IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 3, December 2024

A Review on Arduino-Based Technology which Revolutionize Fruit Preservation by Optimizing The Shelf Life of Banana

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Abstract*: Fruit producers and distributors suffer large financial losses as a result of the serious issue of fruit spoiling during transit. Heat accumulation inside the storage container is one of the main reasons why fruit deteriorates, While being transported. In order to control field heat in terms of temperature and humidity monitoring and evaluate its impact on the fruit specimen's skin color, firmness, and bruising, this study was conducted to design and construct an Arduino-based field heat regulator for fruit storage and transportation. Innovative Preservation Techniques are required because Banana rotting during transportation causes significant financial losses for fruit growers and distributors. This paper describes the creation of an Arduino-based system that closely monitors and regulates the storage environment to maximize the shelf life of bananas.The system ensures ideal conditions for fruit preservation by monitoring and controlling temperature, humidity, and gas levels using cutting-edge technology. Remote data monitoring and realtime notifications improve the preservation procedure' efficacy. This technical advancement provides a sustainable, economical, and effective way to prolong the shelf life of bananas, which eventually helps to increase food security, decrease spoilage, and save money for growers and distributors. Following the analysis, it was discovered that the regulator was tested in a real transportation process and went through multiple revisions throughout product development.*

Keywords: Arduino, Regulator of Field Heat, Fruit Storage, Losses After Harvest, Monitoring of Temperature, Monitoring of Humidity, Non-Destructive Examination, The Internet of Things, or IoT, Intelligent Sensors, Storage and Transportation, Safety of Food, Technology for Preservation.

I. INTRODUCTION

A crucial component of the fruit industry and the agricultural sector more broadly is the movement of fruits from the farm to the market. Fruits may, however, be subjected to high humidity and temperatures during transit, which might hasten their deterioration . Low humidity and temperature Farmers, shipping firms, and merchants may suffer significant financial losses as a result of poor management, which can cause spoiling and quality degradation [2]. Up to 60 Percent of all fruits and vegetables end up in landfills, making them the food category with the largest losses and waste of all food categories, according to the Food and Agriculture Organization [3]. Of them, fruit degradation accounts for the majority of fruit waste. Of them, fruit deterioration during storage and transit accounts for the majority of fruit waste. When consumed, spoiled fruit can cause discomfort and illness in humans due to the presence of foodborne pathogens and spoilage bacteria [4]. Fruits should be stored and transported at ideal temperatures since temperature is the main factor affecting their quality. While greater temperatures can produce browning and softening, low heat content during storage and transit can alter the color and texture of fruit [5]. Specifically, humidity Conversely, the amount of water vapor in a waterair mixture is measured by relative humidity (IAES Int J Rob and Autom ISSN: 2722-2586). Creation of a field heat regulator for fruit storage using Arduino (Hannah Fretchie A. Britana) 315 as much as is practical [6]. When the humidity˜ is high, the fruit will ripen more quickly. High humidity

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also helps to keep the fruit's skin from drying out, which can cause it to crack or split. On the contrary, low humidity can cause fruits to dry out and become unripe or overripe [7]. A high relative humidity along with temperature fluctuations can lead to condensation of water. Yeast, mold, fungus, and bacteria can all thrive as a result of water condensation. Condensed water droplets may also obstruct perforated plastic

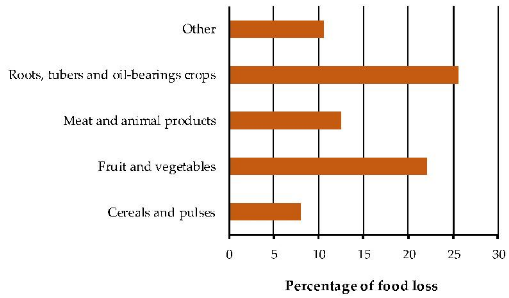

Fig. 1. Food losses and waste along the supply chain (percentage for each food group[12]).

containers, which would slow fruit respiration and hasten fruit deterioration. Additionally, it may also cause fog inside the package, which would impact the customer's decision to buy the product due to an obscure vision of the product [8]. The temperature differential between the harvested crop's actual temperature and the ideal storage temperature is known as field heat [9]. In order to guarantee the freshest, longest-lasting produce and improve competitive positioning with downstream producers, field heat regulation is an essential first step. For the majority of farm commodities, controlling field heat is the most crucial thing a farmer can do to preserve harvest sellable weight, attractiveness, nutrition, and farm profits [10]. Fruit deterioration and senescence processes may be accelerated if field heat is not controlled [11].

One of the biggest issues facing the fruit sector is fruit spoiling during storage and transit, which provides a good foundation for research and innovation. Although numerous research have examined the use of Arduino-based systems to regulate humidity and temperature, few or none have produced and specifically made for fruit storage and transportation, this Arduino-based field heat regulator preserves the highest quality of fruits and potentially other agricultural items that are essential to meeting communities' daily needs. Therefore, the following research questions are intended to be addressed by this study: i) How will the field heat regulator based on Arduino be created? ii) Will temperature and humidity monitoring enable the product to control heat? iii) What effects will the field heat regulator have on the fruit specimen's firmness, color, and bruising?

A. Methods and Materials Used

1. The DHT11/DHT22 sensors use a capacitive humidity sensor and a thermistor to offer digital readouts for temperature and humidity.
2. MQ-135 and MQ-4 Gas sensors are used to detect gases such as carbon dioxide, methane, and ethylene. The Arduino processes the changes in resistance based on the concentration of the gas to keep an eye on the levels of the gas.
3. The Arduino Uno serves as the control hub, analyzing information from multiple sensors to preserve the best possible fruit storage conditions.
4. A fan or ventilation system that slows down fruit ripening by introducing fresh air and expelling ethylene-rich air is controlled by the Arduino.
5. Relay Module: Enables the low-power Arduino to regulate high-power equipment, such as fans, in response to sensor data in order to preserve the storage environment.
6. GSM Module: Uses SIM900A or SIM800L modules for wireless connectivity to send SMS notifications when environmental conditions surpass safe thresholds.
7. The ESP8266 Wi-Fi Module allows real-time data transmission to cloud services or IoT platforms for remote monitoring by enabling internet connectivity.
8. LCD Screen: Instantaneously provides a summary of storage conditions by displaying current temperature, humidity, and gas levels.

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II. LITERATURE SURVEY

Since temperature and respiration are directly correlated, the rate of respiration increases by 10°C for every degree Celsius that the temperature rises. Because bananas are more susceptible to chilling harm, we cannot keep them at temperatures lower than 13 or 14°C, even though their respiration rate slows down at lower temperatures (Kader, 2012). Likewise, transpiration and the relative weight loss of the commodity are inversely correlated with the relative humidity of the storage atmosphere. Thus, it is best to keep RH between 90 and 95 percent to reduce weight loss and slow down transpiration rate; if this is exceeded, infections are once more an issue (Kerbel, 2004). The methods used to improve the post-harvest shelf-life of bananas, in addition to temperature and relative humidity, were examined in the areas that follow.

Fruit spoiling causes huge financial losses and food waste, making it a major worldwide problem. It describes how fruits deteriorate, degrade, or rot as a result of adverse circumstances from harvest to consumption. Every year, over 20 percent of all fruits and vegetables produced are lost to spoiling. During harvest, packaging, transportation, exhibition, and consumption, post harvest losses in the Philippines might amount to as much as 28 percent. Mishandling, inadequate storage, distribution system inefficiencies, and disease and pest damage are some of the factors that lead to these losses. Transporting goods from their point of origin to customers is crucial, but it also causes 80 percent of fruit and vegetable losses. Although it is a popular technique, cold chain transportation uses a lot of energy and raises delivery costs because it keeps temperatures low to guarantee freshness. Despite previous research on controlling temperature and humidity with Arduino-based systems, there is still a need to create a field heat regulator that is especially made for transporting and storing fruit. By closing this gap, postharvest losses might be greatly decreased and the quality of fruits that are preserved could be improved. Proper shipping and storage are essential to reducing fruit rotting. Fruits are shielded from the environment and biological degradation are avoided by proper storage prior to transportation[13]. By acting as an ethylene absorber, 1 percent $KMnO_4$ significantly decreased banana yellowing, maintained flavor for up to 15 days at room temperature (28°C), and increased the fruit's shelf life for up to 45 days at(Tan, 2009) 13°C. According to Ahmed et al. (2021), banana fruits treated with 1 percent $KMnO_4$ and kept at a low temperature (7°C ± 2°C) enhance the majority of post harvest quality indicators and lengthen their shelf life (19.51 days). Applying 10 g of $KMnO_4$-zeolite per sachet prevents ripening, preserves banana fruit quality, and boosts marketability for 15 days (Yin et al., 2020).The banana fruits that were placed in sealed polyethylene bags and treated with 0.5microl/l 1-MCP had the longest shelf life, lasting almost 58 days. The inhibition of both C_2H_4 evolution and respiration by 1 MCP was confirmed by measuring the concentrations of C_2H_4 and CO_2 in polyethylene bags (Jiyang et al., 1999). Banana fruits stored at 25°C and 75–80 percent relative humidity with 1 mM H_2S have a longer postharvest life because their oxidative metabolism is down-regulated (Siddiqui et al., 2021)[14].

IoT is used in the project to increase the management and efficiency of fruit warehouses. IoT sensors, actuators, and data transmission networks should be integrated, according to the authors, to track and Real-time control over fruit storage conditions. Temperature, humidity, and ethylene data are sent from the system to a central control system. The control system can use this information to automatically change the ambient warehouse conditions, preventing fruit from spoiling. The research indicates that the proposed IoT system enhances operational efficiency, waste reduction, and quality control. Through the use of IoT, this study assists the fruit industry in developing creative warehousing solutions that enhance fruit quality and storage conditions [15]. A comprehensive, reasonably priced IoT framework for tracking the quality of fruits and vegetables during transit in India is shown in this paper. During transportation, perishable food quality is monitored and guaranteed using IoT technology.

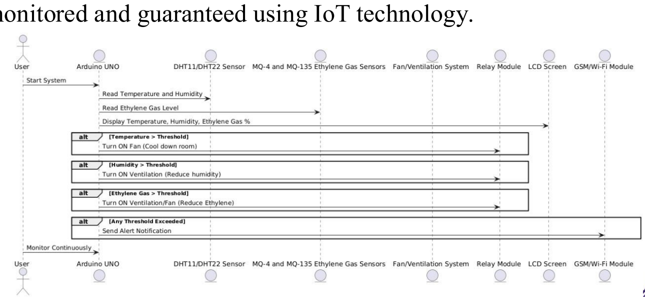

Fig. 2. Representation of Working Principle of Optimizing shelflife of Fruits [19]

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Data analytics and smart sensors track the temperature, humidity, and gas composition during Journey. Real-time data processing enables the assessment of quality and initiates measures to guarantee the freshness of fruits and vegetables. Because of its low cost, the framework is appropriate for India's economical solutions. By decreasing post-harvest losses and providing consumers with higher-quality products, an IoT-based system may improve the dependability and efficiency of fruit and vegetable transportation [16].

III. METHODOLOGY

This study used developmental research as its research design, which is described as a "systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet criteria of internal consistency and effectiveness" [17]. Accordingly, in this kind of study design, as well as the development and analysis of the product. The finished product was also assessed to see if the predetermined research goals were fulfilled. In this investigation, the experimental research design was also employed. An experimental design is a set of guidelines and practices developed to carry out scientific experimental research with two sets of variables [18]. Using a variety of materials to ensure the product's durability and heat-regulating capabilities, the researchers created an Arduino-based field heat regulator store for fruit transportation. Materials comprised an Arduino Uno, polyurethane foam, sheet metal, DTH11 temperature, Along with humidity sensors, a 20x4 LCD, a DC fan, a 9 V battery, a battery snap connector, jumper wires, additional supplies including electrical tape, magnetic catch, stainless steel handles, and the fruit to be tested—Lakatan (Musa acuminata) bananas—took place. Together, these components produced a robust and efficient storage system that maintains a steady temperature and humidity level to keep the fruit fresh while being transported.

The sequence diagram shows how parts work together in a system intended to track and regulate environmental factors like humidity, temperature, and ethylene gas concentrations. An Arduino UNO serves as the system's central CPU, reading

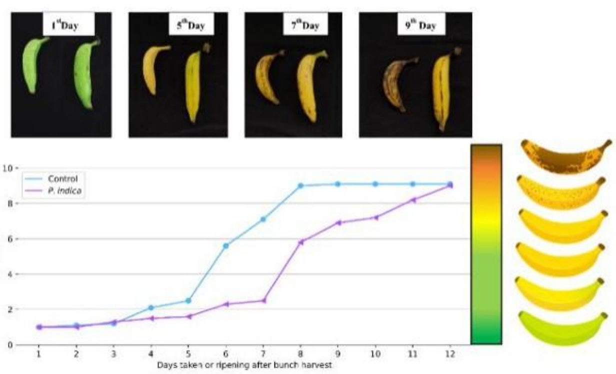

Fig. 3. Comparative analysis of progressive ripening rate and shelf life of banana fruits from plants with or without P. indica.[20]

data from MQ-4 and MQ-135 sensors for ethylene gas and DHT11/DHT22 sensors for temperature and humidity. The system begins with user involvement. This real-time data is shown on an LCD panel. To control climatic conditions, the Arduino uses a relay module to drive a fan or ventilation system that is part of the system. The GSM or Wi-Fi module notifies the user if any parameter above predetermined criteria. By keeping the storage environment within safe bounds, this arrangement helps to prolong the shelf life of fruits that are kept in storage[19].

In the picture, a control group and a group treated with Piriformospora indica (P. indica) are compared in a study on the ripening phase of bananas. Photographs of two bananas, one from the control group and one treated with P. indica, are shown in the top part on the first, fifth, seventh, and ninth days. The treated bananas ripened more slowly than the control group, as seen in these photos, illustrating the variations in ripening stages (Venkatachalam et al., 2023).The ripening process over a 12-day period is plotted on a line graph beneath the photos. The x-axis is labeled "Days taken for ripening after bunch harvest," while the y-axis is a scale with values ranging from 0 to 10.The control group is shown by a blue line on the graph, while the P. Indica-treated group is represented by a purple line. The blue line indicates a quicker ripening phase. Acolor scale that visually represents the stages of banana ripening, ranging from

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green (unripe) to brown (overripe), is located to the right of the graph. This picture successfully illustrates the effects of P. indica treatment, demonstrating that it slows down the ripening process, potentially extending banana shelf life and lowering food waste (Venkatachalam et al., 2023).

IV. RESULT AND DISCUSSION

The study investigated a number of elements that affect fruit deterioration and the efficiency of various technologies in prolonging banana shelf life. The fact that the rate of respiration in bananas rises by 10°C for every degree Celsius of temperature increase was highlighted. According to Kader (2012), bananas cannot be stored below 13 or 14°C due to their susceptibility to chilling damage, even though their respiration rates are slower at lower temperatures. According to Kerbel (2004), the ideal relative humidity (RH) for storage is between 90 and 95 percent to minimize weight loss and transpiration; however, going over this can result in infections. The study found that postharvest losses in the Philippines might reach up to 28 percent, with over 20 percent of fruits and vegetables lost each year as a result of spoiling. Eighty percent of these losses are attributable to transportation alone, underscoring the inadequacy of the distribution networks in place. The use of 1 percent KMnO4 as an ethylene absorber considerably decreased banana yellowing and increased shelf life for up to 45 days at 13°C, according to experimental data (Tan, 2009). Bananas exhibited higher quality indicators and a longer shelf life when treated with KMnO4-zeolite, 1-MCP in polyethylene bags, and 1 mM H2S (Ahmed et al., 2021; Yin et al., 2020; Jiyang et al., 1999; Siddiqui et al., 2021).The use of IoT technology to improve the efficiency and management of fruit storage was also investigated in the study. To track variables like temperature, humidity, and ethylene levels in real time, IoT sensors and data transmission networks were combined. Through the automatic modification of storage conditions in response to sensor data, the suggested IoT system increased operating efficiency, decreased waste, and guaranteed greater quality control[21].

The results demonstrate how important temperature and humidity regulation are in prolonging banana shelf life. The study demonstrates how important it is to maintain ideal temperature and relative humidity levels in order to lower respiration rates and weight loss, two major contributors to fruit spoiling. Fruit preservation is further improved by the use of ethylene absorbers like KMnO4 and technologies like 1-MCP and H2S treatment, which slow down the ripening process and preserve fruit quality. Fruit preservation with IoT integration presents a viable way to address the shortcomings of the current transportation and storage infrastructure. Throughout their trip from farm to customer, fruits are kept in ideal conditions thanks to IoT technology, which offers real-time monitoring and automatic changes. By doing this, postharvest losses are decreased and the fruits' overall quality and marketability are enhanced.Overall, the study emphasizes how critical it is to implement cutting-edge fruit preservation technology in order to combat the worldwide problem of food waste. According to the results, ethylene absorption, temperature and humidity control, and Internet of Things based monitoring can all be used to greatly increase fruit shelf life, which has both financial and environmental advantages. Future studies should concentrate on creating scalable and reasonably priced solutions to enable small-scale distributors and farmers to use these technologies[21].

For growers, the shelf life of bananas is a top concern. It is classified as a particularly perishable fruit. The ripening fruits were harvested from plants infested with P. indica. was left at ambient temperature for a week, while the fruit from the control plants matured in five days. Fruit shelf life (maturity to rotting) showed a similar pattern (Fig. 3). It was found that the fruits from P. indica-colonized plants had a shelf life of over two weeks, but the fruit from control plants was totally rotten by the twelfth day of room temperature storage[20].

Deep learning and other cutting-edge machine learning techniques may be used in next developments that seek to further increase prediction accuracy. Additionally, Real-time imaging technology and a larger variety of sensors could be investigated in order to enhance the system's ability to recognize and respond to minute variations in crop conditions[21].

V. FUTURE DEVELOPMENT

Specific benefits or uses from the review have been greatly aided by the developments in Revolutionizing Fruit Preservation. Nevertheless, a number of obstacles still exist in spite of these successes, including [important gaps or restrictions]. Future research can address these problems and achieve [ertain objectives, such as increasing scalability,

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ISSN (Online) 2581-9429

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Impact Factor: 7.53

Volume 4, Issue 3, December 2024

efficiency, or application. Potential future development paths are examined in this part, with an emphasis on certain themes, such as cutting edge techniques, developing technologies, or multidisciplinary methods.

Maintaining optimal storage conditions for bananas is the main objective in order to extend their shelf life. For bananas to ripen, the system's primary goals are temperature control, humidity management, and ethylene gas level monitoring. Post-harvest processing results in a fruit loss of roughly 40 percent. Its tropical origins make it more vulnerable to chilling harm at storage temperatures that are sufficiently low (¡13ºC). When banana fruits are stored at the ideal temperature of

13–14 degrees Celsius and at a higher relative humidity of 90–95 percent, their shelf life can be extended by 7–12 days. The respiration rate, ethylene evolving rate, ripening delay, and senescence process are all slowed down while maintaining the post-harvest storage temperature and relative humidity. Because temperature fluctuations can speed up the ripening process and accelerate rotting, it is advised that bananas be stored at 18°C (65°F). The project uses an array of sensors, Arduino-based controllers, and alert systems to keep the storage room's climate at the optimal level for banana preservation. The system continuously checks the temperature and humidity in the storage space using DHT11 or DHT22 sensors.

The control system receives real-time data from these sensors, which are very good at identifying even the smallest changes in temperature and humidity. More precision and a wider measurement range make the DHT22 the better choice, while the DHT11 has more basic features. In the event that the temperature rises above the optimal threshold of 18°C, the sensors will identify the change and the system will react by activating different Arduino Uno-connected components. As part of the corrective steps, the atmosphere is controlled to keep the temperature and humidity level constant, guaranteeing that bananas are stored in the best possible conditions.These sensors are excellent at detecting even the slightest variations in temperature and humidity, and they provide real-time data to the control system. The DHT22 is a superior option because to its greater precision and broader measuring range, whilst the DHT11 offers more basic functions. The sensors will detect the temperature change and the system will respond by turning on various Arduino Uno-connected components if the temperature exceeds the ideal threshold of 18°C. To ensure that bananas are stored in the best possible circumstances, the environment is regulated as part of the corrective actions to maintain a steady temperature and humidity level.

The system monitors and controls the storage environment for bananas to prevent premature ripening caused by elevated ethylene gas levels. It utilizes sensors such as the DHT22 and MQ-135 to detect temperature, humidity, and ethylene concentration. The Arduino Uno acts as the central controller, analyzing sensor data and activating appropriate responses. A relay module manages high-power components, like fans or ventilation systems, to regulate storage conditions when thresholds are exceeded, such as temperatures above 18°C or high ethylene levels. The fan and ventilation system remove ethylene-rich air, ensuring optimal conditions for storage. Alert systems include a GSM module, which sends SMS notifications to farmers when environmental factors exceed safe ranges, and a Wi-Fi module (ESP8266) that supports email alerts, IoT integration, and remote monitoring. Additionally, an LCD display provides real-time feedback on temperature, humidity, and ethylene levels. Together, these components maintain ideal storage conditions, minimize spoilage, and enable farmers to monitor and respond to environmental changes effectively. Furthermore, an LCD monitor offers realtime feedback on ethylene levels, humidity, and temperature. These elements work together to avoid spoiling, maintain optimal storage conditions, and let farmers properly monitor and react to environmental changes.

VI. CONCLUSION

Using Arduino-based technology to revolutionize fruit preservation presents a promising way to address the issues of decreasing post-harvest losses and increasing shelf life. This system offers accurate environmental management by combining sensors like MQ-135 or MQ-4 gas sensors for identifying spoiling signs and DHT22 or DHT11 sensors for temperature and humidity monitoring. Fans, relay modules, GSM modules, and Wi-Fi modules (ESP8266) guarantee effective operation, remote monitoring, and communication, while the Arduino Uno acts as the central processing unit.

From cold storage and transit to retail and customer use, this technology tackles important supply chain nodes. It is appropriate for both individual home solutions and large scale industrial applications due to its scalability and affordability. Incorporating IoT capabilities also improves data driven decision-making and real-time monitoring, which

DOI: 10.48175/IJARSCT-22847

promotes more intelligent farming methods and sustainable food systems.Arduino-based fruit preservation systems demonstrate how technology may be used to cut waste, boost productivity, and provide consumers with high-quality produce in a world where food security and resource management are major issues. These developments are a big step in the direction of a more robust and sustainable global food supply system.

VII. ACKNOWLEDGEMENT

We would like to express our sincere gratitude to all of the people and institutions that have contributed to this review paper on ”Revolutionizing Fruit Preservation: Optimizing Shelf Life of Banana with Arduino-Based Technology.” First and foremost, we would like to sincerely thank our mentors and academic advisors for their insightful criticism and invaluable advice during this project. Their knowledge has greatly influenced the course of this paper. The authors and scholars whose work we have referenced are likewise deserving of our gratitude. Their groundbreaking research and writings served as a wealth of information and motivation for our review. We would especially want to thank our universities for giving the assistance and resources needed to conduct this study. In order to finish this study, financial support, research facilities, and access to scholarly databases have been essential. We also value our peers' and colleagues' contributions, which included insightful comments and productive debates throughout the review's development.

In conclusion, we would like to thank our family and friends for their unwavering support, whose understanding and encouragement have been vital throughout our quest.

We appreciate all of your help and efforts.

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