An Automated Controlled System for Electrical Energy Saving in Trough Withering

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BACKGROUND

Black tea processing

I. Withering
II. Rolling and roll breaking
III. Fermentation
IV. Drying/ Firing
V. Grading & Packing





Withering

- First and most important unit operation
- Directly impacts to the quality of made tea.

➢ **Process Parameters considered in withering**

I Relative Humidity - (hygrometric difference)

non wet leaf 4 - 6 °F

wet leaf 8 -10 °F

II Temperature - < 90 °F (Hot air damper)

III Airflow Rate - 20 cfm/kg GL (0.6 m3/ min/kg GL)

(Ambient & Hot air dampers)

"Withering consumes 49-61% from the total electrical energy"

40 % saving of electrical energy can be achieved by using VSDs (Daranagama, *et al.*, 2002)

Solution → Control System

In practice, above saving can only be achieved if someone pay attention on VSD and keep it continuously controlling manually, during the withering time according to the parameters.

➢ Real benefit of VSD not achieved since the lack of controlling.

Solution elaborated …

If we can do ..,

- Automatically control of
  VSD
  Withering Air Temperature

We shall be able to achieve a successive withering with low cost

How we built-up the solution ….?

We have based the system on …

"Computer based mathematical model, developed for withering"

(Botheju *et. al* 2009)

Approach

This project was conducted to develop and establish the automated control withering system.

To Do that …..,

- The model was modified and further developed for airflow rate at different frequencies of VSD.
- Developed a software program interfaced with a microprocessor based controlling system.

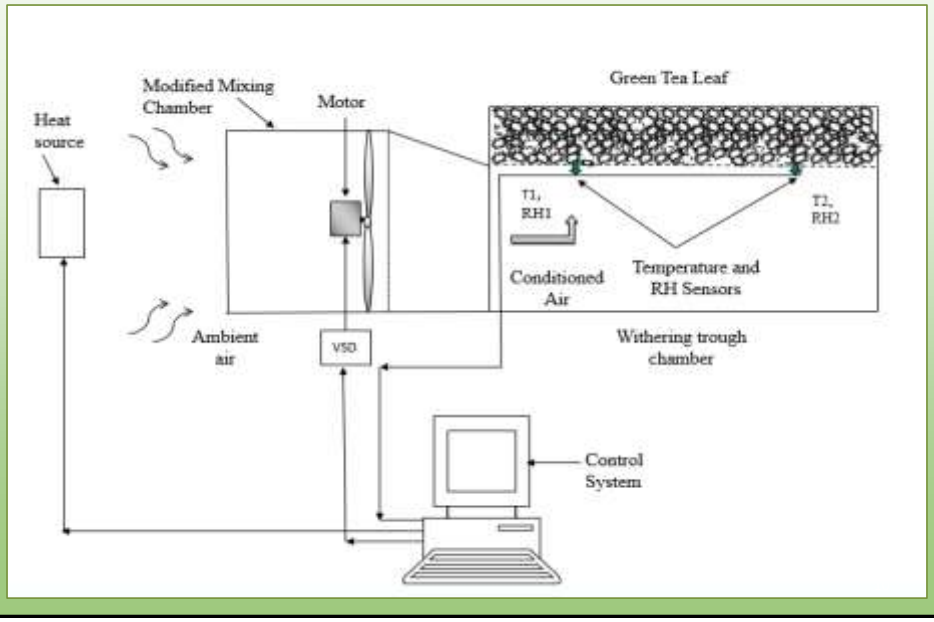
OBJECTIVE

To develop a control system for trough withering for minimizing the electrical energy consumption while preserving the quality of withered leaves.

Where We Did the Experiment ?

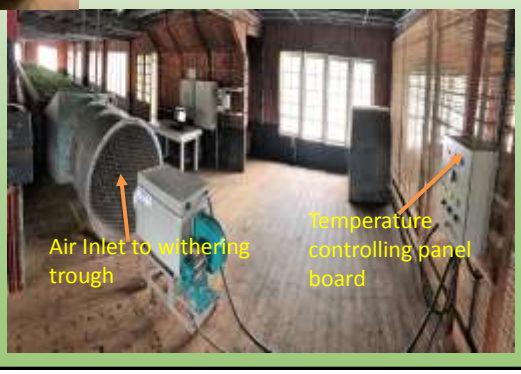
- Location - St. Coombs Estate tea factory, Tea Research Institute, Talawakelle
- Commercial withering trough
  - Size - 60'x6'
  - Fan size - 48"
  - Motor capacity - 7.5Hp

The experimental setup for withering



Developed control system

Experimental Withering setup



System Architecture

Relative Humidity

Initial Moisture content

Leaf temperature

Software Program

Temperature

calculate

Real time, predicted Moisture content /Air flow rate

Real time Moisture content

Functionality

- Comparing Predicted moisture content with Standard withering curve and take the difference
- Adjusting mass flow rate of air iteratively to minimize the difference according to above difference.
- Providing necessary output signal to the VSD and the heat source

Don't Forget …

Airflow controlling optimizes the consumption of electrical energy

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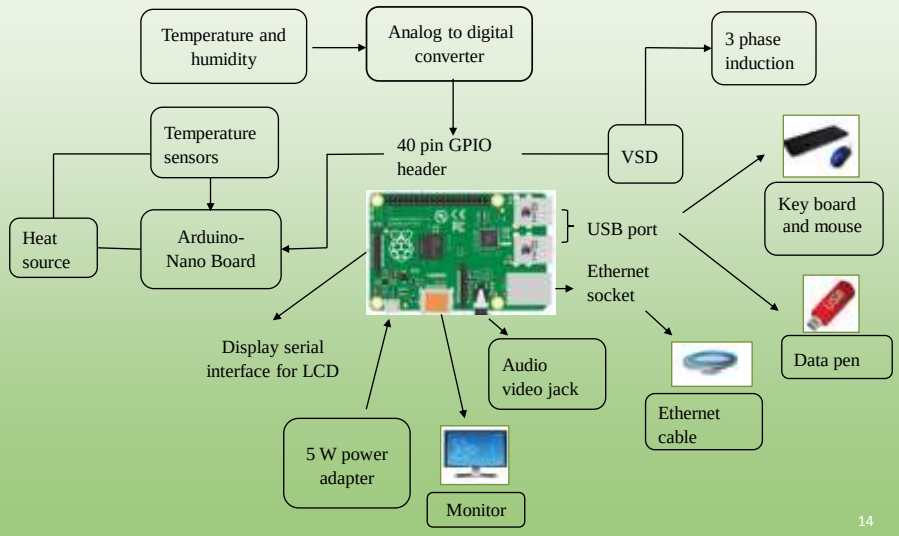
Electronics components used to develop control system

(a) Raspberry pi 3 Model B



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(B) Variable speed drive (ATV 312HU15N4)

(C) Arduino-nano (AT mega 328)

(D) Sensors

(i) Humidity sensors
(Honey well, HIH 4000 series)

(ii) Temperature sensors
(LM35, Texas instruments)

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Data Collected With Control System

- Loading Tea leaves - @ 2.5 $kg \cdot ft^{-2}$.
- Determining moisture content
  - Initial moisture content using MW oven method
  - 1 hr intervals
- Withering using control system.
- Recording Data.
  - Temperature,
  - Relative Humidity
  - Moisture content
  - Frequency

Without Control System

- VSD frequency

  - 50 Hz until the 1st turning of leaf
  - reduced to 45 Hz and operated for 4 Hrs.
  - reduced to 40 Hz. after 4 hours and operated till the end

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Analytical Instruments and Methods

- Measuring power consumption
  (Fluke, model 434 series ii, Romania)

- Analyzing quality parameters of tea samples
  (Robert and Smith method)

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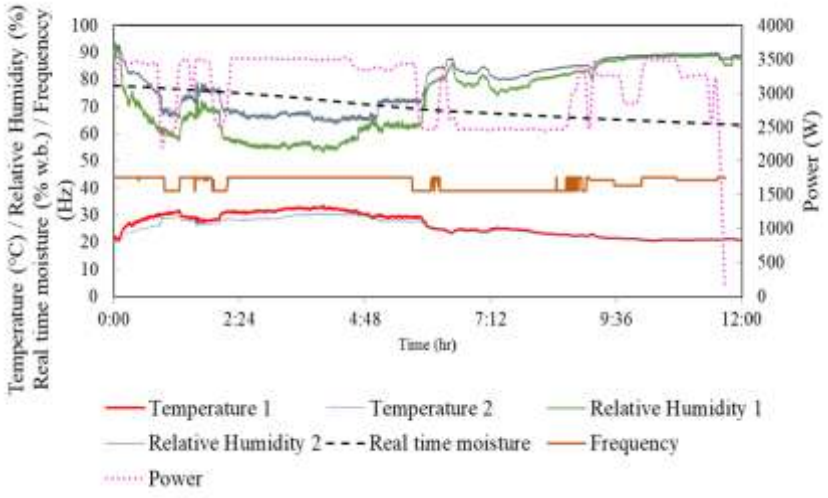
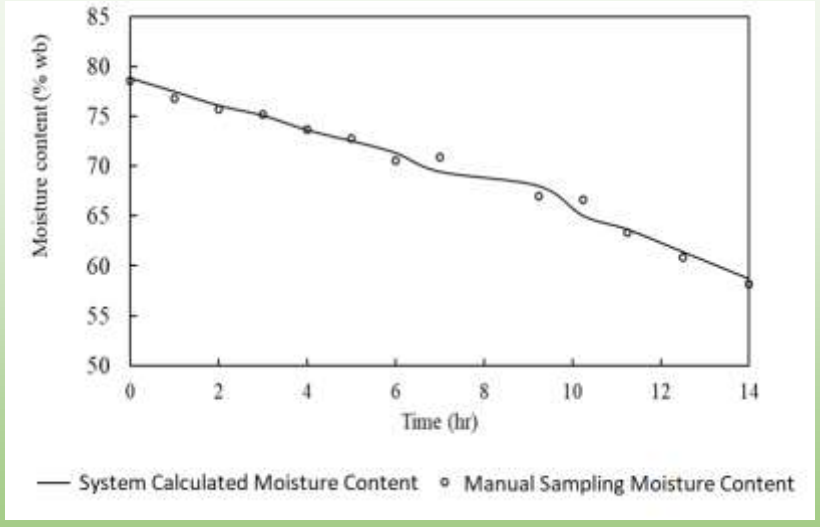
RESULTS – Obtained from control system



Comparison of Moisture Content



System calculated moisture contents is closely follows the withered leaves moisture contents

The initial and final leaf moisture content, energy consumption, removal of moisture comparison

Experiments		Initial MC % w.b.	Final MC % w.b.	Withering period hr	Energy kWh	Removal of Moisture $kg.kW^{-1}h^{-1}$	Specific Electricity consumption $kWh.kg^{-1}$
With control system	Trial I	78	57.5	11:45	36.25	11.97	0.18
	Trial II	76.2	57.6	11:00	38.76	10.18	0.18
	Trial III	75.2	56.6	12:00	38.57	9.9	0.17
Without control system	Trial I	77.2	57.1	16:00	55.92	7.55	0.27
	Trial II	79.3	56.3	16:40	64.34	8.48	0.35
	Trial III	78.6	57	15:45	66.24	6.82	0.34

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Quality Parameters of the Made Tea

Quality parameters	Theaflavins (TF)	Thearubigins (TR)	Color	Brightness (%)	TR/TF
With control system	0.95	14.8	4.98	17.8	15.5
	0.94	13.7	3.84	23.3	14.7
Without control system	0.84	13.7	3.9	21.2	16.3
	0.86	13.6	3.9	19.8	15.8

SUMMARY

A. Electricity energy varied between 55 and 67 kWh without control system. It was reduced to 36 - 39 kWh with control system leading to a saving of 39%

B. Specific electricity consumption reduced from 0.27 – 0.35 kWh to about 0.175 kWh with the use of control system

C. The saving of electrical energy by 0.13 kWh.kg $^{-1}$ would save electrical energy by 19.5 GWh with the adoption rate of 50 % of control system

D. Above saving would lead to reduce COP of one kg of made tea by Rs. 2.00. Hence, a factory produce 40,000 kg/month would save approx. Rs. 1 Mn annually.

FUTURE PROSPECTS

- Microprocessor based

User console Main Controller

- User friendliness (GUI)
- Precise controlling in the process
- Data logging and monitoring

  (temperature, humidity, power consumption etc.)
- Web interface to monitor real time & historical data

Thank you

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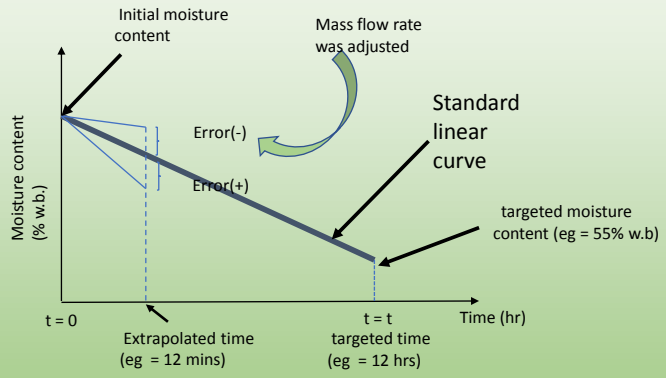
Standard linear curve



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