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Effectiveness of Timber Solar Dryers in Reducing Drying Time and Drying Defects in Comparison to Air Drying

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Abstract: An air drying shed and two green-house type of solar dryers of different designs were constructed at the Forest National Corporation sawmill at Suki town, Sennar State. Timber stacks in all three dryers consisted of 120 sunt (*Acacia nilotica*) boards each stacked in 15 rows with 8 boards in each row..Three sample boards were selected in each stack for periodic measurement of moisture content (M.C.) and following the progress of drying in the three dryers. The three sample boards were placed at different levels of each stack. Each sample board was taken out at two days interval, weighed and returned to the stack. The dry-blub and wet-bulb thermometer readings were recoded and relative humidity worked out for each dryer. The moisture content was also calculated at two days interval. The results obtained showed that the average temperatures in the two solar dryers were significantly higher than that of the air dryer (ambient temperature). This resulted in a lower average final M.C. and lower equilibrium M.C. in solar dryers than in the air dryer. Solar dryer with high collector (SH) was the most efficient of the three dryers, with average final M.C. of 10.7% and equilibrium M.C. of 6.7%. This was followed by the solar dryer with low collector (SL) with average final M.C. of 11.9% and equilibrium M.C. of 7.5%, and lastly the air dryer with average final M.C. of 13.8% and equilibrium M.C. of 9.2%... The drying defects observed included minor warping incidents in the form of bowing which was more pronounced in air drying than in the solar dryers.

Keywords: Lumber drying - Solar energy - Rate of drying

Introduction

Wood has great virtues and there is urgent need to recognize these virtues and develop means of protecting and rationalizing the use of such a valuable resource. When used for construction, furniture, millwork and other similar uses wood will perform better if it is dried prior to use to a moisture content (M.C.) close to the level it will equiliberate at in use (Wengert, 1977). The benefits of timber drying include improved stability, reduced defects such as checks and distortions, increase in strength, improved gluability and improved thermal properties (Bootle, 2004). Observations made at different timber depots in Sudan as well as sawmills, showed that splitting and distortion of timber, resulting from uncontrolled drying, are among the major causes of timber losses and failures if not the major ones (Nasroun, 1979). This is due to two main reasons: lack of proper drying and the hot dry conditions prevailing in many parts of Sudan. Proper wood drying is, therefore, an essential process in nearly all wood utilization practices. This means that timber must be dried to the proper moisture content for end-use requirements. This is essential because the inherent value of timber and its potential commercial uses are generally affected by the nature and magnitude of the defects that occur during drying. This is why timber markets are demanding greater emphasis on improved quality of timber drying and in-service moisture content.

Wood drying, however, is the most energy intensive of all wood manufacturing processes. The intrinsic energy required to dry a thousand board feet of sunt wood , for instance, from 80 % to 7 % M.C was estimated at 3288 thousands btu’s (Skaar, 1977; Nasroun, 1983). Water is removed from wood by supplying a large amount of thermal energy. The different drying methods differ from one another by the source and method of supplying this energy. Air (or natural) drying is simple and not costly, but it takes a long time and dries timber to the equilibrium moisture content only. Kiln drying, on the other hand, is faster and dries wood to any moisture content desired, but it is very expensive to install and operate and requires skilled operators. Solar drying is expected to be in the middle and have most of the advantages of the two traditional methods mentioned above, so solar energy applications began to look more attractive in the past decades (Simpson and Techernitz, 1977).

Solar dryers should improve drying conditions because the temperature available for drying is raised above ambient temperature, air circulation is sustained over the drying period and some control is exercised over the relative humidity (Troxell, 1977). If solar drying reduces drying time over that of air drying and if drying defects are within acceptable limits, then this will be a great achievement, since only the sun will provide all the energy required. When compared with conventional steam or direct-fired drying kiln solar assisted air drying shows significant savings in capital and operating costs, but longer drying time is required. Various designs ranging from simple tents to automated solar kilns are reported. The performances of the solar dryers are satisfactory in respect to the final moisture content, drying time and quality of timber. Solar drying is found technically viable and economically feasible except for some sophisticated solar kilns (Sattar, 1993). However, the design of the kiln and the configuration inside it must be carefully set. The aim of this investigation was to search for a relatively simple, cost-effective and energy efficient solar dryers which will speed up the rate of drying over that of air drying with minimum wood degradation.

Materials and Methods

Design and construction of dryers

An air drying shed and two green-house type of solar dryers of different designs were constructed at the Forest National Corporation sawmill at Suki town, Sennar State. All three dryers were of wooden frame construction. The air dryer had a corrugated zinc roof to shade the wood stack but no side walls, so that the wood stack was exposed to free flow of natural air. In both solar dryers all walls and roofs were covered by one layer of transparent plastic sheet. The collectors in both dryers consisted of black- painted corrugated zinc absorber plates.

The two greenhouse type solar dryers differed from one another in the position, area and orientation of the collectors as well as the method of transferring heated air inside the dryer. The first solar dryer denoted SL had a low, flat collector on the dryer's floor on the northern side of the timber stack. The area of the collector was only 8.3 square meters. The total area of this dryer was 4 by 6 meters, running north/south, while the timber stack had east/west orientation. One 18-inch diameter electrical fan was set on the northern wall to blow the heated air over the collector into the timber stack. Two small vents, 30 by 30 cm each, were set on the opposite wall to facilitate the removal of excess humidity during drying. The vents were placed about 50 cm above ground level and were two meters apart.

The second solar dryer denoted SH had a total area of 4 by 4 meters. The collector was (high) placed above the timber stack and below the roof. It was tilted to face the south at an angle which will make it approximately perpendicular to the mean position of the sun at noon at that particular latitude. Helwa *et al* (2004) working in Egypy increased the roof angle in winter from 37° in summer to 47°. The area of the collector in this dryer was approximately 12 square meters. One 18-inch electrical fan was set immediately under the roof on the eastern wall to push the heated air above and below the collector and over the stack to the other side, where there was another fan at a lower level of the western wall to push the heated air into the timber stack. The timber stack was oriented north/south. Here again two small vents, the same size as above were set on the eastern wall at about 50 cm above ground level for getting rid of humid air during drying. On each of the two solar dryers a hinged door was fixed on the same wall as the fan pushing heated air into the stack.

Procedure

This investigation was carried out in the winter season of 2011, precisely between January, 9 and February, 13. The stacks in all three dryers consisted of 120 sunt (*Acacia nilotica*) boards each. The boards measured 2″ x 4″x 9′ (5X10X270 cm). They were stacked in 15 rows with 8 boards in each row. The boards were stacked in a standard manner, with 1.5 inch thick stickers separating between the different rows.

Three sample boards were selected in each stack for periodic measurement of moisture content and following the progress of drying in the three dryers. The three sample boards were placed at different levels of each stack: one at the bottom of the stack (middle of the second row from the bottom) , one at the top (middle of the second row from top) and one in the middle of the stack .

Each sample board was taken out at two days interval, weighed and returned to the stack and the moisture content (M.C.) was calculated at these intervals. The dry-bulb and wet-bulb thermometer readings were also recoded and relative humidity worked out in each dryer. The collected data was statistically analyzed using analysis of variance and regression analysis.

Results and Discussion

Table 1 shows the progress of the drying process in the three dryers during the 34 days of the experiment. Due to some delays in stacking the timber, some samples lost appreciable amount of moisture after their initial M.C. was determined. Some of them reached fiber saturation point (F.S.P) like sample A in air drying, sample C in solar dryer with high collector (SH) and sample A in solar dryer with low collector (SL). The table indicates the variation of M.C. with time.

Table 1: Variation of moisture content with time in the three dryers

Type of dryer	Sample	Variation of moisture content with time in days									Ave. Final MC%
		2	6	10	14	18	22	26	30	34	
Air drying	A	30.0	25.83	22.5	20.0	20.0	17.5	11.67	10.0	9.17	
	B	40.0	35.0	31.67	29.16	27.5	25.0	20.0	17.5	16.66	13.76
	C	37.2	32.72	30.0	27.27	24.54	22.72	19.1	15.45	15.45	
Solar dryer with high collector	A	48.33	35.83	30.0	25.83	22.5	19.17	14.17	12.5	10.83	
	B	47.27	39.01	32.27	28.18	25.45	22.72	20.0	16.36	14.54	10.68
	C	24.17	20.0	15.83	14.17	13.33	10.0	9.17	6.67	6.67	
Solar with low collector	A	27.5	22.5	18.33	15.0	14.17	14.17	10.0	7.5.0	7.5	
	B	40.0	32.73	28.18	24.55	22.73	22.73	17.27	12.73	12.73	12.19
	C	43.64	37.27	31.82	29.09	25.45	25.45	20.0	17.27	16.36	

The samples with initial M.C. higher than fiber saturation point in the three dryers showed the following results: Sample B in air drying showed the slowest rate of drying and ended up to 16.7% final M.C. after 34 days. Sample A of solar dryer (SH), on the other hand, showed the fastest rate of drying and ended up to .10.8% M.C., while sample B of solar dryer (SL) had an intermediate rate of drying and intermediate final M.C. (12.7%) compared to the other two dryers. This reflects the environmental conditions in the three dryers as can be seen from table 2.

Table 2: Variation of environmental conditions with time in the three dryers

Type of dryer	Parameter	Variation of environmental conditions with time (days)																
		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
Air dryig	Dry.b.temp	25	20.5	21.5	20	26.5	24	25	19	27	27	29.5	33	40	30	30	25.5	38
	W.b.temp	17	11.5	11.5	12	16.5	11	13	11	19	19	20.5	19.5	30	24	19	15.5	20
	R.H.%	44	30	27	37	35	45	22	36	47	47	43	27	48	_-	35	34	17
SH	Dry.b.temp	32	32	26	26	24	31.5	30	32	25	32	32	33	40	34	30	29	45.5
	W.b.temp	23	24	19.5	19.5	14.5	21	19	20.5	15	24	24	24	24.5	25	25	16.5	25
	R.H.%	46	51	54	54	34	38	35	35	33	51	51	47	29	48		26	20
Sl	Dry.b.temp	31	30	26	23	31	29	31.5	24	32	32	33	44	49	33	37	29.5	45
	W.b.temp	20	21	14.5	12.5	15	16	17.5	14	20	20	23	24	27	17	24	16	26.5
	R.H.%	36	44	27	14	24	22	31	32	32	42	20	14	17	34	22	25	25

SH = Solar dryer with high collector
SL = Solar dryer with low collector
R.H.= Relative humidity

By looking at the samples with the lowest initial M.C. in each dryer (sample A in air drying, sample C in SH and sample A in SL) we got a rough estimate of the equilibrium M.C. under all three conditions which is the M.C. content which remains constant at the end of drying. The equilibrium M.C. of Suki area (from air drying) was about 9.2%. In solar dryer (SH) it was 6.7%, whereas in solar dryer SL it was 7.5% (Tables 1 and 3). Table 3 is a summary of tables1 and 2. These tables also indicate that the average final M.C. was lowest in case of SH, followed by SL and highest in case of air drying; this in spite of the fact that the solar dryers started with higher average initial M.C. than air drying (table 2). This means that the equilibrium

M.C. for Suki area in winter is about 9.2% and that the two solar dryers can dry timber to M.C. lower than the equilibrium M.C, of the area. These results agree with Helwa, *et al* (2004) who found that within the same drying time solar dried boards were dried to a moisture content lower than air dried boards.

All these results indicate that the solar dryer with high collector (SH) is the most efficient of the three dryers, followed by solar dryer (SL) and lastly air drying. Air drying also resulted in the highest equilibrium M.C. and highest average final M.C. because it was exposed to significantly lower temperature than the two solar dryers (Table 2). The two solar dryers had significantly higher temperatures than the ambient temperature (from air drying). Solar dryer (SL) also had a significantly lower R.H. than the other two dryers (table 2 and table 3). This is why the two solar dryers had lower equilibrium M.C. and faster rate of drying than air drying. Bekkioui *et al* (2011) working in India concluded that a period of 17 days was necessary to dry pine wood in a solar dryer from 35 % to 10 % M. C. This means a loss of 1.4 % per day. In this investigation, under winter conditions and the limited collector sizes the rate was a little bit lower, averaging to 1.1 % loss per day. This calls for some modifications in the designs of our solar dryers in future trials until we reach the most efficient designs..

Table 3: Average environmental conditions and average M.C. in the three dryers.

Dryer type	Average temperature ° C	Average R. H. %	Ave. initial M.C. %	Ave. final M.C. %	Eqilibrium M.C. %
Air Dryer	27.1 b	35,0 a	35.7 b	13.8 a	9.2
SH	31.4 a	40.9 a	40.0 a	10.7 a	6.7
SL	32.9 a	27.1 b	37.0 ab	11.9 a	7.5

SH = Solar dryer with high collector (above the wood stack)
SL = Solar dryer with low collector (at ground level)

Drying Defects

Drying defects were confined to minor warping incidences in the form of bowing which was more pronounced in air drying than in the solar dryers. No clear surface checks were observed. However, some shakes and end splits which were on the boards before starting the drying process were there. Shakes are usually due to wind effect and growth stresses on the tree, while end splitting is caused by inaccurate sawing of logs. All these results indicate that sunt wood can be dried at a reasonably rapid rate with minimal drying defects.

Conclusions and Recommendations

Conclusions

- The following conclusions could be drawn from this study: The results indicated that the two solar dryers, SH and SL were more efficient, with faster rate of drying than air drying.
- The two solar dryers dried wood to a M.C. lower than the equilibrium M.C. of the area, the thing which cannot be achieved by air drying.

- Solar drying did not result in serious drying defects. It was better than air drying in this respect.
- Sunt wood proved to be a durable wood which can be dried at a reasonably rapid rate without much degradation.
- This was the first trial for the investigators with solar dyers. It was a good experience from which they learned many lessons which will help them in improving the designs of solar dryers in the coming trials**.**

Recommendation

The area of the internal collectors used were rather small because internal collectors are usually limited by the size of the dryer; it is, therefore, recommended that in future trials to increase the area of the dryers or use external collectors.

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أثر المجففات الشمسية للأخشاب على خفض مدة التجفيف وعيوب التجفيف مقارنة بالتجفيف الهوائي

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المستخلص

تم تشييد مظلة للتجفيف الهوائي ومجففتين في شكل البيوت الزجاجية للتجفيف باستخدام الطاقة الشمسية. وتم تشييد هذه المجففات في منشار السوكي التابع للهيئة القومية للغابات من هياكل خشبية. وتمت تغطية المجففتين الشمسيتين بطبقة من البلاستيك الشفاف ولكنهما اختلفتا عن بعضهمافي موقع ومساحة واتجاه الأسطح الجاذبة لحرارة الشمس(collectors). كما اختلفتا في طريقة نقل وتوزيع الهواء الساخن داخل المجففة. وقد تم تنفيذ برنامج البحث في فصل الشتاء.واشتملت كومات الخشب في كل مجففة على 120 لوح خشبي تم رص الألواح في 15 طبقة في كل طبقة 8 ألواح. وتم إختيار ثلاثة ألواح خشبية في كل مجففة لجمع البيانات اللازمة لمتابعة مراحل التجفيف كما تم تسجيل قراءات المحرار الرطب والمحرار الجاف لتحديد درجات الحرارة والرطوبة النسبية داخل المجففات. وقد أظهرت النتائج أن المجففة الشمسية ذات السطح الجاذب للحرارة العالي (SH) كانت الأعلى كفاءة بين المجففات الثلاث حسب سرعة التجفيف ومتوسط المحتوى الرطوبي في نهاية التجربة والمحتوى الرطوبي المتزن داخل المجففة تليها المجففة الشمسية ذات السطح الأرضيٍ(SL) وأخيراً المجففة الهوائية. أما عيوب التجفيف فقد انحصرت في إنحناءات بسيطة في نسبة قليلة من الألواح أكثرها في التجفيف الهوائي. الدروس المستفادة من هذه التجربة الأولية ستمكن الباحثين من إجراء تحسينات في تصاميم المجففات الشمسية لتحسين كفاءتها.