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Vibha Sharma
Department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh, India

Rajneesh Kumar
Department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh, India

Bhupender Dutt
Department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh, India

Heena
Department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh, India

Rajesh Kumar Meena
Department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh, India

Corresponding Author:
Vibha Sharma
Department of Forest Products, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni (Solan), Himachal Pradesh, India

Toona ciliata M.Roem.: Effect of heat treatment on shrinkage and swelling

Vibha Sharma, Rajneesh Kumar, Bhupender Dutt, Heena and Rajesh Kumar Meena

Abstract
The attempt made to study the shrinkage and swelling (longitudinal, radial and tangential) of thermally modified wood of *Toona ciliata* at different temperatures (80, 120, 160 and 200°C) and durations (2, 4 and 6 hours) in vacuum oven. The maximum value of swelling in transverse plane (4.81%), radial plane (4.06%), tangential plane (4.81%) and volumetric swelling (17.76%) were recorded at control, while minimum value of swelling in longitudinal plane (0.57%), radial plane (2.72%), tangential plane (3.34%) and volumetric swelling (5.22%) were recorded at 200°C. Among different temperatures the maximum value of shrinkage in transverse plane (0.61%), radial plane (3.62%), tangential plane (3.84%) and volumetric shrinkage (8.49%) were recorded at control. While the minimum value of shrinkage in transverse plane (0.27%), radial plane (2.54%), tangential plane (2.69%), volumetric shrinkage (0.89%) were recorded at 200°C.

Keywords: Thermal treatment, duration, shrinkage, swelling, transverse, radial, tangential

1. Introduction
Wood is an anisotropic, porous, hygroscopic, heterogeneous, composite material consisting cellulose, hemicelluloses and lignin. Botanically, it is described as secondary xylem tissue formed during the secondary growth. *Toona ciliata* M. Roem. is commonly known as Indian Red Cedar, Burma Cedar and Toon, belonging to the family Meliaceae. In India, this tree is found in the plains of Madhya Pradesh, Tamil Nadu, Karnataka, Eastern and Western Ghats and Himachal Pradesh up to 1200 m (rarely 1300 m) (Singh,1982) [10]. Toon is a multipurpose tree especially used as a timber in India. Apart from its utility as a timber, the bark of Toon is used for medicinal purposes to treat chronic dysentery, its flower contains red matter which is used as sulphur dye and fruits are used to extract aromatic oil. Wood of Toon is moderately hard, light weight, tough and durable. It has been identified as a suitable species for the production of good quality and economically valuable products (Edmonds, 1993; Heinrich and Banks, 2005) [3, 4]. Along with the versatile properties of wood, it has some derelictions as it is moisture sensitive, dimensionally unstable and have moderate durability. Therefore taking these properties into consideration modification treatment came into existence. Thermal modification is one of the eco-friendly and appropriate method to modify the properties of wood. In this technique, wood is treated at high temperatures in order to strengthen the durability and dimensional stability. Therefore, due to application of thermal modification technique, quality and value of wood for different construction purposes was improved. Under heat effect, amorphous cellulose decreases because of the removal of hydroxyl groups due to heat treatment and attains a more crystalline structure; as a result, the accessibility of water molecules to the cellulose which in turn lowers the moisture content of heat treated wood (Sahin, 2008) [9] to improve the dimensional stability and biological durability of wood.

2. Material and Methods
2.1 Preparation of Samples
The logs were converted into required sample sizes (50 mm x 20 mm x 20 mm), as per the required specifications. The samples were properly planed and sanded for maintaining the smoothness.

2.2 Thermal Modification of Samples
Toon wood samples were modified according to the following procedure:
- **Step 1:** Oven-drying of samples at room temperature in order to evaporate water from the samples.

- **Step 2:** Vacuum oven-heating of samples at the target temperatures (80±2°C, 120±2°C, 160±2°C and 200±2°C) for assumed time (2, 4 and 6 h).
- **Step 3:** Placing samples in a desiccator in order to cool down the samples to room temperature and constant weight without access of moisture.

2.3 Analysis of Physical character

2.3.1 Swelling (%)

It is mainly calculated as the dimensional swelling coefficient (longitudinal, radial and tangential planes) and as volumetric Swelling Coefficient. All the planes was measured with the help of Digital Vernier Caliper to avoid errors.

a) **Dimensional swelling coefficient (%):** It is measured among all planes *viz.*, longitudinal, radial and tangential planes. The formula used for measuring dimensional swelling is as follows:

$$\text{Swelling (\%)} = \frac{l2-l1}{l1} \times 100$$

Where,
l_1 = Length of a wood sample (oven dry) in a plane before treatment (cm)
l_2 = Length of a wood sample in a plane with treatment (cm)

b) **Volumetric Swelling Coefficient** (%) was calculated as follows:

$$S(\%) = \frac{V2-V1}{V1} \times 100$$

Where,
S = Volumetric Swelling Coefficient
V_1 = Wood volume of a oven-dried wood sample before treatment (cc)
V_2 = Wood volume with treatment (cc)

2.3.2 Shrinkage (%)

Shrinkage is calculated as the dimensional shrinkage coefficient (longitudinal, radial and tangential planes) and as volumetric shrinkage coefficient. All the planes were measured with the help of Digital Vernier Caliper to avoid errors.

a) **Dimensional Shrinkage coefficient (%)** were in three different planes *viz.*, longitudinal, radial and tangential was calculated as follows:

$$\text{Shrinkage (\%)} = \frac{l2-l1}{l1} \times 100$$

Where,
l_1 = Length of a wood sample (oven dried) in a plane after treatment (cm)
l_2 = Length (wet) of a wood sample in a plane with treatment (cm)

b) **Volumetric Shrinkage Coefficient** (%) was calculated as follows:

$$S(\%) = \frac{V2-V1}{V1} \times 100$$

Where,
S = Volumetric shrinkage coefficient
V_1 = Wood volume of a oven-dried sample after treatment (cc)
V_2 = Wood volume (wet) with treatment (cc)

Statistical analysis

The recorded data were subjected to Completely Randomized Block Design

3. Results

3.1 Swelling

The swelling of thermally modified Toona wood in transverse, radial and tangential planes at different temperatures and durations was found to be significant at 5 per cent level of significance. Also the data illustrated in Table 1 showed the swelling of wood in Transverse radial, tangential planes and volumetric swelling coefficient at various temperature and durations. In Transverse plane the highest (0.91%) value was recorded in control and lowest (0.57%) value recorded in 200°C at different temperature. Although, in mean duration was recorded highest (0.80%) and lowest (0.75%) at 2h and 6h, respectively. Among the interactions between temperature and duration, maximum value (0.91%) was observed in control which was at par with 80°C (0.89%) at 2h, whereas minimum value (0.53%) was recorded at 200°C (6h). Whereas, in radial Plane the highest (4.06%) value recorded in control and lowest (2.72%) was in 200°C. Although, in durations highest was recorded in 2h (3.64%) and lowest in 6h (3.39%) and in combination of temperature and durations the maximum value (4.06%) was observed in control and minimum (2.50%) value was recorded at 200°C for 6h. The swelling percentage of thermally modified wood in tangential plane showed a notable difference with highest (4.81%) value recorded in control and lowest (3.34%) recorded at 200°C in temperatures. Among durations, maximum (4.25%) and minimum (4.03%) value was observed at 2h and 6h, respectively. And in the interaction between temperature and durations highest (4.81%) value recorded at control and lowest (3.25%) value was observed at 200°C for 6h.

Table 1: Swelling of heat treated wood

Temperature (ºC) and Time (h)		Swelling			
		Transverse Plane (%)	Radial Plane	Tangential Plane	Volumetric
Control		0.91	4.06	4.81	17.76
80°C	2h	0.53	2.50	3.25	4.29
	4h	0.57	2.72	3.32	5.12
	6h	0.62	2.95	3.44	6.25
120°C	2h	0.69	3.05	3.65	7.64
	4h	0.72	3.18	3.75	8.60
	6h	0.75	3.31	3.95	9.82
160°C	2h	0.77	3.48	4.06	10.91
	4h	0.80	3.76	4.14	12.45

	6h	0.82	3.90	4.29	13.70
200°C	2h	0.85	3.87	4.38	14.46
	4h	0.86	3.94	4.58	15.43
	6h	0.89	3.99	4.78	16.91
Mean Temperature	80°C	0.87	3.93	4.58	15.60
	120°C	0.80	3.71	4.16	12.35
	160°C	0.72	3.18	3.78	8.69
	200°C	0.57	2.72	3.34	5.22
	Control	0.91	4.06	4.81	17.76
Mean Duration	2h	0.80	3.64	4.25	12.89
	4h	0.77	3.53	4.12	11.87
	6h	0.75	3.39	4.03	11.01
$CD_{0.05}$	T	0.014	0.025	0.023	0.293
	D	0.011	0.019	0.017	0.227
	T×D	0.024	0.043	0.039	0.508

For different temperatures the maximum volumetric swelling coefficient (17.76%) was found in control and minimum (5.22%) was found at 200°C whereas, in duration mean the highest was recorded at 2h (12.89%) and lowest at 6h (11.01%). The combination of temperature and duration was statistically significant where maximum value (17.76%) was noticed in control and minimum (4.29%) at 200°C for 6h.

3.2 Shrinkage

Shrinkage in transverse, radial and tangential planes was found to be significant with different temperatures and durations. Also the data illustrated in Table 2 showed the swelling of wood in Transverse radial, tangential planes and volumetric swelling coefficient at various temperature and durations. At transverse plane the highest shrinkage value recorded in control (0.61%) and lowest was recorded at 200°C (0.27%). In duration, highest value was recorded at 2h (0.50%) and lowest at 6h (0.45%). At interaction the maximum shrinkage (0.61%) was recorded in control which was at par with 80°C (0.59%) at 2h and minimum (0.23%) at 200°C for 6h. Whereas, in radial plane at different temperatures highest (control) and lowest (200°C) value recorded 3.62 and 2.54 per cent, respectively. Whereas in mean durations maximum (3.17%) and minimum (3.01%) value recorded at 2h and 6h, respectively. Also in interaction of temperatures and durations maximum value was found in control (3.63%) while minimum (2.44%) at 200°C for 6h

Table 2: Shrinkage of heat treated wood

Temperature (ºC) and Time (h)		Shrinkage			
		Transverse Plane (%)	Radial Plane	Tangential Plane	Volumetric
Control		0.61	3.63	3.84	8.49
80°C	2h	0.59	3.51	3.73	7.27
	4h	0.56	3.33	3.65	6.77
	6h	0.55	3.22	3.55	6.33
120°C	2h	0.52	3.15	3.46	5.67
	4h	0.50	3.11	3.35	5.21
	6h	0.47	3.02	3.26	4.67
160°C	2h	0.45	2.94	3.11	4.11
	4h	0.42	2.85	3.06	3.66
	6h	0.37	2.75	2.95	2.97
200°C	2h	0.32	2.63	2.85	2.41
	4h	0.27	2.55	2.68	1.85
	6h	0.23	2.44	2.54	1.43
Mean Temperature	80°C	0.57	3.35	3.65	6.79
	120°C	0.50	3.09	3.36	5.17
	160°C	0.41	2.84	3.04	3.58
	200°C	0.27	2.54	2.69	1.89
	Control	0.61	3.62	3.84	8.49
Mean Duration	2h	0.50	3.01	3.39	5.59
	4h	0.47	3.09	3.32	5.19
	6h	0.45	3.01	3.23	4.77
$CD_{0.05}$	T	0.016	0.023	0.029	0.227
	D	0.012	0.018	0.022	0.176
	T×D	0.028	0.039	0.051	0.394

At tangential plane among temperatures, the highest value in shrinkage of tangential plane was recorded in control (3.84%) and lowest at 200°C (2.69%). At mean durations, highest (3.39%) and lowest (3.23%) was recorded at 2h and 6h, respectively. In the combinations maximum value was recorded (3.84%) in control and minimum (2.54%) at 200°C at 6h.The maximum volumetric shrinkage (8.49%) for temperatures was found in control and minimum (1.89%) was recorded at 200°C. The highest (5.59%) and lowest (4.77%) value for duration was observed at 2h and 6h, respectively. Whereas, in interaction between temperature and duration maximum value (8.49%) was recorded in control and minimum (1.43%) value was noticed at 200°C at 6h.

4. Discussion

4.1 Swelling

Swelling can be defined as increase in the volume due to absorption of the moisture by cell wall of the wood and occurs mainly above fiber saturation point. This phenomenon is based on the absorption of the water, which requires the presence of free hydroxyl groups in the cell wall. Heat treatment decreases the presence of hydroxyl group in wood

(Kol, 2010) [6]. According to Akylidiz *et al*. (2009) and Jimenez *et al*. (2011) [5] there is decrease in swelling in Transverse plane radial and tangential plane of heat treated wood as compared to untreated wood. Similarly, in the present study the swelling in heat treated wood has been recorded lesser than untreated sample in transverse plane.

This may be because of presence of less amount of hydroxyl group in the wood or high amount of crystalline structure of cellulose due to thermal modification. Which lead the formation of layer on the surface of wood and decreases the hygroscoposity of wood. Therefore, the results of the present investigation on swelling of thermally modified *Toona ciliata* M. Roem. in transverse, radial, tangential plane and volumetric swelling are in conformity with earlier studies of Kol (2010) [6], Cademartori *et al.* (2015) [2] and Mohebby and Sanaei (2005) [7] where with increase in temperature the swelling percentage decreases.

4.2 Shrinkage

Shrinkage is the phenomenon that occurs below fiber saturation point due to desorption of the moisture. In water absorption and desorption the presence of free hydroxyl group play an important role whereas, heat treatment decreases the hydroxyl group in wood which result in the decrease in shrinkage of all direction in Pine and Fir species (Kol, 2010) [6]. According to the Sinkovic *et al.* (2011) [11] the transverse, radial, tangential and volumetric shrinkage decreases with increase in temperature (Beech wood, Ash wood and Hornbeam wood). This might be because of degradation of hemicelluloses, removal of hydroxyl groups and formation of cross-linking polymers (Rousset *et al.,* 2004) [8]. Similarly, Akyildiz *et al.* (2009) [1] also reported that there is a significant decrease in the transverse, radial and tangential plane in Anatolian Black Pine wood at 130, 180 and 230°C for 2 and 8h. Also the decrease in volumetric shrinkage is might be because of more stability and decrease in the transverse, radial and tangential shrinkage with increase in temperature. So the present investigations are in compliance with the earlier studies performed by different researchers in which there were decrease in the shrinkage of wood in transverse plane, radial plane and tangential plane with increase in the temperature.

5. Conclusions

From current investigation it concluded that heat treatment eliminates the hydroxyl group from the wood cells so it does not absorb moisture from atmosphere and prevent shrinkage and swelling as well as become more resistant to insect attack. Which results more stable and durable wood for different outdoor construction purposes where moisture levels fluctuate more often in environmental conditions. So heat treated wood has potential to be used in wood products where durability and strength are the prime goals desired.

6. Reference

1. Akyildiz MH, Ates S, Ozdemir H. Technological and chemical properties of heat-treated Anatolian Black Pine wood. African Journal of Biotechnology. 2009; 8(11):2565-2572.
2. Cademartori PHG, Missio AL, Mattos BD, Gatto DA. Effect of thermal treatments on technological properties of wood from two *Eucalyptus* species. Journal of Anais da Academia Brasileira de Ciencias. 2015; 87(1):471-481.
3. Edmonds JM. The potential value of Toona Species (Meliacea) as multipurpose and plantation trees in Southeast Asia. Common Wealth Forestry Review. 1993; 72(3):181-186.
4. Heinrich I, Banks JCG. Dendroclimatological potential of the Australian Red Cedar. Australian Journal of Botany. 2005; 53:21-32.
5. Jimenez JP, Menadro NA, Ramon AR, Ponciano SM. Physico-mechanical properties and durability of thermally modified Malapapaya wood. Philippine journal of science. 2011; 140(1):13-23.
6. Kol SH. Characteristics of heat-treated Turkish Pine and Fir wood after thermo-wood processing. Journal of Environmental Biology. 2010; 31(6):1007-1011.
7. Mohebby B and Sanaei I. Influences of the hydro-thermal treatment on physical properties of beech wood. The international research group on wood protection (IRG). 36th Annual Meeting, Bangalore, India 24-28 April 2005; IRG Document No. IRG/WP 05-40303.
8. Rousset P, Perre P, Girard P. Modification of mass transfer properties in poplar wood (*P. robusta*) after a thermal treatment at high temperature. Holz als Roh-und Werkstoff. 2004; 62(2):113-119.
9. Sahin HT. Wood water interactions as affected by chemical constituents of wood. Asian Journal of Chemistry. 2008; 20(4):3267-3276.
10. Singh RV. Fodder trees of India. Oxford and IBH Publishing Company. New Delhi, India, 1982, 663.
11. Sinkovic T, Govorcin S, Sedlar T. Comparision of physical properties of untreated and heat treated Beech and Hornbeam. Drvna Industrija. 2011; 62(4):283-290.