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Intelligent waste management: Maximize profits and minimize waste using IOT and AI

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Abstract

The article presents an innovative waste Container Management System for restaurants which incorporates the IoT and AI to increase effectiveness and decrease waste. Through smart dust bins that has embedded sensors and machine learning, the system can classify and measure food waste effectively in real time. This innovation affords the restaurants precise data on the waste cycles as well as the stock control to avoid over-ordering. The success of the proposed system can be also attested through high classification accuracy of food waste and the usage of models such as MLP which reached up to 96.44%. Through these technologies, food wastage, and operational costs are reduced while at the same time ensuring sustainable practices that have a reduced impact on the environment are employed. In general, the system supports better decision-making and increased profitability in the restaurant business concerning waste management and supply chain management. This optimised approach does away with the wastage which would have reduced revenues, consequently improving the business' financial performance.

Keywords: IoT (Internet of Things); Machine Learning (ML); TensorFlow; Food Waste; Recycling; Sensors; Classification; Mobile Application; Waste management

1. Introduction

An automated garbage disposal system for restaurant food waste management combines the IoT, (Internet of Things) as well as artificial intelligence (AI) to analyse waste and decrease food waste (e.g., tomatoes, curry, rice). The revolutionary method uses sensors and machine learning algorithms to determine food waste type and amount. Uneaten veggies, rice, curries, beverages, and snacks are included. It identifies and categorises many food items to provide real-time waste statistics. Statistics gathered from the system's machine learning algorithms improve manufacturing procedures, reduce ordering too much, and improve kitchen productivity. The inductive method approach and capacitive detectors can classify food waste accurately across several types. Remote tracking takes place using GPS as well as GSM to send data [1].

Effective waste management and quick upgrades are possible. Restaurants may change their buying strategy, reduce excess inventory, and reduce waste by analysing food waste trends. As garbage processing expenses are lowered, this strategy boosts profits. As food waste is decreased and resource utilisation is raised, environmental objectives are improved. The changes made the restaurant industry more sustainable and profitable.

Food waste contributes to environmental damage and operational inefficiencies, therefore technologically keeping track and evaluating waste helps restaurants make better decisions. The solution simplifies supply chain improvement by providing real-time data on food waste. Thus, non-essential orders can be managed, improving inventory management accuracy. This data-driven technique helps reduce unnecessary ordering and detect food use and disposal

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patterns, which promotes ecologically beneficial behaviours. Lowering food waste strengthens the health of the environment through decreased landfill compelled and releases of greenhouse gases, and it boosts earnings at restaurants by cutting the costs of overspending and rubbish elimination of foods [2]. The initial step in the study procedure is to analyse the literature and analyse food waste management methods from previous studies. Finally, it describes how the IoT cameras gather data for garbage monitoring, and then proceed to artificial intelligence evaluation. The data support the finding that this technique improves logistics processes and reduces food waste.

Aim

This article presents a sophisticated food waste control system that uses the Internet of Things as well as artificial intelligence to maximise revenue and minimise waste of foods in restaurants.

Objectives

- To integrate Internet of Things detectors for wastage food analysis in real-time to track and manage foods in restaurants.
- To create the algorithms that can be used to identify as to which types and how much of the food waste is produced in restaurants.
- To execute efficient waste disposal by categorizing and analysing food trash for better recycling and disposal methods with a mobile application.
- To help restaurants adapt and practice sustainable methods within the supply chain of food manufacturing to reduce wastage and operating cost.

2. Literature review

Restaurants using smart dustbins to reduce wasteful food production is an innovative solution with the help of IoT and machine learning models. This system helps restaurants better monitor and manage food waste by combining Internet of Things devices and AI-powered analytics. The sophisticated garbage can has detectors that track both the type and quantity of rubbish thrown out [3]. The reason for this is that the garbage can collect data continuously. Following that, the data is processed by a central system, which gives restaurant management detailed waste patterns. These data points might be accessed via a web dashboard or a restaurant-specific smartphone application. Competent wastebaskets analysed consumer preferences and adjusted food preparation to substantially minimise garbage in the "Turkish quick-service restaurant (QSR)" to maximise its return on investment [5]. Intelligent garbage cans have sensors that measure waste, temperature, and environmental gases. Edge computing settings evaluate the real-time rubbish amount and content data from these containers.

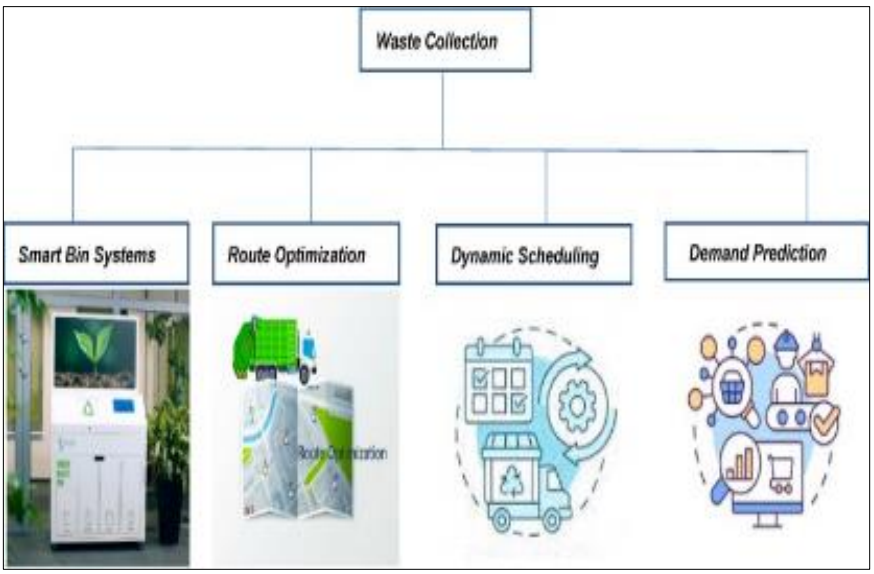

Figure 1 Waste food controlling mechanism using smart bin

The above image portrays the route optimisation and dynamic scheduling procedure to collect food waste using a smart dustbin. The IoT devices monitor garbage levels, enabling prompt collection, fuel savings, and flood prevention. The

smart dustbin automates waste monitoring, reducing human error and ensuring precise food waste analyses [7]. This requires restaurants to identify which ingredients and meals squander the most. This permits purchasing, measurement of portions, and menu planning changes. Machine learning techniques can predict waste trends and offer ways to reduce food waste by detecting data trends. Such a technique reduces food waste, lowering operating costs and promoting green practices for restaurants. The AI-driven garbage can also notify eateries about customer tastes. This data would help restaurants determine which items are least popular based on rubbish production [6]. This makes managing supplies as well as catalogue revisions more efficient, reducing overproduction. This optimises collection timetables and reduces unnecessary collections. This helps eateries increase production, save costs, and help the environment.

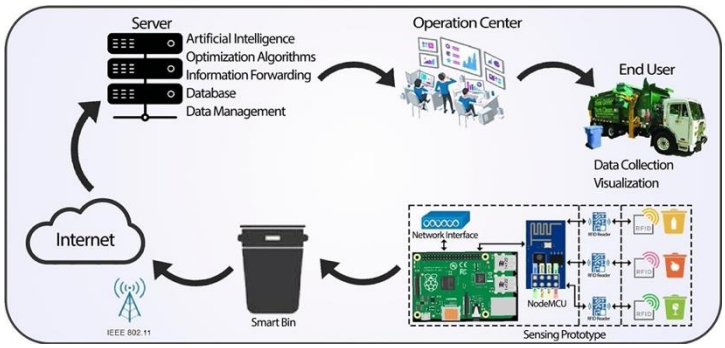

Figure 2 Smart dustbin system using IoT and AI

The illustration above demonstrates a computerised waste management method's construction. This method aims to break down more rubbish and enhance environmental sustainability. It consists of savvy receptacles with ultrasonic and gas detectors to measure rubbish and detect harmful pollutants. These sensors are good at autonomous bin lid actuation and real-time waste status reporting. Autonomous bins are linked utilising IoT to provide data to a central management system. This technology uses cloud databases to aggregate and evaluate data. This streamlines trash collection and sorting. The architecture uses machine learning algorithms to categorise rubbish and predictive modelling to produce an efficient and responsive system to handle waste.

These advanced bins help in managing waste on a real-time basis and, relay information that helps businesses manage the food preparation and purchasing strategies accordingly. With the use of sensors, smart dustbins help in measuring the amount of waste produced which is divided into raw material waste types like spoiled vegetables and over-prepared processed food waste [8]. Some of the valuable insights, which will be derived from such data include the likelihood of observing excess supplies and the best ways that restaurants can use to avoid this. For instance, smart dustbins employ optical sensors to detect the fill level of the dustbins and only call for collection when full. This eliminates all those unnecessary pickups and thus the costs that may be incurred. Moreover, IoT systems can detect through temperature and humidity sensors and control the freshness of the food’s ingredients. Thus it is stored at the right temperature and appropriate humidity thereby increasing the shelf life of food products and minimising the rate of spoilage. According to the National Restaurant Association survey, half of the restaurant operators do not even take the time to monitor food waste, something that could be solved by smart bins [9]. At the same time, such innovations contribute to more efficient usage of materials, thus illustrating the growth of durability.

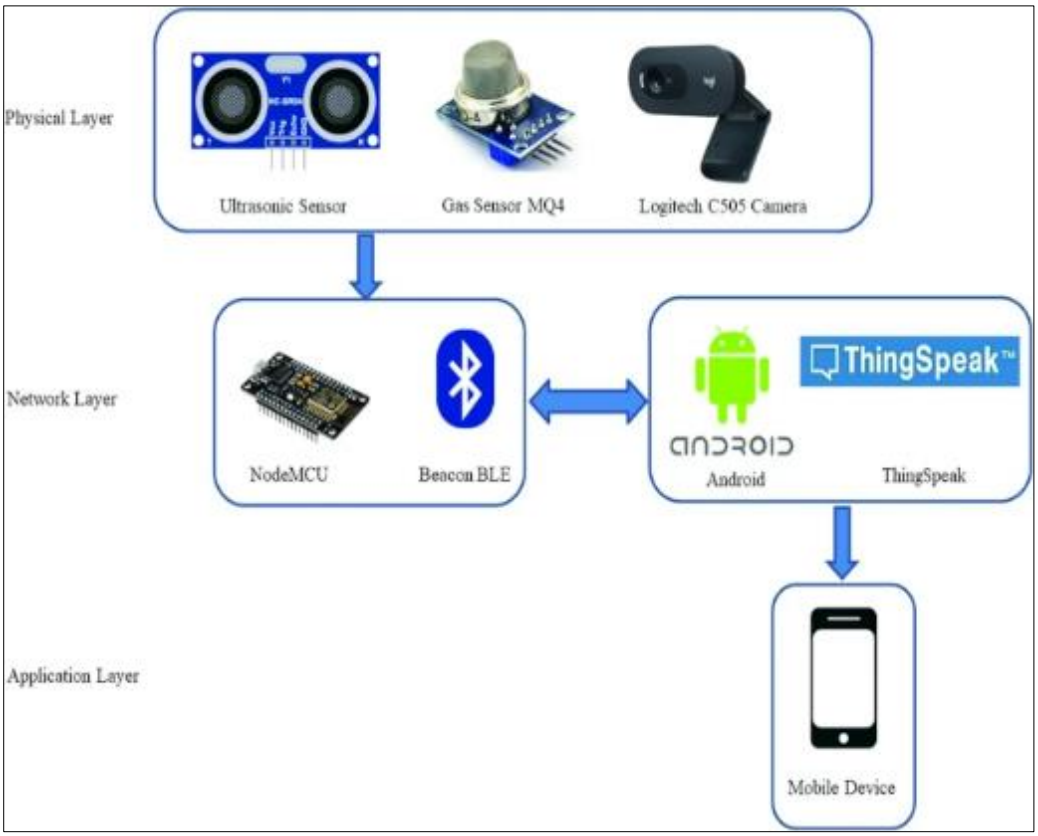

Figure 3 AIoT-based smart waste management technology

The image above shows the smart garbage can's IoT-based system architecture. The architecture has three layers: physical, network, and application. These layers underpin the system building design. Autonomous garbage bins are part of the physical layer. The actuators and sensors in these bags allow them to track and manage waste production [5]. These sensors continually assess bin filling and other relevant data. Once collected, these sensors send data over the network layer to link containers and a central server. This layer includes every interaction mechanism and network that provides data safety for execution. Data analysis and presentation use the program layer as the interface. This system's software analyses physical layer data. Thus, they give waste handling regulators information and actionable alerts. The technology's real-time waste collection handling and management improves throughput and reduces unnecessary collection trips.

Leveraging the mobile application, the restaurant staff is able to view, in real-time, information on the status of smart bins including their filling levels, battery levels and any faults [10]. Applying integrated AI, the plans for bins' disposal can be predicted, which will minimise the overflowing of bins and further timely pickup. IoT features let each bin send specific information about the type and weight of the waste thrown to the server. This analytical approach defines that due to information technology, restaurant owners are in a position to make sound decisions that would minimize wastage because they can easily determine which foods are usually wasted. The application also allows integration of billing and payment via RFID-based transactions further associating waste disposal data with the end users or their shifts [11]. This smart system also increases productivity and accuracy and at the same time minimizes food waste and helps to maintain sustainability in restaurants.

3. Data and methods of implementation

The image classification method of image data collection has been deployed with several components to create a smart dustbin to manage food wastage in restaurants. Smart weight sensors connected to the IoT structure installed in the dustbin make it possible to monitor the weight of foods being disposed of in the dustbin. The waste is weighed and images of it are also taken by an in-built camera and then transferred to a central processing unit. These datasets help the AI model categorise and reduce the loss of food. Machine learning predictive models aid in measuring data points of these images and identifying the nature of waste that is food-related.

The system applies TensorFlow Lite on Raspberry Pi for image classification [4]. The collected data including food type and weight is channelled to an analytical cloud source from which detailed reports on wastage can be obtained. Through this information, restaurants can identify their consumption pattern with regard to food waste and management to have efficient systems for avoiding total food wastage.

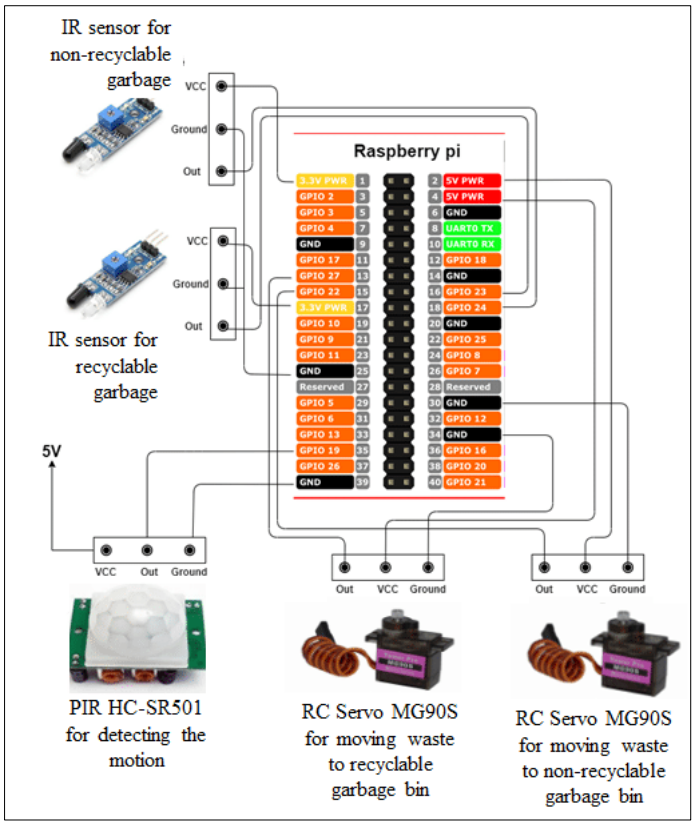

Figure 4 Circuit diagram of developing smart dustbin

A functional structure of the circuit with components of the smart bin with IoT devices and Raspberry Pi has been attached in the above figure. IoT devices, predictive models, and an iOS or Android application are used to develop an effective bin for restaurant food waste to detect and control waste from raw ingredients and prepared meals [12].

Modern technology automates rubbish recognition and tracking in the sophisticated trash bin system to offer real-time restaurant data. Weight detectors within the container allow it to independently record food waste. Every discarded item and its weight are documented. The data is instantly transferred to a computer system for analysis. The sensors' great sensitivity allows them to identify waste volume swings and track both natural rubbish like rotting vegetables and manufactured food waste from pre-preparation [13].

A camera in the smart bin increases the system's utility. This camera takes photographs of abandoned food. The processing unit receives all photographs and weight data. Image analysis utilising machine learning (ML) algorithms determines the food being eliminated. AI algorithms trained on vast datasets could have been equipped to recognise visually appealing patterns in popular food items. Employing the machine learning method to distinguish raw materials like vegetables from processing food waste, it is feasible to accurately identify discarded goods. Therefore, restaurants can distinguish between losses from over-ordering supplies and waste from having too many pre-prepared meals. A mobile analytics platform receives meal and weight data. This program, which can be accessible through a smartphone app, lets managers of restaurants monitor food waste in real time. The smartphone application and garbage database interface smoothly. React-Native has been employed to build the cross-platform smartphone app [14]. Buyers may monitor and regulate the trash bin system using the app's simple user interface. The information is extensive and covers garbage can conditions and food types thrown. The application enables users to add or delete trash from the surveillance list to tailor their garbage disposal system. By collecting large amounts of trash trend data over time, the device helps restaurants optimise the way they handle garbage [15].

Labelled images and weight data from discarded food is the first step in using SVM, Random Forest, MLP, and Naive Bayes algorithms to identify food that has been wasted. SVM classifies trash by establishing the ideal border in a multi-dimensional space. The Random Forest technique uses the dataset to create decision trees to classify garbage. MLP neural networks identify non-linear trends in food photographs. The Naive Bayes approach uses probabilistic approaches to estimate rubbish categorisation likelihood from past statistics. These algorithms are trained to leverage structured data sets and evaluated for accuracy to identify food waste across classes [16]. The machine learning system analyses the data to find patterns in food waste types and volumes. This includes monitoring raw ingredients like vegetables that may deteriorate or be oversupplied, as well as treated food waste from excessive processing. This data helps restaurants simplify their procurement procedures, reducing over orders and food preparation waste.

4. Results

The webcams as well as weight detectors of IoT devices can efficiently capture and send wasteful food data images to a central system over the internet. All this data is provided to a consolidated system to improve the real-time collection of waste and reduce food spoilage. This helps enhance waste management by properly tracking waste food volumes and types. TensorFlow Lite, based on MobileNetV2, has 85.59% performance on a major dataset. However, using a carefully selected secondary dataset for image annotation, the model obtained 71.00% accuracy. Using image augmentation on a centralised dataset raised the classification rate to 90% [4]. The Raspberry Pi can classify images and link them to PIR sensors along with servo motors to perform automated rubbish processing. It gets real-time trash can alarms and updates from its React-Native smartphone program as well as Firebase. It highlights the garbage's state, simplifies bin management, and alerts when the bins are full. Restaurant owners may benefit from this function given that it allows food waste tracking and quick ecological administration responses. This helps restaurant owners improve operations and reduce food waste [17].

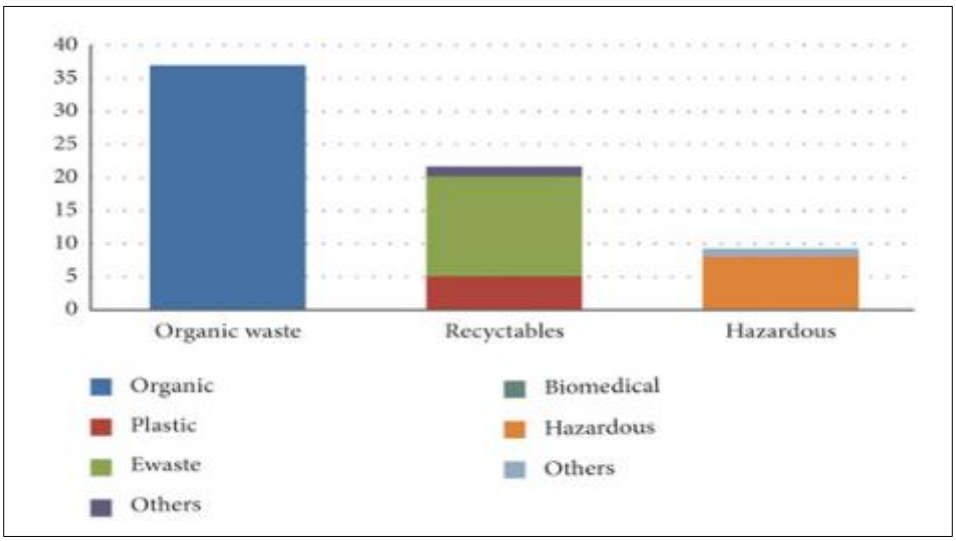

Figure 5 Different categories of waste materials

The image indicates various kinds of waste disposals after detecting those using IoT sensors and ML models. IoT sensors weigh the waste thrown and also take pictures of the waste. Such inputs are then filtered through machine learning algorithms for categorization and estimation of the nature and quantity of waste such as raw produce like spoilt vegetables and prepared food in excess of the cooking/baking process. The result is sent to an application where one can know the current status and also past performances [19]. This integrated system assists restaurants in controlling inventory and portioning to minimize wastage by using mathematical models to analyse wastage trends. The smart bins track food waste in two distinct groups using weight sensors and webcams. The primary component involves the raw substance, encompassing overproduced crops. The second type involves the treatment of food waste from over preparation. For restaurant evaluation, the data is transferred to a cloud platform. Internet of Things (IoT) weight detectors and artificial intelligence-driven waste categorisation provide exact rubbish data collection and classification [20].

Machine learning algorithms like the Random Forest Algorithm, Support Vector Machine, Multi-Layer Perceptron, and Naive Bayes categorise waste using sensory and weight data. The MLP Classifier has 96.44% accuracy, followed by the

SVM model with 89.51%. A very accurate classification approach utilised the Random Forest Classification and Naive Bayes performed more detrimental with 81.46% accuracy [18]. These models allowed the system to distinguish between food waste kinds, allowing for more targeted waste behaviour observation over time. By tracking garbage from broken raw materials and prepared meals, diners had the opportunity to understand their waste trends. This led to practical information on over-ordered or under-cooked meals, which affected the company's earnings. Due to poor inventory management, additional raw resources, especially perishable commodities like groceries and vegetables, contribute to waste. The elimination of prepared food waste from overbearing preparation revealed cooking effectiveness and portion control issues [21].

The technology gave restaurants real-time and historical data, allowing them to change their food procurement and preparation procedures. As a consequence of this, less food was wasted due to over ordering, and serving sizes improved. The computerised trashcan provided useful data that helped management improve their supply chain, reducing waste and increasing profits. The system's capacity to detect and emphasise waste, whether from basic supplies or excessive pre-preparation, provided the data needed to improve culinary processes and enable a more ecologically friendly alimentary management strategy. In the end, the automated garbage receptacle's waste classification and real-time monitoring made it very effective [22]. Restaurants reduced losses, improved operational effectiveness, and protected earnings by substantially reducing food waste.

5. Conclusion

The use of a smart dustbin system connects IoT and AI in order to improve the procedure of food waste disposal in restaurants. It uses sensors, and through the machine learning algorithms, it properly categorizes waste food thereby avoiding wastage and cutting on costs. It can be seen that real-time data and analytics enhance decision-making and help to minimize the problem of overstocking. The system is efficient in classifying waste and generating a 90% accuracy in the data augmentation procedure. This creative bin system helps restaurants streamline their supply chains and decrease food waste. IoT sensors, machine learning-based image identification, and an online application provide eateries with a complete garbage management solution. The application of smart dustbin systems based on IoT and AI helps to improve food waste management systems in restaurants. Through sophisticated sensors and AI, the system identifies the food waste, for both, the ingredients and servings. It also means that real-time data collected is accurate for monitoring and reporting to avoid over-ordering of products. MLP and SVM are proved to possess high efficiency on the categorization of wastes so that decision-making can be promoted on procurement and portion control. The systems of precedent based monitoring and alert systems used by the system makes sure that operating and other expends are cut down; the systems also promote maximum carrying out of operating sustainability activities. Therefore, this technology has not only the positive outcome for enhancing the restaurants' profitability through the consideration of the amount of wasted food but also for creating the successful food chain system.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

Additional information

The views expressed in this article are the author's own and do not necessarily represent the views of Chewy

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