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Post-harvest crop management system using IoT and AI

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ABSTRACT

With the fast pace of modern lifestyle, there is an increase in demand for perishable food (fruits and vegetables) in marts and retail groceries. The increasing demand leads to higher profit; meanwhile, large quantities and a wider variety of food items impose further challenges on the management of the food supply chains. All of these factors can lead to a significant amount of shortage of food items and a substantial retail loss. The recent development of tracing and tracking technologies, which facilitate effective monitoring of the inventory level and product quality continuously, can greatly improve the performance of the food supply chain and reduce spoilage waste. This work aims to develop a highly cost-effective system for food supply chain management system and connect our farmers with this technology through the internet. It will monitor the foods (crops) stored in the supply chain inventories using IoT and AI and provide status about their quality (state of deterioration) and estimate stock value/price based on it. We prove the existence of optimality for the design of the perishable food supply chain. We gave the single-item supply chain problem searching algorithm to produce the optimal allocation of shelf space among these items for practical implementation. Finally, we provide numerical examples to demonstrate the effectiveness of our solution.

Keywords— *Post-harvest, Perishable food, Supply chain, Demographics, Thingspeak, IoT, AI*

1. INTRODUCTION

Today, one of the main global challenges is how to ensure food security for a world growing population whilst ensuring long-term sustainable development so it's a core part of the concept of sustainable development. Because, according to the FAO, food production will need to grow by 70% to feed the world population which will reach 9 billion by 2050. This concept requires a thorough understanding of agro-ecosystem functions. Solving the persistent hunger problem is not simply a matter of developing new agricultural technologies and practices. Most poor producers cannot afford expensive technologies. They will have to find new types of solutions based on locally-available and cheap technologies combined with making the best of natural and human resources. the use of the best available technologies and inputs such as best genotypes, best agronomic management practices and best postharvest technologies to maximize yields, while at the same time minimizing or eliminating harm to the environment. Postharvest losses are caused by external such as mechanical injury (bruising, cutting, breaking, impact wounding), Parasitic Diseases (fungi, bacteria, other organisms) and internal factors such as physiological deterioration, mineral deficiency, low or high-temperature injury, or undesirable environmental conditions. Postharvest losses which average between 24 and 40% in developing countries, and between 2 and 20% in developed countries are a major source of waste. High levels of waste result in higher prices for fresh produce, and the farmer increasingly facing poverty. Therefore, this review will be focused on the postharvest physiology and management including harvesting, handling, packing, storage, transportation and hygiene of fruits and vegetables to enhance using of new postharvest biotechnology. When fruit crops are harvested from the parent plant it begins to deteriorate. Every year there are 16-36% post-harvest losses in fruit crops by mechanical, microbial and physiological losses. To reduce these losses, we follow post-harvest technology. These mainly include cooling, cleaning, sorting and monitoring the environmental conditions of the supply chains. These techniques avoid moisture loss and slow down undesirable chemical changes. Various methods and techniques are followed for processing and various value-added products are made. These products are nutritionally enriching and also helps to increase the income of the farmers. Now with advanced technologies and machines, this small scale industry has attained a very big market place. The value-added products are manufactured from these products is jam, jelly, pickle, sauce, chutney, juices and wines. We can reduce these post-harvest losses by adopting these techniques. It prevents the losses and also opens new market opportunity and generate new jobs. India is the second largest producer of fruits. Total production of fruits is 81285 thousand million tones and area 6982 thousand ha in India. Production of fruits is 2.8 per cent in the total area of India. Post-harvest losses in fruits and vegetables are very high (20-40%). About 10-15% fresh fruits and vegetables shrivel and decay results in cause lowering their market value and consumer acceptability. Minimizing these losses can increase their supply without bringing additional and under cultivation.

2. BACKGROUND

In this section, we develop the fundamental models required for the whole process regarding post-harvest crop management in supply chains and cold storages including product arrival, sales induced by the shelf space allocation decision, and the disposal of the expired goods.

2.1 Quality Deterioration

Quality degradation is a major issue for perishable food. Tracking and predicting the quality of perishable food was a challenging and costly task prior to the introduction of modern sensing technologies, such as humidity-temperature sensors. Using these technologies and quality prediction models, parties in the perishable food industry can make a more accurate prediction about the remaining shelf life or the product quality, which are the retailers' main concerns and can greatly influence the retail demand.

The quality degradation can be expressed using the following equation:

$$\frac{dq}{dt} = -kq^n \tag{1}$$

Where q is the quality of a perishable product, k is the rate of degradation, and n is the chemical order of the reaction. In Equation (1), n could be equal 0 or 1, for the facilitation of two types of different degradation models. When n = 0, the quality decays at a constant rate. When n = 1, the quality decays exponentially. This setting appears to be more realistic and hence has been used widely in research relevant to perishable food items. For this reason, our research assumes n = 1. In Equation (1), k can be expressed as:

$$k = ke^{-(Ea/RTo)} \tag{2}$$

Where k0 is a constant, Ea. is the activation energy, which can be estimated from empirical data, R is the gas constant, and T0 is the absolute temperature. According to Equations (1) and (2), the quality of perishable product at time t can be modelled by:

$$q(t) = q_{\circ}e^{-\lambda t} \tag{3}$$

Where the value of lambda ($\boldsymbol{\lambda}$) is given as

$$\lambda = \mathrm{k}e^{-(Ea/RTo)} \tag{4}$$

2.2 How it works?

Android application: A user-friendly Android application is being developed that would display all the data received from the sensors. It consists of four fields i.e. Temperature, moisture, humidity and ethylene. The ethylene content let us know about the level of food deterioration and its quality, while temperature, moisture and humidity give information about the environment of cold storage. The mobile application fetches the real-time data of the sensors from ThingSpeak API, then corresponding data in the desired format will be displayed in the specified field. Further, the details are represented graphically so that the user can visualize and monitor the environmental condition in the food supply chain.

Web Page: The functions of the web page are similar to that of an android application, but the motive is to enable the user to remotely access the data and control the environmental condition from there itself to avoid any loss also can download and view the historical data.

Analysis and prediction using AI: This module uses Python as a programming language and its libraries such as Pandas, Numpy and Matplotlib, etc. to analyse the data sent at ThingSpeak site and then uses AI to predict the future values parameters like temperature, moisture and humidity in order to avoid the further deterioration of food crops stored in cold storages also predict the stock values of the crops stored.

2.3 Quality analysis and prediction

Our research work provides the information to supply chain management system about the stored crop's quality and rate of degradation using graphical representation through various platforms and interface such as SMS (short message sent), twitter notification, android application and web page. The user(s) can view the results as well as he/she can monitor the environmental conditions of the supply chain or cold storages.

This prediction is applied using machine learning technique(s) such as regression analysis using python programming language. The model uses the previous data of stored crops like temperature, humidity, soil and moisture content as well as the degradation percentage to predict the future deterioration stage and the stock values of the stored crops.

Regression Analysis is a set of statistical processes for estimating the relationships among variables. It includes many techniques for modelling and analysing several variables when the focus is on the relationship between a dependent variable and one or more independent variables (or 'predictors'). More specifically, regression analysis helps one understand how the typical value of the dependent variable (or 'criterion variable') changes when any one of the independent variables is varied, while the other independent variables are held fixed.

3. RESULTS AND CONCLUSIONS

At the local site that is at cold storages, there are alarms in each chamber, in case if the environmental condition (temperature, humidity, moisture and gaseous content) changes they will alert the user/worker on site. Android application and web app continuously fetch data from ThingSpeak and display real-time data, in case of any deterioration of food quality, the application will send a notification to the user of this system. An educated, as well as uneducated user of this application, can easily interpret the data as it also presented in graphical form and highlighted using red, green, and yellow colour respectively to identify quality as bad, good and need to check. Analysis and prediction using AI help us to automatically control and monitor the cold storage's environment without any human intervention. Send data to the user (government, supply chain management) to identify where they need to invest more capital in order to increase the revenue and decreases the post-harvest losses. According to demographical data

analysis, the government can pass budget and crop insurance policy according to region and variety of crops stored in local cold storages and help our farmers to reduce post-harvest loss.

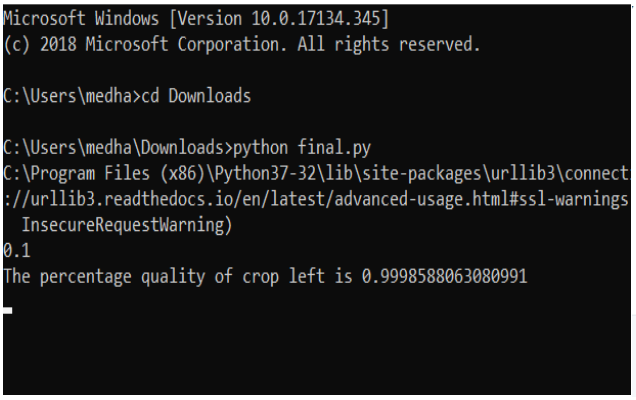

Fig. 1: Shows the stock value in supply chain

Fig. 2: Shows the notification sent to the user

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