print(F("°F  Heat index: "));
sdcardfile.print(hic1);
sdcardfile.print(F("°C "));
sdcardfile.print(hif1);
sdcardfile.println(F("°F"));
//for dht sensor 2
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
sdcardfile.print(F("DHT_2:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h2);
sdcardfile.print(F("%  Temperature: "));
sdcardfile.print(t2);
sdcardfile.print(F("°C "));
sdcardfile.print(f2);
sdcardfile.print(F("°F  Heat index: "));
sdcardfile.print(hic2);
sdcardfile.print(F("°C "));
sdcardfile.print(hif2);
sdcardfile.println(F("°F"));
//for dht sensor 3
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
sdcardfile.print(F("DHT_3:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h3);
sdcardfile.print(F("%  Temperature: "));
sdcardfile.print(t3);
sdcardfile.print(F("°C "));
sdcardfile.print(f3);
sdcardfile.print(F("°F  Heat index: "));
sdcardfile.print(hic3);
sdcardfile.print(F("°C "));
sdcardfile.print(hif3);
sdcardfile.println(F("°F"));
//for dht sensor 4
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
```

```
sdcardfile.print(F("DHT_4:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h4);
sdcardfile.print(F("%  Temperature: "));
sdcardfile.print(t4);
sdcardfile.print(F("°C "));
sdcardfile.print(f4);
sdcardfile.print(F("°F  Heat index: "));
sdcardfile.print(hic4);
sdcardfile.print(F("°C "));
sdcardfile.print(hif4);
sdcardfile.println(F("°F"));
//for dht sensor 5
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
sdcardfile.print(F("DHT_5:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h5);
sdcardfile.print(F("%  Temperature: "));
sdcardfile.print(t5);
sdcardfile.print(F("°C "));
sdcardfile.print(f5);
sdcardfile.print(F("°F  Heat index: "));
sdcardfile.print(hic5);
sdcardfile.print(F("°C "));
sdcardfile.print(hif5);
sdcardfile.println(F("°F"));
//for dht sensor 6
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
sdcardfile.print(F("DHT_6:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h6);
sdcardfile.print(F("%  Temperature: "));
sdcardfile.print(t6);
sdcardfile.print(F("°C "));
sdcardfile.print(f6);
sdcardfile.print(F("°F  Heat index: "));
sdcardfile.print(hic6);
sdcardfile.print(F("°C "));
sdcardfile.print(hif6);
sdcardfile.println(F("°F"));
//for dht sensor 7
sdcardfile.print(rtc.getDateStr());
sdcardfile.print(" -- ");
sdcardfile.print(rtc.getTimeStr());
sdcardfile.print(" -- ");
sdcardfile.print(F("DHT_7:   "));
sdcardfile.print(F("Humidity: "));
sdcardfile.print(h7);
sdcardfile.print(F("%  Temperature: "));
```

```
    sdcardfile.print(t7);
    sdcardfile.print(F("°C "));
    sdcardfile.print(f7);
    sdcardfile.print(F("°F  Heat index: "));
    sdcardfile.print(hic7);
    sdcardfile.print(F("°C "));
    sdcardfile.print(hif7);
    sdcardfile.println(F("°F"));
      Serial.println("Data written in SdCard");
      for (int i = 0 ; i <= strlen(msg4)+16; i++) { // loop through the string
          update_lcd_buffer(msg4[i]); // update lcd with each character
          delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
   }else{
        Serial.println("SdCard failed to write");
        for (int i = 0 ; i <= strlen(msg5); i++) { // loop through the string
          update_lcd_buffer(msg5[i]); // update lcd with each character
          delay(500);
        }for(int i=0; i<=16; i++){
        line2[i]=" ";
        }
     }
    sdcardfile.close();
  }
  //Serial.println("Wait a few seconds between measurements.");
  for (int i = 0 ; i <= strlen(msg6)+16; i++) { // loop through the string
        update_lcd_buffer(msg6[i]); // update lcd with each character
        delay(500);
     }for(int i=0; i<=16; i++){
      line2[i]=" ";
     }
  // Wait a few seconds between measurements.
 delay(1000);
}

void update_lcd_buffer(char c) {
    char *buffer = &line2[1]; // create pointer to the second character of line2
    strncpy(line2, buffer, 16); // set line2 = the second character of line2 to the end
    line2[15] = c; // append our new char to end of line2
    lcd.clear(); // clear the screen
    lcd.setCursor(2, 0); // set cursor to beginning of first line
    lcd.print("TIME:");// print the static string on the first line
    lcd.print(rtc.getTimeStr());
    lcd.setCursor(0, 1); // set cursor to beginning of second line
    lcd.print(line2); // print line2
}
```