SOLAR SEASONING OF TIMBER IN BANGLADESH

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ABSTRACT

A greenhouse type solar kiln developed at the Bangladesh Forest Research Institute for seasoning timber has been extensively tested for the last ten years. Twenty-one such solar kilns have been installed by the private and public wood industries for commercial seasoning of timber. Timbers of different species for various enduses have been satisfactorily seasoned. The technique is found simple, inexpensive and effective throughout the year. Solar seasoning of timber thus offers an excellent prospect in Bangladesh.

সারসংক্ষেপ

কাঠ সিজনিং করার জন্য বাংলাদেশ বন গবেষণা ইনষ্টিটিউটে উদ্ভাবিত গ্রীন হাউজ ধরনের একটি সৌর চুল্লী গত দশ বছর যাবত ব্যাপকভাবে পরীক্ষা নিরীক্ষা করা হয়েছে। একুশটি এই ধরনের সৌর চুল্লী ব্যক্তি মালিকানাধীন ও সরকারী কাঠ প্রতিষ্ঠানে বাণিজ্যিকভাবে কাঠ সিজন করার জন্য স্থাপন করা হয়েছে। বহুবিধ কাজে ব্যবহারের বিভিন্ন প্রজাতির কাঠ সন্তোষজনকভাবে শুকানো হয়েছে। এই পদ্ধতি সহজ, সুলভ ও সারা বছর কার্যকর। তাই বাংলাদেশে সৌর চুল্লীর সাহায্যে কাঠ সিজন করার খুব ভাল সম্ভাবনা রয়েছে।

INTRODUCTION

Bangladesh, with her high population density, is facing an acute crisis for timber. The present total roundwood supply is estimated at 7.9 million m^3/annum against the demand of 13.6 million m^3/annum (Anon 1993). The supply thus fails to meet the demand of sawnwood and industrial wood of the country. It is reflected in the percapita consumption of only 0.07 m^3 of sawnwood and 0.073 m^3 of fuelwood which are the lowest figures compared to even the neighbouring developing countries. With the increase of population, the requirement of timber will also increase resulting in more deficit.

There are generally two options to bridge the widening gap between the supply and demand of timber. The first one is to increase the productivity of the forest, and the second approach is the optimum utilization of the forest produce. The increased production of the forest produce is a long term task, while the quick augmentation of the supply position of the forest resource is its proper processing and scientific utilization. Seasoning, i. e., drying, is an important aspect in this regard. It improves the physico-mechanical properties, prevents premature damage and wastage caused due to physical degrade and biodeterioration. Seasoning thus enhances the service life of timber, and in turn, conserves the forest resource. It is estimated that over 0.24 million m^3 of sawn timber can be annually saved from degradation if about 50 per cent of the total sawnwood is seasoned prior to use (Sattar 1988).

Seasoning can be accomplished by various drying methods. Among them air drying is a simple and cheap method; but it is very slow and not efficient throughout the year. The steamheated kiln drying is the widely practised method. It is efficient, but expensive, complicated and energy intensive. It

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is therefore prohibitive for the small to medium scale wood industries. The situation calls for a simple and inexpensive technique which should be comparatively fast and effective round the year. The solution of the problem has been found in solar kilns which can season timber properly by using an inexhaustible solar energy. It is an environmentally benign technique which can also conserve the traditional sources of energy like coal, oil, gas, electricity or wood waste needed for conventional steam kiln drying.

DESIGN AND CONSTRUCTION

Numerous designs of solar kilns have been developed and large varieties of kilns have been constructed in different parts of the world (Aleon 1979, Bank 1970, Campbell *et al.* 1976, Casin *et al.* 1969, Chen 1981, Gough 1977, Harpole 1988, Lumley and Choong 1979, Plumptre 1979, Sattar 1993a, Sharma *et al.* 1972, Simpson and Tschernitz 1984, Wengert 1971, Yang 1980). These range from the most simple tent like structures to fully engineered structures equipped with automatic control systems. It is therefore not possible to make direct comparisons among them for deriving any standard solar kiln specifications. The purpose of drying as well as local conditions also vary so widely that no single design can meet the demand. But, in general, where labour is relatively cheap, the complexity aimed at increasing the efficiency is not necessarily beneficial.

In Bangladesh, like most of the developing countries, a large investment and the skilled manpower are not generally available for installing expensive and complicated driers. A simple and inexpensive solar kiln was thus designed at the Bangladesh Forest Research Institute (BFRI), Chittagong (Sattar 1982). It is of greenhouse type comprising a wooden frame superstructure. The roof is made with 5-6 mm thick glass sheet with an inclination towards the south at an angle equal to the latitude i. e., 21 to 27°N. All the walls, except the north side, are glazed either with ordinary 3 mm thick glass sheet or with transparent polythene sheet. For minimizing heat loss from within the kiln, the northern wall is made of timber cladding. Painted black corrugated iron sheets are fixed 30 cm beneath the glass roof as a heat absorber. One electric fan is incorporated for air circulation inside the chamber. Two vents, on inlet and another outlet, are provided to control the humidity. The floor is made of concrete which may be painted black. The design is for drying 3.5 to 6.0 m^3 timber which can be conveniently constructed using entirely local materials and facilities. Based on this design, one glazed by glass and the other by polythene sheets, were installed at the BFRI campus in the early eighties (Sattar 1982, 1987, 1989). Since then these kilns are being used mainly for research purposes and in a restricted form for commercial operations.

PERFORMANCE OF SOLAR KILNS

A total of twenty timber species of different dimensions were properly dried throughout the year for various enduses. Four charges of commercial timbers for flushdoor, tea-chest and jute mill shuttle were also dried. Conventional air drying and steamheated kiln drying were simultaneously undertaken for comparison (Sattar 1987). The satisfactory results of these studies encouraged the wood based industry to adopt this technology. Twenty-one such solar kilns of varying capacities ranging from 3.5 to 6.0 m^3 were installed by both private and public wood industries in different locations of the country. Timbers of various commercial species for furniture, joinery, construction and some specialty products were seasoned in these solar kilns (Sattar 1987, 1990, 1991). The results of the solar seasoning of timber have been based on the experimental trials so far conducted at the Institute. The following are the aspects which have been investigated.

Temperature

Temperature and relative humidity data of the ambient and inside the solar kiln were recorded during the process of solar seasoning. The maximum, minimum and mean values covering the four seasons of the year are given in Table 1 (Sattar 1992).

Table 1. Temperature and relative humidity in ambient condition and inside the solar kiln during drying

Time of Observation	Temperature (°C)							
	Ambient				Solar kiln			
	Day time			Night	Day time			Night
	max	min	mean	mean	max	min	mean	mean
1987-88								
i) Winter (Dec-March)	32.2	20.6	27.6	21.5	60.3	34.2	51.1	32.1
ii) Postwinter (April-May)	34.6	22.6	30.1	25.2	65.7	36.1	55.8	35.2
iii) Monsoon (June-Aug)	33.9	23.6	28.2	24.4	64.2	35.2	52.5	34.8
iv) Postmonsoon (Sep-Nov)	32.9	22.1	28.8	22.2	62.4	35.5	53.6	33.0
Time of Observation	Relative Humidity (%)							
	Ambient				Solar kiln			
	Day time		Night		Day time		Night	
	max	mean	max	mean	max	mean	max	mean
1987-88								
i) Winter (Dec-March)	85	60	90	80	80	45	100	92
ii) Postwinter (April-May)	90	70	95	85	82	51	100	94
iii) Monsoon (June-Aug)	100	85	100	94	85	60	100	98
iv) Postmonsoon (Sep-Nov)	90	72	95	87	84	53	100	96

It is seen from Table 1 that the solar kiln maintains an appreciably high temperature throughout the year. It attains the maximum temperature from 60.3 to 65.7°C between 12.00 noon and 2.00 pm on clear days. The average temperature inside the drier ranges from 51.1 to 55.8°C against the ambient temperature range of 27.6 to 30.1°C during the day time (Table 1). Even on cloudy days, the solar kiln can absorb intermittent sunlight and diffuse radiation. In similar studies in India, Sharma (1975, 1981) also observed that in cloudy weather the solar kiln could make use of the available intermittent sunlight and diffuse skylight to trap heat maintaining 5 to 7°C higher temperature than the ambient. The mean temperature inside the kiln during the night ranges between 32.1 to 35.2°C compared to the average atmospheric temperature of 21.5 to 25.2°C (Table 1). The higher night temperature in the solar kiln was also recorded with a lower ambient temperature by some other workers (Plumptre 1973, Sharma *et al.* 1981, Troxell and Mueller 1968).

Timber drying requires a temperature of 40 to 65°C for satisfactory operation. This range of temperature can be maintained even in a simple greenhouse type solar kiln of a suitable design. This is demonstrated by the BFRI solar kiln (Table 1).

Relative humidity

During drying the mean day relative humidity inside the solar kiln varies from 45 to 60% against the ambient mean day relative humidity of 60 to 85%. The maximum value likewise was markedly lower in the drier than that of the ambient. It is interesting to note that the relative humidity reaches up to 100% i.e., the saturation point, every night.

It is necessary to maintain a higher humidity during the early stages of drying to retard too fast drying to prevent the damage to the timber. This is why in all the conventional steam kiln drying schedules, there is a provision for a higher humidity and a lower temperature in the early stages of timber drying (Boone *et al.* 1988, Sattar 1980, Stevens and Pratt 1969). The solar kiln, more or less, maintains automatically a similar schedule. The high evaporation of moisture from the timber during the initial drying helps to achieve a higher humidity. The vents of the solar kilns, however, need to be regulated periodically to remove the excess moisture.

Drying time

Timbers of different species with various enduses were dried using the solar, air and steam drying methods (Sattar 1987, 1992). Typical drying times of ten important species are presented in Table 2. The overall higher temperature followed by the lower humidity inside the solar kiln leads to a faster evaporation of moisture from the timber compared to timber for air drying. Thus the solar kiln takes 10 to 32 days to dry 2.5 cm thick timber. In contrast these timbers require 26 to 84 days to air dry even in favourable periods (Table 2). Solar drying is more or less effective throughout the year. More importantly, solar kiln can dry timber to a desired lower level of moisture content which cannot be achieved by air drying. It is found that solar drying is 54 to 72% faster than air drying. However, it needs 38 to 69% longer time than steam kiln drying (Table 2).

Drying defect

The qualitative assessment of drying defects was made visually at the conclusion of each drying (Sattar 1987, 1993b). Table 3 contains such drying defects developed in ten timber species in different processes. Drying defects were also assessed quantitatively from four timber species (Sattar 1993b) and are presented in Table 4.

No objectionable drying degrade is noticed in any batch of solar dried timber (Table 3). Checks, split and some form of distortion are found in many air and steamheated kiln dried timber. However, the average defect values in the solar dried timbers range from 0.02 to 0.18% (Table 4). These are low in magnitude and can be easily discarded during sizing and planing operations. These values in air dried timber vary from 0.90 to 2.37%, while the steam kiln dried timbers may cause 0.57 to 3.17% defects. These are markedly higher than those of solar dried timber and cannot be dressed out by normal woodworking operations. It is to be noted that the four categories of defects in solar dried timber are only 2.2 to 7.9% relative to those of air and steam kiln drying (Table 4). Thus the quality of the solar dried timber is superior to both conventional air and steam kiln dried stocks.

Table 2. Comparative drying times for 2.5 cm planks using different drying methods

Drying period and species	Sp. gr. (Green vol.)	Drying time (days) from green to 12% mc		
		Solar	Air	Kiln
i) Winter period : November-March				
Chapalish (*Artocarpus chaplasha*)	0.48	10	22	6
Toon (*Toona ciliata*)	0.46	12	26	7
Teak (*Tectona grandis*)	0.55	13	28	8
Champa (*Michelia champaca*)	0.58	15	34	9
Koroi (*Albizia procera*)	0.60	17	38	10
Chickrassi (*Chuckrassia velutina*)	0.62	17	40	10
Jarul (*Lagerstroemia speciosa*)	0.62	18	45	10
Garjan (*Dipterocarpus turbinatus*)	0.65	18	48	10
Jam (*Syzygium grande*)	0.67	21	50	12
Gamar (*Gmelina arborea*)	0.46	26	68	14
ii) Post-winter period : April-May				
Chapalish (*Artocarpus chaplasha*)	0.48	12	32	6
Toon (*Toona ciliata*)	0.46	14	36	7
Teak (*Tectona grandis*)	0.55	15	34	8
Champa (*Michelia champaca*)	0.58	18	34	9
Koroi (*Albizia procera*)	0.60	20	48	10
Chickrassi (*Chuckrassia velutina*)	0.62	20	51	10
Jarul (*Lagerstroemia speciosa*)	0.62	22	60	10
Garjan (*Dipterocarpus turbinatus*)	0.65	23	64	10
Jam (*Syzygium grande*)	0.67	26	68	12
Gamar (*Gmelina arborea*)	0.46	30	79	14
iii) Monsoon period : June-August			(18-20% mc)	
Chapalish (*Artocarpus chaplasha*)	0.48	18	58	6
Toon (*Toona ciliata*)	0.46	20	62	7
Teak (*Tectona grandis*)	0.55	21	74	8
Champa (*Michelia champaca*)	0.58	27	85	9
Koroi (*Albizia procera*)	0.60	28	93	10
Chickrassi (*Chuckrassia velutina*)	0.62	29	90	10
Jarul (*Lagerstroemia speciosa*)	0.62	32	106	10
Garjan (*Dipterocarpus turbinatus*)	0.65	31	110	10
Jam (*Syzygium grande*)	0.67	34	114	12
Gamar (*Gmelina arborea*)	0.46	40	123	14
iv) Post-monsoon period : September-October				
Chapalish (*Artocarpus chaplasha*)	0.48	12	36	6
Toon (*Toona ciliata*)	0.46	15	38	7
Teak (*Tectona grandis*)	0.55	16	40	8
Champa (*Michelia champaca*)	0.58	18	46	9
Koroi (*Albizia procera*)	0.60	21	50	10
Chickrassi (*Chuckrassia velutina*)	0.62	20	53	10
Jarul (*Lagerstroemia speciosa*)	0.62	24	65	10
Garjan (*Dipterocarpus turbinatus*)	0.65	24	67	10
Jam (*Syzygium grande*)	0.67	27	70	12
Gamar (*Gmelina arborea*)	0.46	32	84	14

Table 3. **Comparative drying defects developed in timbers of different drying processes**

Species	Drying defects developed in timbers of		
	solar drying	air drying	steam kiln drying
Chapalish	Nil	Minor end split and distortion	Minor end split and distortion
Toon	End check	Tendency to distortion	Tendency to distortion
Teak	Nil	End check	Nil
Champa	Nil	Severe end and surface check	End split and surface check
Koroi	Minor end and surface check	Tendency to distortion	Tendency to distortion
Chickrassi	End check	End check	End check
Jarul	Nil	Nil	Nil
Garjan	Minor end and surface check	End split and distortion	End split and distortion
Jam	Minor end check	Severe end split	Severe end split
Gamar	Nil	Nil	Nil

Drying stress

A high quality of drying is reported by many workers in different designs of solar kilns (Chen 1981, Exell 1990, Plumptre 1973, Ryley 1980, Sharma *et al.* 1972, Yang 1980). The reason is attributed to the reduction of drying stresses during the night due to rehumidification. The hypothesis however has not been experimentally verified. A study was undertaken to assess this aspect in the BFRI solar kiln. Along with the drying defects, the moisture gradients were ascertained from four timber species during solar, air and steamheated kiln drying (Sattar 1993b). The moisture gradients were taken to be an indirect measure of drying stresses.

It is found that the mid-drying is the critical stage when the moisture gradient is quite severe (Sattar 1993b). In the steam kiln drying, the stresses resulting from the moisture gradients connot be reduced during the drying process except at the end of drying when a conditioning treatment is applied. Thus the defects developed at the early stages cannot be avoided. But the solar kiln attains a moderate temperature and humidity during the critical stages of drying. So comparatively less severe drying stresses develop in the solar dried timber. Further, the cycling of humidity that occurs in the solar kiln from the day to night also relaxes the drying stress to a greater extent than is possible in conventional steam kiln drying. It is observed that the relative humidity reaches 100% over night (Table 1). This also causes a cooling of the solar kiln. Thus the timber surfaces also cool and become colder than their interiors which induces water movement

Table 4. Average drying defects developed in timber during drying by different methods

Drying method and species		Defect (as per cent of the surface area of planks)			
		surface check	end split	Distortion	
				bow	twist
Solar :	Chapalish	0.10	0.08	0.09	0.08
	Champa	0.11	0.06	0.10	0.10
	Mango	0.09	0.08	0.11	0.10
	Garjan	0.18	0.18	0.06	0.02
Air :	Chapalish	2.37	2.25	1.50	1.48
	Champa	2.11	2.18	1.71	1.58
	Mango	1.76	1.65	1.95	1.60
	Garjan	2.37	2.27	1.23	0.90
Steam :	Chapalish	2.43	1.68	1.51	1.67
	Champa	2.50	2.04	1.50	1.58
	Mango	1.23	1.45	2.58	2.23
	Garjan	2.86	3.17	1.24	0.57

Species	% Relative defects on average value							
	Solar to air drying				Solar to steam kiln drying			
	check	split	bow	twist	check	split	bow	twist
Chapalish	4.2	3.6	6.0	5.4	4.1	4.8	6.0	4.8
Champa	5.2	2.8	5.8	6.3	4.4	2.9	6.7	6.3
Mango	5.1	4.8	5.6	6.3	7.3	5.5	4.3	4.5
Garjan	7.6	7.9	4.9	2.2	6.3	5.7	4.8	3.5

from the inside to the surface of the wood. It is found that some moisture is actually absorbed by the surface (Sattar 1993b). This suggests that the development of less drying defect in solar drying is mainly due to the beneficial effects of nightly conditioning which reduces the drying stresses. In the air dried timber, there is no absorption of moisture by the surfaces. It thus does not get any chance of relieving the stresses to any extent. There is also less protection of rain and rays of the sun in air drying. In the crucial time between 12.00 noon and 2.00 pm, the ambient temperature reaches the maximum and so the humidity drops to the lowest level. This climatological condition also aggravates the drying defect in the air dried timber.

Thermal efficiency

Thermal analyses of the solar kiln were conducted for drying 1 m^3 timber from green condition to 12% moisture content during four seasons of the year (Sattar 1993c). The results show reasonable heat balances. Averaged throughout the year a total heat energy of 255 Mcal amounting to 22.8% of the input was utilized for drying timber. The remaining 77.2% of the heat energy totalling 868 Mcal was lost through various sources like ventilation, and conduction/convection from the walls, floor and roof. The peformance of this greenhouse type solar kiln can, thus, be improved considerably by minimizing these heat losses.

The BFRI solar kiln seems to be quite efficient, because its combined overall efficiency is found 18% (Sattar 1993c) which is higher than those of other similar kilns (Prins 1981, Win Kyi 1983). The efficiency which determines the drying potential of the solar kiln is thus acceptable.

Table 5. Heat use and loss from the solar kiln during drying timber in different drying seasons

Components of energy use and loss		Total energy required for drying from green to 12% moisture content Mcal (%)				Average of all seasons
		Winter	post-winter	monsoon	post-monsoon	
Evaporation of water (latent heat of vapourisation)		205 (19.8)	181 (17.3)	169 (12.6)	186 (17.4)	185 (16.5)
Hygroscopic water (heat of wetting)		12 (1.2)	13 (1.2)	17 (1.3)	13 (1.2)	14 (1.3)
Energy to heat timber load and other materials		50 (4.8)	58 (5.6)	66 (4.9)	50 (4.7)	56 (5.0)
Sub-total		267 (25.8)	252 (24.1)	252 (18.8)	249 (23.3)	255 (22.8)
Ventilation loss		44 (4.3)	53 (5.1)	61 (4.6)	53 (5.0)	53 (4.7)
Heat losses through	a) walls	338 (32.7)	340 (32.6)	487 (36.4)	351 (32.8)	379 (33.8)
	b) floor	164 (15.9)	169 (16.2)	241 (18.0)	178 (16.7)	188 (16.8)
	c) roof	220 (21.3)	230 (22.0)	297 (22.2)	237 (22.2)	246 (21.9)
Sub-total		766 (74.2)	792 (75.9)	1086 (81.2)	819 (76.7)	866 (77.2)
Total energy output		1033	1044	1338	1086	1221
Total energy input		998	1004	1305	1034	1085
Overall efficiency (%)		21.4	18.6	13.8	18.2	18.0

Drying economics

The economics of seasoning in the solar kiln along with the conventional drying methods was studied with various species and timber of different dimensions (Sattar 1982, 1987, 1989, 1992). Table 6 shows comparative drying economics of such four indigenous timber species (Sattar 1993d).

The high cost is the main constraint in installing conventional steam kilns for small wood using industries. The installation cost for a 3.5 m^3 capacity solar kiln is Taka 30,000 while the cost of an imported steam kiln is about 35 times higher in Bangladesh. It is of particular importance to mention that no materials for the solar kiln need to be imported; all components can be procured from the local market. The operating cost of a solar kiln is much lower compared to that of a conventional kiln (Table 6). A substantial expenditure is involved in the supply of steam to the conventional kiln, but the solar kiln receives free solar radiation for the required heat energy. It is interesting to note that the unit solar drying cost is less even than that of air drying. It is less than half that of kiln drying. It is further observed that the return on investment is as high as 107% which indicates that the capital investment will be paid back in less than a year.

Table 6. **Comparative drying economics for 2.5 cm thick planks of *Artocarpus chaplasha*, *Michelia champaca*, *Albizia procera* and *Gmelina arborea***

Sl. No.	Item	Solar kiln 3.5m^3	Air dry 9.0m^3	Steam kiln 14.0m^3
1.	Output of dried timber/annum	52.5 m^3 (15 runs)	54.0 m^3 (6 runs)	420.0 m^3 (30 runs)
2.	Operational expenditure/annum (Tk)			
	a) Interest on value of timber @ 15% annum	12,000	30,000	47,000
	b) Rent/interest on land value	6,000	10,000	10,000
	c) Fuel	-	-	220,000
	d) Electric power	3,400	-	13,500
	e) Loading and unloading charges	3,000	1,200	12,000
	f) Operating cost	2,300	-	72,000
	g) Water charges	-	-	10,000
	h) Maintenace	500		500
	Total	27,200	41,200	385,000
3.	Capital expenditure (Tk)			
	a) Initial installation	30,000	-	1000,000
	b) Cost of beams, sticks, etc.	3,000	5,000	10,000
	c) Working capital (1/4 operational exp.)	6,800	10,300	96,250
	Total	39,800	15,300	1106,250
4.	Total expenditure (Tk)			
	a) Operational expenditure	27,200	41,200	385,000
	b) Interest on total capital exp. @ 15%	5,970	2,300	165,940
	c) Depreciation on initial installation @ 10% for solar kiln and 5% for steam kiln	3,000	-	50,000
	Total	36,170	43,500	600,940
5.	Drying cost/m^3 timber of 2.5 cm planks (Tk)	689	806	1430
6.	Return on investment (assuming drying cost of Tk 1500/m^3)	107.0%	244.9%	2.7%
7.	Pay back period	11.2 months	5.0 months	37.6 yrs.

Conclusion

Timber can be seasoned properly to the desired lower level of moisture content in suitably designed solar kilns. The greenhouse type solar kiln developed at the BFRI is found to be suitable for this purpose. The quality of the solar dried timber is superior to both conventional air and steam kiln dried timbers. Solar seasoning is found technically sound and economically attractive. This type of solar kiln can thus conveniently be used for seasoning timber in tropical locations like Bangladesh.

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