Indian Journal of Science and Technology, *Vol 9(31), DOI: 10.17485/ijst/2016/v9i31/93838, August 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Ethylene Gas Measurement for Ripening of Fruits Using Image Processing

V. Srividhya[1], K. Sujatha[1] and R. S. Ponmagal[2]

[1]EEE/CSE Department, Center for Electronics, Automation and Industrial Research (CEAIR), Dr. M.G.R. Educational and Research Institute, Maduravoyal, Chennai – 600095, Tamil Nadu, India; sripranav2007@gmail.com, rsponmagal@gmail.com
[2]EEE Department, Meenakshi College of Engineering, Maduravoyal, Chennai – 560064, Tamil Nadu, India; drksujatha23@gmail.com

Abstract

Objective of the Work: The highlight of this research work is to discover the ethylene gas level used for ripening of fruits by detecting ethylene gas (C_2H_4 in ppm) level employing soft sensor built using image processing and Artificial Neural Networks (ANN) algorithms. **Methods/Statistical Analysis:** The proposed method relies on the color which denotes the various stages in ripening and in turn indicates the amount of ethylene gas required. The changes in color, texture, intensity variation, mean, variance and standard deviation extracted from the images are the features which enable the personnel to determine the amount of ethylene gas. The Feed Forward Neural Network (FFNN) is used for ethylene gas estimation. This is made possible using Back Propagation Algorithm (BPA) for training the FFNN. As a part of image processing the intensity values in color images and its variation are tracked by dithering which is used as a unique feature input to train the FFNN. **Major Findings:** The novelty of the proposed method depends on the FFNN estimating the ethylene gas needed for ripening process in a feed forward fashion thereby providing the precision and recall values spontaneously for every instance. **Application/Improvements:** Earlier a circuit with capacitance model is used to generate ethylene gas for this purpose. Nearly 51 images are considered for training and testing respectively. Testing and confirmation result shows the required precision and recall level are in range of 80 to 89% and 100% respectively.

Keywords: Back Propagation Algorithm, Ethylene Gas, Feed Forward Neural Network Feature Extraction, Image Processing

1. Introduction

The fruits liberate ethylene gas augmented with respiration rate[1] during the process of ripening. It is difficult to handle the ripe fruits as they are squashy and flimsy and they usually cannot endure the rigors during transport. Hence, these fruits are harvested in a fully mature state which is hard and green. Little quantity of ethylene stimulates the ripening process near consumption zones in a controlled environment of temperature and humidity. They include mango, guava, fig, apricot, banana, kiwi, apple, plum, pear and passion fruit[1]. The other categories of fruits are non-climacteric fruits. They are harvested only when they are completely ripened. They do not react to ethylene treatment as they emit a tiny amount of ethylene. They include orange, grapes, litchi, watermelon, blackberry etc[3].

2. A Survey on Existing Methods in Practice for Ripening of Fruits

There is no quicker and simple methods for uniform ripening of fruits available in the fruit industry which causes a major setback. The existing methods of ripening have their own pros and cons. There are numerous straightforward technologies are available nowadays for

**Author for correspondence*

accurate ripening. The duration for ripening differs for different fruits under customary climatic conditions so as to make it edible. They include

1. Mango ripening in an air tight rice container. This is a natural process of ripening but not applicable on large scale.
2. Smoking inside smoke chambers using acetylene gas
3. The ripening means includes sheet of paddy husk or wheat straw.
4. The unripe fruits but attained full growth are dipped in 0.1 per cent ethrel solution[13] and wiped dry and distributed over a newspaper or clean cloth without touching each other
5. In an air tight room, a vessel containing five liters of water is mixed with 10 ml of ethrel and 2 gm of sodium hydroxide pills[13] and placed near the fruits which acts as ripening chamber.
6. Fruit ripening using calcium carbide

The artificial ripening agent includes the water dissolved calcium carbide which emits acetylene. When the fruits ripened with the above artificial ripening agent are consumed it affects the entire nervous system of a human as it reduces the oxygen supply to brain. Hence Prevention of Food Adulteration (PoFA) has forced harsh rules to abandon it. Similarly fruit ripening using Arsenic and phosphorus are poisonous and revelation may cause rigorous health vulnerabilities. Hence from this survey it is identified that ethylene gas of exact concentration under controlled temperature and pressure can be used for ripening process which is considered as a safe process.

3. Ripening Process Using Ethylene Gas

The natural hormone Ethylene does not induce any side effects to the human community when consumed in large quantities over long periods[1]. This de-colouring hormone is capable of converting the green coloured chlorophyll in the fruits to yellow colour which indicates the carotene under optimal ripening conditions[2]. The optimal conditions are listed in Table 1.

The exposure to ethylene depends on price, expediency and security factors. It is safer to use diluted ethylene gas mixture rather than using concentrated ethylene. Pure ethylene is explosive and flammable in nature at 3% concentration[3]. An airtight room kept at a constant temperature is used to place the fruits to be ripened. Optimal ripening temperatures for a variety of fruits are given in Table 2.

Table 1. Optimal Ripening Conditions

Sl. No.	Physical Parameters	Optimal Range
1.	Temperature	18 °C to 25°C
2.	Relative humidity	90 to 95%
3.	Ethylene concentration	10 to 100 ppm
4.	Period of handling	depends on fruit type and stage of maturity - 24 to 74 hours
5.	Air flow	adequate to guarantee circulation of ethylene
6.	Aeration	Adequate air exchange is necessary in order to avoid accumulation of O_2 which diminishes the result of C_2H_4.

Table 2. Optimal ripening temperatures for a variety of fruits

Sl. No.	Name of the Fruit	Ethylene Concentration (ppm)	Ethylene exposure time (hrs)	Ripening temperature °C	Storage Temperature °C
1.	Avocado	10-100	12-48	15-18	4.4-13
2.	Banana	100-150	24	15-18	13-14
3.	Honey dew melon	100-150	18-24	20-25	7-10
4.	Kiwifruit	10-100	12-24	0-20	0.5-0
5.	Mango	100-150	12-24	20-22	13-14
6.	Orange degreening	1-10	24-72	20-22	5-9
7.	Stone fruit	10-100	12-72	13-25	-0.5-0

Fruits are exposed to ethylene in two ways. In trickle method, ethylene gas is dripped into room for the whole day to uphold a concentration of 10 ul per litre. Room is ventilated after that day to avoid 1% concentration of excess CO_2, since it would impede ripening. Fruits are packed in aerated bags which are facilitated by forced air circulation at controlled temperature when they are placed in a room that is poorly sealed. To ensure a uniform continuous flow of ethylene through the room, a small fan could be used. This type of forced-air ripening method affords further uniform temperature and ethylene concentration all through the ripening room.

There is another safer method of ripening. Instead of using pure ethylene, ethylene produced by passing ethanol over a bed of activated alumina could be used for ripening. Care should be taken to ventilate the ripening rooms daily so as to ensure that Carbon Dioxide (CO_2) levels do not exceed 1%.

4. Challenges in Ripening Process

Ethylene gas is introduced into ripening rooms from high-pressure cylinders via flow-meters or by ethylene generators, which convert alcohol into ethylene via a heated metal catalyst. Controlling the ripening rate effectively for ripening the fruits so as to meet the consumer demands is a complex task, which requires considerable experience.

The various factors such as initial fruit maturity, temperature, relative humidity, air flow, as well as ethylene and carbon dioxide concentrations within the ripening room may all affect the rate of ripening. Carbon dioxide, a by-product of ripening; process on excess levels (>5%) will rotten the fruits and vegetables. Hence an effective method for measurement of the ethylene gas as well as carbon dioxide from the color of the fruits is proposed.

5. Proposed Method for Fruit Ripening Process

The ripening is a process dependent on step by step color change of the fruit, initially from green to yellow color stands as a base for this work. Color image processing finds application in this area to measure the ethylene and CO_2 gas levels with respect to the color of the fruit[4,5].

The video of the fruits image is acquired using the infra red camera. The video is converted into frames using video splitter and these frames are further analyzed. The features are extracted from the images captured and these features are used for C_2H_4 and CO_2 gases estimation as discussed earlier[6]. The major steps involved in the proposed ripening quality monitoring system as depicted in Figure 1 includes the following:

1. Camera as an image sensor with servo motor mechanism
2. Vigilant monitoring set up is placed in the control room
3. Video Transfer Device (VTD) for transferring the video from the CRT monitor on to the PC
4. Image processing packages are loaded in the laptop using VTD
5. Frame grabber for segregating the video file into frames
6. Image processing algorithms for analyzing the constituents of the images.
7. Intelligent control strategy to monitor and estimate the ripening process
8. The validation of the developed algorithms.

6. Objective of the Proposed Method

The primary objective of this work is to develop a fruit ripening quality monitoring system using fruit image analysis by colour image processing in the container. According to the brightness value of the image pixels, the ripening characteristic parameters are picked up from the images. The online monitoring of ripening quality, C_2H_4 and CO_2 gas estimation using intelligent image processing technique thereby offers dynamic adjustment of C_2H_4 flow rate so as to ensure effectual ripening process.

Figure 1. Schematic diagram of the proposed fruit ripening monitoring system

7. Results and Discussion

The results for a variety of expected and intellect maneuver for systematic review of fruit ripening process is discussed opulently in this chapter. The images are subjected to preliminary processing to ensure that it should be clatter free and the preferred images are only used for examination and monitoring purposes alone. The schematic for the planned concept is shown in Figure 2.

The fruit pictures are captured by the infra red camera placed at the top corner of the room with a servomotor machinery for changing the direction of the camera. The infra red camera is of Sony make. The record acquired is converted to frames using video splitter software. The images acquired are preprocessed, analyzed before characteristic mining and classification. The collected data is recorded in Table 3.

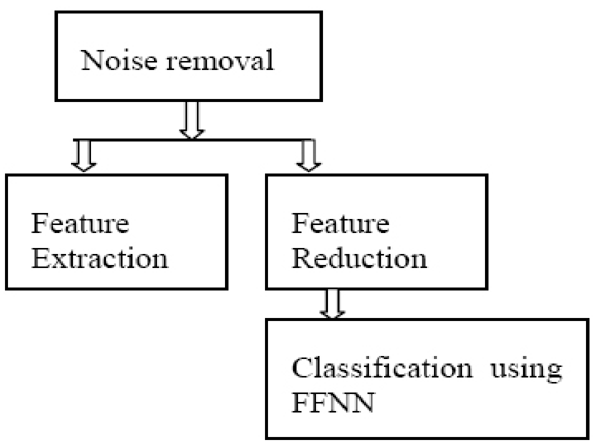


Figure 2. Approach and evaluation for ripening method using image processing

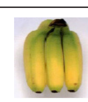
The preprocessing includes fickle filtering and border revealing[7,8]. The filtering removes clatter so that the clatter free image can be used for further examination and the edge revealing is carried out to extract the region of interest which in turn determines the features to be extracted.

Image rough calculation is done to trim down the number of colors in an image[9,10]. As a result the image might look inferior, since some of the colors are lost. Hence, Fickle is executed to increase the apparent number of colors in the output image. This also helps to change the colors of the pixels in a region and hence the standard color in each region approximates the original RGB color as depicted in Figure 3.

The histogram in Figure 4 denotes the plot between the pixel strength and their rate of occurrence. Throughout the early stages (from 1 to 3 stages denoted as class: 1. of ripening, the pixel strength values lie between a minimum intensity of 100 to a maximum of 175 which states that the fruit is entirely green in colour (Figure 4(a) to (c)). For the stages 4 and 5 (denoted as category, 2. the maximum and minimum strength range is 175-225 (Figure 4(d) to (e)). These stages are partially green and yellowish. For the remaining 2 stages (denoted as class, and 3. which is entirely yellowish; the strength values range from 175-255 which is clear from Figure 4(f) to (h). This histogram analysis is done to verify that the colour variation facilitates the dimension and control of the ethylene gas supply which is used as the ripening agent.

The various features like mean, standard deviation, mode and variance are extracted from the images are indicated in Table 4. The features represent the basic pattern that gets repeated in various directions to form an image. Hence by extracting the choosy features the ripening state

Table 3. Ripening parameters corresponding to different stages of Banana fruit

Ripening parameters	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7
Imagery of Banana fruit							
Ethylene concentration (ppm)	140-150	130-140	120-130	115-120	110-115	110-100	100 -10
Ethylene coverage time (hrs)	24	24	24	12	12	6	6
Ripening temp. oC	15-15.25	15.25-15.5	15.5-16.25	16.25-16.5	16.5-17.25	17.25-17.5	17.5-18

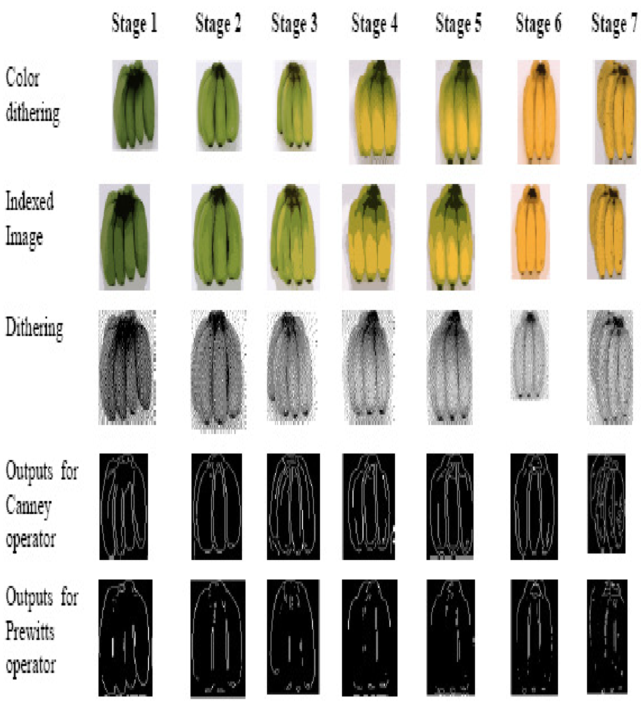
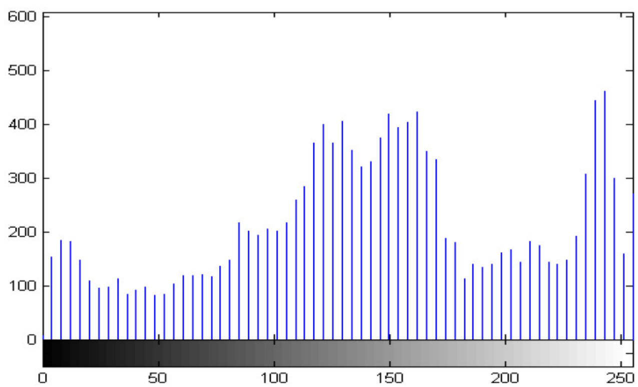
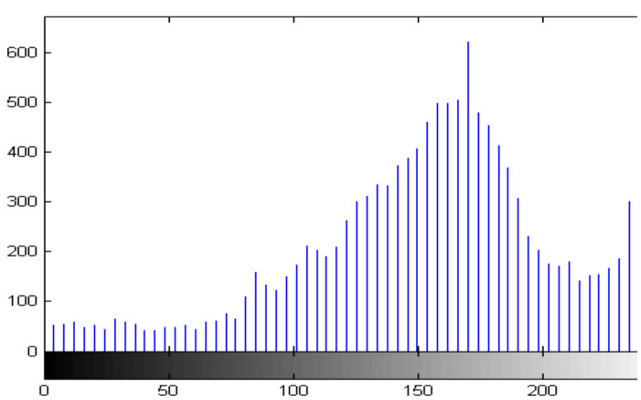


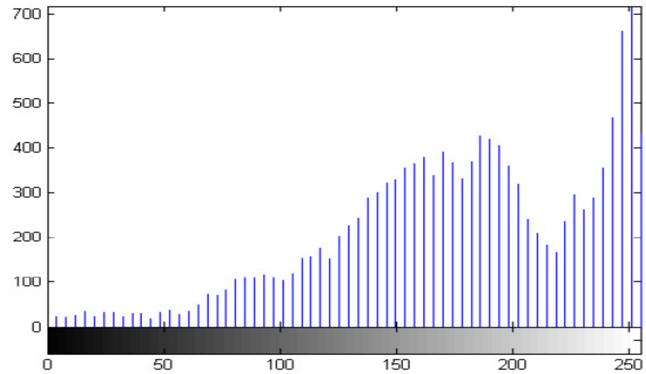
Figure 3. Outcomes of Dithering and Filtering



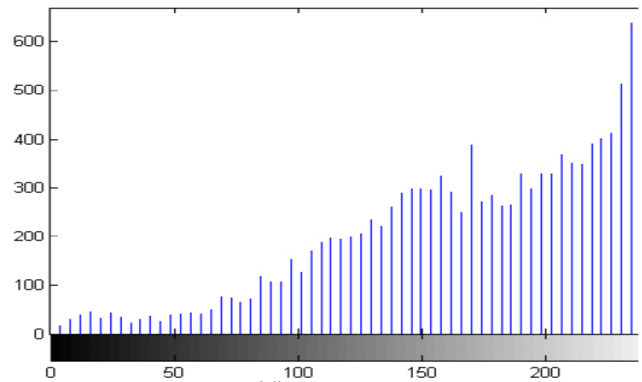
(a). Stage 1



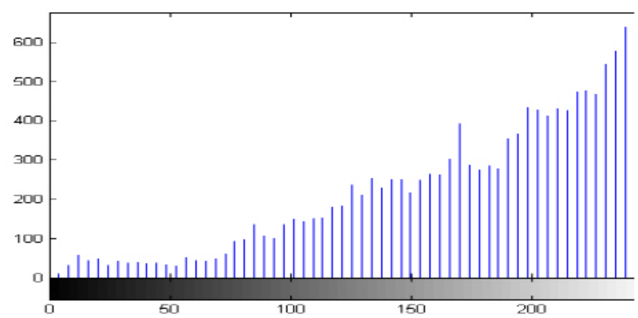
(b). Stage 2



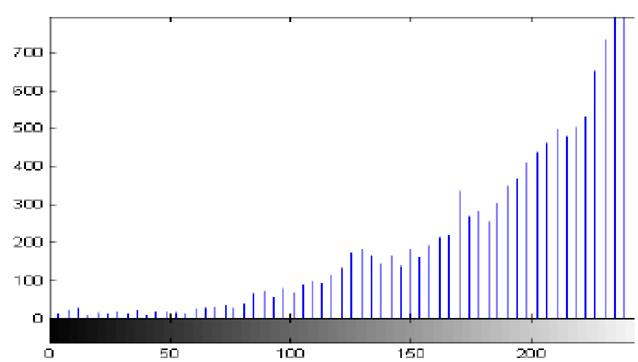
(c). Stage 3



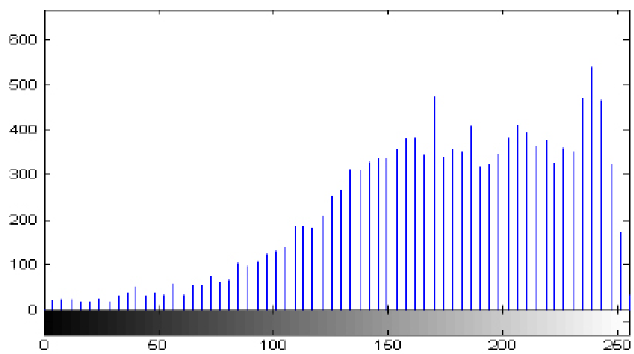
(d). Stage 4



(e). Stage 5



(f). Stage 6



(g). Stage 7

Figure 4. Histogram for ripening process

Table 4. Feature Extraction

Sl. No	Mean	StdDev	Mode	Median
1.	110.541	68.044	255	91
2.	140.89	59.907	244	125
3.	174.705	56.475	246	170
4.	187.24	55.931	255	206
5.	181.119	57.356	218	199
6.	231.265	35.707	246	245
7.	196.985	38.898	221	203

as well the amount of ethylene gas inside the ripening hall can be measured.

The évaluation was done using Feed Forward (FF) architecture of trained with Back Propagation Algorithm (BPA). To perform simple arithmetical operations, FF Neural Network (NN) is built by exceedingly interconnected processing units (nodes or neurons). The inherent characteristics of neural networks such as topologies (number of unknown layers and connection between nodes in the unknown layers), power vectors and activation function such as sigmoid, hyperbolic tangent and sine which are used in the unknown layers and output layer are used.

A perception or ADAptive Linear Element (ADALINE) refers to a computing unit which forms the fundamental building block for neural networks. The input to a perception is the summation of input pattern vectors by weight vectors. Information flows in a feed forward manner from input layer to the output layer through unknown layers. The number of nodes in the input layer and output layer is fixed. In this work, a neural network model with seven input variables and one output variable is constructed. In this proposed work, the network parameters such as the number of nodes in the unknown layers and the number of hidden layers are found by trial and error method. In most of the applications one unknown layer is adequate. As the name implies BPA the weight updation takes place in the undo order i.e. from the output layer to input layer[11,12].

FFNN structure trained with BPA is used to identify the évaluation of ethylene gas for ripening process so as to prevent the fruits from rottening during the process of de-greening. Emission of CO_2 is likely to rotten the ripenend fruits. The features obtained from the images are given as the inputs to the FFNN. Table 5 contains the values for various features extracted. The target is the value of the C_2H_4 gas concentration. The normalized values of the features are used for obtaining results from the various intellectual classifiers. For normalization each value of the feature divided by the maximum value of that feature is used as the formula so as shrink the computational difficulty. The inputs for FFNN trained with BPA require 4 features as given in Table 5. A set of ultimate weights are obtained by training with required target value (C_2H_4 gas concentration). Testing the proposed algorithm to infer the ripening state and C_2H_4 gas concentration from the fruit image is done with ultimate weights obtained after training to achieve feed forward control C_2H_4 gas concentration. The outputs of the FFNN trained with BPA are shown in Figure 5. Similarly the FFNN was trained and tested as discussed above. The Table 5 shows the network parameters with values prescribed for the objective function.

Confirmation of FFNN with four features as input and one output is done. Table 5 given below shows the data relating to the fruit images together at some other period of time. The results in Table 6 support that intel-

Table 5. Network Parameters for training the ANN

Sl. No	Network Parameters	Values
1.	No. of nodes in the input layer	4
2.	No. of nodes in the hidden layer	3
3.	No. of nodes in the output layer	1
4.	No. of patterns for training	51
5.	No. of patterns for testing	51
6.	Mean Squared Error	0.0198
7.	Activation function	sigmoid
8.	Network Architecture	Feed Forward
9.	Algorithm used	BPA

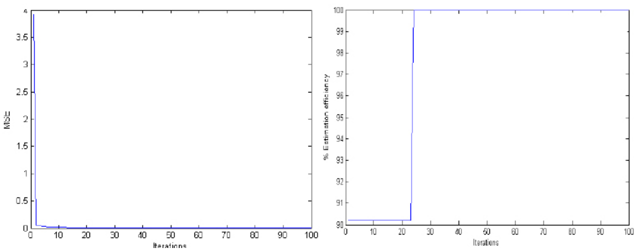


Figure 5. Functioning results for Feed Forward Architecture trained with BPA

Table 6. Comparison of performance criteria for testing and validation

Comparison Testing/ confirmation	Class 1		Class 2		Class 3	
	Recall	Precision	Precision	Recall	Precision	Recall
Testing results	1	1	0.894	1	0.85	1
Confirmation results	1	1	0.8358	1	0.8	1

lectual evaluation is beneficial for fruit ripening worth monitoring. The training and testing results are very close to the confirmation results. The accuracy and recall for all the three classes are shown in Table 6.

8. Conclusion

The ultimate outcome of this work indicates that nearly 100 samples were gathered from the ripening area. The images are reprocessed and characteristics are extracted. Training of FFNN using BPA is done with 51 images. Testing and confirmation of the results shown in Table 6 indicate that highest categorization is achieved. Categorization performance can be enhanced by further reprocessing the acquired images. Depending on the worth of ripening; corresponding to the colour of the fruit images, essential action is taken to raise or shrink the C_2H_4 gas supply so as to ensure whole effectual ripening process. The estimated parameters can be presented in the control centre and hence it offers a cost effective solution. To wind up with, there is a further range to extend the work by considering the pixel intensities in R, G and B plane for classification.

7. References

1. Nelson SO, Bartley JPG. Frequency and temperature dependence of the dielectric properties of food materials. Transactions of the American Society of Agricultural Engineers. 2002; 45(4):1223–1227.
2. Nelson SO, Wen-chuan G, Samir T, Stanley JK. Dielectric spectroscopy of watermelons for quality sensing. Measurements Science and Technology. 2007; 18:1887–1892.
3. Nelson SO, Wen-chuan G, Samir T, Stanley JK. Investigation of dielectric sensing for fruit quality determination. IEEE Sensors Applications Symposium. 2008 February; 12-14.
4. Ragni L, Gradari P, Berardinelli A, Giunchi A, Guarnieri A. Predicting quality parameters of shell eggs using a simple technique based on the dielectric properties. Biosystems Engineering. 2006; 94(2):255–262.
5. Salvador A, Sanz T, Fiszman SM. Changes in color and texture and their relationship with eating quality during storage of two different dessert bananas. Postharvest Biology and Technology. 2007; 43:319–325.
6. Sirikulrat K, Sirikulat N. Dielectric properties of different maturity soybean. King Mongkut's Institute Technology Ladkrarang Science and Technology Journal. 2008; 8(2):12-18.
7. Sujatha K, Pappa N. Combustion Quality Monitoring in PS Boilers Using Discriminant RBF. Instrumentation, Systems and Automation Society Transactions. 2011; 2(7):2623-2631.
8. Sujatha K. Soft sensor for temperature measurement in gas turbine. International Journal of Applied Engineering and Research. 2014; 9(23):21305-21316.
9. Sujatha K, Pappa N, Senthil K. Kumar, Siddharth Nambi U. Monitoring Power Station Boilers Using ANN and Image Processing. Advanced Materials Research. 2013; 631-632:1154-1159.
10. Sujatha K, Kumaresan M, Ponmagal RS, Vidhushini P. Vision based Automation for Flame image Analysis in Power Station Boilers. Australian Journal of Basic and Applied Sciences. 2015; 9(2):40-45.
11. Sujatha K, Pappa N, Raja Dinakaran CR. Intelligent Parallel Networks for Combustion Quality Monitoring in Power Station Boilers. Advanced Materials Research. 2013; 699:893-899.
12. Sujatha K, Bhavani NPG, Godhavari T, Ponmagal RS, Su-Qun Cao. Smart Sensor for NO_x and SO_2 Emissions in Power Station Boilers. Indian Journal of Science and Technology. 2015; 8(27).
13. www.agritech.tnau.ac.in