

A SMALL SCALE OPEN SUN DRYER FOR SHEET RUBBER DRYING

**S Siriwardena, K K C K Perera, T A S Siriwardena
and J A D S S Ranasinghe**

SUMMARY

A model sun dryer, which utilizes direct solar radiation, has been devised to investigate the effectiveness of the dryer for drying of sheet rubber. Sun drying of sheets followed by smoking in a conventional dryer for a single day converts sun dried sheets to the form of Ribbed Smoked Sheets (RSS). This system has shown promising results, indicating possibility of using the system for drying of sheet rubber. Results indicate that drying could be completed within 3-4 days without any adverse effects on the raw rubber properties while enhancing the quality in terms of visual grading standards. Firewood consumption is also reduced as smoking is carried out only for a single day. This system significantly eliminates the cumbersome handling of sheets in conventional smoke houses and introduces more convenient and clean working environment. This system therefore, is in line with the current social demands for more user friendly systems in industrial sector.

INTRODUCTION

Sri Lanka produces four forms of natural rubber namely Ribbed Smoked Sheet (RSS), Crepe Rubber (CR), Centrifuged Latex (CL) and Standard Lanka Rubber (SLR). The total rubber production in Sri Lanka in the year, 2008 was 129,243 MT of which over 43% was produced in the form of RSS by mainly small and medium scale rubber farmers (Anon, 2009). In traditional smoking process, milled and undried rubber sheets with ribbed marks on the surface are smoke dried in conventional smoke houses. Hot smoke produced by burning firewood in clay furnaces directs to flow through the sheets hung in the smoke house. Smoke acts as the carrier medium for heat and the chemical substances presence in the smoke. Some of these chemical substances deposit on the sheets and help to prevent mould growth on the sheets during storage and enhance the resistance of sheets to oxidation. This conventional drying process requires 0.8-1 kg of firewood per one kilo of rubber and takes 5-6 days to achieve the complete dryness. Drying characteristics of conventionally dried RSS are given in Table 1.

Firewood, which was earlier considered as a cheap source of energy, has now become a scarce and expensive source of energy. This situation leads to narrow down the profit margin and to reduce the income of rubber sheet producers and workers involved in the industry in rural areas. Apart from the scarcity of firewood, increased demand of high quality and reluctance of workers to engage in this unhealthy smoking process have been a recurrent problem and have encouraged the

investigations on alternative and more user friendly drying systems for drying of sheet rubber.

Table 1. *Drying characteristics of RSS*

Characteristic	Value
Initial moisture content by weight (Wb) %	40 - 50
Final moisture content by weight (Wb) %	<0.7 - 1.0
Drying temperature (°C)	48 - 54
Average drying period (days)	4 - 5 days
Critical moisture content % (Wb) (w/w)	10 - 15
Falling rate period (% of total drying period)	85 - 95

Open sun drying which was considered as a cause of deterioration in quality of rubber has now been recommended for the drying purpose under controlled conditions by Rubber Research Institute of Sri Lanka (RRISL) (Tillekeratne *et al*, 1995). While open sun drying carries many advantages, it has its inherent disadvantages such as necessity of daily loading and unloading, quick unloading in rainy periods, possible contamination with dirt particles and difficulty in controlling the temperature.

This led to design a small scale “Green house type sun dryer” which utilizes solar radiation. This system avoids many of the draw backs mentioned earlier. Temperature developments, drying efficiency and properties of final products were investigated in this study.

Experimental

Model dryer

A model sun dryer (Fig. 1) having a chamber with dimensions of 1.2 m (L) x 0.9 m (W) X 1.9 m (H) and total capacity of 25 kg of rubber (approx. 50 sheets) was designed and fabricated. For ventilation purposes a chimney with a height 1.7 m and diameter 0.17 m was fixed. An inlet opening of $0.5 + 0.003 \text{ m}^2$ was maintained. The frame of the dryer was made out of timber and covered by polythene of gauge, 700. The dryer was installed on a rock bed.

Materials

Rubber sheets used in this study were manufactured according to the standard procedure at Dartonfield Rubber Factory, RRISL (Karunaratne, 1983). They had dimensions of 430 – mm (W) X 560-mm (L) X 3 –mm (T) and weights of sheets were varied between 0.5 0.6 kg.

Solar insulation measurements

Pyronometer (sensitivity 11 micro volts, temperature dependence $\pm 1.5\%$ from -20°C to 40°C) was used to measure the solar radiation.

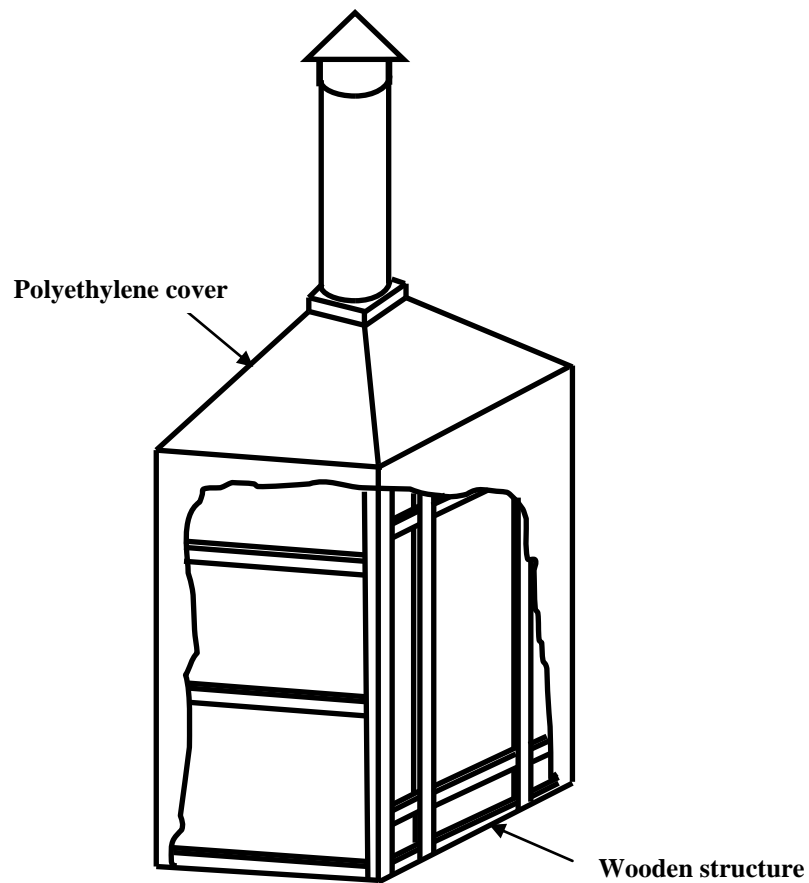


Fig. 1. Open sun dryer

Procedure

The experiment was carried out from 9.00 am to 6.00 pm every day, since sufficient solar radiation was mainly available during this period, forty rubber sheets (approximate weight and thickness of a sheet 0.5 kg and 0.3-0.4 mm respectively) were loaded at 9.00 am and temperature inside the dryer was measured at regular time intervals. Ambient temperature and solar radiation were also recorded with time. In the first step, an experiment was carried out without rubber sheets to investigate the heat build up in the dryer. At the second step, rubber sheets were loaded and temperature profile and weights of three rubber sheets hung at three different locations in the dryer (upper, middle and bottom) were recorded simultaneously on hourly basis. A few sheets were dried in the open sun and their weights were also recorded at the same time intervals. Total drying period was five days for all samples.

Few sheets were smoked at the same time in a conventional smoke house for the purpose of comparison. Drying curves and the system drying efficiency (η) calculated following the equation (I) were then determined.

$$\eta = \frac{W \times \Delta H_L}{I_c \times A_c \times T} \quad (01)$$

Where

- W = mass of moisture evaporated (kg) in time t (hour)
- ΔH_L = Latent heat of evaporation of water (J/kg)
- I_c = Insulation on collector surface (W/m^2)
- A_c = Collector area (m^2)
- T = Drying period (days)

Although one of the intentions was to study the airflow variation through the dryer, it was difficult to do so due to the very low air velocity generated inside the dryer by natural convection. Raw rubber properties of the dried sheet rubber were determined and subsequently they were compared with those of conventionally manufactured smoked sheets.

RESULTS AND DISCUSSION

The temperature variation inside the empty dryer and ambient temperature during the day time is given in the Figure 2. Solar radiation during the same period is also given in the same Figure. It shows that the temperature inside the dryer was always higher than the ambient temperature during the day, while minimum and maximum differences being around 5 and 9 degrees respectively. This type of dryer directly gains heat by the absorption of solar radiation by the materials being dried inside the dryer.

Figure 3 shows the temperature variation inside the loaded dryer. Ambient temperature profile and variation of solar radiation are also indicated in the same Figure. The air inside the empty dryer is hot and hence the temperature inside the dryer is higher than ambient temperature. When the rubber sheets are loaded they too absorb heat and as a result temperature inside dropped. However, it has been observed that still the inside temperature maintains a higher level than the ambient temperature. In these experiments, it was noted that when the temperature inside the dryer reached a temperature higher than 42°C, rubber sheets tend to melt. Therefore, as a remedial measure, the size of the air outlets was increased, so as to prevent the temperature rising above 42 °C. This however, needs to be practiced only during the peak hours of solar radiation normally between 12.00 noon and 3.00 pm.

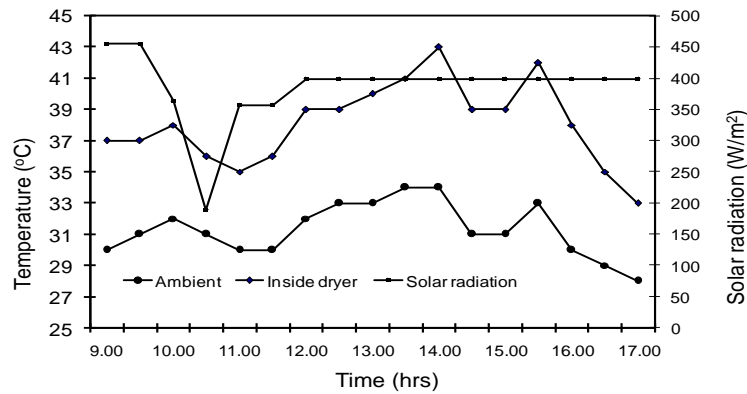


Fig. 2. Variation of ambient temperature, inside temperature of the empty dryer and solar radiation with time (Environmental conditions: sky bright, wind speed 2.5 m/s)

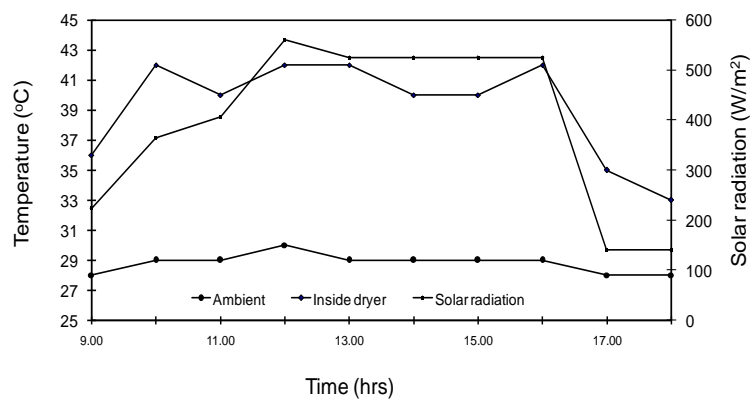


Fig. 3. Variation of ambient temperature, inside temperature of the loaded dryer and solar radiation with time (Environmental conditions: sky bright, wind speed 2.5 m/s loaded capacity 22.2 kg)

Drying curves of samples dried in upper, middle and bottom locations of the dryer and of the sundried sample (outside sample) are shown in Figure 4. It shows that drying rates outside the dryer were comparable to that of inside the dryer. There was a higher airflow outside, but the ambient temperature was comparatively low. However, this observation suggests that higher airflow outside the dryer has compensated the low ambient temperature. Condensation of moisture was observed in the early mornings on the walls at the top part of the dryer and evaporated during the first two hours of the day. However, this did not lead to any mould formation in sheets.

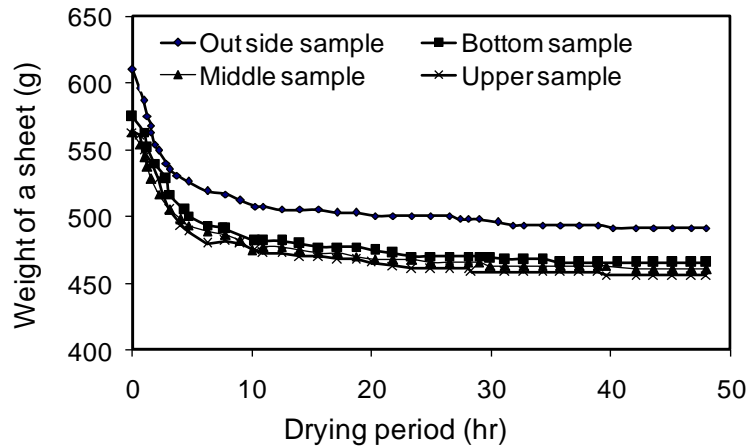


Fig. 4. Drying curves for rubber sheets

Drying efficiency

The system drying efficiency was calculated according to the equation no.01 using the data given in Table 2. It was 17% which is on the high side of the expected system drying efficiency of natural convection dryers which lies between 10-15% (Anon, 1997).

Table 2. Data used in determination of drying efficiency

Parameter	Value
The average moisture content in a sheet rubber % (w/w).	17.12
The average weight of a dried rubber sheet (kg)	0.554
Total weight of sheet rubber loaded in the drier (40 sheets)	22.2
Latent heat of vaporization of water. (kJ/kg).	2320
Total isolation incident on the drier (MJ/M ² /day).	12.096
Effective absorbing area of the drier (m ²)	1.08
Drying time (days)	4

Raw rubber properties of dried sheet rubber

Physical properties of rubber sheets dried at various conditions are given in Table 3.

It can be seen from the Table 3 that completely open sun dried sheets possesses minimum Po and PRI values indicating less tolerance to thermal oxidation. This may be due to direct exposure of the sheets to solar radiation. Higher values for Po and PRI were observed in sheets dried inside the dryer than those dried outside in the open sun. However, it should be noted that Po and PRI of all the samples were above the required minimum standards (Po - 30, PRI - 60) except the open sundried

sheets where PRI is 46. Sheets fully dried and smoked in the conventional smoke house exhibit the highest Po and PRI values probably due to absorption of more antioxidants from the smoke. However, these sheets had higher volatile matter content than the un-smoked or partially smoked rubber sheets. This may be due to the interruption of evaporation of volatile matter by covering the surface from the heavily deposited carbons suites on the sheets preventing migration of water diffusing to the surface. High volatile matter content favours mould growth. This observation favours the sun drying or partial smoking of the sheets.

Table 3. *Physical properties of rubber sheets dried at various conditions*

Sample	Dirt % (wt)	Ash % (wt)	Volatile matter % (wt)	Wallace plasticity		Colour
				Po	PRI	
Dried at the bottom of the drier	0.090	0.10	0.46	45	82	VLHB
Dried at the middle of the drier	0.036	0.10	0.38	47	74	VLHB
Dried at the top of the dryer	0.015	0.15	0.39	46	64	VLHB
Dried in the dryer for three days and followed by one day smoking	0.240	0.18	0.76	40	80	LHB
Open sun drying for four days	0.068	0.13	0.45	38	46	LB
Dried in 5 days in a smoke house.	0.560	0.38	1.42	48	88	BB

VLHB – Very light – honey brown, LHB – Light honey-brown, LB – Light brown, B- Brown.

As sheet rubbers are visually graded, colour and appearance play an important role in marketing of them. Light honey brown colour sheets fetch the highest price. Sheets dried in the sun dryer are free from ash particles and tar. Also, unsmoked or partially smoked sheets have very low dirt content indicating low level of contamination of foreign matter on sheets. Therefore, the quality of these sheets is higher than the fully smoked sheets in terms of colour and appearance.

CONCLUSIONS

The dryer has the system efficiency similar to conventional natural convection dryers. Installation of this system for drying of sheet rubber can reduce the use of firewood consumption and improve the quality of the rubber considerably. It has obvious advantages over open sun drying too. Adverse effects of open sun drying such as dirt and dust contamination, insect attacks are eliminated in this dryer. This drying system could be effectively used with subsequent smoking of sheet rubber for a single day to prevent mould growth and to achieve certain resistance to oxidation. Complete dryness of sheet rubber could be achieved within 3-4 days without adverse effect on the raw rubber properties of natural rubber. Main disadvantages of this dryer are necessity of an operator to control the temperature and short lifetime of the cover material compared to conventional smoke houses. Further research has to be carried

out to evaluate the technological properties of these rubbers dried in this Green House type dryer and to find a durable cover material with optimum thickness.

ACKNOWLEDGEMENT

Mr T C U Jayanetti, Mr T A U Jeyalal and Mr U Kalugalage, Undergraduate students from University of Moratuwa are acknowledged for their good work done in executing the project under their industrial training program during their undergraduate period.

REFERENCES

- Anon (2009). Statistical Pocket Book. Planning Unit, Ministry of Plantation Industries, 55/75, Vauxhall Lane, Colombo 2.
- Anon (1997). Project Report on Construction and testing of a green house type dryer for rubber industry. University of Moratuwa, Sri Lanka.
- Tillekeratne, L M K, Nugawela, A, Jayasuriya, M, Weeraman, S and Siriwardena, T A S (1995). Utilisation of sun light for drying of rubber. *Journal of Natural Rubber Research* **10**, 77-81.
- Karunaratne, S W (1983). Manufacture of ribbed smoked sheet. *Hand Book of Rubber Cultivation and Processing*, (Ed. Peries, O.S.), Rubber Research Institute of Sri Lanka, 1983.