SMART INSULIN REFRIGERATOR

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Abstract— A novel and cost-efficient solution, the Smart Insulin Refrigerator aims to address the challenges diabetic patients face in storing insulin at the correct temperature. Insulin requires storage at temperatures below 28 °C to maintain its potency and effectiveness, but traditional refrigerators, while capable of achieving this, are often expensive and not always accessible to all patients. The Smart Insulin Refrigerator provides a more affordable alternative, operating at approximately one-tenth of the cost of a conventional refrigerator, making it an attractive option for patients in low-resource settings. This device is designed to be both eco-friendly and reusable, offering a sustainable method for insulin storage. The system is automated to ensure consistent temperature regulation, eliminating the need for manual monitoring and reducing the risk of insulin degradation. This paper discusses the engineering and design principles behind the Smart Insulin Refrigerator, including a detailed examination of its circuit diagram, which is integral to the automation process. The development of this device represents a significant step forward in enhancing the accessibility and affordability of insulin storage, potentially improving the quality of life for diabetic patients globally.

Keywords: Insulin Pot, Pipe, Relay, B 547, LM317, DC motor pump, ESP8266.

I. INTRODUCTION

The Smart Insulin Refrigerator is a groundbreaking device tailored to meet the specific needs of diabetic patients, providing a reliable and cost-effective means of storing insulin without the need for a traditional refrigerator. Proper storage of insulin is crucial, as it must be kept at a stable temperature below 28°C to maintain its efficacy. However, conventional refrigerators, while effective, are often costly and may not be accessible to everyone, particularly in rural or low-resource settings. The Smart Insulin Refrigerator addresses this challenge by offering an affordable and efficient alternative that autonomously manages the temperature requirements for insulin storage.

This device is an enhanced version of the original Insulin Pot, an innovation developed by Udaan, an NGO based in Aurangabad, Maharashtra, India. The upgraded system integrates several key components: an insulin pot, a 5-liter water storage tank, a circuit box, a pipe, and a DC motor pump. These components are interconnected to form a system that automatically regulates the environment within the insulin pot, ensuring that insulin remains at a safe and stable temperature.

In summary, the Smart Insulin Refrigerator is a highly practical and innovative solution that not only makes insulin storage more accessible and affordable but also offers a sustainable alternative to traditional refrigeration. Its design and functionality are particularly suited to meet the needs of diabetic patients in diverse settings, ensuring that insulin remains potent and safe for use, regardless of external conditions.

A. Working of Smart Insulin Refrigerator

The working mechanism of the Smart Insulin Refrigerator is both innovative and user-friendly, ensuring that insulin is stored under optimal conditions without the need for a traditional refrigerator. The system's design focuses on automation and simplicity, making it accessible to a wide range of users, particularly those in areas where conventional refrigeration might not be practical or affordable. When the Smart Insulin Refrigerator is activated, the core of its operation begins with the circuit, which plays a critical role in managing the overall functionality of the device. The circuit is programmed to control the DC motor pump, a vital component submerged in a 5-liter water storage tank. This pump is responsible for drawing water from the tank and delivering it through a connected pipe into the Insulin Pot. The delivery of water is not continuous but occurs at carefully timed intervals, regulated by a relay switch within the circuit. This relay is programmed to activate the pump periodically, ensuring that the insulin pot receives just the right amount of water to maintain a stable and cool environment necessary for insulin storage.

The process of watering the insulin pot is crucial because it helps regulate the humidity and temperature inside the pot. By maintaining a consistent level of moisture, the system creates a cooling effect through the process of evaporation. As water evaporates from the surface of the pot, it absorbs heat, which helps to lower the temperature within the pot and keep the insulin at a safe level below 28 °C. This natural cooling method is both energy-efficient and effective, providing a sustainable way to store insulin without relying on traditional refrigeration. To further enhance the reliability of the Smart Insulin Refrigerator, especially in regions where electricity supply is inconsistent, the system is designed to be compatible with an external power bank. This feature ensures that the device can continue to operate even during power outages, which are common in rural and underserved areas. The ability to use a power bank means that the insulin stored within the pot remains protected, regardless of external power conditions. In terms of maintenance, the system is designed to be low-effort for the user. The primary maintenance task involves refilling the 5-liter water storage tank approximately every 5–6 days. This task is simple and can be easily managed by the user, ensuring that the system continues to function effectively. By keeping the water tank filled, the user ensures that the automated process of cooling through moisture regulation remains uninterrupted, thereby safeguarding the insulin stored in the pot.

Overall, the Smart Insulin Refrigerator's operational process is a blend of automation, efficient design, and practical features that make it a highly effective solution for insulin storage. It offers a reliable and affordable alternative to traditional refrigeration, particularly for those in areas with limited resources. By combining innovative technology with user-friendly operation, this device helps ensure that diabetic patients have access to safe and effective insulin storage, regardless of their environment.

II. LITERATURE REVIEW

Proper insulin storage is vital for preserving its effectiveness, especially in areas where access to reliable refrigeration is limited. Various studies have sought to develop alternative storage methods that are both cost-effective and suitable for low-resource environments. This literature review examines three key studies that contribute to this field and contextualizes the development of the smart insulin refrigerator.

1. Traditional Evaporative Cooling Techniques for Insulin Storage

Patton et al. (2018) investigated the use of traditional evaporative cooling techniques, such as clay pot coolers, for insulin storage in rural regions. These methods rely on the natural cooling effect of water evaporation to maintain a lower temperature, making them particularly effective in dry, hot climates. While these traditional methods can keep insulin at a safe temperature, the study identified some drawbacks, such as the need for regular water replenishment and inconsistent cooling performance depending on the surrounding environment. These limitations highlight the necessity for more reliable and automated solutions, such as the Smart Insulin Refrigerator, which can offer more consistent and dependable temperature control.

2. Solar-Powered Insulin Storage Innovations

Smith et al. (2020) explored the use of solar-powered refrigeration systems designed to store insulin in remote areas with limited access to electricity. Their research involved developing and testing portable solar-powered coolers that could maintain a stable temperature suitable for insulin storage. While the study confirmed the viability of using solar power for this purpose, it also noted some challenges, such as the high initial costs and dependence on consistent sunlight, which may not be available in all locations. The Smart Insulin Refrigerator provides an alternative by offering a more affordable solution that can operate using a battery during power outages, making it particularly useful in areas with unreliable electricity.

3. Cost-Effective Insulin Storage Technologies

Kumar et al. (2022) reviewed various low-cost technologies aimed at providing insulin storage solutions for low-resource settings. The study examined a range of devices, from insulated containers to passive cooling systems, assessing their effectiveness in different environmental conditions. One of the key insights was that while these solutions are generally affordable, their effectiveness can be highly dependent on the availability of certain materials or specific climate conditions. The Smart Insulin Refrigerator builds on these findings by incorporating an automated moisture regulation system, which ensures consistent cooling regardless of external environmental factors.

A. *Comparison And Analysis of Literature Review*

The reviewed studies each offer distinct approaches to addressing the challenge of insulin storage in resource-limited settings, highlighting both the progress made and the ongoing limitations in this field.

- Traditional Evaporative Cooling vs. Automated Systems

Patton et al. (2018) focused on traditional evaporative cooling methods, which are simple and effective in certain climates. These systems rely on natural processes and are highly cost-effective, making them accessible in low-resource settings. However, their effectiveness is heavily dependent on environmental conditions, such as humidity and temperature, and they require frequent user intervention, such as refilling water. In contrast, the Smart Insulin Refrigerator automates the cooling process, reducing the need for constant user involvement and providing more consistent results. This automation addresses one of the key limitations of traditional methods by ensuring reliable temperature control, regardless of external conditions.

- Solar-Powered Solutions vs. Battery-Operated Systems

The study by Smith et al. (2020) explored solar-powered refrigeration as a solution for insulin storage in areas with limited electricity. While solar-powered systems offer a sustainable and renewable energy source, they come with high initial costs and are dependent on continuous sunlight, which may not be reliable in all regions. The Smart Insulin Refrigerator, by incorporating the option to use a battery or power bank, provides a more flexible and reliable alternative. This battery-operated capability ensures that the system can function during power outages or in areas with inconsistent sunlight, addressing the key limitations identified in solar-powered solutions.

- Cost-Effective Technologies vs. Consistent Performance

Kumar et al. (2022) reviewed various low-cost insulin storage technologies, emphasizing affordability and accessibility. While these solutions are beneficial in reducing costs, their performance can vary significantly based on the materials used and environmental factors. The Smart Insulin Refrigerator improves upon these low-cost technologies by integrating a moisture regulation system that maintains a stable environment for insulin storage, offering consistent performance regardless of external variables. This ensures that insulin remains safe and effective, which is crucial for patients in varying climates and conditions.

Overall Analysis

The comparison of these studies reveals that while each solution offers unique advantages, they also have specific limitations that may hinder their widespread adoption or effectiveness. Traditional evaporative cooling methods are simple and inexpensive but lack consistency and require regular maintenance. Solar-powered systems provide a sustainable option but are expensive and dependent on sunlight. Low-cost technologies are accessible but often lack the reliability needed for critical insulin storage. The Smart Insulin Refrigerator stands out by addressing these limitations through its automated system, which ensures consistent cooling, flexibility in power sources, and affordability. By combining these features, it offers a comprehensive solution that is well-suited to the needs of diabetic patients in diverse and challenging environments. This analysis highlights the importance of developing insulin storage solutions that are not only cost-effective but also reliable and adaptable to various conditions, which the Smart Insulin Refrigerator successfully achieves.

III. PROPOSED SYSTEM

A. Simulation Diagram

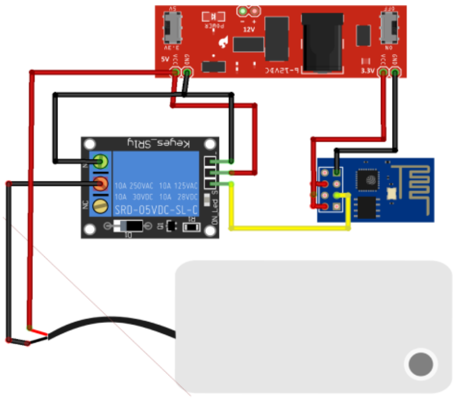

Fig.1: Circuit diagram

The diagram highlights in figure 1, a vital component of the Smart Insulin Refrigerator's circuitry, designed specifically to keep insulin at a safe temperature below 28 °C. This system features an ESP8266 Wi-Fi module, a key element that facilitates remote control and automation. The module is linked to a relay, which functions as an electrically operated switch, controlling a DC motor pump responsible for circulating water or coolant to maintain the ideal temperature inside the Insulin Pot.

A power supply module is also included, converting a higher input voltage, likely 12V, into a lower, stable voltage that powers both the ESP8266 and the relay. This setup ensures that the entire system runs efficiently and reliably. The ESP8266 is programmed to monitor the temperature inside the insulin pot using sensors. When the temperature nears the 28°C thresholds, the ESP8266 triggers the relay, which then powers the DC motor pump to cool the interior.

This automated process eliminates the need for manual monitoring, making the system both practical and dependable. By autonomously maintaining the optimal storage temperature for insulin, the Smart Insulin Refrigerator offers a cost-effective alternative to traditional refrigerators. This is particularly beneficial in low-resource areas where conventional refrigeration may be too expensive or unavailable, thus ensuring that insulin remains potent and accessible for diabetic patients in various settings.

B. FLowcharts

a) Sytem Flowchart

The flowchart Figure 2 illustrates an automated system that uses an ESP8266 microcontroller to control a motor pump for irrigation. Upon powering on, the ESP8266 is initialized and begins a cycle where it waits for 4 hours, then activates a relay to turn on the motor pump for 10 seconds, watering the plants. After watering, the system sends relevant data to the cloud, such as the time of the watering and the system status. The pump is then turned off, and the process repeats indefinitely until the system is powered off.

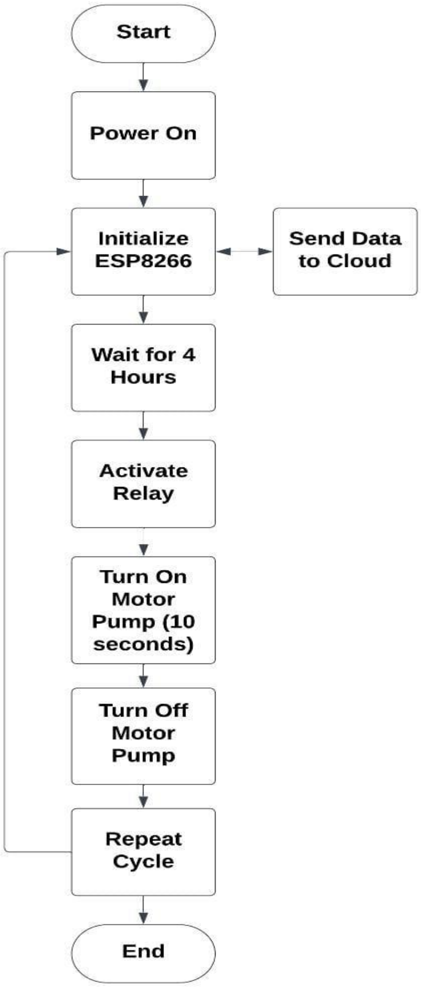

Fig.2 Flowchart

b) System Block Diagram

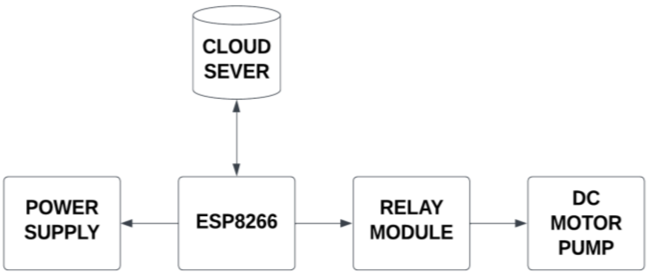

Fig. 3 Block Diagram

The block diagram as shown in above figure 3, depicts a system where the ESP8266 microcontroller acts as the central unit, managing a DC motor pump through a relay module. The power supply feeds the entire system, ensuring that the ESP8266 can control the relay, which functions as a switch to operate the motor pump. The motor pump is responsible for sprinkling water, activated by the relay. Data regarding the system's operation is sent from the ESP8266 to a cloud server, enabling remote monitoring and data logging.

IV. RESULTS

Features	Simple Insulin Pot	Smart Insulin Refrigerator
Electrical Equipments On/Off	No	yes
Working	Manual	Automatic
Mobile App Support	No	Yes
Water Storage	No	Yes
Cost	Low	High
Supervision required?	Yes	No
Easy to use?	Yes	Yes
Emergency Services	Yes	No

Table.1: Comparison with Simple Insulin Pot

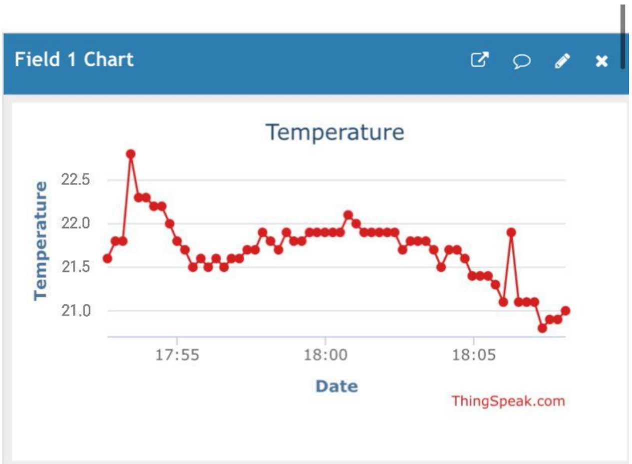

Fig.4 Data Showcased on ThingSpeak Server

The result confirms that the ESP8266 effectively transmits temperature data to the cloud via the Thing Speak server, in figure 4, with the recorded temperatures consistently staying below 26 degrees Celsius. This outcome highlights the system's capability to accurately monitor environmental conditions and reliably upload data to the cloud, ensuring that the desired temperature threshold is maintained within the specified range.

V. CONCLUSION AND FUTURE SCOPE

In conclusion, the Smart Insulin Refrigerator represents a significant advancement in the field of healthcare technology, particularly for diabetic patients who require consistent and reliable insulin storage. By addressing the limitations of traditional refrigeration, such as cost and accessibility, this innovative device offers a practical, affordable, and sustainable alternative that can be tailored to meet the needs of diverse populations, including those in low-resource settings. The potential for further enhancements, such as real-time monitoring, broader medication applications, and integration with renewable energy sources, underscores the device's capacity to evolve and expand its impact. As this technology continues to develop, it holds the promise of improving the quality of life for countless individuals, ensuring that essential medications remain effective and accessible to all.

uture Scope

- The future scope of the Smart Insulin Refrigerator is expansive, with numerous opportunities for innovation and broader impact. As technology continues to evolve, there is potential to integrate advanced smart monitoring systems that allow for real-time tracking of the refrigerator's internal temperature. Through a connected mobile app, users could receive instant notifications if the temperature deviates from the safe range, ensuring the insulin remains effective.

- Beyond insulin, the device could be adapted to store other temperature-sensitive medications, making it a versatile tool in healthcare. Expanding production capabilities and improving distribution channels, particularly in low-resource and rural areas, could make this innovative solution more widely accessible, helping to address the global challenge of inadequate medication storage.

- Furthermore, collaborations with healthcare providers, NGOs, and government agencies could facilitate widespread adoption and implementation, ensuring that even the most vulnerable populations have access to reliable and affordable medication storage. With continuous research and development, the Smart Insulin Refrigerator could also incorporate renewable energy sources, such as solar power, enhancing its sustainability and reducing reliance on traditional power grids. Overall, this device has the potential to revolutionize medication storage, providing a crucial lifeline for diabetic patients and others who require temperature-controlled medications.

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Biography

Nakul Pravin Tiwari has currently completed his B.E in Electronics and Telecommunications and he also worked on various app, website project. He also holds the position of the winner of IdeaSpark 2023 in Nashik and was one of the candidates invited for Dipex 2023. Recently he is applying for Germany for his MSC.

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Shreyas Manoj Rajput is working as an Associate Embedded Engineer at KPIT Technologies and also provides proficiency in Machine Learning. He completed his B.E. from Pune Vidyarthi ology (June 2024) with Honors in Griha's College of Engineering and Technology (June 2024) with Honors in Artificial Intelligence and Machine Learning. He also holds a position for the Top Performer in IIT Bombay's Bio Analytics partenered by Proteomics India.

Shivani Janardhan Kshirsagar is currently working as an Embedded Engineer at Technical Studio and she also worked on Drone Development and Wireless Technology like IoT, GSM, GPS, RFID, XBEE. Also has 3 years of experience in the Design, Maintenance, and Development of All Engineering Education training kits at Onix Technology. She Completed her B. E. from Peoples Education Society (P.E.S) of Engineering, Aurangabad.

Pravin R Nawate is currently working as an R&D Engineer at Technical Studio and also Designed and Developed a Ventilator with Forbes and Company Ltd. He also worked on oxygen concentrator with Fintek Engineers to improve the oxygen concentration level of the device, also he has 2 years' experience in New Product Design Division at Eco-Sense Appliances Pvt. Ltd and he developed a Sanitary napkin incinerator, Former PCB Designer at CBROZ training & Research center. His project has received the Best Idea award at the IMeche Process Division Event held at IIT Bombay in 2018. He is also a technical consultant at Desire Automation, Etechno solutions, and a Former Lecturer at Govt. Polytechnic Aurangabad, Awarded his B-Tech from the National Institute of Electronics and Information technology (NILELIT).