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Image Processing Based Edibility Analysis of Spinach Leaves using Machine Learning Approach

Bhagavatula Aiswarya, Anushka Sharma, Rupsa Chakraborty, Malathi.G, T Raghav Kumar

Abstract* —Analyzing the edibility of food consumed by the human body is very crucial to identify the nutritional values absorbed. Lack of the right amount of nutrients can lead to various health issues like food poisoning, low immunity and nutritional diseases. Thus, identifying such problems at the stage of consumption can help in preventing several foodborne diseases and improve health. But this aspect is given little importance in our country, due to the heavy expenses involved and the infeasibility of large scale deployment of existing methods, which are mainly chemical experiments. Thus, the main goal of this work is to provide a simpler, cost-effective solution to address the given issue. Green leafy vegetables, specifically spinach plants are considered for this research as they are highly nutritious with very low longevity. Given the normal storage conditions, the shelf life of spinach leaves can be extended to a maximum of 5-7 days[1]. During the course of this research, we analyze the edibility of spinach leaves using Image Processing techniques and Machine Learning in order to provide simpler solutions that can replace the existing methods. A data-set was created to capture the deteriorating stages of the spinach leaves at regular intervals of time for ten days. Image Processing techniques were used to extract the chlorophyll and nitrogen content of the leaves. By using Machine Learning, these values were correlated with the age of the leaf. After the training process, testing was performed to identify the performance of the proposed system.

Keywords: Chlorophyll, Nitrogen, Spinach Leaves, Image Processing, Machine Learning, Multiple Linear Regression, Edibility.

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* Correspondence Author

Bhagavatula Aiswarya* School of Computing Science and Engineering, Vellore Institute of Technology, Chennai Campus

Anushka Sharma School of Computing Science and Engineering, Vellore Institute of Technology, Chennai Campus

Rupsa Chakraborty School of Computing Science and Engineering, Vellore Institute of Technology, Chennai Campus

Dr. Malathi.G, Associate Professor, School of Computing Science and Engineering, Vellore Institute of Technology, Chennai Campus

T Raghav Kumar, School of Computing Science and Engineering, Vellore Institute of Technology, Chennai Campus

I. INTRODUCTION

Food spoilage is the method main to a product becoming both undesirable and unacceptable for human consumption with associated adjustments involving amelioration in taste, smell, appearance or texture.

This complex ecological phenomenon is the consequence of the biochemical activity of microbial chemical techniques which will subsequently dominate in accordance to the prevailing ecological determinants .[2] Food borne illness, more commonly referred to as food poisoning, is the result of ingesting contaminated, spoiled, or toxic food.The health effects of eating expired food range from "none" to "severe".[3]Uncooked meats and eggs are the typical suspects when it comes to food poisoning, however any meals that have expired would possibly lead to an increase of the bacteria that can lead to illness. Food poisoning takes place when you devour unsafe bacteria that are capable to grow more effortlessly on expired foods. Foodborne illness comes from contamination, now not from the herbal manner of decay. That said, microorganism like listeria thrive in hotter temperatures, so it's vital to continually hold your perishables refrigerated at the ideal temperature. The Food and Drug Administration says your fridge need to be set no higher than 40° F [4].Often the "best if used by," "sell by," and "use by" designations are just manufacturers' best guesses about how long their food will taste its freshest. Supermarkets may additionally use the dates as a guide when stocking shelves. But the dates have little to do with how secure the food is. "Sell By" is the date set by manufacturers to inform retailers when to remove the product from shelves. The purpose is to make sure that the consumer has the product at its best quality, which can be numerous days to several weeks, depending on the item. For instance, milk, assuming proper refrigeration, ought to last five to seven days [5] past its sell-by date before turning sour. "Use By" is the ultimate date that ensures the best quality of a product. This is also not a safe date except when used on.The existing methods are either too luxurious or are not viable in terms of deployment. At present, Digital Image Processing techniques have been used to determine whether or not a plant is diseased, but the domain of edibility of plants is not much explored. Most of the existing techniques are in the testing stages[6].

Timothy Swager [7] is testing an electrically-conductive material that shows modifications in the values of the resistance of the material in the presence of gases known as amines, which are released when food starts going bad. By reading that resistance from outside a package, you can conclude whether or not the food inside is edible. Recently, the relationship [8] between microbial growth and the chemical changes occurring during food storage has been identified as a potential indicator that may be useful for keeping track of the freshness and safety.

For this purpose, interesting analytical approaches have been developed for rapid and quantitative evaluation [9] of food spoilage. These are based totally on bio-sensors, sensor arrays and spectroscopy techniques in tandem with chemo metrics [10][11]. Various tactics have been utilized to prevent the microbiological spoilage of foods and beverages, amongst which low temperature storage and heat treatment [12] seem to be the most effective. The application of a rich carbon monoxide atmosphere as part of a modified atmosphere packaging system is also effective in suppressing spoilage microorganisms [13].

With respect to our work, we analyzed the edibility of certain variants of green leafy vegetables using image processing techniques in order to provide simpler solutions for the existing methods. This technique can be further extended in the form of an application, which can be made accessible to masses so that everyone can test for the edibility of what goes into their bodies.

II. SCOPE OF PROJECT

This work intends to shed some light in the domain of edibility of food, specifically in this case green leaved variant of spinach plant over an observed period of time and how beyond a certain threshold limit the food item ceases to be fit to be consumed by people. With the exponential increase in e commerce, through which people have edibles delivered at their doorstep, it is very necessary for people to be able to assess whether or not the product is consumable, and if so then for how long. Taking a small step towards this, determining the edibility through the usage of image processing techniques, people can be aware of the quality of their food intake

III. OBJECTIVES

A cup of raw spinach contains: 7 calories, 0.86 grams (g) of protein, 30 milligrams (mg) of calcium, 0.81 g of iron, 24 mg of magnesium, 167 mg of potassium 2,813 international units (IU) of Vitamin A and 58 micrograms of folate [14]. Spinach also contains vitamin K, fiber, phosphorus, and thiamine. But the plant is known to lose its nutrients very quickly. Thus, the main objective of the project involves determining the edibility of spinach leaves once it is detached from the plant, using image processing techniques, by a measure of their nitrogen and chlorophyll content and drawing inferences accordingly.

IV. MATERIALS AND METHODS

1.1. DATA COLLECTION

For this research work to be carried out, a dataset was created from the scratch. Freshly plucked leaves were transported from an organic farm to the observation room safely. The leaves were placed in optimal temperature conditions of around 25 degrees Celsius. Also, separate observations were made by giving the leaves different environments with respect to the moisture levels provided. One leaf was placed in water, and the other was observed in normal dry conditions of the room having a temperature around 25°C. Pictures were taken of these instances in regular intervals of four hours, for a period of ten days, in the following manner:

1. Leaf is placed on a white sheet.

2. Camera should be approximately 15 cm away from the leaf while identifying the leaf whereas the camera should be as close as possible to the leaf while calculating the chlorophyll and nitrogen content(just make sure the whole leaf is visible in the image)

3. Leaf image should be taken in such a way that it should have only leaf and white paper in it.

4. There should not be any shadow in the leaf image.

The pictures for the image processing segment were captured using a 13MP, f/2.2 mobile phone camera. This helps in keeping a clear record of the degradation of the leaves. MATLAB was used to run the image segmentation and processing techniques, along with machine learning.

1.2. DATASET USED

Fig 1: Dataset of spinach leaves

This data-set basically represents a consistent change in quality and freshness of the spinach leaves. The images in fig.1 illustrate the same.

4.3 METHODOLOGY

In sample collection, firstly, an organic farm was visited to get a better understanding of the plant and its growth. Spinach is a very nutritious plant that provides numerous nutrients [14]. Leaf samples were collected from the farm, and taken for observation.

Image data-set was carefully created by capturing the leaves degradation through a span of ten days. Each picture is manually numbered according to the number of days since the detachment of the leaf. The data-set is a representation of the depletion of nutrients like chlorophyll, which is sourced by the plant stem. Once the leaf is detached, the leaf uses up its energy stored in the form of chlorophyll and eventually degrades.

The entire data-set consists of around 150 image samples of Spinach Leaves. The image is firstly read on MATLAB, and the R-G-B components are distinguished. Using these components, the picture is split into foreground and background, that is, the leaf and the white background. With the given values, the averages are computed to calculate the chlorophyll and nitrogen values. For each leaf, during the training phase, the number of days since detachment are manually added to the details. A relation between these variables is made subsequently. The model is trained using a machine learning algorithm. Multiple linear regression was made use of, which models the relationship between two or more explanatory variables and a response variable by fitting a linear equation to observed data. The chlorophyll and nitrogen values were taken to be the independent variables, based on which the number of days were predicted. Once the training module is executed, a few samples are taken to test the performance of the work. Various cases are considered, like freshly detached leaves and old leaves, and run through the algorithm, which helps in analyzing the nitrogen and chlorophyll values to predict the number of days. Based on this, a metric can be arrived at to check if the tested leaf is in a state of edibility or not.

Firstly, the chlorophyll and nitrogen content values of the spinach leaves are calculated. For this, image processing is used. The image is passed through the ‘imread’ command, which firstly distinguishes the leaf part (the object) against the white background. The image is then categorized into the R-G-B components.

Stage 1: Feature Extraction

1. The leaf is captured, it is saved as original_image
2. In order to subtract the white part from the whole image and detect the geometrical shape of the leaf it is found that value of B in RGB image should be less than 60
3. Apply the complement function to make the white portion as leaf and black portion as background
4. Fill all the small unwanted holes in the leaf

Stage2: To assess Chlorophyll Content

1. Check the B component value in RGB ,
if it is greater than 90, then it is white paper,
else
it is leaf
2. Find the leaf area in the image and make the background as black.
3. Find mean of each RGB component in the leaf image
4. Use the chlorophyll formula i.e.
choloro = G -(R/2) -(B/2)

Stage 3: To assess For Nitrogen Content

1. *Check the B component value in RGB,*
if it is greater than 90, then it is white paper,
else
it is leaf
2. Find the leaf area in the image and make the background as black
3. Find the average of each component and divide it by 255 (to get average in 0 to 1)
4. Find max and min among these average values
5. Find the HSB values using the below mentioned algorithm
if max = R average
*Hue =((G -B)/(max-min))*60*
if max = G average
*Hue = (((B-R)/(max-min))+2)*60*
if max = B average
*Hue =(((R-G)/(max-min))+4)*60*
Saturation = (max - min)/ max
Brightness = max
Nitrogen content = ((H - 60)/60 + (1 - S) + (1 - B))/3

V. RESULTS

The training phase was performed on the data-set. A few spinach leaf samples were tested against the algorithm, and were successfully predicted as shown in table 1.

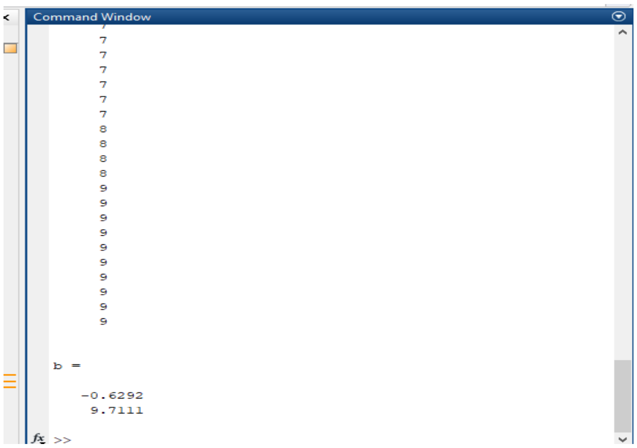
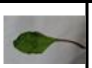


Fig 2: Regression constants

The Fig.2 represents how multiple linear regressions is performed on the data-set to train the data-set and further test it with a separate set of images. Each image in the training phase is associated with the number of days passed since detachment from the plant. The individual RGB components of the images are extracted. Computations like finding the average are performed on these components to calculate values for chlorophyll and nitrogen content.

Table1: Predicted age and nutrients for Spinach leaf.

S.No	Image	Chlorophyll	Nitrogen	Predicted no of days old	Actual number of days old
1		7.4437	0.5348	0.51	0.5
2		6.7174	0.5485	1.1	1
3		6.2737	0.5726	1.55	2
4		1.501	0.6824	5	3
5		2.3164	0.6019	4.38	4
6		2.2839	0.6107	4.49	4
7		0.6499	0.6499	5.9	6
8		0.6247	0.8141	5	7
9		0.713	0.5751	6	7
10		0.6786	0.634	6	7

The regression line treats the number of days to be a dependent variable on the two parameters, chlorophyll and nitrogen. Thus, by making a correlation between these values along with the number of days, the regression coefficients are found.

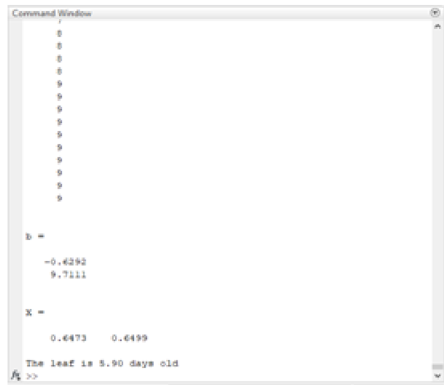


Fig 3: Chlorophyll and nitrogen content values

Fig.3 represents the chlorophyll and nitrogen values in the two columns respectively

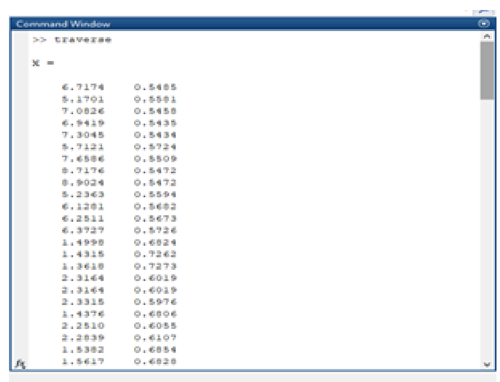


Fig4. A sample of a 6-day old leaf

In the testing phase, the values of chlorophyll and nitrogen content are determined through image processing computations. Using the regression coefficients from the trained data, the number of days are predicted for the images used in testing as given in Table1 and fig 4.

The spinach leaves captured from the time it is plucked till day 7 is given in Fig.5

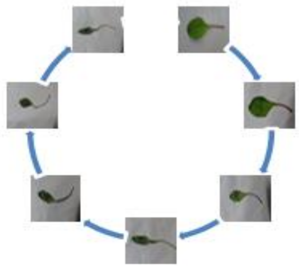


Fig.5 Spinach leaves captured from day1 to day 7

VI. CONCLUSION AND FUTURE WORK

The proposed work involves the concept of assessing nutritional values of food ,estimating the chlorophyll and nitrogen content of the spinach leaf through image processing techniques and then successfully incorporating machine learning algorithms to predict the age or the number days old the leaf is, essentially catalyzing the process of predicting the edibility of the spinach leaf. Spinach leaf being very difficult to handle in extreme weather conditions, a study as accurate as possible was made regarding its edibility as it ages. This research stresses on the need to understand the necessity of assessing nutritional values of food before consumption to ensure a healthy and disease free lifestyle. The accuracy of the work can be improved by collecting several more samples of leaves and creating a bigger dataset. Also, the object of analysis can be extended to other green leafy vegetables, and further to other forms of food like fruits and vegetables. The appropriate detection of other photosynthetic pigments beyond chlorophyll can be used to predict the freshness and nutritional quality of green leafy vegetables. This thorough analysis of the target food can further be deployed in real case scenarios. It can be deployed as a mobile application for consumers, which can guide them about the real nutritional values of food prior to their consumption, to promote a better quality of living.

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