Food Grain Storage Monitoring System

Dr. U B Mahadevaswamy
Professor
Dept.of Electronics & Communication
Sri Jayachamarajendra College of Engineering
JSS Science and Technology University
Mysuru, India

Megha K M
Assistant Professor
Dept.of Electronics and Communication
JSS Science and Technology University
Mysuru, India

Arjun V Srivatsa
Dept. Of Electronics & Communication
JSS Science and Technology University
Mysuru, India

Ayushi G Jain
Dept.of Electronics & Communication
JSS Science and Technology University
Mysuru, India

Bhoomika Rani B
Dept.of Electronics & Communication
JSS Science and Technology University
Mysuru, India

***Abstract*—Agricultural practices proves to be India's largest source of livelihoods with 80 percent of its total rural household population dependent on agricultural produce as their main source of income. The total food grains production in India is estimated to increase two percent in the 2020-2021 crop period to an all-time record of 303 million tons which is a lot of produce compared to other countries. Also, the country manages to waste 67 million tons of food every year that has been valued at around Rs 92,000 crores—an amount equal to feed the people of a whole state. A major problem lies in the fact that food wastage mainly occurs during the harvesting, processing, distribution and retailing process. There is an urgent need to reduce the amount of food wasted, to which a proper storage technique to safeguard the food grains need to be implemented. This is done through automation in the form of IoT which helps through the continuous monitoring and tracking done on the food grains that enter the storage warehouses. Thus, the proposed method involves an IoT system which consists of an ESP8266 NodeMCU module interfaced with two sensors that collect data such as humidity, temperature and percentage of CO_2 and is uploaded to the cloud database. This data gets notified to the user and in case of variations in the parameters, control measures are placed to ensure that the food grains remain in the optimum conditions with respect to the surrounding environment.**

Keywords—IoT; ESP8266 micro-controller; Food grain storage; Cloud computing; Arduino IDE.

I. INTRODUCTION

The cultivation of food crops takes up the highest percentage in the total agricultural produce in India. This is due to the fact that India has to supplement its ever-growing population with food in order to keep the growth aspects of its country in a steady state. This leads to cultivation and storage of grains being heavily invested in every budget declaration made by the governments. Since most of the population practices agriculture, it becomes important to have a proper channel through which the produce reaches to every citizen. But there are a lot of problems involving the damage to the produce at the fields, during transportation or storage. This unfortunately results in 25 to 30 percent wastage due to poor support, lack of cold storages, procurement issues, improper transportation and underdeveloped marketing channels. Internet of things (IoT) is an approach through which the problems can be resolved. The impact that Internet of Things has in today's world has made people around us intelligent and more perceptive by bringing new changes through combining digital and physical universes. The sensors and communication modules are being equipped into mobile devices with communication technologies like Wi-Fi have penetrated the market making IoT a common research topic.

The proposed model is a food grain monitoring system based on IoT for implementation in storage warehouses that consists an ESP8266 NodeMCU module interfaced with a DHT11 temperature and humidity sensor and MQ-135 air quality sensor (CO_2). The basic working includes the sensors collecting the data of the parameters inside the storage system which mainly contribute to the spoilage of food grains and communicating with the user if there are variations detected, so that necessary control measure gets applied. This paper is divided into following sections: the motivation behind taking up this project is discussed in Section II. Section III is about the objectives of the proposed work. Section IV is about the related works going on in this field. Section V talks about the food grain parameters which should be taken into consideration while storage. Section VI discusses the experimental setup for this work. Section VII elaborates about the working procedure of the food grain monitoring system. Section VIII reveals the results obtained by this work. Section IX talks about the novelty of the project. Section X is about the conclusions derived by this work. Section XI is to acknowledge the authors and the staff contributions to this work. Section XII talks about the future scope of this work.

II. MOTIVATION

The maintenance of safety and hygiene of the food is important as it keeps the produce fresh and edible which decreases the food wastage. The freshness of the food is a measure of how good the food is in terms of edibility and free of germs, insects and various micro-organisms. Food grains is the important source of nutrition and is a basic item for any kind of food preparation. This is why it is important to store the food grains in a suitable environment with optimum conditions. These conditions vary according to the weather, seasons and many other factors. The main motivation for this project was the fact that there is more wastage than usage of food grains due to the extended keep even after expiration date of the grains in many storage warehouses. 25 to 30 percent of losses occur during the period from harvesting to marketing. This trend is far worst in storage warehouses which are government-run due to poor maintenance standards. Since farmers invest more time and resources in farming and harvesting of these precious food grains, it comes as an injustice to let the food grains rot at a corner of the warehouse.

Thus, implementing a system which communicates with the client about the changes in the parameters of the food grains kept over a long period of storage becomes essential. This retains the food grain quality by its nutritional standards and make sure that the maintenance of the warehouse becomes easier and reliable.

III. OBJECTIVES

The objectives that this project need to achieve after the successful implementation include:

- To reduce the food grain spoilage in the government-run warehouses, warehouses reserved for exclusive grain storage by usage of the food grains before its expiration.
- To maintain optimum conditions in the warehouses over a long period of storage by notifying the real time updates to the client using ThingSpeak service.
- To maintain the quality of food grains kept for a longer period of storage retains its nutritional value.
- To prioritize premature stocking of the food grains and utilized first avoiding the expiry.
- To minimize food spoiling which leads to potential health risks.
- To ensure the pricing of food grains in the market do not get hiked due to spoilage of food grains especially in the demand season.

IV. RELATED WORK

The major developments in the field of agriculture are widely based on the applications of IoT. In recent times, there has been lot of work going on for a storage warehouse system design that is based on the contents coming in and out of the warehouse using RFID tag technology [1]. The prominence of IoT in the agriculture industry can be mentioned by stating few examples which include the supply chain management [2]. Also, there are works which deals with the construction of an IoT-based logistics platform for food based on a IoT three-tier architecture in China [3]. Implementation of the monitoring system with the help of Node-RED visual programming and AWS is another design which comes through as an effective way in realizing the main target of food grain preservation but lacks in the aspect of industry application [4]. Many theoretical realizations and reviews have been provided on how to implement the IoT monitoring system in storage facilities for optimum storage during severe weather conditions. There has been works which dealt with the modelling and architecture of the warehouses for different regions with different weathers and fluctuating environment variables [5]. Technological variations have been introduced where it consisted of implementation of monitoring system using Zigbee transceiver (ETRX357) and buzzer circuit [6]. The pcb implementation of sensors in the monitoring system is quite a different approach fulfilling the same conditions [7]. Usage of computer vision with image analysis toolkit in the monitoring system architecture is a recent concept with technology that can be successfully applied in the inspection and evaluation of grain quality using parametric sensors, automated sampling device and computer interface [8]. The behavior of food crops under sustainable conditions is one of the factors which needs attention while determining the environmental parameters inside the storage warehouses [9]. On an experimental basis, there have been extensive research based on the temperature and spectral responses when the food grains are exposed to different wavelength of light with the parametric variations recorded using NIR spectroscopic analysis [10]. Storing perishable items inside the warehouses has its own limitations. This has been addressed by considering different implementation techniques at different stages of food supply chain [11]. There has been works related to the process of multispectral imaging in seed phenotyping and quality monitoring which have provided satisfactory research results [12].

V. FOOD GRAIN PARAMETERS

The moisture content of the grain and the temperature are two critical factors which contribute towards good quality of food grains during storage. There are always chances that under unsafe temperatures and grain humidity content, the food grains undergo decomposition and the by-products like water, carbon dioxide (CO_2), and heat is released. All the living things perform respiration, be it as small as grains, insects, worms, microbes to even large animals. During this process, the elements like carbohydrates, fats, or proteins undergo oxidation to release heat and energy. The respiration process can be defined using the equation 1:

$$C_6H_{12}O_6 + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O + 2870\,kJ \qquad (1)$$

From equation (1), analogy can be drawn out saying that for every gram of $C_6H_{12}O_6$ broken down, 15.7 kJ of heat gets produced. During the season where the moisture content increases, it becomes more difficult to distinguish between the grain and the mold respiration process. In actual, the most contribution for the heat produced in damp and wet grain is the presence of mold which accounts to 85 to 95 percent.

For instance, when wheat is stored at 24% moisture content environment, it can quickly deplete the oxygen to 0% in the period of two to three days, meanwhile the CO_2 buildup increases steadily. Table I shows the temperature and relative humidity for various food grains.

TABLE I. TEMPERATURE AND RELATIVE HUMIDITY VALUES FOR DIFFERENT FOOD GRAINS

Food Grain	Temperature in °C	Relative Humidity (%) gm/cm^3
Rice	22-32	50-75
Wheat	15-37	20-45
Maize	05-30	18-30
Turmeric	26-32	12-18
Groundnut	07-35	65-80

The humidity and moisture content of food grains varies with the duration of their storage. The values mentioned below shows the moisture content for different food grains with respect to their long storage periods. Table II details about the moisture content level in food grains.

TABLE II. MOISTURE CONTENT LEVELS FOR VARIOUS FOOD GRAINS

Sl No.	Food Grain	% Of moisture content in food grain
1.	Rice	12.2 - 13.8
2.	Wheat	12.2 - 13.9
3.	Cereals: maize flour	11.5
4.	Millet	16.0
5.	Sorghum	13.5
6.	Pulses: broad bean, cow pea	15.0
7.	Lentils	14.0

*Below 27 degrees Celsius

VI. EXPERIMENTAL SETUP

A. ESP8266

The ESP8266 microcontroller is interfaced with DHT11 sensor module and MQ-135 sensor module to measure the temperature, humidity and CO_2 ppm levels inside the storage environment. The sensors in interface send the data collected from the environment to ESP8266 module in both analog and digital form. The information obtained from the sensors through ESP8266 is transmitted to ThingSpeak cloud database.

B. DHT11 Temperature and Humidity Sensor

The DHT11 Temperature and Humidity sensor module consists of a humidity measuring component, a NTC thermistor with a microcontroller. The DHT11 sensor module comes precalibrated from a laboratory and the calibrated data is stored in the sensor's OTP memory. This module is used to get the temperature and humidity values from the storage environment and send it to the interfaced ESP8266 module in the form of digital signal.

C. MQ 135 Gas Sensor Module

The MQ-135 gas sensor is basically used as an air quality measurement and control equipment. This sensor has various applications which include the detection and measurement of NH_3, alcohol, smoke, NO_x, CO_2 and benzene. This sensor module requires calibration in order to detect the CO_2 gas concentration present in the environment it is placed in. The calibration of MQ135 sensor module is discussed in the next section.

D. Calibration of MQ135 gas sensor.

In order to determine the concentration of CO_2 present in the air, there is a need to find the ratio (R_S/R_O). R_O and R_S represents the internal resistance values of the sensor. Using this, the value of R_S from V_{RL} (voltage flowing across R_{Load}) needs to be found. This is done by using the ESP8266 microcontroller to find the value of voltage (V_{RL}) across the load resistance R_{Load}. A formula is derived to find the R_{Load} from V_{RL}.

The voltage flowing across the R_{Load} is given by,

$$V_{Load} = I\, R_{Load} \tag{2}$$

substituting for current I, we get the equation as,

$$V_{Load} = (VR_{Load}) / (R_S + R_{Load}) \tag{3}$$

From the equivalent circuit, we get the equation

$$V = I\,(R_S + R_{Load}) \tag{4}$$
$$I = V / (R_S + R_{Load}) \tag{5}$$
$$R_S = (V - V_{Load}) / V_{Load} \tag{6}$$

where V denotes the supply voltage.

The MQ-135 gas sensor operates with SnO_2 as its gas sensing material which has a higher resistance to clean air. Thus, to measure the CO_2 concentration in terms of ppm, the data from the (R_S/R_O) v/s ppm graph which is found in the MQ135 datasheet is collected.

Figure 1 shows the graphical representation of typical sensitivity characteristics of MQ-135 sensor module for several gases. R_O represents the resistance of the sensor in fresh air (or the air around the sensor module) and R_S represents the resistance value of the sensor in a gas concentration (in this case, CO_2).

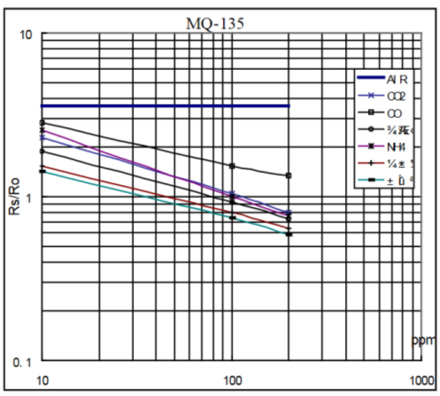

Fig 1. The typical sensitivity characteristics of the MQ-135 for several gases.

E. ThingSpeak and IFTTT

The ThingSpeak is an IoT- based analytical platform service which helps in storing the data inside a cloud. This data is sent to the ThingSpeak service from the IoT based devices where it is mainly used to create visualizations of the data and implement many other functions. In this project, ThingSpeak is used to visualize the changes in the parameters that occur inside the storage environment which can be accessed through the website and the android platform which is shown in Figure 2.

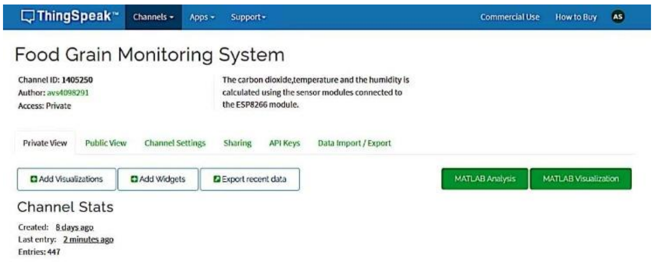

Fig 2. ThingSpeak website interface.

IFTTT (If This Then That) is a service which allows its users to send requests, event notifications by programming a response through their partnered services. The email service provided by them is used to send the real time status through a service called as Webhook. This requires the user to sign up to their database and provide the device information and the specifications. IFTTT Webhooks offers Gmail service through the generated Arduino code.

VII. WORKING.

There is long process that the crops grown in the fields have to undergo before they are made available to the consumer. This includes the crops being harvested, dried under the sun to remove any moisture content thoroughly and transported to the processing plants where they undergo cleaning. The processed grains are stocked up in the warehouses, sometimes for longer durations than expected. At the end, they are available to send to the markets. In order for the consumers to gain better understanding of the food grains purchase that also includes the conditions in which the grains were grown, processed and stored, these monitoring devices are installed at the storage warehouses.

Figure 3 represents the block diagram showing the flow of data throughout the architecture of the monitoring system.

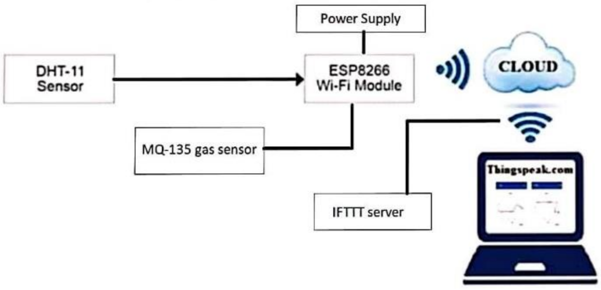

Fig 3. Block diagram.

The working steps are as follows:

Step 1: The food grains are stored inside the storage space with the sensors in direct contact to the environment inside acting as an input to the module.

Step 2: If there is a change in the temperature or humidity, this is sensed by the DHT11 sensor module and the signal is sent the ESP8266 module which is in turn connected to the Wi-Fi. The received data is stored on ThingSpeak database.

.

Step 3: If there is a change in the concentration of CO_2 gas, the MQ135 sensor is activated and triggers the microcontroller in sending a response over the Wi-Fi and the received data is stored on ThingSpeak database.

Step 4: The stored data are in graphical representation which records the changes in the parameters like temperature, humidity, and CO_2 gas concentration (in ppm) with respect to the time.

Step 5: In case there is an abnormal change in the mentioned parameters, the data is sent to the ThingSpeak cloud and there is a spike in values represented on the either graph on the ThingSpeak website. *Step 6:* Also, this triggers an email notification by the IFTTT webhooks service which sends a predetermined service message of the current status to the registered user email.
ThingSpeak can also be accessed through the android app making it accessible through the smartphone.

The circuit is designed as an integration of both MQ135 and DHT11 with ESP8266 NodeMCU as shown below. The connection of MQ-135 gas sensor with NodeMCU is as shown in the Figure 4. The V_{CC} and Gnd pin of the MQ135 sensor module is connected to the V_{IN} and Ground of the ESP8266 NodeMCU module. The A0 pin of the sensor module is in turn connected to the A0 pin of the ESP8266 NodeMCU module.

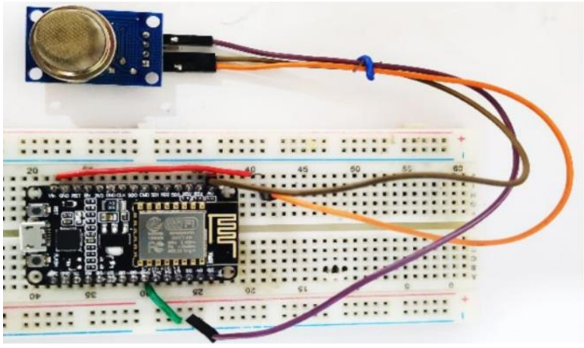

Fig 4. NodeMCU ESP8266 with MQ 135 sensor module.

The DHT11 sensor is pre-calibrated in the laboratory, which makes it ready to use component. The connection of DHT11 sensor module with the ESP8266 NodeMCU module is as shown in Figure 5. The V_{CC}, Gnd and the data pins of the DHT11 sensor are respectively connected with the V_{IN}, Gnd, and D4 pin of the ESP8266 module. A special function is invoked by using the Arduino Adafruit libraries for DHT11 sensor, through which the temperature and humidity values are obtained.

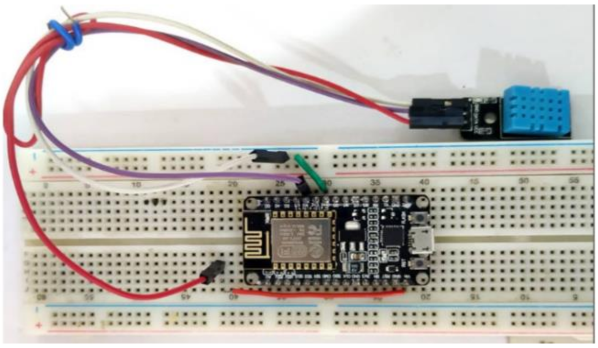

Fig 5. NodeMCU ESP8266 with DHT11 sensor module.

Figure 6 shows the overall circuit contains the storage environment which is filled with food grains and the surface of the storage environment is integrated with the MQ135 gas sensor and DHT11 sensor. The Arduino code is loaded to the NodeMCU module which is connected to the Wi-Fi and the microcontroller directs the sensors action by sending and receiving data from both of the sensors simultaneously and loading to the ThingSpeak server.

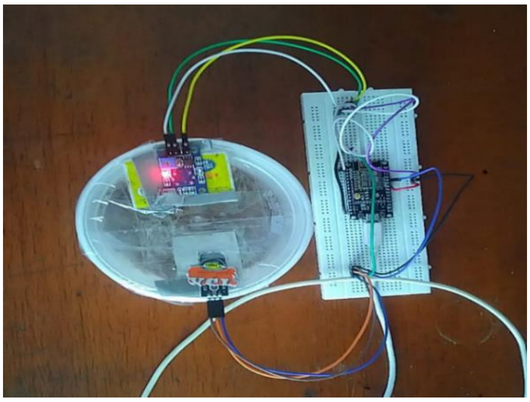

Fig 6. IoT based food grain monitoring system.

RESULTS

A. Under normal storage environment

The food grain storage monitoring device is used to read the temperature, humidity and CO_2 percentage values at the storage warehouse from which the data can be represented in three forms. Figure 7 shows the variations in the temperature, humidity and CO_2 concentration in ppm on the serial monitor display of the Arduino IDE.

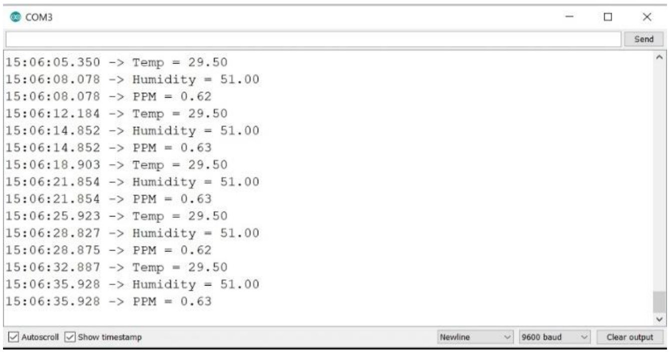

Fig 7. Serial monitor display showing the environment parameters.

Figure 8 shows the data in the form of graphs on the website which is loaded from the ThingSpeak database. Figure 9 shows the ThingSpeak user interface accessed through an android application.

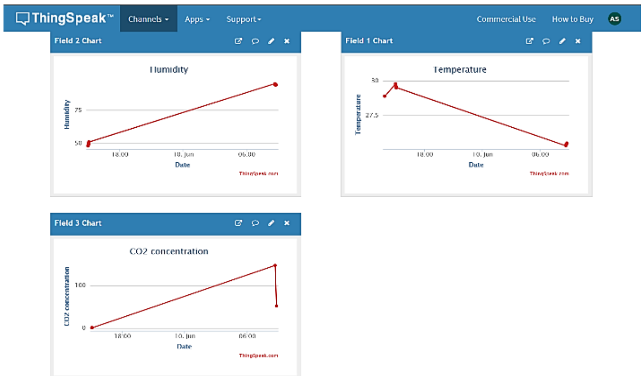

Fig 8. ThingSpeak website showing the variations in environment parameters.

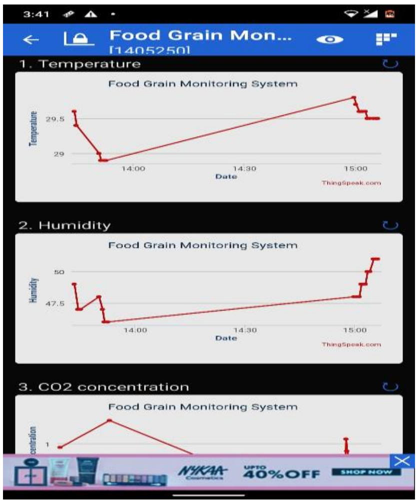

Fig 9. ThingSpeak android application showing the variations in environment parameters.

B. *Under food grain degradation.*

When the food grains inside the warehouse starts to degrade due to the breakdown of glucose, this results in the spike of the parameters which is observed as follows. Figure 10 shows the values of parameters on a serial monitor of Arduino IDE.

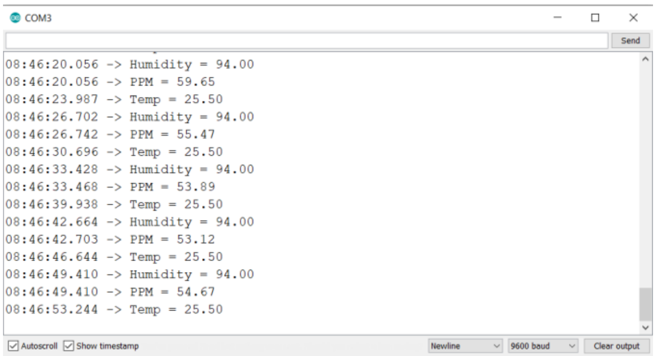

Fig 10. Serial monitor display showing the environment parameters compared to Case A.

Figure 11 shows the data in the form of graphs on the website which is loaded from the ThingSpeak database. Figure 12 shows the ThingSpeak user interface accessed through an android application. Here, we notice the changes in humidity and percentage of CO_2 values.

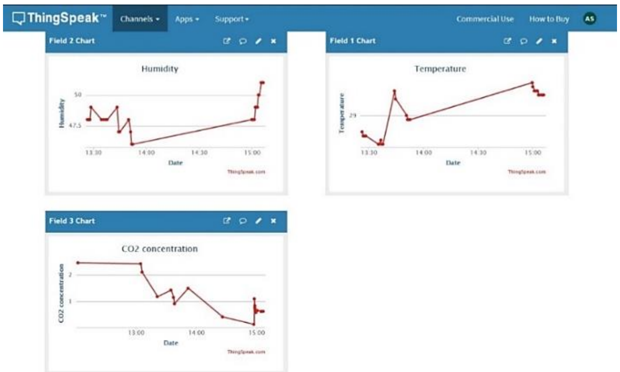

Fig 11. ThingSpeak website showing the variations in environment parameters in comparison with Case A.

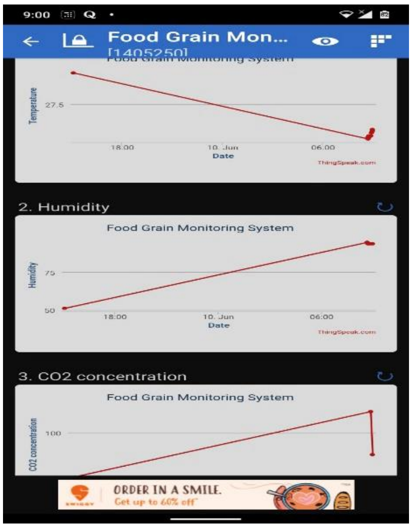

Fig 12. ThingSpeak android application showing the variations in environment parameters in comparison with Case A.

Figure 13 shows the email notification received when there was an abnormal change in the values of the parameters considered.

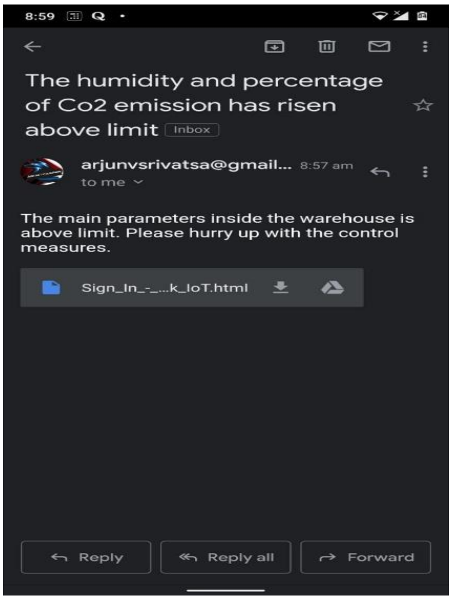

Fig 13. Email notification sent through IFTTT webhooks service.

VIII. NOVELTY

- This system is designed to get real time parametric values through continuous monitoring system. Any change or variations is swiftly detected and notified to the client.
- The system is economically feasible with the easy components availability and there is no complexity in the circuit build.
- The power consumption is less as the voltage required for the system components to turn on is less.
- The system is enabled with remote access and cloud computing with which the client has an option of modifying certain parametric thresholds anywhere.
- The system programming is flexible so that with slight modifications it can be further developed with increased functionality.

- Table III represents the comparison of the proposed system with the existing works with clear indications of the technologies and the services provided in each of the cases.

TABLE III. COMPARISON BETWEEN PROPOSED SYSTEM AND EXISTING WORKS.

Reference Works	Technologies							Services provided					
	Temperature Sensor	Humidity Sensor	CO_2 Percent.	Arduino IDE	IFTTT	Light intensity	Experimental Setup	Remote alert notify.	Real-time analysis	Webserver	Remote monitoring	SMS & Email services	Wi-Fi
[4]	✓	✓	✓	✓				✓		✓	✓		✓
[1]	✓	✓		✓				✓	✓				✓
[8]	✓	✓	✓		✓	✓	✓		✓			✓	✓
[10]	✓					✓	✓			✓			
Proposed work	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓

IX. Conclusion

This project deals with the real-world scenarios, which makes it a tremendous resource for research and development. It also gives an insight into food grain-management relations, and human health. Thus, the hardware approach taken in this project is a simple solution that can be implemented, and demonstrates its effectiveness over the long term. In addition, there is a strong need for concepts that can improve the storage techniques of food grains in warehouses. This project is primarily concerned with the maintenance of all such storage systems, which are easier to implement due to the continuous monitoring of changes in the parameters over time.

X. ACKNOWLEDGEMENT

The authors thank the principal, faculty and all the technical staff of electronics and communication engineering department of Sri Jayachamarajendra College of Engineering, JSS Science and Technology University, Mysuru, India.

XI. FUTURE SCOPE

In the proposed work, the parameters such as temperature, humidity, and CO_2 levels measured is only limited to the storage system environment. The monitoring system can be further enhanced and implemented in applications which include the measurement of quality of the soil, the amount of pesticides and insecticides required to use, and measuring the amount of rainfall received during the year. They can help consumers to make intelligent decisions about the safety of the food that they eat, and also be used for the improvement of agriculture practices. Also, various grains have different parameters as well as specifications which is hard to maintain in a multi-grain storage facility. Inputting all these parameters and maintaining them remotely over the server can be implemented as well.

REFERENCES

[1] A. Sagaya Selvaraj and S. Anusha "*RFID Enabled Smart Data Analysis in a Smart Warehouse Monitoring System using IoT*" Conference Series 1717 (2021) 012022 IOP Publishing.

[2] K. G. Manishkumar Dholu, "*Internet of things (iot) for precision agriculture application*," in 2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI), 2018.

[3] H. Fan, "*Theoretical Basis and System Establishment of China Food Safety Intelligent Supervision in the Perspective of Internet of Things*," in IEEE Access, vol. 7, pp. 71686-71695, 2019.

[4] R. K. Kodali, J. John and L. Boppana, "*IoT Monitoring System for Grain Storage,*" in 2020 IEEE International Conference on Electronics, Computing and Communication Technologies (CONECCT), 2020.

[5] Julius, Olorunfemi.."*Post-Harvest Loss and Grain Storage Technology-A Review*" in Turkish Journal of Agriculture - Food Science and Technology. 9. 75-83, 2021.

[6] S.Muthukumar, W.Sherine Mary.W "*Sensor based warehouse monitoring and control*" in IEEE Conference Record # 42487, 2018.

[7] E. A. G. K. A. V. Robert N. Dean, Jeffery D. Craven, "*A pcb sensor for status monitoring of stored food stocks*," in IEEE Sensors Letters, vol. 3, 2019.

[8] Aviara, N.A. & Fabiyi, O & Ojediran, John & Ogunniyi, O & Onatola, I. "*Application of Computer Vision in Food Grain Quality Inspection, Evaluation and Control during Bulk Storage*", 2016.

[9] Deepika Uppala et al.,"*Rice Crop Discrimination Using Single Date RISAT1 Hybrid (RH, RV) Polarimetric Data, Photogrammetric Engineering & Remote Sensing*",Volume 81, Issue 7, 2015.

[10] Shah, Mehul & Bhatt, Chetan & Dave, Jaimin. "*Temperature Dependent NIR Spectroscopic Analysis for Food Grain Samples*" in Indian Journal of Science and Technology, 2016.

[11] Mona Haji , Laoucine Kerbache , Mahaboob Muhammad and Tareq Al-Ansari, "*Roles of Technology in Improving Perishable Food Supply Chains*", 2020.

[12] Gamal ElMasry, Nasser Mandour, Salim Al-Rejaie, *Etienne Belin and David Rousseau , "Recent Applications of Multispectral Imaging in Seed Phenotyping and Quality Monitoring—An Overview*", 2019.

AUTHORS PROFILE

Dr. U B Mahadevaswamy is working as Professor in the department of Electronics and Communication Engineering, Sri Jayachamarajendra College of Engineering, JSS Science and Technology University, Mysuru, Karnataka, India. He received his Bachelor of Engineering in Electronics and Communication from University of Mysuru in the year 1988, and obtained his Master's degree in Industrial Electronics from Mangalore University in the year 1995 and Ph.D. in the area of Wireless Sensor Networks from University of Mysore, Mysuru in the year 2013. His areas of interest include Control Systems, Analog and Mixed Mode VLSI Circuits, Linear Integrated Circuits and Signal Processing.

Megha K M is working as Assistant Professor in the department of Electronics and Communication Engineering, Sri Jayachamarajendra College of Engineering, JSS Science and Technology University, Mysuru, Karnataka, India. She received her Bachelor of Engineering in Electronics and Communication from GSSS Institute of Engineering and Technology for Women, Mysuru in the year 2015, and obtained her Master's degree in Digital Communication and Networking from CMRIT, Bengaluru in the year 2017.

Arjun V Srivatsa is pursuing B.E. in Electronics and Communication Engineering at Sri Jayachamarajendra College of Engineering, JSSSTU, Mysuru, Karnataka, India.

Ayushi G Jain is pursuing B.E in Electronics and Communication Engineering at Sri Jayachamarajendra College of Engineering JSSSTU, Mysuru, Karnataka, India.

Bhoomika Rani B is pursuing B.E in Electronics and Communication Engineering at Sri Jayachamarajendra College of Engineering JSSSTU, Mysuru, Karnataka, India.