IC-RACE

International Conference on Recent Advances in Computer Science and Engineering (IC-RACE) 2019

Proceedings

ज्ञान-विज्ञान विमुक्तये

Organized By

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
UNIVERSITY COLLEGE OF ENGINEERING AND TECHNOLOGY
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A digital device to monitor the colour changes during fermentation stage of black tea processing

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Abstract—**Tea industry is one of the famous industry for its economic importance in the world. Generally, Tea quality is defined by its taste factors. Actually these taste factors are defined by its Theaflavin(TF) and Thearubigins(TR) ratio. For a good quality of tea, TF/TR ratio is defined as 1/10. This is defined by the transformation from polyphenols to Theaflavins and Thearubigins during fermentation period. This fermentation time could be depend on the environmental and chemical factors of the fermentation bed of tea leaves as it colour changes from green to brown. Tea officers are using their visual method to estimate the exact fermentation time of the tea leaves now a days. Actually this cannot be reliable to decide the fermentation time without knowing the exact condition of the tea leaves and it might vary to individual. This is a new method to develop the relationship between the factors influencing the fermentation process. A device was developed with a set of sensors such as humidity, moisture, temperature, moisture content of tea leaves to calibrate the details of the fermentation bed for the dhool 1 sample of each batch at every 5 minute. Digital images were taken from the iPhone 6s camera module to predict the colour variation of the fermentation bed tea leaves for every 5 minutes. Fired sample of the batch which was analyzed for fermentation were taken for the Theaflavin test. Also tea infusion colour was monitored using colour monitoring device regarding RGB values and UV spectrophotometer. All these data were analyzed to predict the relationship between environmental and chemical factors. Average Temperature (Leaves), Temperature difference (Leaves) and Average Room Temperature are statistically significant with Fermentation Time at 0.05 level of significance and R^2 = 96.6%. TF% showed a decrease with the time which is the trend expected. TFs decreased steadily from 50 min and a little change was observed at 100 and 180 min.**

I. INTRODUCTION

Tea isthe most popular beverage all over the world. Tea consumption stay second behind the drinking water in the list of beverages. Tea is providing more health benefits compared to coffee or other dinking liquids such as Tea contains antioxidants, it has less caffeine compared to coffee, it may reduce the risk of heart attack and stroke, it may help to reduce the weight and it may help to protect bones. Due to the benefits habit of tea consumption is increasing day by day all over the world [3].

Production of black tea undergoes a gradual biomass process of withering, maceration, fermentation and drying. Each step influences the production of tea in different ways. Out of the above procedures, fermentation plays a major role to decide the quality of black tea. The fermentation step actually represents enzymatic oxidation of the polyphenols present in the leaves in presence of atmospheric oxygen to produce various oxidized pigments. The theaflavins and thearubigins formed as a result of enzyme oxidations of polyphenols during the fermentation process in tea manufacture.Black tea's quality could also be determined by chemical analysis methods by measuring and calculating the ratio of theaflavins (TF) and thearubigins (TR) levels in the tea. TF/TR ratio is accepted as 1/10 for a high quality tea while mid quality tea has a ratio between 1/25 – 1/20. Determining the colour of a tea liquor and some of the other liquor characters recognised by tea tasters [5]. Black tea's quality could also be determined by chemical analysis methods by measuring and calculating the ratio of TF and TR levels in the tea.Quality of tea is one of the complicated task which is carried out by a group of human panel called 'tea tasters' in industry. Gradation of tea is carried out according to the marks given by these tasters on a scale of 1–10 separately for flavor, aroma, taste as well as overall quality of the sample.[2]

UV spectrophotometry can be used to measure the absorbance of the specimen. Tea extract colour can be measure in the UV spectrophotometer. This is mainly needed to get the amount of TR% and TF% found on the black tea sample. Extraction method can be varied according to the need. Reading is generally taken at 380 nm wavelength and it is multiplied by 2.25 to get TF%.

Black tea processing technique is a popular research topic around the world. Different kind of researches has been done in recent past years about fermentation quality of black tea processing. Even some of the physical parameters were tested already

with different set of conditions. In some advanced researches tea tasters have been used as the reference point for their result. Even more advanced level research have been done with digital devices too.

On another study, temperature with time and Tea Polyphenol oxidase (PPO) is reported to have optimum activity at 30 °C [6]. Further they have described that the Thearubigins (TR) formation also favored at high temperatures.Black tea odor has been tested with a total 13 Figaro brand MOS sensors in another study [8]. All sensors are tested with 64 samples of black tea samples but the sensor results had the accuracy of 74.19%. This type of classification only determining the samples according to the odor only.

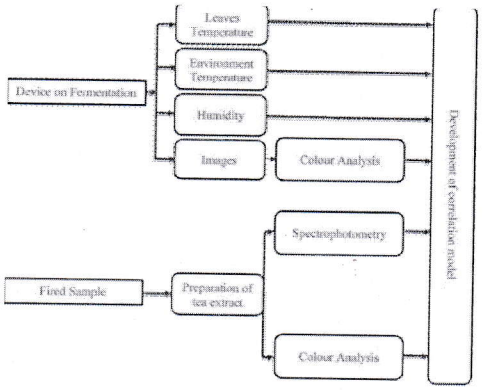


Figure 1: Developed Device for the fermentation stage of Black Tea

Variations in the polyphenols and the theaflavins were observed by another study explaining the trend with time [4]. This study showed that the TFs climbed steadily reaching a maximum at 45 min and a little change was observed after 110 min. For chemical tests especially TR and TF has been tested in past years too. A study with camera with illumination was used to estimate the TR and TF content in tea sample. Image of liquor sample was directly captured by the camera and image analysis techniques had been employed for extraction of different colour features. But, the formation of overlapping cluster indicated a nonlinear relationship among the colour image data with TF and TR values [1]. Further accuracy of this study was increased by neural network algorithm. Even though it showed similar results but comparatively improved

Main objective of the research to develop a relationship between fermentation time, humidity, environment temperature, temperature inside the tea leaves, RGB colour variation and Theaflavin content in the tea leaves. Through this relationship, variations between parameters can be predicted and it could be able to track the variation of the Theaflavin which will lead to visualize the effect of the physical environment.

II. Problem Statement

Tea quality depends on the fermentation time of the tea leaves but internal and external parameters may influence the quality of black tea during fermentation process. Internal transformation role of polyphenol oxidase (PPO) and peroxidase (PO) transforming catechin compounds to TR and TFs affects the colour and odor of the process qualitatively. Degradation of catechin may affect according to the physical condition of the fermentation system. External factor such as temperature with a prolonged time influence the quality of tea at considerable amount [6]. Other factors such as time of fermentation, moisture content and humidity of the fermentation room also affect the quality of tea.

Generally tea testers are used to predict the quality of tea by their experience but most cases everyone cannot have same sensing ability [7]. Even some days they allow more time for a specific batch. This is the main problem to have a different quality of tea. Poor quality of tea leaves might occur due to lack of ensuring the time for the fermentation. Generally fermentation time is fixed for the particular season. But this might be varying according to the physical condition and chemical composition. This research will be concentrating on the method to track the physical condition variations which can be ensured using the Theaflavin test of that fired sample batch.

III. System Modeling

A device was developed to test fermentation of tea leaves. Importantly Dhool 1 type tea leaves were taken into consideration. Main purpose of this device was to collect the data of Environment temperature, humidity, Temperature inside the tea leaves and digital image of the fermentation bed. Every five minutes data were taken and recorded.

Then Second part was done in laboratory. Fired sample was taken after the tested fermented sample came from furnace. TF% was tested and calculated using Ultraviolet spectrophotometer using the sample taken from the factory. Photo of the tea extract was taken to measure the RGB value of tea extract. Finally Correlation between the data was taken for the final decision.

A. Device Development

This is a new technique to monitor the fermentation parameters in the field of digital analysis around the Tea industry. For testing on the fermentation bed, a device setup was developed using Arduino UNO as the microcontroller. 20×20×40 cm table was used as the base for the device. Arduino was coded to take the reading from sensors in every five minutes and those data were transferred to SD card module.Digital image of the fermentation bed was taken using phone 6s camera module at the real time

for every five minutes.12V Lithium Polymer 9800mAh DC Battery was used to power the micro controller and 5V power supply was designed to supply the constant voltage to the sensors. Arduino was fixed inside a box on the table and sensors were fixed in appropriate way to measure the data.

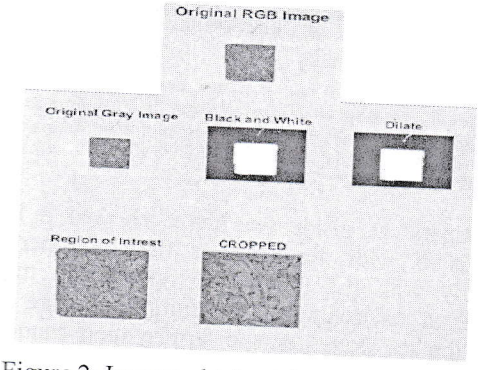
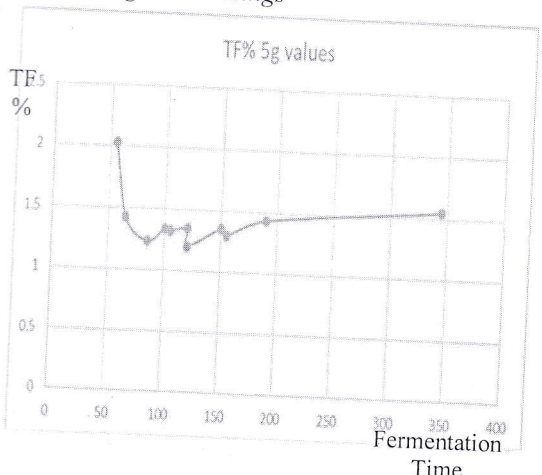


Figure 2: Images obtained from the series of dialation to obtain region of interest

This device was placed on the fermentation bed to measure the physical readings around the bed environment. Here the height of fermentation bed was set as constant by a wood piece. So the height of the fermentation leaves bed was 2 inches. Height was maintained as constant in order to avoid the problem in the thickness. Then the device was turned on after the bed arrangements. Data was recorded from the start until the officer asked worker to transfer the tea leaves for firing.

B. Digital Image Processings



Important part of this research was to convert the image to the portion where the region of interest was obtained. Orange colour square metal was placed for the easiness of obtaining the area of interest. Image taken from the fermentation bed was fed into the MATLAB software. Code was designed to get RGB values automatically from a specific area on region of interest. Through series of dilation of the image and removal of the boundary, region of interest was obtained. Center area of the region was cut to ensure the accuracy of the images obtained from each batches. RBG colour from the image was separated and analyzed simultaneously.

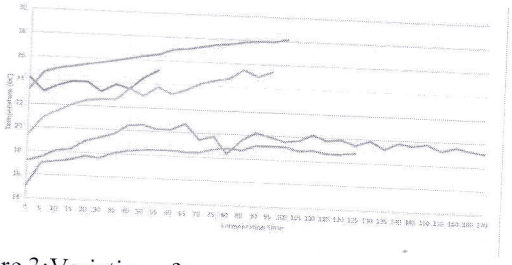


Figure 3:Variation of temperature inside the tea leaves with fermentation time before 7.00 am on different 5 days

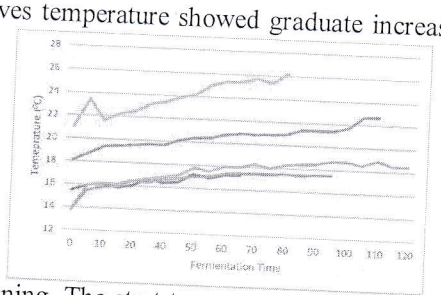
C. Chemical Analysis

Standard TF content method was used. Following steps are involved in the TF content measurement.

1. Measure 5g of tea sample.
2. Measure 125ml of hot water at 100 °C
3. Mix the hot water and 5g of sample well and allow to cool down
4. Filter and remove the tea particles using the usual tea filter.
5. Take 25ml of tea filtrate and 25ml ethyl acetate and mix well
6. Separate the organic layer after settlement
7. Take 4ml of organic layer and add methanol up to 25ml from the 4ml of organic layer
8. Test for absorbance using UV spectrophotometer while taking Blank for reference.

IV. Statistical Analysis

Tea leaves temperature showed graduate increase



in early morning. The start temperature varies due to the time that take to transfer the tea leaves from the roll breaking area to fermentation area. Heavy oxidation of the polyphenols cause the temperature increase and sweating. Apart from this after 7.00 am showed same characteristics. At the start it showed an increase but after few hours temperature increase is dropped due to the complete conversion ofpolyphenols. Through temperature of leaves and

sweating, optimum time for fermentation can be predicted.

In a fermenting room where 90 - 95% RH is required to be maintained, the air is always very near saturation i.e. the dew point temperature. But in this fermentation bed they just maintained the humidity through the circulating air through windows. Humidity should be high to get the good quality of tea. Even humidity level varies between 40-60% during early mornings, it provides a better environment. But to get the higher quality of tea maximum humidity level should be achieved during fermentation period.

Here moisture content variation in the tea leaves are same. Values obtained from the moisture sensor were same. But there was still small amount of moisture content during fermentation time also. This content can affect the fermentation of tea leaves. Some other mechanical devices has to be used to record the moisture content of leaves and eliminate this error.

RGB analysis is important when considering the colour change in tea leaves. Red, Green and Blue colour finally decreases with variations throughout the time. But compared to the Red and Green colour, drastic changes were observed only in Blue colour region.

UV spectrophotometer was used to find the TF content in the fired tea sample. As usual TF% was measured at 380nm. RGB test also performed on the 5g of the fired sample. Standard sample test on the UV Spectrophotometer showed a perfect graph.

Above graph on figure 5 shows that the plot of TF content with respect to fermentation time. One point is heavily deviated due to mismatch of sample from furnace area. This is the expected result from the past researches [4].

Tea infusion digital images were taken to analysis the RGB of organic liquor (Sample of 5g). MATLAB code was used to analysis the RGB. This graphs display that the RGB values at maximum between 100 – 120 min for 5g sample.

Above results were analyzed statistically shows that there is 3.8%, 0.9%, 0.6% of regression value between fermentation time and Red, Green and Blue colour. These values express that it has a weak relationship. On the other hand, significant relationship between leaves temperature and time were obtained. Regression value of 83.7% explain how the temperature vary according to the time.

This standard TF% results doesn't connect well with the fermentation time as it shows 0.6% linear regression. So through this analysis TF% cannot be related with the fermentation time.

Further with the correlation results indicated that all there variables: Average Temperature (Leaves), Temperature difference (Leaves) and Average Room Temperature are statistically significant with Fermentation Time at 0.05 level of significance and R^2 = 96.6%. However, there is no any other significant relationship. Even RGB colour cannot be related with the other factors. Colour varies due to the climate and condition directly. RGB final results cannot be defined easily.

V. Results and Discussion

Temperature inside tea leaves showed a linear relationship with fermentation time. It increases gradually with the time. This relationship mainly depend on environmental condition. Moisture level inside the tea leaves on the fermentation cannot be predicted using soil moisture sensor as its moisture content is very less as it cannot be measured using this electronic sensor. Temperature and humidity changes according to the climate of the area. Final conclusion cannot be obtained in the statistical RGB analysis of the tea leaves as it linear regression value is comparatively low. Still some variations are obtained in the graph. Average Temperature (Leaves), Temperature difference (Leaves) and Average Room Temperature are statistically significant with Fermentation Time at 0.05 level of significance and R^2= 96.6%. Humidity variations cannot be estimated practically as it has to be maintained constant to get good quality of tea.

TF% showed a decrease with the time which is the trend expected.TFs decreased steadily from 50 min and a little change was observed at 100 and 180 min. 1g aqueous solution TF% didn't showed a specific trend.

RGB analysis of the standard 5g tea infusion proves that there is no any linear relationship. Even blue color showed R^2 = 63.8% and a significant relationship compared to other colours. There is no other significant relationship with RGB analysis of 1g aqueous solution.

Acknowledgements

This research funded under the grant of NRC 17-038 and facilities were provided by the Uva Wellassa University of Sri Lanka

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