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Monitoring Fermentation of Black Tea with Image Processing Techniques

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ABSTRACT

The possibility to use digital images of tea particles as a tool to monitor fermentation of black tea processing is studied in this project. Copper green color is the predicted color used to measure the degree of fermentation; therefore, determining the fermentation level by observing the copper green using naked eye is error prone and affects the complete product outcome. Tea particles of a certain batch after rolling step are categorized in to three difrent groups as dhool 1-3 based upon paricle size.Therefore, the duration of fermentation is varied by dhool number of a given batch due to varied sizes of tea particles. The method used in this project is divided into three main phases, image pre-processing, identification of the dhool number, and prediction of the fermentation level. Image processing techniques are used to extract features of tea leaves and Support Vector Machine (SVM) is used as the classifier to train the system and obtain accuracy in each stage. The results indicate higher accuracy in predicting the dhool 1 which is over 77% accurate while dhools 2 and 3 indicated accuracy levels of 69% and 73% respectively. The fermentation time can be predicted with average accuracy of 94% for dhool 1 and 92% and 91% for dhools 2 and 3 respectively. Therefore, results indicate that image processing techniques can be used to develop a methodology for quality control processing of black tea.
Keywords: Fermentation, Image processing, SVM

1. INTRODUCTION

Tea cultivation plays a major role in the country's economy as it is the leading agricultural crop in export market. In 2014 Sri Lanka earned about Rs. 210.2 billion from tea export and ranked number two among global tea exporters surpassing China. [1] Ceylon Tea is renowned for its high quality, aroma, and taste. Therefore, producing and maintaining quality of the tea produced is a necessity to remain in top ranking among tea exporters.

1.1 Tea Manufacturing Process

Black tea is the only tea that is fully oxidized. The manufacturing process of black tea may differ from country to country and even region to region. But there are always four basic stages involved in the production of black tea, namely Withering, Rolling, Fermentation, and Firing. [2] The taste and aroma of black tea are achieved during the fermentation step. The oxidation of polyphenolic compounds in tea leaves to theaflavins and thearubigins results in color changes and flavor enhancement.[3] In the fermentation process particles of tea leaves are spread out in thin layers under cool, humid air and left to oxidize for 50 – 80 minutes. The factory maintains humidity inside at a constant value and temperature differences are also taken into account when deciding the duration of fermentation.

"Fermentation process" plays a vital role in assuring the quality and the flavor of black tea. The method practiced in most of the tea factories to find the time for the termination point of fermentation is by using the naked eye of an experienced worker. The sign for the termination point will be the copper brown color of tea leaves. However, the color detection will vary by each person. Consequently, tea leaves may be sometimes kept for over fermentation or less. Another method is to check by touching the tea leaves and smelling it, which may not be hygienic. A computational method is proposed in this project to detect the level of the fermentation process. Currently available computer assisted methods use electronic nose [4] or image processing methods.[5,6] The proposed method is based on image processing techniques using MATLAB software.The software is used to monitor statistical feature changes of images taken during fermentation. Support Vector Machine (SVM) is used to train the system and obtain accuracy in each stage which is a different approach compared to literature reported methods.

2. METHODOLOGY

A factory manufactures several batches of tea per day. Tea particles after rolling step are loaded to rotorvane to separate smaller tea particles from larger pieces. The first set of smaller tea particles is called the 'first dhool" and directly left for fermentation. Then larger particles undergo rolling step again and loaded back to rotarvane to separate. The second set of smaller particles is called the "second dhool" and the tea particles from a third repeat of this cycle are called the "third dhool". This process is illustrated in Figure 1 below. Since fermentation is already initiated when the first dhool is separated, time duration of fermentation is in the decreasing order from the first dhool to the third dhool. Furthermore, the particle size is also decreased from the first dhool to the third dhool.

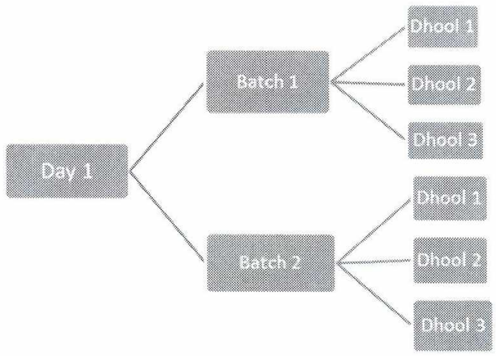

Figure 1: Hierarchy of tea processing

The main objective of this project is to propose a computational method to find the time left over for fermentation, independent from human intervention. The proposed system will require only an image of tea particles and the output of the computational model should identify the dhool number and the time spent on fermentation. Therefore, the methodology consists of three main steps; image preprocessing, identification of the dhool number and calculation of the fermentation time.

2.1 Image Pre-Processing

Images collected during tea fermentation process were the initial input to start up the process. Images are collected using Canon -650D model with 18 megapixels camera. The manual mode of the camera was used where ISO value 400, shutter speed 1/250 Sec, and focal length of 36 mm were set. White balance was set manually. A light box is used to capture images in order to maintain a controlled environment.

The captured image samples of tea contained with irrelevant area. In order to further analyze the image, the region needed for analyzing was extracted from the original image samples. Then it was resized to1024 x 1024 pixel size in order to lower the processing time. MATLAB software was used in this project for image processing. The image captured may include shadow areas. In order to remove shadow regions, a threshold value was set to 0.11 (white 1, black 0) based on trial and error. This step enhanced the image quality significantly. The enhanced image consists of three separate matrices for red, green, and blue. These matrices were used in further calculations.

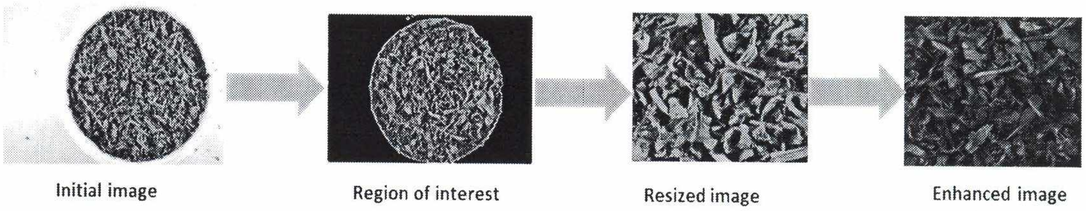

Figure 2: Steps in image preprocessing

2.2 Identification of the Dhool Number and the Fermentation Time

The fermentation time for tea particles vary significantly based on the dhool number. The longest fermentation time is for the first dhool and the lowest time is for the third dhool. Therefore, it is important to identify the dhool number of a given image prior calculation of the fermentation time. In order to predict the dhool number, it is necessary to extract quantifiable features from a given image. Feature extraction is a method of capturing visual contents of an image for indexing and retrieval purposes. The feature is defined as a function of one or more measurements, each of which specifies some quantifiable property of an object, and is computed such that it quantifies some significant characteristics of the object. [7] In this project, Entropy, Standard deviation, Mean, Variance, Skewness and Kurtosis are calculated for the green matrix of sample images.[7] This will provide necessary information to identify features that can be used to identify dhool number and fermentation time using a Support Vector Machine (SVM) classifier.[8]

3. RESULTS AND DISCUSSION

The first step was to find the variation of Red, Green, and Blue colors as a function of fermentation time. Color variations are analyzed for each dhool separately. The plot of change in the mean value of RGB for dhool 1 is illustrated in Figure 3 below. According to results, the green color line shows a decrease as expected, because the initial green color of tea leaves turns copper brown during fermentation. Furthermore, results obtained for the trends in RGB are in agreement with literature.[6] Since, green color line shows comparatively higher deviation, green matrix was used at the next steps of finding the dhool number and fermentation time.

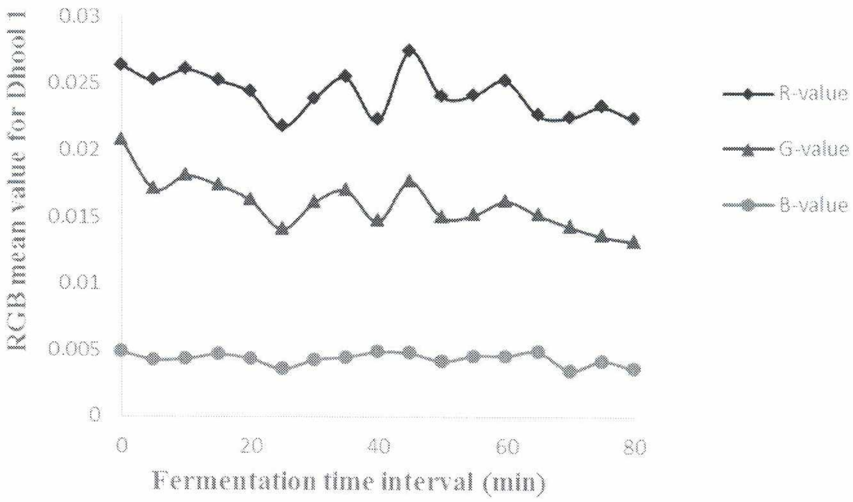

Figure 3: Time Vs. RGB mean values for Dhool 1

3.1 Feature Analysis of Different Dhools of Tea Particles

In order to predict the dhool number it is important to identify the features of a given image showing significant deviations based on the dhool number. Therefore, Entropy, Standard Deviation, Mean, Variance, Skewness and Kurtosis are calculated for the green matrix of sample images. The Figure 4 shows comparison of above features with respect to dhool number. According to results, standard deviation, entropy, and variance indicate higher deviation for dhool 1 compared to dhool 2 and 3. However, mean, skewness, and kurtosis do not show significant variations between dhool numbers. Therefore, values of standard deviation, entropy, and variance are chosen to predict dhool number using the SVM classifier.

3.2 Prediction of Dhool Number using SVM Classifier

The input for SVM analysis consists of values of standard deviation, entropy and variance obtained for the green matrix of each image. In order to maintain accuracy, six images from six different batches are collected for a given fermentation time for each dhool. Therefore, total of 102 images (6 images x 17 time slots) were used for dhool 1 and all were labeled as 1. Similarly, total of 78 and 66 images were collected for dhool 2 and 3 respectively. Consequently, the input file for SVM classifier consists of 246 features from images to train the system. The SVM classifier splits the data set into training data (70%) and testing data (30%).

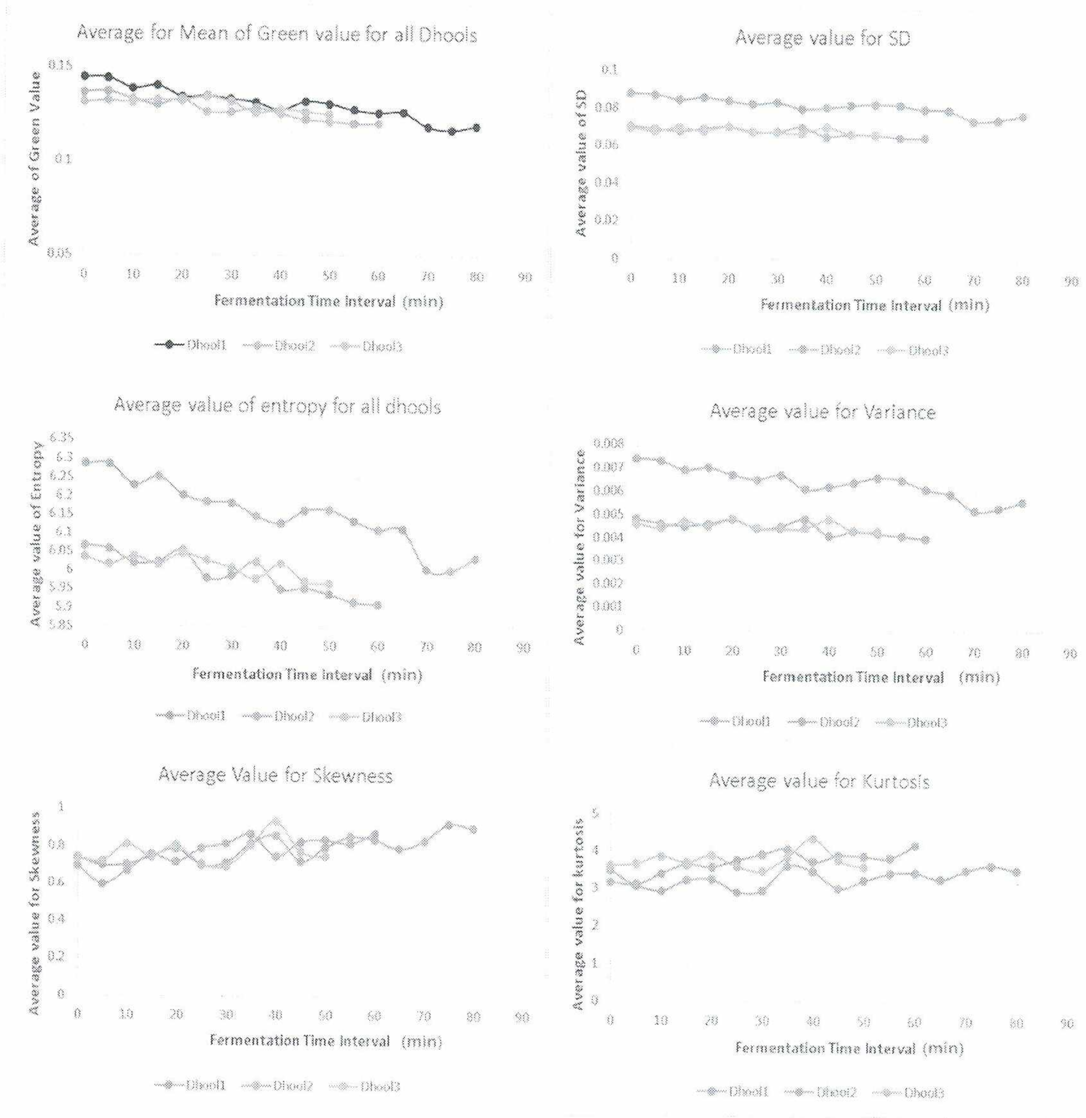

Figure 4: Comparison of mean, standard deviation, entropy, variance, skewness, and kurtosis for the dhools 1-3

Table 1 indicates the accuracy levels for the prediction of dhool number. According to the results, dhool 1 can be identified with over 77% accuracy while dhool 2 and 3 indicated accuracy levels of 69% and 73% respectively. These results are in agreement with the feature analysis where standard deviation, entropy, and variance for dhool 1 is clearly distinguished from dhool 2 and 3. These images were collected from the tea factory during rainy season. Since tea leaves are too moist, processing method results in equal particle sizes for dhools 2 and 3. Therefore, features obtained for dhools 2 and 3 are similar.

Table 1: Accuracy levels for prediction of dhool number of a given batch

Attempt	Accuracy for Dhool 1	Accuracy for Dhool 2	Accuracy for Dhool 3
1	81	69	73
2	74	69	73
3	78	69	73
4	77	69	73
5	78	69	73
6	80	69	73
7	78	69	73
8	80	69	73
9	77	69	73
10	82	69	73

3.3 Prediction of Fermentation Time of Tea Particles

Here, same features (standard deviation, entropy, and variance) were used to construct the input file for SVM analysis. In the SVM classifier, separate input files for each dhool is constructed where each time interval (5 minutes) is labeled as 1, 2, 3, etc. The input data set is split into training data set (70%) and testing data set (30%) in SVM classifier. The accuracy of the prediction of fermentation time is given in Table 2 below. Results indicate a higher accuracy in predicting fermentation time for dhool 1 compared to dhools 2 and 3.

Table 2: Accuracy levels for prediction of fermentation time

Dhool number	Accuracy
Dhool 1	94 %
Dhool 2	92%
Dhool 3	91%

4. CONCLUSIONS

The project focused on developing a computational method by using image processing techniques to predict the fermentation level, which can be used as a quality controlling tool. The results presented in this paper are in the initial phase, which seeks possibility to use images of tea particles as a tool to monitor fermentation level. The results indicate higher accuracy in predicting a given image as the dhool 1, which is over 77% accurate. Dhools 2 and 3 indicated accuracy levels of 69% and 73% respectively. The fermentation time can be predicted with an average accuracy of 94% for dhool 1 and 92% and 91% for dhools 2 and 3 respectively.

Features obtained for dhools 2 and 3 do not show clear distinction due to similarity in particle sizes. Therefore, ongoing work includes a further collection of images under various weather conditions such as dry season, where processing steps are different from rainy season. Also, it is important to take into account temperature and humidity variations as well. The use of alternative classifiers to identify dhool number and fermentation time is currently under investigation. Finally, the results obtained from image processing of tea leaves will be validated with chemical changes that are taking place during fermentation.

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