

**Energy Efficiency Improvement of Tea driers in Sri Lanka**  
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## **Abstract**

The tea industry is one of major agro-industrial sectors and it is the second largest black tea producer in the world. The thermal energy, produced by burning mainly firewood is used in processing of tea.

The energy study done on combustion systems in Sri Lanka, mainly in tea drying, has found that moisture content (43 %) and large sizes of firewood used for combustion are directly related to the low combustion efficiency (60%) of the existing furnace.

The National Engineering Research and Development Centre of Sri Lanka (NERDC) conducted studies at a tea factory to reduce thermal energy requirement for the tea dryer. Wood chips were introduced instead of wood logs, as a fuel for the drier.

The pilot scale plant is in operation at the same factory, introducing wood chipper, new grate and controlled screw feeder to feed wood chips to the existing furnace, without modifying it. It maintained a constant temperature inside the dryer by sensing temperature inside the dryer and adjusting the motor speed accordingly of the screw feeder. Further, by introducing an agitator it prevented lumping up of wood chips on the grate at the end of the screw feeder.

When producing of tea, the net saving of fuel wood is between 35- 45 %, which resulted due to, reduction of warming up period of the furnace with introduction of wood chips, screw feeder control in the system and less moisture content of wood. The other advantages are improvement of quality of tea produced due to constant temperature inside the dryer, reduction of utility of labour, less electricity consumption, reduction of environmental pollution, introduction of fast growing wood species and hence deforestation and creation of employment opportunities for villagers.

**Key words:** Tea industry, wood logs and wood chips.

## **1. Introduction**

Tea industry is the biggest agro base industry in Sri Lanka and it is the major income of the up country people. It is contributing the national economy through potential employment creation and export earnings and also largest exporter of this product. Due to better quality of the Sri Lankan tea, it is famous throughout the world as Ceylon tea. In production of tea, it consumes both thermal and electrical energy in the ratio of about 85:15. Firewood is the main source of thermal energy used for tea drying. It is the biggest industrial consumer of fuel wood in the country and accounts for about 24 % of the total consumption in the industrial sector <sup>[3]</sup> accounting for about 326,000 metric tons (1997) of annual consumption of fuel wood <sup>[1]</sup>. At

present, wood logs are the main form of fuel wood used to generate hot air for tea drying and a small amount of heat is also used for withering.

Since 1990's, the industry is affected badly due to scarcity of fuel wood (mainly rubber wood) in the country. Some factories have been converted conventional wood fired air-heating systems to diesel fired air-heating systems. As a result the country's dependency on fossil fuels for its energy needs was further increased. Further, the cost of production is increased rapidly due to increase of oil prices in the world market making our product less competitive in the international market. This affects badly the national economy. Also burning large amount of oil annually contributes to environment pollution and health hazards due to emissions of sulfur dioxide and carbon dioxide to the atmosphere. Due to the above facts, the tea factory owners who are having fuel oil fired heaters are looking forward to switch back to wood based system.

## 2. Methods and Materials

### 2.1 Conventional method of tea drying

After plucking, withering, rolling and fermentation of tea leaves, it dried using hot air at a suitable temperature decided by the type of dryer being used for the operation. For example, Endless Chain Pressure (ECP) type dryers are operated at a temperature of 102 – 110<sup>0</sup> C. The hot air is generated by fuel wood or oil fired hot air furnace (fig 1) for this purpose.

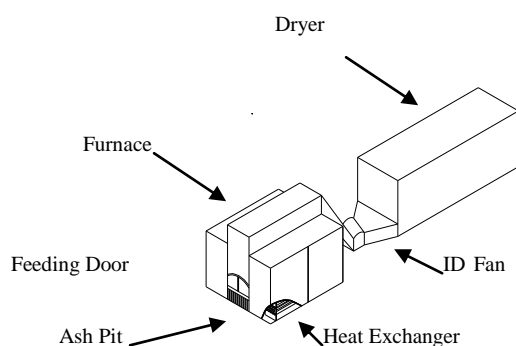


Fig.1. View of the Existing System

Furnace cum air heater is coupled to a suitable dryer. The atmospheric air is sucked through the heat exchanger and delivered to the dryer using an Induced Draught (ID) fan. The required quantity of air is controlled by manual adjusting of the flap. However, there is a difficulty in maintaining dryer inlet air temperature at a desired level.

### 2.2 Performance of the Conventional Tea Dryers

The National Engineering Research and Development Centre (NERDC) have been carried-out an energy study to find the performance of conventional tea dryers and according to the study, there is a wide variation of fuel wood consumption among the tea factories. Some tea factories,

especially in up country, use diesel fired air heaters in addition to fuel wood heaters. Fuel wood consumption for tea processing in three regions in Sri Lanka is summarized in Table 1.

Table 1 Energy Requirement for Processing of Tea

Region	Fuel wood consumption (Kg/Kg of made tea)
Up country	1.75
Mid country	1.80
Low country	1.81

The furnaces of wood fired tea factories are designed for wood logs for burning in it. Therefore, wood logs are split into 75mm x 75mm 1000mm before they are fed in to the furnace. The wood logs are fed to the furnace by labourers manually. Although provisions are available to control air / fuel ratio, it is difficult to do finer adjustments due to practical constraints. Controlling of air and feeding of logs, is too much operator dependant making it difficult to achieve an efficient operation consistently.

The major findings of an energy audit carried out by the NERDC at the Deen Side tea factory, Gampola are as follows,

The current overall efficiency of hot air generation system is around 40 %

The excess air level in the flue gasses is more than 100 %, whereas the expected level is 40 %

The Moisture Content in Wet Basis (MCWB) of wood logs is more than 43 %



Fig. 2. Manual Feeding of Wood Logs

Range of fluctuation of hot air temperature is almost  $\pm 20$  % affecting the quality of the Made Tea (MT).

The specifications of the furnace and dryer at the Deen Side Tea Factory are given in the Table 2.

Table 2. Specifications of the Furnace & Dryer

Item	Specifications
Furnace	Fixed grate type, Tubular air heater, Cast iron tubes 400 kW <sub>th</sub> hot air generating capacity
Dryer	ECP type, 4 ft width, 125 Kg /h (made tea) drying capacity

### 2.3 Developed Method

The NERDC developed method to improve combustion efficiency, to minimize the fluctuation of hot air temperature and also to minimize the moisture content of fuel wood of the wood fired tea drying furnaces include the following,

- Instead of wood logs, wood chips are used. The most suitable size of the wood chips was found as 40 mm x 40 mm x 7 mm.
- Wood chipper (Figure 3). The required sizes of wood chips (Figure 4) are prepared using this equipment
- To maintain the moisture content of the wood chips below 20 %
- A special screw conveyor designed and fabricated for this purpose. It has been developed to have a smooth operation.
- Modified grate replacing the existed one. The replaced grate has a special feature of having an inclination across the grate & along the grate in order to spread wood chips evenly.
- Agitator attached to the end of the screw conveyor to enhance the spreading of wood chips.
- Electronic wood chips feed controller system



Fig.3. Wood Chipper Developed by NERDC



Fig.4. Rubber Wood Chips

After manufacturing all items of the developed system, it was incorporated to the existing wood log furnace. Then the system was tested for wood chips which were produced by the chipper (Table 3) & Gliricidia pieces which were produced by manually (Figure 5).

Table 3. Specifications of the NERDC Wood Chipper

Parameter	Designed Value
Capacity	300 kg/h, 40 % moisture in wet basis
Motor power	15 kW
Maximum wood diameter	50mm
Wood chips size	40mm x 40mm x 7mm

This system was tested at Deen Side tea factory at Gampola in the Central Province of the country. There are two furnaces cum air heaters coupled to two dryers separately. The improved system was retrofitted to one set of furnace & dryer.



Fig.5. Gliricidia Pieces Produced Manually

Screw conveyor (Figure 6) is the device which is used to convey wood chips to the furnace. This machine was developed to feed- rubber wood chips & Gliricidia pieces. Fuel wood chips are loaded into the hopper to flow down gradually onto the screw with the assistance of a vibrator, which operates intermittently. The operation period and idling period of the vibrator can be changed according to the necessity. The screw, which is located at the bottom of the hopper, is rotated by an electric motor through a gear box. The chipped fuel wood travels into the furnace, with the rotation of the screw. The maximum rotation speed of the screw has been limited to 5 rpm. An attachment is fitted at the end of the screw shaft to spread out the chips on the fire grate.



Fig.6. Screw Coveyor Couple to the Existing Furnace

The prevailed grate was designed for burning of wood logs and therefore it was not suitable for wood chips. When wood chips are burnt on that grate, it can be observed that a poor spreading of chips on the grate. As a result, it showed a bad combustion performance, while forming wood chips lumps on it. Apart from that, a gap between fire bars of is high and hence a considerable amount of chips fall down to the ash pit without burning. The best option for wood chips combustion is to have a moving grate. But, this system is more complicated and the cost is comparatively high. Considering all these facts, the NERDC designed and constructed a grate having a shape, which assists to spread wood chips on the grate as much as possible.

Electronic wood chips feed controlling system is incorporated into the fuel wood feeding system. The temperature sensor senses the temperature of hot air and is used to control the rotation speed of the feeding motor via the variable speed drive. Thus, the rate of feeding of wood chips is controlled according to the hot air temperature and to maintain it within a close range. Fig.7. shows the schematic diagram of the system. The set temperature range of the controller is  $102^{\circ}\text{C}$  to  $110^{\circ}\text{C}$  for this system. The frequency of the input current for the motor of the screw feeder is not changed (50 Hz) up to the temperature of  $102^{\circ}\text{C}$ . Then, the frequency is gradually decreased up to 25 Hz, when the dryer inlet temperature reached at  $110^{\circ}\text{C}$ . Thereafter, the frequency does not drop further for increased temperature and it maintained at 25 Hz level (see fig.8.), and which prevents stall of motor. This control mechanism was incorporated with the system to maintain smooth combustion process in the furnace.

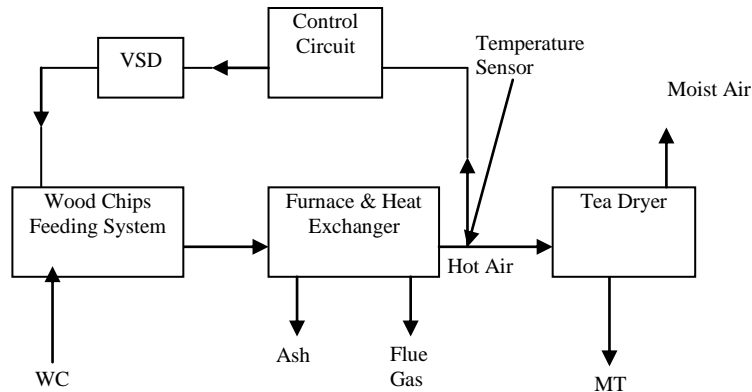


Fig.7. Schematic Diagram of the Developed System

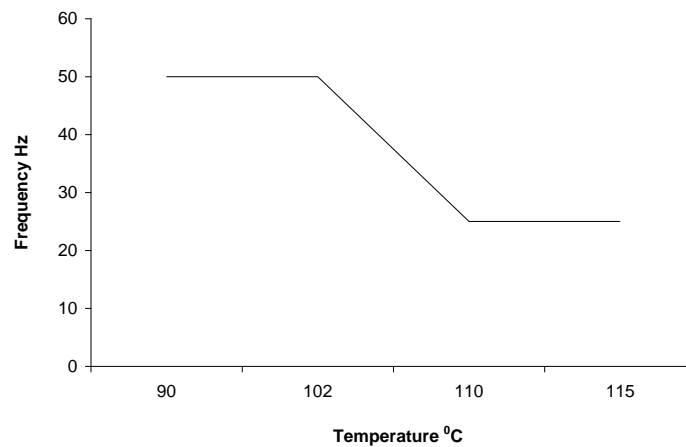


Fig.8. Frequency Variation According to the Temperature

### 3. Results

Separate tests were carried-out more than six months using wood logs, wood chips and Gliricidia as fuel and measured the following.

- a) Fuel wood consumption
- b) Quantity of made tea
- c) Amount of ash collection in the ash pit
- d) Amount of ash collection in the heat exchanger tubes
- e) Mean flame temperature just before the heat exchanger

The average results of the above are tabulated in table 4 & 5.

Temperatures at difference locations were recorded using temperature data logger at 10 minutes intervals. Further, moisture level of the fuel wood was measured using digital moisture meter.

Table 4 Summarized Results of the Test for Fuel Wood Consumption

Trial no	Type of wood	Fuel wood consumption @ 15 % MCWB (Kg)	Made tea (Kg)	Fuel wood consumption Kg/ Kg of made tea
1	Rubber wood chips	840	653	1.29
2	Rubber wood logs	1068	445	2.41
3	Gliricidia	753	572	1.32

Table 5 Summarized Results of Other Information of the Test

Type of wood	Ash collection in the ash pit (Kg)	Ash collection in the heat exchanger tubes (Kg)	Mean flame temperature just before the heat exchanger (°C)
Rubber wood chips	24.0	2.5	620
Rubber wood logs	19.5	4.5	557
Gliricidia	17.0	1.3	608

The percentage saving of the improved system, when compare with the conventional system was calculated based on the following data (in 2003).

Price of 1yard of rubber wood logs :Rs. 850.00  
 Weight of 1yard of rubber wood logs at 40 % moisture content on wet basis :250 kg  
 Price of 1kg of Gliricidia at 20 % moisture content on wet basis : Rs. 2.50

According to the above data, calculated results are summarized in the Table 6

Table 6 Summarized Results of the Test for Fuel Saving (in 2003)

Type of wood	Fuel wood saving (%)	Specific fuel wood cost (Rs/Kg MT)	Fuel wood cost saving (%)	Pay back period (months)
Rubber wood chips	-	8.20	-	-
Rubber wood logs	46	4.40	46	5.5
Gliricidia	46	3.30	60	2.5

After firing up the furnace, some time period is taken to warm up the furnace body. This was measured using a thermometer which is attached to furnace body. When it reaches to 120<sup>0</sup>C the furnace can generate hot air at the required level. This time period is called as the warming up period. The feeding rate is almost constant during this period, because there is no hot air delivery to the dryer. Therefore, the system is operated with the maximum feeding rate during this period. Once the furnace is warmed up, it can generate hot air with the temperature 100<sup>0</sup>C or above.

#### 4. Discussion

According to the results the lowest warming up period of one hour, illustrated for rubber wood chips. The main reasons are low moisture content (18% moisture content on wet basis), smaller size high bulk density ( $225 \text{ Kg/m}^3$  -  $250 \text{ Kg/m}^3$  at 20% moisture content on wet basis). As a result, flame temperature becomes highest with rubber wood chips (RWC) combustion.

It takes about one and half hours to warm up furnace body with the gliricidia pieces (GP) are used. The bulk density of gliricidia is ( $200 \text{ Kg/m}^3$  -  $225 \text{ Kg/m}^3$  at 20 % moisture content on wet basis) lower than RWC. Further, moisture content (22 % moisture content on wet basis) is little higher than RWC. These reasons cause to reduce the flame temperature and hence to increase the warming up period.

The highest warming up period is recorded for rubber wood logs (RWL) combustion. The main reasons are high moisture content (30 % moisture content on wet basis), large pieces and frequently opening the furnace door.

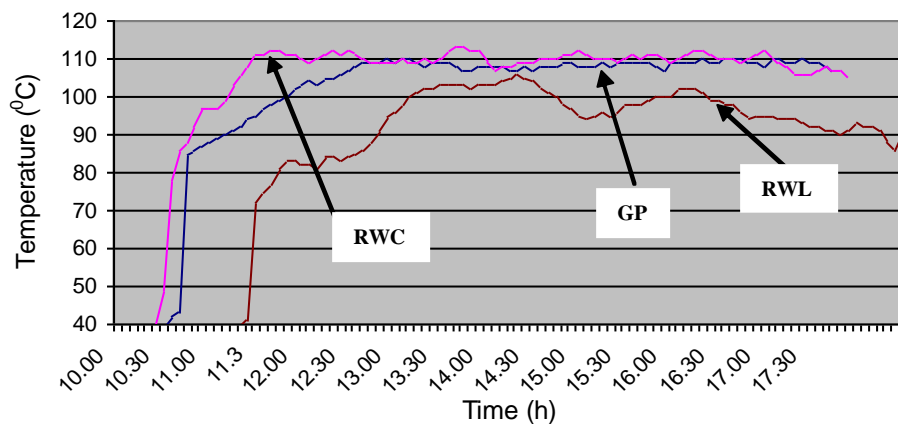


Fig.9. Dryer Inlet Air Temperature Variation

The results show that, there is around 45 % saving of fuel wood when the improved system is used. Therefore, if this technology is implemented to tea industry, the expected potential saving of fuel is around 146,700 metric tons. In other hand, there is a good controllability of the temperature of hot air with only around  $\pm 3$  % variation to the required value, whereas, in the conventional wood log firing system, this variation is about  $\pm 20$  %, according to our field trials.

In this semi-automated improved fuel wood feeding system, the operator is not exposed to radiation heat of the furnace, while feeding. The operator has only to feed fuel wood chips, stored in bags, into the hopper of the feeding system and hence it is a user friendly system. It was observed that ash deposition is less when the wood chips are used. This effect is help to obtain required temperature level even long operational periods. Otherwise, temperature level of the hot air can be decreased due to poor heat transfer.

## 5. Conclusion

The saving of fire wood, user friendliness of the system and ability to produce better quality tea makes this system more viable for our tea producing factories. There are about 1250 hot air furnaces operated in Sri Lanka. The economic benefit that can be achieved by converting all these furnaces into wood chip operated systems is given below, assuming an average production of made tea per factory per month as 40,250 kg,

The net saving on fuel wood per month per hot air furnace	- Rs. 113,102
Total saving for 1250 furnaces is approximately	- Rs. 140 million.

Apart from that, the following advantages are also associated with this system,  
Value addition due to improvement of quality of tea produced  
Reduction of utility of labour  
Less electricity consumption  
Introduction of fast growing wood species and hence deforestation and creation of employment opportunities for villagers

Therefore, it can be concluded that, wood chip combustion system are very much appropriate for replacement of wood logs combustion system.

## 6. Acknowledgement

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