Smart Shelf - Life Prediction System for Packaged Foods

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Abstract: The Smart Shelf-Life Prediction System for Packaged Foods is an Internet of Things system that watches storage conditions and calculates how much time a packaged food product still has before it goes bad. The Smart Shelf-Life Prediction System uses an ESP32 microcontroller to gather temperature and humidity readings from a DHT22 sensor in time. Those readings are sent to a database where they are stored and examined. Using the data about how the food's stored the Smart Shelf-Life Prediction System figures out how long the food will last and spots any changes that could lower food quality. Every food package gets its QR code so that a user can scan it with a mobile phone and see the food's details when it was made, its original expiry date, the current temperature and humidity the storage history and the estimated remaining shelf life. If the storage conditions turn bad or if the Smart Shelf-Life Prediction System thinks the food is, near the end of its life the system can send alerts to the user. The Smart Shelf-Life Prediction System brings together sensor hardware, on-board processing, wireless links and cloud monitoring to make food storage easier to manage. To confirm that the Smart Shelf-Life Prediction System works well experiments must be done to check how accurate the sensors are, how precise the shelf-life calculations are and how reliable the alerts are. The Smart Shelf-Life Prediction System wants to cut food waste keep food safe and help people keep track of packaged food products efficiently.

Keywords: Internet of Things (IoT), ESP32 Microcontroller, DHT22 Sensor, Shelf-Life Prediction, Temperature and Humidity Monitoring, QR Code, Cloud Database, Food Safety, Food Waste Reduction.

INTRODUCTION

Packaged food products can have their quality change when stored in conditions like high heat and moisture. Wrong storage can hurt the quality, safety and how long the food stays good. This can cause food to go to waste and be bad for health [1]. Regular expiry dates show how long food should last if stored properly.. They don't tell what really happened to each package. So using sensors with the Internet of Things can make it easier to watch food storage and give up to date info, about the environment [2]. IoT makes devices gather and share data through internet connections. This lets people check storage conditions from away. In the system being suggested an ESP32 microcontroller gets data from a DHT22 temperature and humidity sensor [3]. The data helps watch the storage and guess how long the food will last. If the conditions get bad the system can spot problems. Tell the user [4]. A cloud database keeps food info and sensor readings for checking and watching [5]].

A key feature of the proposed system is the integration of a QR code with each food package [6]. By scanning the QR code using a phone users can access food details, manufacturing date original expiry date, current temperature, humidity, storage history and estimated remaining shelf life through the cloud platform. The ESP32 communicates with the cloud platform through Wi-Fi enabling updated sensor information to be accessed by users [7]. The system aims to provide a way to monitor packaged food conditions and identify potential storage-related risks. When the estimated remaining shelf life reaches a warning level or the storage conditions become unsuitable alerts can be provided to inform users [8]. The proposed Smart Shelf-Life Prediction System combines sensors, embedded processing, cloud-based data management and QR code identification to support efficient food monitoring [9]. Its performance can be evaluated by examining sensor accuracy shelf-life estimation, response time and communication reliability [10]. Further testing is required to validate the

accuracy of the prediction model under storage conditions [11]. The system aims to reduce food wastage improve food safety and support storage management, for packaged food products [12].

Materials and Methods

The Smart Shelf-Life Prediction System for Packaged Foods uses an ESP32 microcontroller, a DHT22 temperature and humidity sensor, a cloud database and a unique QR code for each food package. The Smart Shelf-Life Prediction System uses the ESP32 as its brain. The DHT22 sensor checks the temperature and humidity in the place where food is stored. These checks help the Smart Shelf-Life Prediction System watch the conditions that might change food quality and how long it will stay good. The Smart Shelf-Life Prediction System takes the temperature and humidity readings every minutes. The Smart Shelf-Life Prediction System sends the collected data to the cloud database over Wi-Fi so the data can be. Looked at from anywhere. The Smart Shelf-Life Prediction System uses the sensor readings and information about the food to guess how time the packaged food will still last. The accuracy of that guess depends on the model the Smart Shelf-Life Prediction System uses and the numbers that are set for that food. Each food package gets a Food ID that is linked to a QR code. The QR code lets people use a phone to get details, about the food. The details show the food name, manufacturing date original expiry date, current temperature, humidity, storage history and the Smart Shelf-Life Prediction System's estimate of how the food will still be good. The Smart Shelf-Life Prediction System can spot warning signs when the storage place becomes bad or when the estimate reaches a warning level that the Smart Shelf-Life Prediction System has set. This way the Smart Shelf-Life Prediction System mixes sensor checks, processing, cloud storage and QR code identification to help people manage food storage better.

System Design and Implementation

The system is built by attaching the DHT22 temperature and humidity sensor to the ESP32 microcontroller. When the system is turned on the ESP32 sets up the sensor. Connects to Wi-Fi on the cloud platform. After the system has started the sensor begins to take temperature and humidity readings from the storage area at intervals. The ESP32 gathers these sensor readings. Sends them to the cloud database. The system then stores the recent readings together with the Food ID and other food details. The shelf-life estimation model takes the sensor data and food information that the system has collected and calculates how long the food will last. This shelf-life estimate lets users see how the storage conditions are affecting the packaged food. The system checks whether the temperature and humidity readings are inside the limits that the system has set and whether the shelf life estimate has reached a warning threshold. If a warning condition appears the system updates the food status. Can send an alert to the user. If the conditions stay within limits the system records the readings. Shows a normal status. The updated data is saved in the cloud database for use. The QR code is created for each food package. Linked to its Food ID. When a user scans the QR code the system pulls the corresponding food information, from the cloud database. The system then keeps monitoring the storage environment by collecting new sensor readings after a fixed interval. This continuous process keeps the storage information current. Helps the system spot unsuitable storage conditions early.

Web-Based Monitoring

The proposed system uses a platform to store and display food information and sensor readings. The ESP32 transmits temperature and humidity data through Wi-Fi so the latest readings are stored in the cloud database. The stored information can include the Food ID, food details, manufacturing date original expiry date, sensor readings, storage history and estimated remaining shelf life. A unique QR code is assigned to each food package to simplify information retrieval. Users can scan the QR code with a phone to access the associated food record. This reduces the need to search for food details manually. Gives a convenient way to check the monitored storage condition of a package. The cloud-based approach lets users access food information without connecting to the physical sensor system. The monitoring interface can display the temperature, humidity estimated remaining shelf life and food status. When a warning condition is identified the system can update the cloud record. Send a notification through the configured alert mechanism. The storage history helps users see how the monitored environmental conditions have changed over time. This information supports food storage decisions and raises awareness of possible quality-related risks. However the

availability of updated information relies on Wi-Fi connectivity, cloud service availability and successful data transmission. If the network connection is interrupted the displayed information may not reflect the storage conditions.

Experimental Evaluation

I think the system that was suggested can be checked by doing a set of tests that look at the parts of the system. First we check the ESP32 microcontroller the DHT22 sensor, the Wi-Fi link and the cloud database. Then we compare the temperature and humidity readings from the sensor with a device that we know is accurate to see how correct the sensor is. We keep taking readings to see how the sensor readings change when we put the food in conditions. We also check the communication by making sure the sensor readings are sent to the cloud and stored properly. We note how long it takes to update the cloud database. We look for any missing readings or any breaks in the connection. We make sure we can get the food data back from the cloud. All these tests show how reliable the data path is between the ESP32 microcontroller and the cloud platform. We also test the QR codes by scanning the code on each food package. Each scan should show the food record that matches the Food ID. We then check that the food details, the manufacturing date, the original expiry date the current sensor readings and the storage history all look right. We test the shelf-life prediction model by using known data. We change the temperature and humidity to see how the predicted remaining shelf life changes with the model. If we have values we compare the predicted shelf life with those values to see how correct the prediction is. The warning system is tested by making sure the system shows a warning whenever we go beyond the set storage limits or reach a shelf-life warning. We record how quickly the warning appears, how quickly the cloud updates and how strong the connection is, during tests. After collecting all the data we look at it to find errors and come up with ways to make things better. We need experiments to show that the system is correct and works well. Because food safety is important. The system should help existing food safety methods instead of taking their place.

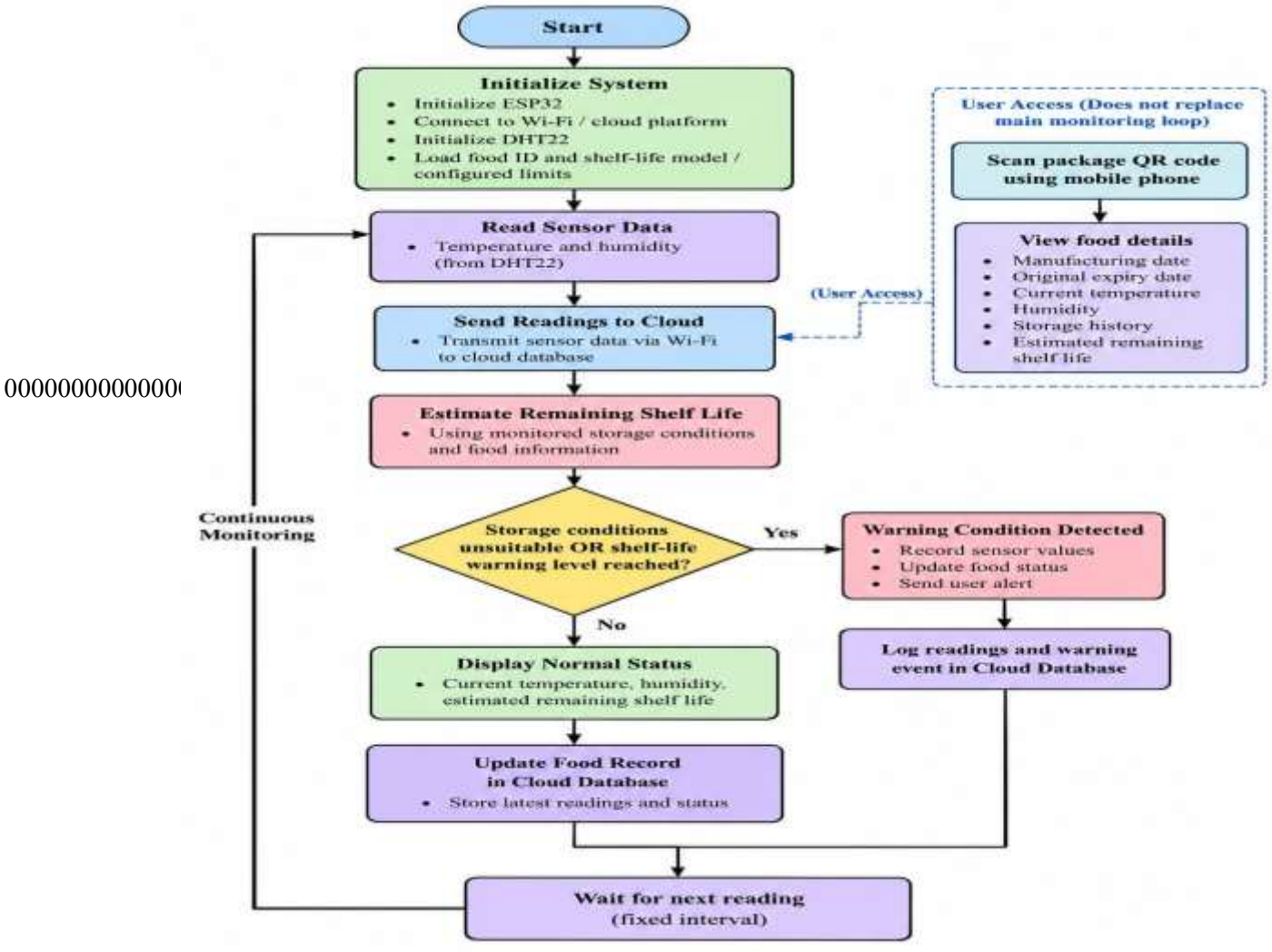


Fig. 1 Work flow for monitoring systems

RESULTS

I am excited to share how the Smart Shelf-Life Prediction System for Packaged Foods works. The Smart Shelf-Life Prediction System for Packaged Foods uses an ESP32 microcontroller with a DHT22 temperature and humidity sensor to watch the conditions where food is stored. The Smart Shelf-Life Prediction System for Packaged Foods gathers readings from the environment. Sends them to a cloud database over Wi-Fi. The Smart Shelf-Life Prediction System for Packaged Foods uses those readings to guess how much shelf life remains for the packaged food, based on a prediction model and the set storage conditions. A QR code that is unique to each food package lets users open a page on a phone that shows the food details the manufacturing date, the original expiry date the current temperature, the current humidity, the storage history and the guessed remaining shelf life. If the storage conditions become bad or the guessed remaining shelf life hits a warning level the Smart Shelf-Life Prediction System for Packaged Foods can change the food status. Send alerts to users. The Smart Shelf-Life Prediction System for Packaged Foods brings together sensor monitoring, embedded processing, cloud storage and QR code access in one system. I still need to run experiments to check how accurate the sensor is, how accurate the shelf-life guess is, how fast the cloud updates, how quick the alerts are and how reliable the communication is, in different storage conditions.

DISCUSSION

The smart shelf-life prediction system for packaged foods brings together sensing, processing on the device cloud-based monitoring and QR code identification to help manage how food is stored. The DHT22 sensor checks the temperature and the humidity. The ESP32 gathers the data from the sensor. Sends it to a cloud platform using Wi-Fi. This data can be used by the shelf-life estimation model to figure out how long the packaged food will last under the conditions it is stored in. The QR code lets people easily get information about the food and its storage history. This helps users see what the current storage conditions are for each package. The warning system tells users when the storage conditions are not good or when the estimated time left is at a warning level. However how well the system works depends on how well the sensors are calibrated, how accurate the shelf-life model's if there is a good internet connection and if the cloud data is sent reliably. More testing, in storage conditions is needed to make sure the model is accurate and the system is reliable. The system tries to cut down on food waste and make people more aware of how to store food.. It should help with existing food safety practices not take their place.

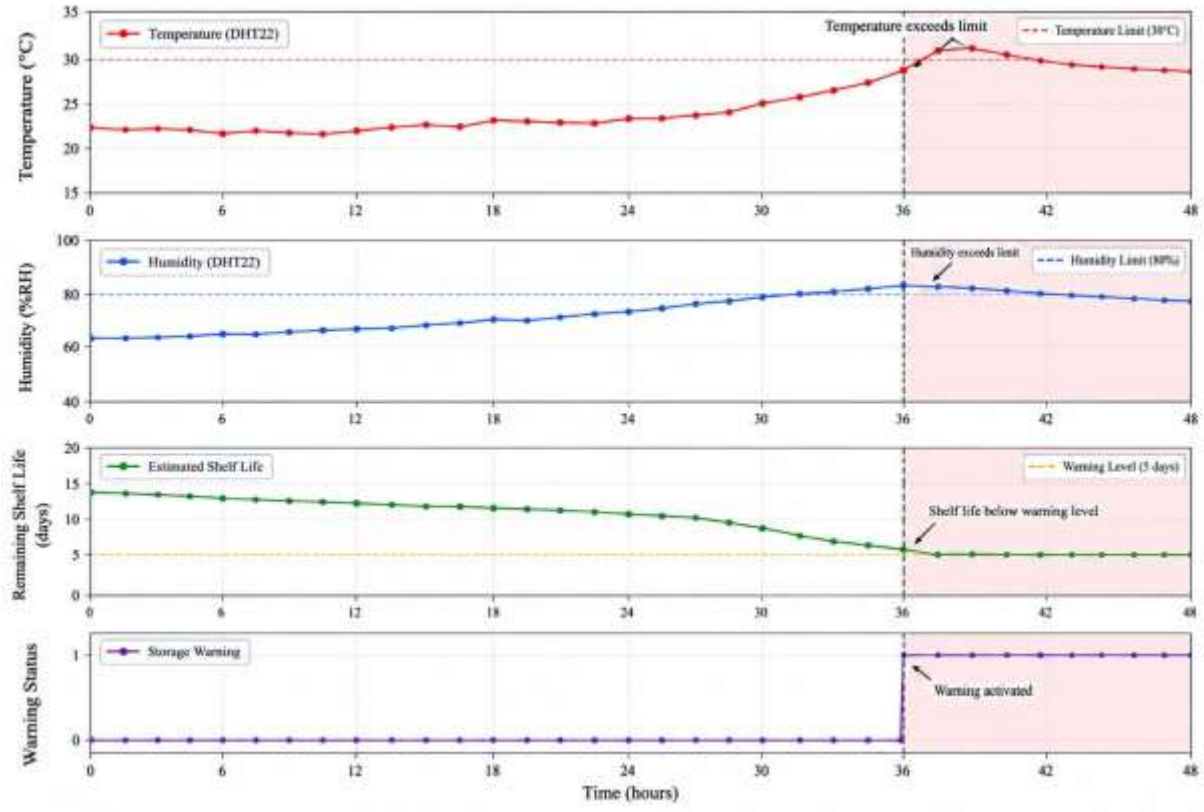


Fig. 2 Real-Time Sensor Readings and shelf -life estimation for packaged food

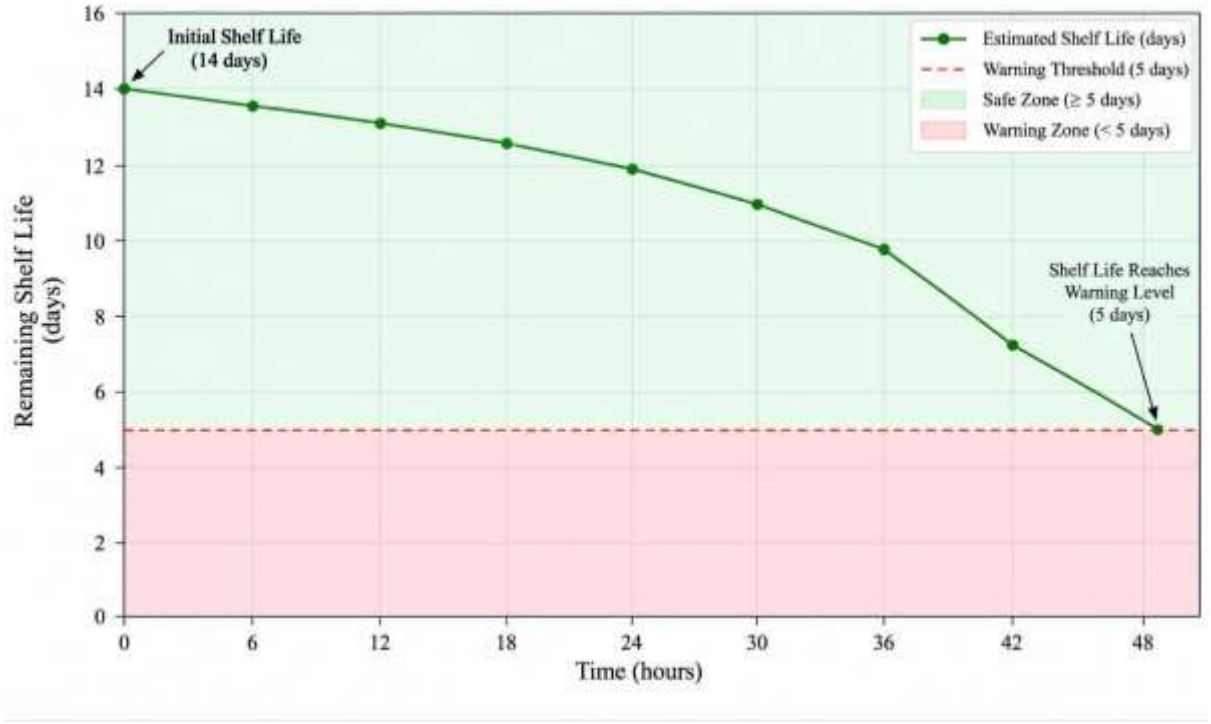
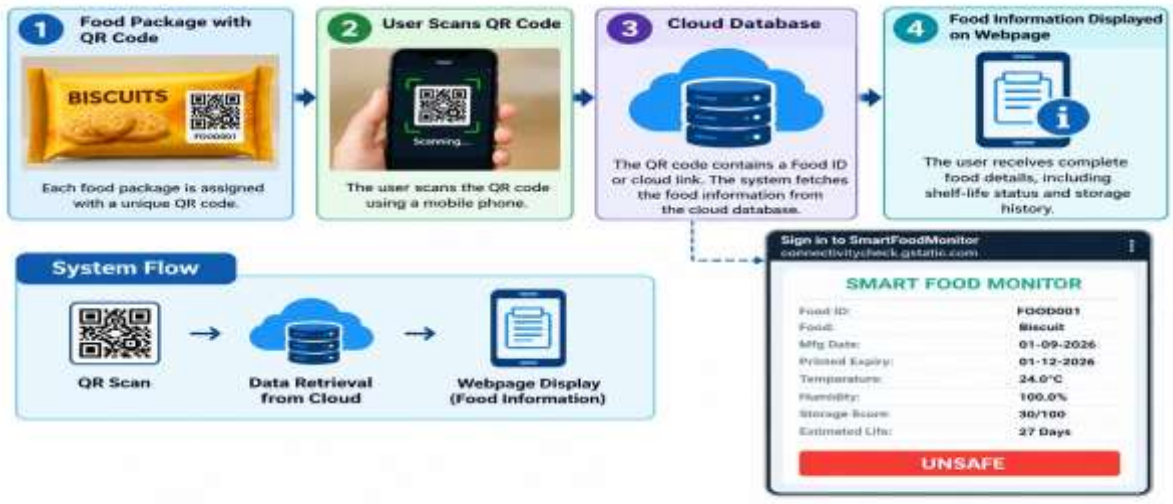


Fig. 3 Shelf -Life Estimation Graph

The graph shows how the estimated remaining shelf life of packaged food changes over a 48-hour period. It starts at 14 days. Gradually drops to 5 days by the end of the observation. The green line tracks the estimated remaining shelf life at each time point. The red dashed line marks the warning level at 5 days. The green shaded area shows the zone. When the estimated remaining shelf life stays at or above 5 days. The red shaded area shows the warning zone. When the estimated remaining shelf life goes below 5 days. In this example the estimated value hits the warning threshold at 48 hours. That means the system would trigger a warning based on the set limit. This can help users spot products that need attention and make choices about storage and eating. The graph shows how the shelf-life monitoring idea is supposed to work.. The numbers shown are just for illustration. They don't come from data. To know how well it really works we need sensor readings, shelf-life data for the specific food and testing in different storage environments. Reaching the warning threshold does not mean the food is bad or unsafe. It just means its getting close to the point where it might no longer be safe or suitable, for consumption.

Fig. 4 QR Code -Based Food Information and Shelf -Life Monitoring Using Implemented Webpage



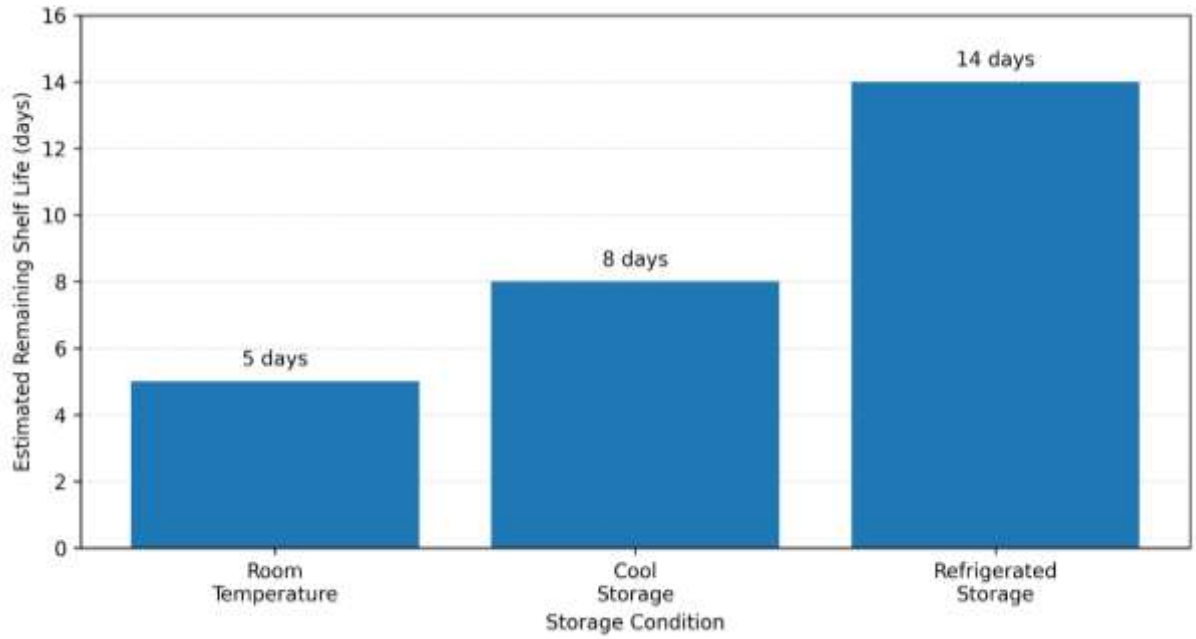


Fig. 5 Performance Comparison of Estimated Food Shelf -Life Under Different Storage Condition

CONCLUSION

The smart shelf-life prediction system for packaged foods is designed to make it easier to keep track of how long food stays fresh. It does this by using sensors that measure the temperature and humidity around the food. An ESP32 microcontroller takes the data from these sensors. Sends it over Wi-Fi to a cloud platform where it can be monitored. The system uses the information about the food. How it is stored to figure out how much time is left before the food might go bad. Users can scan a QR code to see details about the product and the estimated shelf life. The system can also send a warning if the shelf life is about to end or if the storage conditions are not good. This way people can manage their food better. Avoid throwing away food that is still safe to eat.. The system needs to be accurate and work well. That depends on how the sensors are set up the details about each type of food and the model used for predictions. More tests with food, in different storage situations are needed to check if the system works as it should.

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