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The Tea Research Institute of Sri Lanka

Compiled and edited

by

Dr K M Mohotti
Convenor/ Secretary, E & E Forum
Tea Research Institute of Sri Lanka
Talawakelle

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Keynote Address

I Sarath B Abeysinghe

Director, Tea Research Institute

1. World Tea Statistics –Production (Mnkg)

World scenario in tea production during 2017 and 2018 is shown in Table 1.

Table 1: World Crop Statistics – Tea Production (Mnkg)

Country	2017	2018	Change	% Change
North India (up to Nov)	1032.1	1058.3	26.2	2.54
South India (up to Nov)	218.2	199.4	-18.8	-8.62
Kenya (up to Oct)	346.9	395.5	48.6	14.01
Sri Lanka (up to Dec)	307.7	303.8	-3.9	-1.26
Bangladesh (up to Nov)	67.7	66.7	-1.0	-1.48
Malawi (up to Dec)	45.6	50.6	5.0	10.96

Source: Statistical Bulletin, SLTB

2. Tea Production in Sri Lanka – Mnkg (2017 & 2018)

Table 2 presents the tea production during 2017 and 2018.

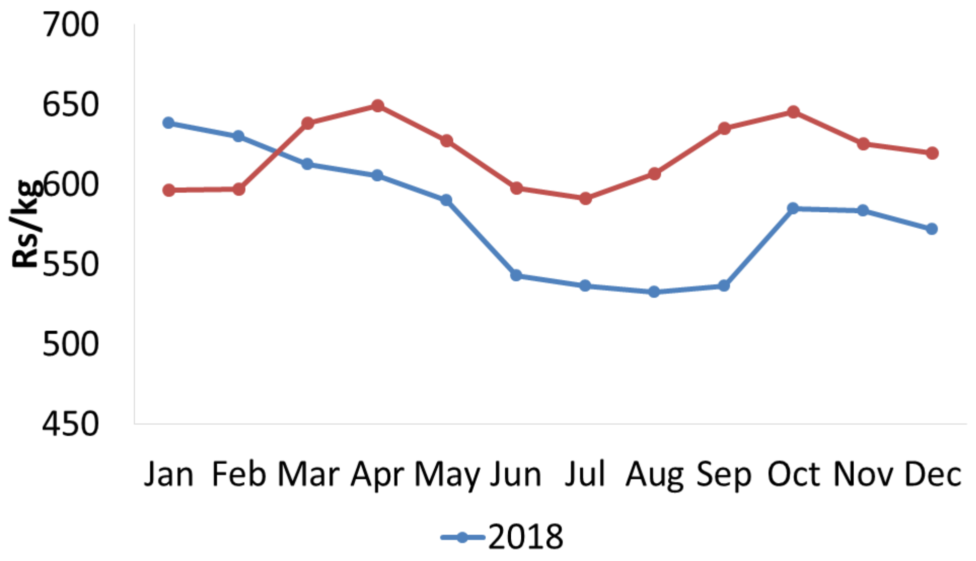
Table 2: Tea production in Sri Lanka during 2017 and 2018

Elevation	2017	2018	Change	% Change
High	64.64	64.81	0.16	0.25
Medium	45.65	47.02	1.37	3.00
Low	197.42	192.01	-5.41	-2.74
Total	307.72	303.84	-3.88	-1.26

Source: Statistical Bulletin, SLTB

3. Fluctuation of Tea Prices at Colombo Auction

Tea prices in the year 2018 at Colombo Auction were seen highly fluctuating as shown in Figure 1 and the drop in tea prices in Colombo Auction was alarming when compared in 2017 and 2018 in the different Auction Centers (Table 3).



Source: Statistical Bulletin, SLTB

Figure 1: Tea prices in the year 2018 at Colombo Auction

Table 3: Change of tea prices in different Auction Centers in 2017 and 2018 up to November

Auction Centers	Price (US$/kg)		
	2017	2018	Change (2017 vs 2018)
Kolkata	2.46	2.46	(0.00)
Cochin	1.82	1.81	(0.01)
Chittagong	2.41	3.11	0.70
Mombasa	2.82	2.45	(0.37)
Colombo	4.07	3.64	(0.43)
Guwahati	2.16	2.15	(0.02)
Malawi	1.84	1.84	0.01
World	2.93	2.71	(0.22)

Source: Statistical Bulletin, SLTB

4. Sri Lankan Tea Exports (Mnkg)

The volumes of different types of teas exported in 2017 and 2018 are presented in Table 4.

Table 4: Sri Lankan Tea Exports in 2017 and 2018 (Mnkg)

Type of Tea	2017		2018	
	Qty (Mnkg)	FOB Price (Rs/kg)	Qty (Mnkg)	FOB Price (Rs/kg)
Tea in Bulk	114.8	732.18	111.1	731.44
Tea in Packets	123.6	759.17	119.6	765.24
Tea in Bags	20.0	1321.55	19.8	1389.19
Green Tea	4.6	1537.69	4.2	1744.14
Total	265.0	807.12	257.0	819.68

Source: Statistical Bulletin, SLTB

5. Non-Tariff Trade Barriers

Among the major tea importing countries, Japan and the EU continue to impose strict regulations on pesticide residues in made tea. Therefore, tea producing and exporting countries are required to comply to the maximum residue limits (MRLs) imposed by health authorities of such destination countries. Meanwhile, Sri Lanka encountered noncompliance to pesticide residue detections in Japan which brought severe threat to exports to Japan especially high growns.

5.1 Detection of MCPA Residues in Japan

With repeated detections of MCPA residues in made teas exported to Japan during the year 2018 & 2019, SLTB and TRI made several attempts. Special interventions taken by TRI were:

Removal of MCPA from the TRI recommended pesticide list on 29th January 2019 and all tea growers were strictly advised to refrain from the use of MCPA in tea fields until further notice.

Repeat field trials to determine the realistic residue levels under GAP and GLP practices as per FAO guided trial protocols as MRL of MCPA in Japan and EU by end February 2019 remained as 0.01 and 0.1 ppm respectively.

5.2 Detection of Hexaconazole Residues in Japan

Detections of Hexaconazole residues in made teas exported to Japan were also continued during the year 2018 & 2019 and SLTB and TRI made several attempts. Special interventions taken by TRI were:

TRI issued a cautionary note to all tea growers on 11th January 2018 not to use Hexaconazole in mature tea fields.

Repeat field trials to determine the realistic residue levels under GAP and GLP practices as per FAO guided trial protocols as MRL of MCPA in Japan and EU by end February 2019 remained as 0.01 and 0.05 ppm respectively.

5.3 Detection of Residues of other chemicals

It was surprised to note Glyphosate detections in China in December 2018 as 1.04 and 0.94 ppm while the Chinese MRL is 1 ppm. Since teas have been produced in July to November 2018 while Glyphosate ban was in force, the residue detection is alarming to the country.

Also, a few other residue detections were notified in Sri Lankan origin teas and they are: 2,6 - DIISOPROPYLNAPTHALENE (2,6-DIPN) in 39 garden marks covering all elevations, Fluazifop-P, Chlorpyriphos in an Uva Estate, Pentachlorphenol in Low Country and d. Mycotoxin, Ochratoxin A (OTA) in various blends.

6. Glyphosate for Tea and Rubber Sectors

After several lobbying being made to the government by TRI, Glyphosate was made available for tea and rubber sectors from December 2018 under controlled circulation and the distribution is done through Ceypetco with a letter of recommendations for RPCs and estates above 50ac on request to Ceypetco.

7. Determination of Sugar Levels in Made Tea

It is mandatory that all Sri Lankan tea exports should conform to ISO 3720 and ISO 11287 standards which specify the basic requirements of Black and Green tea respectively. Hence, addition of any substances during processing is not permitted. Having detected adulteration of teas using sugar during processing to alter the appearance and heaviness of made tea & liquor quality, TRI was requested to determine baseline data on sugar.

In order to set maximum levels for sugar in tea, TRI launched a study program by drawing 360 samples from low country tea growing areas representing 36 factories and 10 grades. The samples were analyzed for Sucrose, Glucose and Fructose using HPLC to determine the maximum levels for Sucrose, Glucose and Fructose naturally present. The studies are underway and the maximum levels will be notified to the SLTB for regulatory purposes.

8. Out Break of Fall Army Worm (FAW)

Fall Army Worm (FAW) is an invasive insect pest not recorded in Sri Lanka causing significant yield losses mainly for maize, rice, sorghum, millet, sugarcane, vegetable crops and cotton and tea has not been recorded as a host for FAW.

The Department of Agriculture (DOA) provides assistance in identifying affected lands and control measures and a National Task Force is established under Ministry of Agriculture to manage FAW outbreaks where TRI, RRI, SRI and CRI are members owing to potential threats.

At present, DOA has issued gazette notifications in view of controlling the pest by restricting transportation of maize stubble and planting of maize temporarily.

AN AUTOMATED CONTROL SYSTEM FOR FLUIDIZED BED DRYING

K Raveendran, L Jayasinghe, W N K M S Dhanawardhana and S H Priyanthi

Process Technology Division, Tea Research Institute of Sri Lanka

ABSTRACT

Fluid Bed Tea Dryers are widely used for drying Orthodox broken type tea in tea factories in Sri Lanka. Manual control of dryer operations fails to maintain the dryer in steady state most of the time. Achieving required fluidization and obtaining moisture content in dried-tea within the acceptable limit of 2.5 – 3.0 % became difficult. Also, smaller tea particles are carried away by the exiting fluid stream leading to blowout. A Process control system based on a Programmable Logic Controller was designed and installed to facilitate steady operation of Fluid Bed Dryer and to ensure drying the tea with moisture content within the acceptable limit. A mathematical model relating tea-bed temperatures to the moisture content of tea at the dryer discharge was developed and incorporated into the control system to adjust feeding rate of tea. The control system also incorporates an additional measure to adjust retention time of tea in the dryer. A programming was done in ladder programming language to provide the input data to the controller and to gradually adjust feeding rate of tea and to regulate retention time.The process control system provide additional advantages such as drying tea with required blackness and tea character leading to increased prices of main tea grades.

Key Words: fluidization, control system, moisture content, blackness, tea character

1. INTRODUCTION

The Tea Research Institute of Sri Lanka (TRI) in collaboration with Colombo Commercial Company (Engineers) Limited (CCC) conducted research on fluidized bed drying of tea and developed a Fluid bed tea dryer in early 1970s. At present this dryer is widely used in almost all the factories that are producing Orthodox broken type tea. During drying moisture is reduced and which results changes in density of tea particles and changes in fluidization velocity. Therefore, maintaining required fluidization is found to be a challenge.

The required moisture content of 2.5 % – 3.0 % is achieved when the tea-bed temperature at the discharge end is maintained at 190 - 210 °F (88 – 99 °C) 95 °C. Monitoring the tea bed temperature and accordingly feeding rate of dhool is varied manually by adjusting spreading thickness of dhool on feeding conveyor during the operation to avoid fluctuation in the tea-bed temperature. However, fluctuations of tea-bed temperature occurs frequently in this manual method as there is time lag (time gap between dhool feeding adjustment and weir-end tea-bed temperature) for response in tea-bed temperature every time as adjustment is made in the feeding rate of dhool. Other factors causing the fluctuations are difficulties in finely adjusting spreading thickness of dhool on the conveyor, varying moisture content in dhool, feeding of different dhool (1st, 2nd, 3rd, etc..) having particles with varying densities, poor condition of dryer and poor performance of dryer thermometers. As a result of these, discharging time of tea from the dryer is affected and tea often get under-fired or over-fired, fine tea particles are carried over by the exiting fluid stream leading to increased entrainment and blowout, output of the dryer is varied and quality and appearance of the final made tea are affected. The under–fired tea and blowout need to be dried again to the required moisture content of 2.5 % – 3.0 % using the drier.

Therefore, in this study, an automated control system for fluidized bed drying of Orthodox-Rotorvane tea in TRI-CCC Fluid Bed Dryer was developed to facilitate minimizing of fluctuations in tea-bed temperature and thus drying tea within 2.5 – 3.0 % moisture content by controlling the feeding rate of dhool into the dryer.

2. STUDY APPRAOCH

2.1 Development of experimental unit

Data acquisition system was installed to TRI-CCC fluid bed dryer at St. Coombs Tea factory to monitor tea-bed temperatures in all drying sections using PT 100 temperature sensors and position of directional louvers in the 3rd and 4th sections using proximity sensors (Figure 1). A Process control system based on a Programmable Logic Controller was designed and installed to the dryer. The control system includes adjusting the speed of the feeding conveyor by changing the speed of the conveyor motor using a variable frequency drive and changing the position of the directional louvers using separate gear motors.

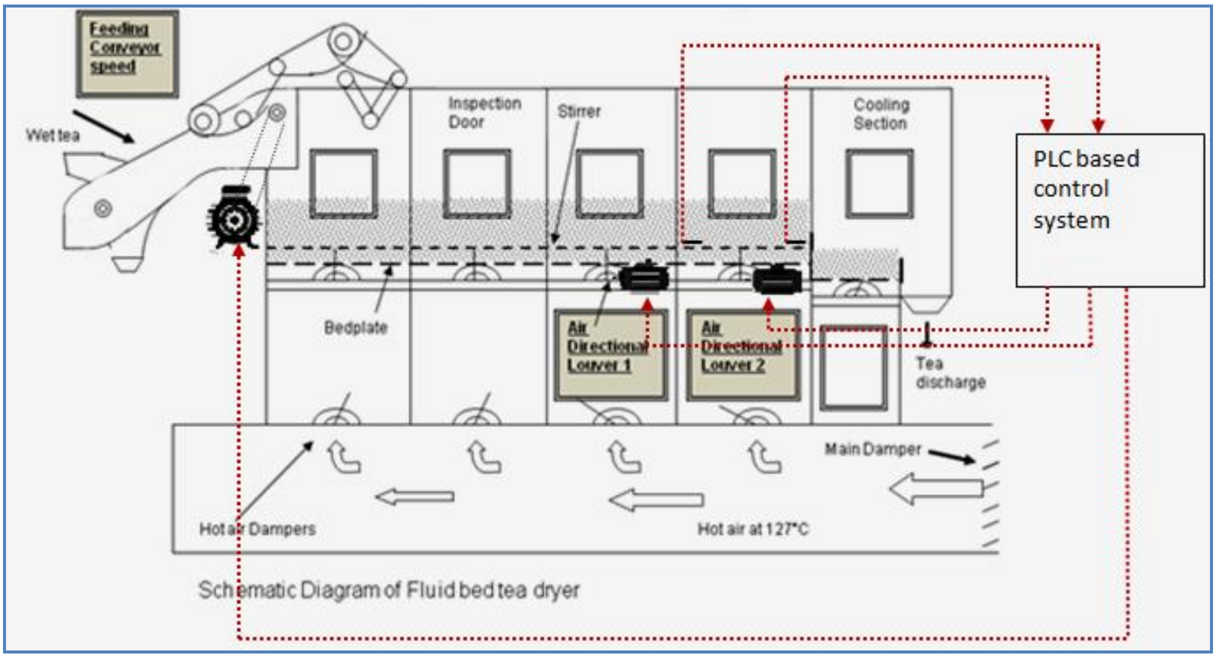


Figure 1: Data acquisition and control system in TRI-CCC FBD

2.2 Methodology

Teas were dried in the dryer at St.Coombs factory under controlled conditions and the dryer temperatures were monitored and recorded. The moisture content of dried tea samples was measured. The collected data was analyzed and a mathematical model relating tea-bed temperature in the 3rd and 4th drying sections with moisture content in dried tea was developed. A programming was done in ladder programming language to provide the tea-bed temperatures as input data to the controller and to gradually adjust feeding rate of tea. The programme include step increase and step decrease of feeding, recovering feeding rate for steady dryer operation & rated output and recovering after disturbances such as power failure. Further, the programme includes changing the louver positioning to reverse, forward and upright in order to regulate retention time. Two separate experiments were conducted to validate the automatic control system for drying the tea in TRI-CCC Fluid Bed Dryer.

2.2.1 Experiment 1

Experiment was conducted to identify improvement in drying tea to the required moisture content and made tea quality. Tea manufacture was followed under controlled conditions at the factory and dhool produced was dried while the dryer was in manual mode (control) and automated mode (Treatment). Six dried tea samples were collected at 10 minutes intervals and their moisture contents were measured using standard oven method. The dried tea was graded into BOPF and Dust 1 grades and the tea grades were sent to professional tea tasters for evaluation.

2.2.2 Experiment 2

Another experiment was conducted to verify results from experiment 1. Tea manufacture was followed under controlled conditions at the factory and dhool produced was dried while the dryer was in manual mode (control) and automated mode (Treatment) for three separate days each. The dried tea was graded into BOP, BOPF and Dust 1 grades and the tea grades were sent to professional tea tasters for evaluation.

3. RESULTS

Data on moisture content of dried tea (MC) and tea-bed temperatures in the four drying sections were analyzed statistically. Best fit equation relating moisture content of dried tea (MC) with tea-bed temperature in 3rd drying section (T_3) and 4th drying section (T_4), $MC = 12.1 - 0.0398T_4 - 0.0731T_3$ was found. This model was incorporated into the control system to calculate moisture content of dried tea and adjust feeding rate of tea into the dryer according to the variation in the calculated moisture content.

3.1 Results of Experiment 1

Variation of tea-bed temperatures with time monitored in dryer with manual mode during experiment 1 is presented in Figure 2 and that in dryer with automated mode is presented in Figure 3. Fluctuation in tea-bed temperatures of first (T_1), second (T_2), third (T_3) and fourth (T_4) drying sections were less when the dryer was with automated mode compared to that with manual mode.

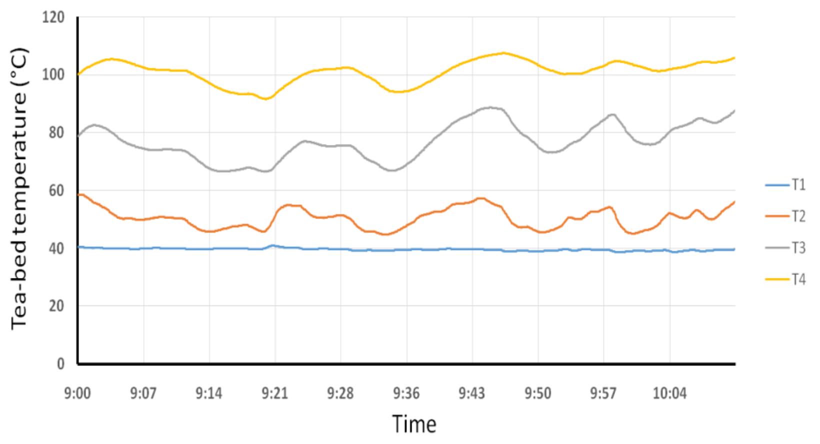


Figure 2 : Variation of Tea-bed temperatures monitored in dryer with manual mode

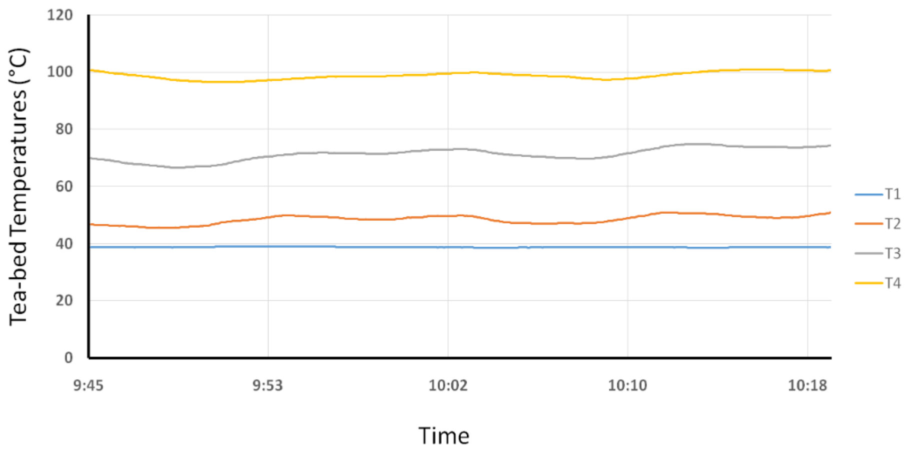


Figure 3 : Variation of Tea-bed temperatures monitored in dryer with automated mode

Results of moisture determination of dried tea samples obtained during drying in dryer with manual and automated modes in experiment 1 are presented in Table1. The dried tea moisture content were within the acceptable limit of 2.5 – 3.0 % when the drying was done in the dryer with automated mode whereas the moisture content in three samples deviated from the acceptable limit when the drying was done in the dryer with manual mode.

Table 1 Results of moisture content in dried tea from dryer with manual and automated mode in Experiment 1

Sample No.	Dried-tea Moisture Content (%)	
	Manual mode	Automated mode
1	2.6	2.6
2	3.1*	2.9
3	4.5*	3.0
4	2.3	2.8
5	3.5*	2.7
6	2.5	2.9

Results of tea tasters' evaluation on blackness, infused leaf appearance and liquor colour, strength and quality obtained for BOPF and Dust 1 grades in experiment 1 are given in Table 2. The tea tasters gave highest scores to all the parameters for both tea grades obtained by drying in the dryer with automated mode. The prices achieved by these tea grades were considerably higher compared to those obtained by drying in the dryer with manual mode (Figure 4.).

Table 2 Results of tasters' evaluation for appearance and sensory parameters for graded tea from Experiment 1

Quality parameters	Manual mode		Automated mode	
	BOPF	Dust 1	BOPF	Dust 1
Blackness	12.3	13	24.6	23.9
Infused leaf	11.7	11.3	25.3	25.6
Liquor Color	17.1	17.5	19.8	19.5
Liquor strength	15.2	13.6	21.7	23.3
Liquor Quality	13.3	15.3	23.6	21.6

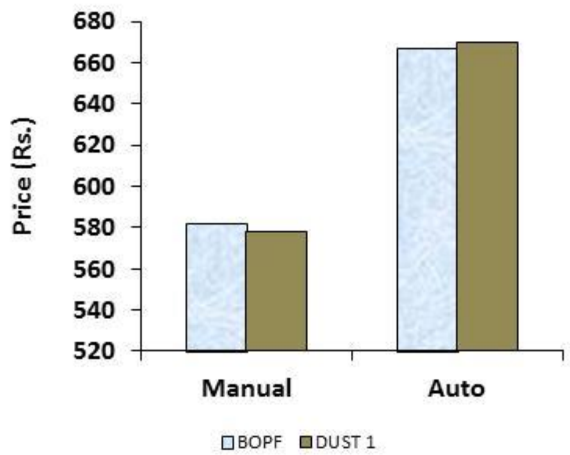


Figure 4: Variation of prices of graded teas obtained from dryer with manual and automated modes in Experiment 1

3.2 Results of Experiment 2

Results of moisture determination of dried tea samples obtained during drying in dryer with manual and automated modes in experiment 2 are presented in Table 3. The dried tea moisture content were within the acceptable limit of 2.5 – 3.0 % when the drying was done in the dryer with automated mode where as the moisture content in many samples deviated from the acceptable limit when the drying was done in the dryer with manual mode. Professional tea tasters gave highest prices for BOP, BOPF and Dust 1 tea grades obtained by drying tea in the dryer with automated mode (Figure 5.). Therefore, it was confirmed that the tea grades produced by drying in the dryer with automated mode achieved higher prices.

Table 3 Results of moisture content in dried tea from dryer with manual and automated modes in Experiment 2

Moisture content in dried tea samples (%)					
Manual			Auto		
Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
2.8	2.7	3.0	3.0	2.5	2.6
2.7	3.0	2.2	3.0	2.6	2.7
2.8	3.6	1.8	2.9	2.6	2.8
3.8	3.7	2.2	2.8	2.8	2.5
3.7	4.0	2.4	2.3	2.7	2.6
4.1	4.4	2.5	2.6	2.6	2.7
3.8	5.0	2.4	3.1	2.6	2.8
3.6	4.3	3.6	3.0	2.5	2.5
3.4	4.1	3.7	2.8	2.4	3.1
3.3	3.9	4.1	2.7	2.5	3.0
3.2	3.3	3.9	2.7	2.7	3.0

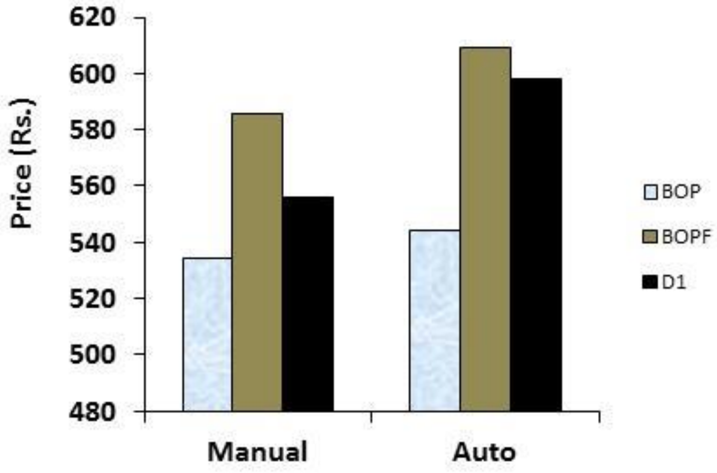


Figure 5 - Variation of prices of graded teas from dryer with manual and automated modes in Experiment 2

Features of the automated control system

The automated control system could facilitate steady dryer operation, improve fibre removal from tea and increase blackness of tea. The system has auto/ manual mode option to operate the dryer without any interruption. The system has the facility to monitor and record dryer operating parameters such as inlet hot air temperature, tea-bed temperatures, direction of air directional louvers and conveyor speed. The system could facilitate maintaining the rated output of the dryer and thereby improving productivity and made tea quality. The system facilitate minimizing blowout of tea and reduce wastage. The system manages the variations occurring in the inlet drying air temperature and maintains the dryer at steady state under such circumstances. The automated control system can be retrofitted to existing fluid bed dryers with minimal modifications and cost (Rs.1.2 – 1.5 million).

Advantages of the automated control system

The control system could ensure drying tea with acceptable moisture content, black appearance and tea character, facilitate to increase productivity and nett sale average (NSA) and facilitate to reduce cost of labour and energy and grading operations. Further, it provides a pleasant working environment. Problems in drying tea in the dryer could be traced back with the facility to monitor and record dryer operating parameters.

Requirements of dryer operating condition

Dryer must be in a good operating condition to ensure effective operation of the automated control system. Side plates should be free of damages, blow-hole suppressor must function properly, the grid plate must have even size perforations, the perforations should not be blocked by foreign particles, sectional hot air dampers and directional louvers must function properly and finally the feeding conveyor should be made to operate smoothly.

4. SUMMARY

Control system for drying tea in fluid bed dryer facilitate minimizing fluctuation in the weir-end tea-bed temperature and ensures that the teas are dried within the acceptable limit of 2.5 – 3.0 %. The control system could facilitate enhancing blackness and tea character of tea grades and thus increase the nett sale average. The control system can be retrofitted to existing Fluid Bed Dryers with minimal modifications.

AN AUTOMATED CONTROLLED SYSTEM FOR ELECTRICAL ENERGY SAVING IN TROUGH WITHERING

W M S Weerawardena[1], K S P Amaratunga[2], W S Botheju[3] and K Raveendran[1]

[1]Process Technology Division, Tea Research Institute of Sri Lanka

[2]Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

[3]Tea Research Institute of Sri Lanka, Talawakelle, Sri Lanka

ABSTRACT

Energy utilization and product quality improvement are the industry issues connected to Cost of Production and price realization where intervention of R&D and new innovations are needed. Therefore, a control system was developed for optimizing the electrical energy consumption in trough withering while preserving the required quality of withered tea leaves. The electrical energy saving was achieved by controlling the speed of the fan through a variable speed drive (VSD) and controlling the hot and ambient air delivering into the trough. The fan speed was determined based on the theoretical mass flow rate requirement of air, calculated by the mathematical model developed for withering. While calculating the thermodynamic properties of withering air and the moisture content of tea leaves in real time. A single board computer, Raspberry Pi 3 model B was used as the controller to run the mathematical model. Software programme was developed to control the VSD with a view to control the mass flow rate of air delivered and temperature of air.

The experiments were conducted with and without control system in order to evaluate the electrical energy consumption of the fan and the quality parameters of tea during withering process. The results showed that the specific electricity consumption was 0.17 to 0.18 kWh.kg^{-1} of made tea with the control system while it was 0.27 to 0.35 kWh.kg^{-1} of made tea without the control system. By introducing the control system, a saving of 39 % of electrical energy was achieved as compared to the withering process without control system. Further, it confirmed that leaf withering using the control system preserved the quality of withered leaf than that of without control system.

Key words: Raspberry Pi 3 model B, Tea Withering

1. INTRODUCTION

Black tea production process involves five major unit operations such as withering, rolling & roll breaking, fermentation, drying, grading & packing. Out of the five major unit operations, withering is the most important as far as quality of made tea and consumption of energy in tea manufacture are concerned. It consumes the highest amount of electrical energy and considerable amount of thermal energy (Haskoning, 1989). Withering consumes about 49% of total electrical energy in the Up-country tea factories and 61% of total electrical energy in the Low-country tea factories. Thermal energy consumption in withering is about 9.0 MJ to produce 1 kg of made tea (De Silva, 1994). The thermal and electrical energy consumption in withering can be minimized by adoption of efficient process control systems.

Withering process parameters such as relative humidity, air flow rate and temperature are needed to be controlled carefully in order to achieve desired and even wither in tea leaves and thereby obtaining better final quality of made tea (Gupta *et al*., 2012). The airflow rate of withering is regulated by adjusting air control dampers to ensure adequate air movement through withering leaves, avoid blowholes in leaf bed and throwing of leaves from the bed especially during latter part of withering. Further, temperature of the withering air is needed to be controlled below 32 ºC (90 ºF) to avoid discoloration of withered leaves. In the conventional method, hot and ambient air dampers in the mixing chamber are adjusted manually to control the air temperature and the rate of air flow.

In year 2002, use of variable speed drives (VSD) was studied and introduced to the tea industry in order to minimize the electrical energy consumption. The study revealed that 40% of electrical energy could be saved by proper control of airflow in the withering process with the use of variable speed drive, without affecting quality of made tea (Daranagama, *et al*., 2002).

Airflow is controlled by adjusting speed of the fan using variable speed drive (VSD) coupled to the motor of the fan. Potentio meter of the VSD is adjusted manually to vary the fan speed by the staff and workers. However, the airflow rate is not closely monitored as withering continued during night hours and speed is not adjusted as required. This leads to wastage of electrical energy as well as poor quality of final product (Ediriweera, 1991).

Therefore, the objective of this study was to develop a control system for trough withering for minimizing the electrical energy consumption while preserving the quality of withered leaves.

2. METHODOLOGY

A control system was developed for the existing tea withering trough to optimize the electrical energy consumption while assuring the required quality of withered tea leaves. The electrical energy saving was achieved by controlling the speed of the withering trough fan through a variable speed drive (VSD). The fan speed was determined based on the theoretical mass flow rate requirement of air. A developed mathematical model (Botheju *et al*., 2010) was used to calculate the mass flow rate requirement for withering and it was assessed based on the thermodynamic properties of air and the moisture content of withering leaves. A single board computer, Raspberry Pi 3 model B is used to run the mathematical model and the software programme to actuate the VSD and the heat source that provided the hot air for withering. Experiments were conducted in assessing the electrical energy saving while preserving the quality of withered leaves.

The experimental setup for withering

The experiment was carried at St. Coombs estate tea factory belongs to Tea Research Institute, Talawakelle, Sri Lanka. The experimental withering trough selected in this study was 18.29 m long and 1.83 m wide and consisted fan of 1.22 m diameter size coupled with a 7.5 HP motor.

Functionality of the control system

The Figure 1 shows the experimental set up for the developed control system. Temperature and RH sensors were placed at two positions *viz*. close to front and rear end in the withering trough chamber to measure temperature and the relative humidity of air. The measured temperature and RH data were used to calculate the real time moisture content, psychometric properties of air and theoretical mass flow rate of air by the developed mathematical model.

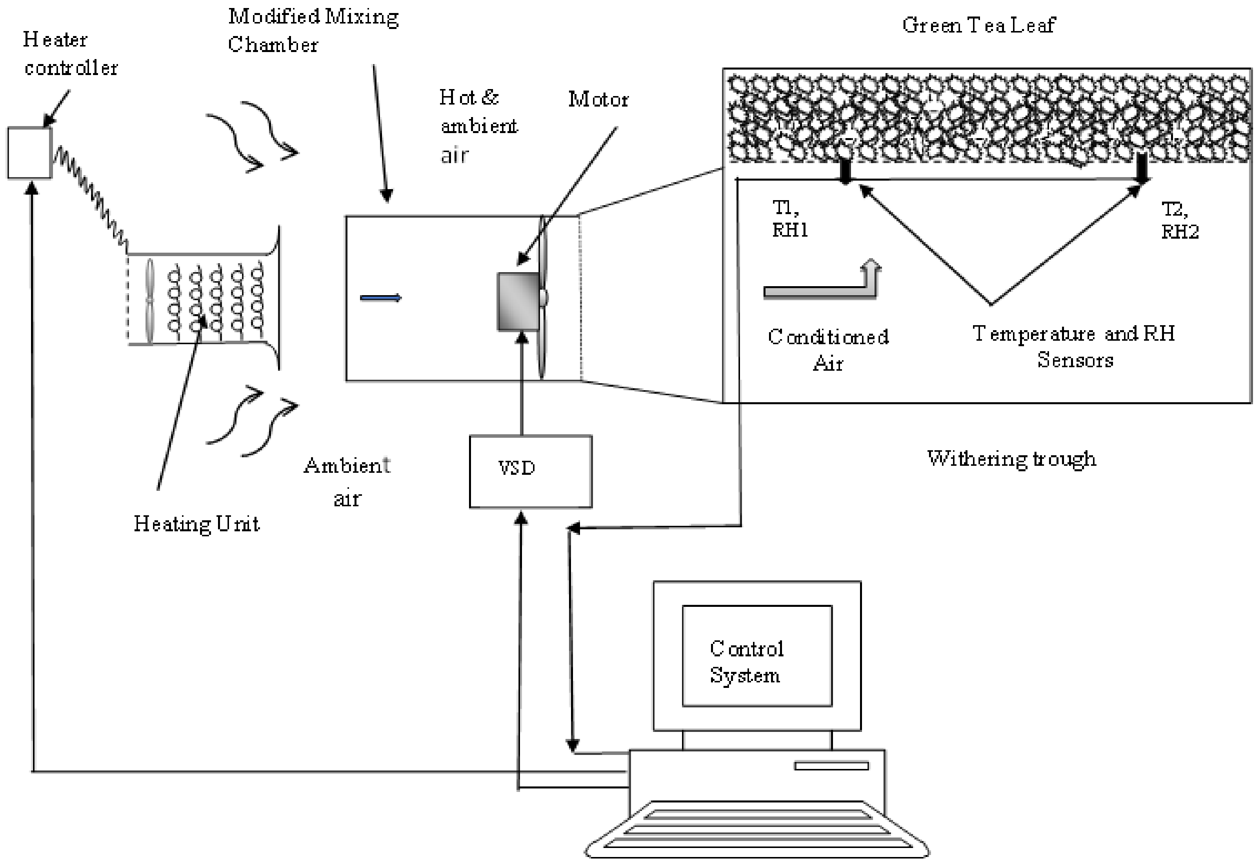


Figure 1: Experimental withering trough

During the withering process, the real time moisture content was taken as the controller output while predicting the moisture content in the next ten minutes of withering, assuming the air conditions are not changed. In this study standard linear curve of moisture contents vs. time was taken as the set point of the control system. The linear standard curve was obtained by setting initial moisture content at time zero and final required moisture content at the desired set time (ex.12 hours). Then the difference between moisture content of the withered leaves calculated by the model and given in the standard withering curve for an extrapolated time of ten minutes was calculated. If the difference was high, the programme tests the error for different mass flow rates iteratively until the minimum error was achieved. The final goal of minimizing the electrical energy was based on supplying the optimum air flow.

A single board computer, Raspberry Pi 3 model B was used to run the mathematical model and the software programme to actuate the VSD and the heat source that provided the hot air for withering. Experiments were conducted in assessing the electrical energy saving while preserving the quality of withered leaves.

Hardware for developing control system for trough withering

The Raspberry pi 3 model B (single board computer) was used as the controller in this study. A programme incorporating the mathematical model, written in 'python' language, was run on the Raspberry pi 3 model B to operate the heater and the VSD of the trough fan. The temperature sensors (LM35, Texas instruments) and the humidity sensors (Honey well, HIH4000 series, USA) were used to measure the temperature and the relative humidity of the withering air of the plenum chamber. The analogue signals produced by the temperature and the relative humidity sensors in this controlled system were converted to digital signals by an analogue to digital converter pi plus (ADC). 15 kW, 380-500 V, three phase variable speed drive (ATV 312HU15N4) was used to vary the speed of the fan and change the mass flow rate of the inlet air to the withering trough. The logic input switches of the VSD were used to communicate with the four-module relay to get the required frequency range as output. **Arduino-nano (**AT mega 328) was used to control the inlet air temperature of the withering air. The controller, Raspberry Pi 3 model B was serially connected with the Arduino-nano board to get the required set temperature of the inlet air.

Energy saving in trough withering to reduce cost of production

The developed control system was operated and withering data such as temperature, humidity and moisture content of withering leaves with time were collected. Three validation trials were conducted with the control system and without the control system.

900kg of tea leaves were loaded to the experimental withering trough at the recommended loading rate of 23.75 $kg \cdot m^{-2}$. The trough fan was switched on and the leaves were loosened properly. Leaf samples were collected randomly and its initial moisture content was determined by microwave oven method (Mohamed, *et al*., 2003). The initial moisture content and the leaf temperature were given as the initial condition to the mathematical model. Then, the withering process was carried out with the Raspberry Pi 3 model B control system. The inlet air temperature, relative humidity, real time moisture content and the frequency of the VSD were recorded by the control system during the withering period. The power consumption for withering was measured using a power analyzer (Fluke, model 434 series ii) throughout the withering period.

The same experimental procedure was applied for withering experiments without control system except controlling of VSD. The initial frequency was kept at 50 Hz until the turning of leaf and after turning of leaf the frequency was reduced to 45 Hz. After four hours of turning of withered leaves, the frequency was reduced again to 40 Hz and this speed was maintained till the end of withering process. The initial moisture and final moisture contents of tea leaves were determined by standard oven method (ISO 1568, 1980) by drawing of 18 samples of withered leaves every one-hour interval. The electrical energy consumption, measured without the control system was compared against that with control system.

3. RESULTS AND DISCUSSION

Energy saving in trough withering to reduce cost of production

Three withering trials were carried out in an experimental withering trough to validate the developed control system for optimization of electrical energy while preserving the quality of withered leaves.

The initial moisture content of the tea leaves of the first trial was 78 % wet basis. The control system automatically changed the frequency of the supply voltage through the VSD as necessary, throughout the withering period. At the start, the frequency of VSD was at 44 Hz and it was reduced automatically to 39 Hz by the control system with increase of temperature of the inlet air to the withering trough. The power consumption varied in the range of 2500 W to 3500 W in this trial. The temperature of the inlet air was maintained always below the recommended temperature of 32ºC (T.R.I. Advisory circular 2003).

The measured thermodynamic properties of inlet air, real time moisture content, frequency and the power consumption during the withering period with the control system in the first trial is shown in Figure 2.

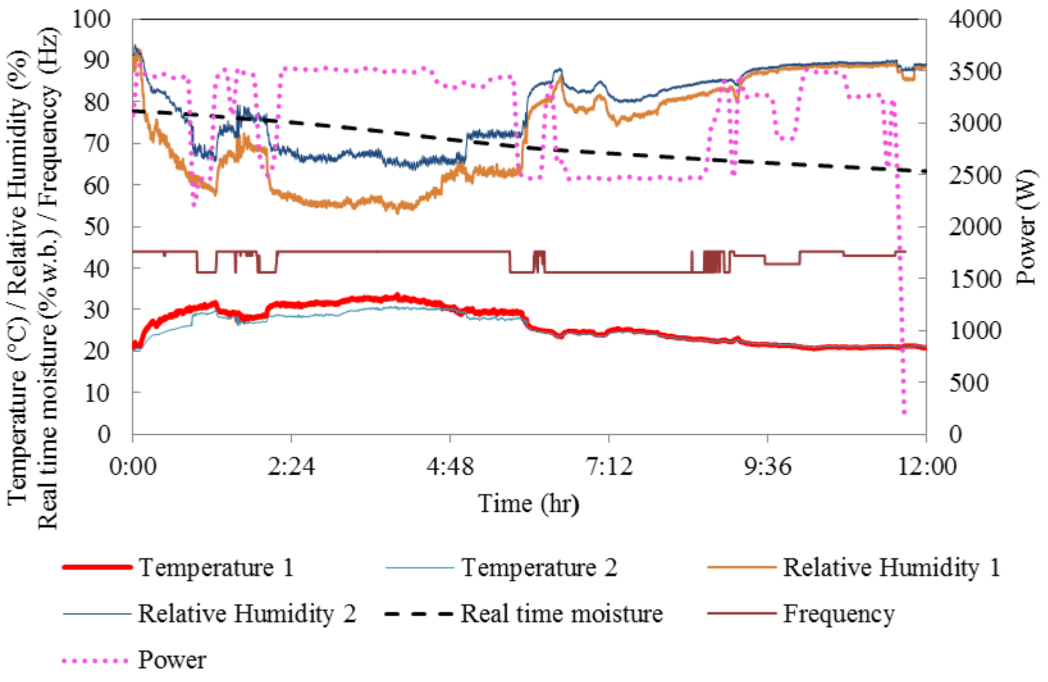


Figure 2: Thermodynamic properties of inlet air, real time moisture content, frequency and the power consumption during the withering period with the control system.

The initial leaf moisture contents were 76.2% and 75.2% in wet basis at the starting of the rest of the two trials. The respective power consumption was varied in the range of 3000 W to 3500 W and 2500 W to 3000 W in the second and third trials while the frequency of the VSD was varied in the range of 39 to 44 Hz. The temperature of the inlet air was maintained always below the recommended temperature of 32ºC.

Table 1 shows that the moisture content of green leaves was reduced from 75 - 78 % wet basis to 56- 57 % wet basis with the control system. The electrical energy consumption was in the range of 36 kWh to 39 kWh with the control system while it was in the range of 55 kWh to 67 kWh without control system. The specific electricity consumption was 0.17 to 0.18 $kWh.kg^{-1}$ made tea with control system and it was 0.27 to 0.35 $kWh.kg^{-1}$ of made tea without control system. De Silva (1994) stated that the theoretical specific electrical power consumption for withering is about 0.16 $kWh{\cdot}kg^{-1}$ of made tea while the actual consumption is about 0.46 $kWh{\cdot}kg^{-1}$ of made tea. The results show that the electrical energy for withering can be saved by 39 % with the control system while controlling the withering parameters.

Table 1 Energy consumption, initial and final moisture content and the specific electricity consumption with and without control system

Experiments		Initial MC (% w.b.)	Final MC (% w.b.)	Withering hours (hr)	Energy (kWh)	Specific Electricity consumption (kWh.kg^{-1} made tea)
With control System	Trial I	78	57.5	11:45	36.25	0.18
	Trial II	76.2	57.6	11:00	38.76	0.18
	Trial III	75.2	56.6	12:00	38.57	0.17
without control system	Trial I	77.2	57.1	16:00	55.92	0.27
	Trial II	79.3	56.3	16:40	64.34	0.35
	Trial III	78.6	57	15:45	66.24	0.34

The quality parameters (Thearubigins, Theaflavins, color, percentage brightness, and ratio of Thearubigins to Theaflavin) of the made tea samples produced with control system and without control withering system were measured in duplicates are presented in Table 2.

Table 2 Quality parameters of the made tea, produced with control system and without control withering system

Quality parameters	TF	TR	Color	Br (%)	TR/TF
With control withering system	0.952	14.8	4.98	17.82	15.5
	0.936	13.7	3.84	23.29	14.7
Without control withering system	0.839	13.7	3.9	21.2	16.3
	0.857	13.6	3.9	19.8	15.8

The ratio of Thearubigins (TR) to Theaflavin (TF) was very much closer in the treatment samples and the control samples. It was reported that TF to TR ratio of 1:10 gives an idealized liquor color and brightness (Robert and Smith, 1963). The results showed that quality parameters such as Thearubigins, Theaflavin, color, and the percentage brightness were not affected in these experiments. Further, it was observed that the withered leaf quality was better with the control system than the without control system.

4. CONCLUSIONS

The developed control system conserved electrical energy for trough withering. The power consumption with control system was varied in the range of 36 to 38 kWh whilst it was in the range of 55 to 67 kWh without control system. The specific power consumption varied in the range of 0.17 to 0.19 kWh per kg of made tea with control system. The electrical energy saving achieved with the control system was about 39% against the withering process without control system. The saving could lead to reduce cost of manufacture to produce one kilogram of made tea by two rupees. Hence, a factory produces 40,000 kg/month would save approximately one million rupees annually. Further, the quality of withered leaf is preserved during withering using the control system.

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AUTOMATIC CONTROL SYSTEM FOR EXISTING HUMIDIFIERS IN TEA FACTORIES

Thammita A S Anuruddha, K Raveendran and W N K M S Dhanawardhana

Process Technology Division, Tea Research Institute of Sri Lanka

ABSTRACT

Tea manufacturing process involves withering, rolling, roll breaking, fermentation, drying and Grading. During the fermentation process required chemical reactions are taking place in tea and the products, Theflavin and Thearubigin deliver required characters to the tea. Control of humidity & temperature in the rolling room environment is very important to avoid moisture loss from rolled leaf and dhool and to control the rate of chemical reactions. In every rolling room, one or more manually controlled humidifiers are installed to do the above task. Hygrometers are placed to monitor relative humidity in the room. It is observed that the humidifiers are not operated properly at most of the time in tea factories due to various reasons such as malpractices of humidifier operation. It could be observed when hygrometer reading gets wrong due to poor maintenance. This leads to surface drying of rolled leaf and dhool or condensation into water droplets on the rolled leaf and dhool. The improper operation of humidifier leads to vary the level of Theflavin and Thearubigin in tea, which finally affects the made tea quality and its price. In this study, an electronified hygrometer with a digital display was developed to measure the relative humidity in the rolling room. An automatic control system was developed for real-time monitoring of the hygrometer reading and control of water and power supply to existing humidifier. The system was found to facilitate to maintain the required dry bulb and wet bulb temperature difference of 2 -3 °F in given environment. The system is low cost and can be attached to any existing humidifier in tea factories while showing dry bulb and wet bulb difference , temperature and relative humidity on a digital display.

Keywords – Tea Fermentation, rolling room, relative humidity, Theflavin, Thearubigin, Electronified hygrometer, Microcontroller

1. INTRODUCTION

Major steps in black tea manufacturing process are Withering, Rolling, Roll Breaking, Fermentation, Drying and Grading. Fermentation is one of major step in black tea manufacture among above steps.

Controlling of chemical reactions is important to produce made tea with liquor quality, appearance and aroma. The chemical reactions start in tea once rolling of withered leaf is started and complete its latter stage on fermentation bed. The optimum fermentation period is judged by visual observation of color change and nose of aroma. The teas are then immediately sent to dryer to raise it temperature above 50 °C in order to arrest the chemical reactions. Controlling relative humidity in the range of 90 to 93 % in the fermenting area is important to avoid loss of moisture from tea as the chemical reactions are affected.

Humidifiers are operated to obtain this condition in the air around the fermenting area. Hygrometers are placed in the fermenting area and the reading is maintained at 2 to 3 °F in this regard according to E.L Keegel,

"Under average conditions, that is to say with a humidifying appliance operating and a hygrometric difference of 2 to 3, and leaf spread at a thickness of 1 ½ to 2 inches, there is a very little change in the temperature on the leaf during fermentation."

(Tea manufacture in Ceylon, E.L Keegel, Page 83)

In most of the tea factories, the Rolling, Roll Breaking and Fermentation steps are done inside the rolling room, an enclosed space. Therefore, it is necessary to operate one of more humidifiers depending on the type and capacity of the humidifier and the total area of rolling room to maintain the required hygrometric difference.

The above method is manual and relative humidity of the air is not controlled properly as seen in most of the tea factories. Hygrometers are not available for monitoring the dry and wet bulb temperatures in some tea factories. Other factors are poor maintenance and attention of hygrometer and poor operation of humidifier. Hygrometers are not in order or not properly placed in the processing area, water supply of the humidifier is not monitored & controlled, humidifiers are not operated when required and humidifiers are operated when not needed. In uncontrolled higher relative humidity conditions, water droplets fall on the leaf & dhool affecting chemical reactions leading to uneven fermentation. Further, the excessive wet condition in rolling room leads to microbial contamination to the rolled tea/dhool affecting liquor quality and human health.

In the context of less relative humidity conditions, surface drying of rolled leaf & dhool can impact not only on chemical reactions but lose its elastic properties which leads to unnecessary breakages of leaves during latter stages of rolling rather than twisting. The varying relative humidity conditions leads to varying rate of chemical reactions in tea results in uneven level of products, theaflavin (TF) & therubigin (TR). Therefore, in this study automatic monitoring and controlling system was developed to sense environmental relative humidity in the rolling room and control any type of existing humidifier(s) that are installed in particular space while displaying dry/wet bulb temperature difference, temperature and relative humidity level digitally to make rolling room operations easy.

2. MATERIAL AND METHODS

An automatic control system was developed to sense hygrometric difference, temperature; calculates relative humidity values using standard mathematical formulae to control humidifier output.

System design was split as two components; electronified hygrometer and controlling system in the aspect of functionality which were integrated later in to a single system. Experiment was conducted at St Coombs factory, Thalawakalle owned by Tea Research Institute. St Coombs factory rolling room and the existing humidifier were used to conduct the trials.

Electronified Hygrometer (for sensing parameters)

A microcontroller based electronified device which placed its sensors to dry and wet bulb positions was developed to replace the conventional hygrometer at Process Technology Division of TRI. This unit can deliver dry and wet bulb temperature difference more precisely and accurately and show the readings on a digital display. Standard mathematical formulas were used to calculate relative humidity using DRY WET bulb temperature difference as follows.

$$e_d = 6.112 * e^{\left(\frac{17.502 * T_d}{240.97 + T_d}\right)}$$

$$e_w = 6.112 * e^{\left(\frac{17.502 * T_w}{240.97 + T_w}\right)}$$

$$\text{Relative Humidity} = \frac{e_w - N*(1+.00115*T_w)*(T_d - T_w)}{e_d} * 100$$

Where, e = 2.71828182845904
T_d = Dry Bulb Temperature (Celsius)
T_w = Wet Bulb Temperature (Celsius)
N=.6687451584

Controlling system

According to the sensing parameters, the same microcontroller was used by placing additional program codes to control the humidifier at St. Coombs factory. The control architecture is described in Figure 1.

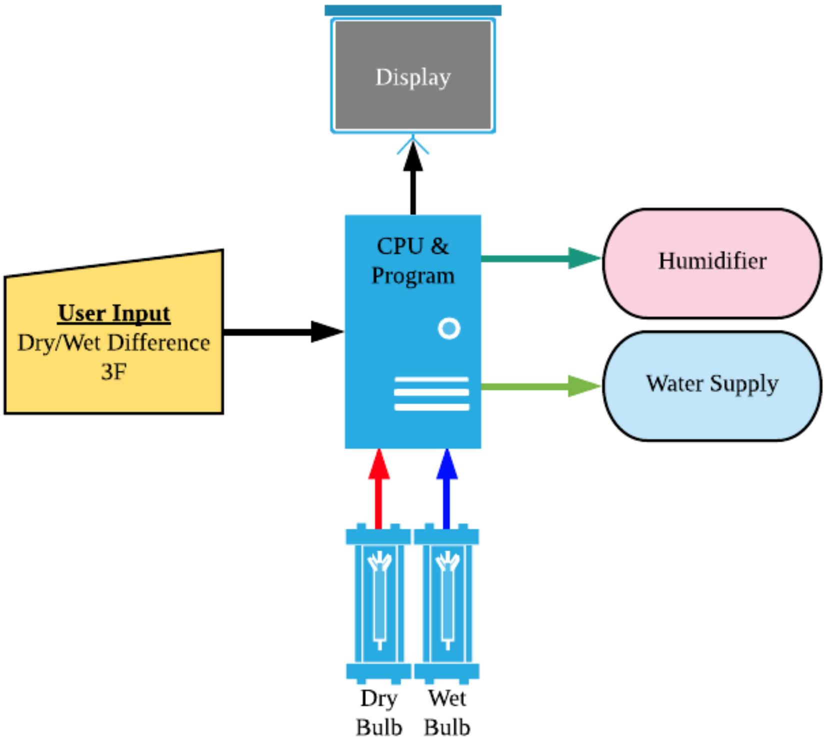

Figure 1: Control Architecture

3. RESULTS AND DISCUSSION

Dry and wet bulb temperature readings, its difference and relative humidity of the environment obtained using the control system during the experiment is presented in Figure 2.

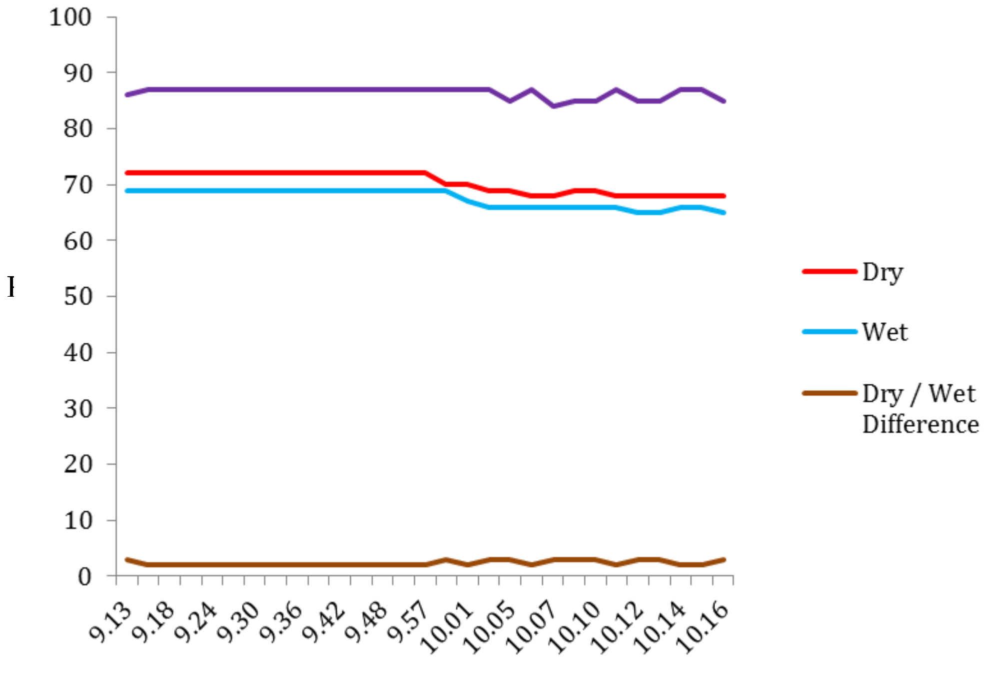

Figure 2 – Reading of dry and wet bulb temperature readings, its difference and relative humidity of the environment.

Dry bulb and wet bulb temperature difference was maintained at three degrees Fahrenheit and relative humidity was maintained at 87% during the experiment.

Advantages of the system

Reducing supervisor/ worker dependency is one of the major advantages of this system. The system shows Dry/Wet bulb values and its difference on a digital display which makes the rolling room operations easy. Human error in maintaining the required relative humidity could be avoided. The system facilitates to control relative humidity perfectly and dripping of water on rolling tea, dhool and floor is reduced leads to maintain favourable hygienic condition as required for implementing good manufacturing practices and food safety system standard.

The control programme facilitates to control various types of humidifiers operated in the industry to control humidification. Depend on the type of humidifier, water flow, fan activity & speed, fog emitters/ nozzles can be controlled using this system.

5. CONCLUSIONS

The automatic control system facilitates to maintain required hygrometric difference of 2 – 3 °F in the environment in the rolling room. The system can be installed to any existing humidifier at low cost around twenty five thousand rupees.

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GENERAL DISCUSSION

Dr I S B Abeysinghe, Director of the Institute prior to open up the technical discussion, solicited the audience to utilize the new innovations on automation in tea processing in view of efficient energy utilization and product quality improvement which are current needs of the industry. He further stressed that such added advantages are tools for minimizing COP on manufacturing, addressing worker shortage and to better position Sri Lankan teas in the competing international markets.

Questions to Director:

Q: (Mr. Saman Premalal)

It was crucial that presence of residues of banned chemicals in Sri Lankan teas. Can TRI take action against the current legal framework regulating pesticide movements in the country?

A: (Director)

Pesticide regulation in the country is legally bound with the Office of the Pesticide Registrar and TRI has no interventions in this regard other than conveying the repercussions to the industry at PeTAC level. As a national interest, it should be a collective responsibility by Crop Life Sri Lanka, Agrochemical agents and stake holders etc. for wise use of inputs.

Q: (Mr. Eranda Welikala)

Residue testing of teas prior to shipment is a huge obstruction for us as the results from overseas laboratories get delayed. How could TRI or the Ministry assist in this regard?

A: (Director)

Unfortunately, no such accredited laboratories are available in the country and need to depend on such overseas laboratories. Additional attention by all stakeholders for strict adherence to TRI recommendations on GAPs in agrochemical usage, rational use of pesticides and record keeping will partly solve this issue. In parallel, SLTB does a routine monitoring of pesticide residues as a surveillance mechanism.

Q: (Mr. Chaminda Wickramasinghe)

Could TRI facilitate to establish commercial tea nurseries at RPCs to cater the demand of planting materials in the small holder sector as a means of accelerating replanting?

A: (Director)

At Tea Research Board level, we have made this request and it is important to formalize a buy back procedure as a guarantee to the RPCs.

Q: (Mr. Kolitha Ariyasena)

Japanese government is continuously adding chemical lists with MRLs which is an impediment for Sri Lankan producers. Could TRI get clarification on these?

A: (Director)

Tea being a beverage as all other food products, invariably need to comply to such additional standards. TRI and SLTB have recognized EU, Canada, USA, Thaiwan, China etc. besides Japan are pay attention how best Sri Lanka could adhere to respective compliances.

Questions on Electrical Energy Saving:

Q: (Mr. Kolitha Ariyasena)

Leaf standards, leaf surface moisture etc. will impact on electrical energy consumption in the factory. How did you consider them in generalizing the findings?

A: (Dr. Botheju)

When designing the study protocol, all attributes to electrical energy consumption were utilized for tabulating data, plotting curves and modeling.

Q: (Mr. Pahathkumbura)

Will the UNDP Funded project support in replacing existing motors with high capacity motors?

A: (Mr Chamila)

Project will not facilitate to change motors but to improve factory efficiency as a whole.

Q: (Mr. Saminda Dissanayake)

What would be cost entire fixing?

A: (Mr Chamila)

Approximately Rs. 200,000 and NAMA project will bear upto Rs. 45,000 and the life spab would be about 10 years.

Questions on Humidifiers:

Q: (Mr. Saminda Dissanayake)

Will an individual sensor cover the entire rolling area?

A: (Dr Anurudda)

Require more observations on RH to decide on the coverage.

Q: (Mr. Ekanayake)

Any observation on industrial appliances as against your research application of humidifiers?

A: (Dr Anurudda)

Most of the units available in the market cannot be continuously used under high humidity conditions in tea factories. Our approach was found to be effective, durable and affordable and also has potential as a component to be adopted to the main control system in the factory.

Questions on Fluidized Bed Drier:

Comment: (Dr Wasantha Gunatilake)

It is important to cost automation operations and payback period etc. for the industry to capture the new technology.

A: (Dr Raveendran)

Approximately Rs. Mill 1.2 – 2.