

## **ANATOMICAL STRUCTURES OF THERMALLY COMPRESSED POPLAR (*POPULUS* SPP.) WOOD**

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### **Abstract**

*The combined effects of press temperature and pressure on the anatomical structure of solid-wood panels produced by European poplar (*Populus tremula* L.) wood were evaluated. The solid wood panels with dimensions of 100mm by 500mm by 25mm were hot-pressed by using a laboratory hot press at a temperature of either 150°C or 170°C and pressure of either 1MPa or 2MPa, respectively, for 45min. Changes in the anatomical structure were detected by using a light microscope. The microscopic investigations revealed that the wood exhibited much degradation in 170°C / 2MPa process condition, and the distribution of deformation was not uniform in the growth rings of the two treatment groups. The results indicated that it is important to know the behavior of wood under different process conditions.*

**Key words:** *thermally compressed wood; anatomical structure; wood densification; cellular failure; poplar wood.*

### **INTRODUCTION**

Wood, as a biological renewable resource, is one of the most fascinating materials by its very complex structure and its wide and intensive uses (Bucur 2006). Although wood has excellent material properties, it has also a number of disadvantages such as dimensional changes in different atmospheric conditions, sensitivity to biological attacks and changes in physical appearance when exposed to weathering (Hill 2006).

Various modification methods have been developed to improve the negative properties of wood. Thermal compression is a wood modification method that combines thermal and mechanical processes and results in densification of wood. The main purpose of combining compression and heat on wood is to improve physical and mechanical properties as well as overcome weakness regarding low wood density of fast growing trees (Gong and Lamason 2007, Tu *et al.* 2014, Guo *et al.* 2015). On the other hand, compression deformation produced during densification process is not stable and the

wood reverts totally or partially to its original shape after re-moistening and heating (Blomberg *et al.* 2006, Guo *et al.* 2015).

Physical, mechanical, anatomical, durability, and surface properties of thermally compressed wood were studied in previous works by Wang *et al.* 2000, Wang and Cooper 2005a, Wang and Cooper 2005b, Gong and Lamason 2007, Unsal and Candan 2007, Unsal and Candan 2008, Unsal *et al.* 2009, Abraham *et al.* 2010, Candan *et al.* 2010, Dogu *et al.* 2010, Unsal *et al.* 2011a, Unsal *et al.* 2011b, Hizal *et al.* 2014, Kutnar *et al.* 2012, Candan *et al.* 2013a, Candan *et al.* 2013b, Tu *et al.* 2014, Guo *et al.* 2015.

As it is known wood properties in nature vary among tree species, between trees of the same species, between pieces from the same tree as well. The behavior of wood in different process conditions will be most likely different. Therefore it is important to know the effects of modification methods in anatomical structure to evaluate the success of the methods.

## OBJECTIVES

Poplar wood (*Populus* spp.) is one of the fast growing tree species in Turkey. Wide availability and the low cost are some of the advantages of poplar wood. However, it has also some undesired properties such as low surface hardness, low density and low dimensional stability and, its wood poses drying problems (Candan *et al.* 2013b). In this paper, preliminary results on the effects of varying temperatures and press pressures on the anatomical structure of solid-wood panels produced by European poplar (*Populus tremula* L.) wood were given.

## METHOD, MATERIALS AND EQUIPMENT

This study was performed by using wood samples obtained from two different thermal processes. European poplar (*Populus tremula* L.) solid wood panels having no defects with dimensions of 100mm by 500mm by 25mm were hot pressed using a laboratory hot press at a temperature of either 150°C or 170°C and pressure of either 1MPa or 2MPa, respectively, for 45min. (Table 1). A total of 6 panels (two compressed panels from each treatment group and two untreated panels) were tested. The panels were pre-dried to a moisture content of 15% before hot pressing (Candan *et al.* 2013b).

Light Microscopy (LM) was employed to reveal deformations in the anatomical structure of the panels subjected to varying thermal compression conditions. Small wood samples were obtained from the outer region of cross sections of the solid wood panels in order to eliminate possible effects of juvenile wood. The samples with dimensions of 10mm (R) x 10mm (T) x 20mm (L) were cut for LM evaluations. These samples were kept under vacuum in the presence of alcohol, glycerin, and water at room temperature in order to become softened and were then cut into thin sections (about 20µm - 30µm) by using a Leica SM 2010R sliding microtome. The microtome knife was often changed to minimize surface roughness and any possible damage on the surfaces of the samples. The sections were then stained with safranin and fast green to supply good contrast between cell walls. The sections were observed under an Olympus BX51 Light Microscope. Images were taken by using analySIS FIVE Software and a DP71 Digital Camera installed and adapted on the microscope.

Anatomical investigations were also performed for untreated panel samples for comparison. All microscopic studies were only realized visually on the microscopic sections.

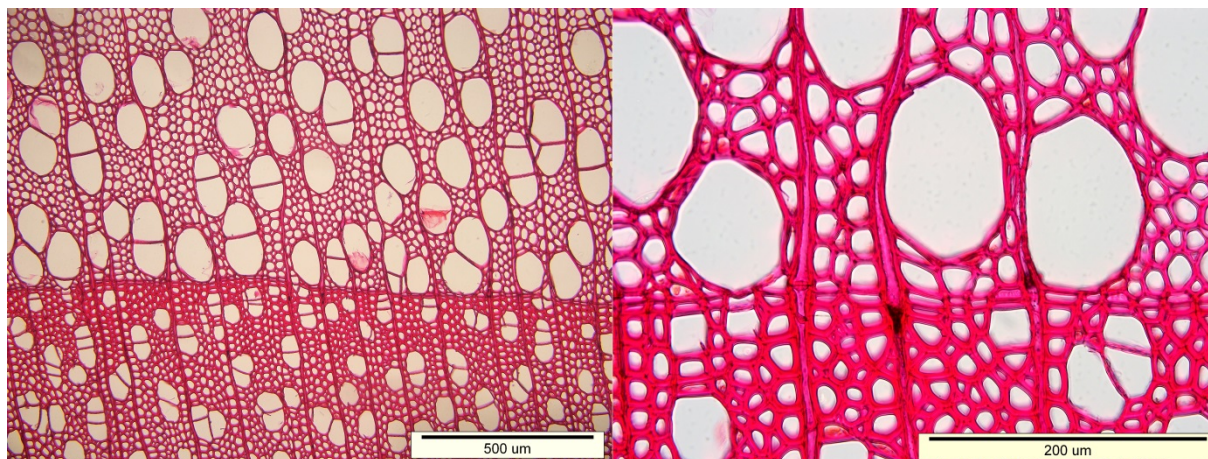
**Table 1**

**Experimental Design of the Thermally Compressed Wood Panels**

Groups	Press Pressure (MPa)	Temperature (°C)	Duration (min.)
Control	-	-	-
A	1	150	45
B	2	170	45

## RESULTS AND DISCUSSION

Changes in anatomical structure were investigated to understand the effects of temperature and press pressure and the results were evaluated separately for each treatment group. Images of untreated wood samples are shown in Fig. 1.

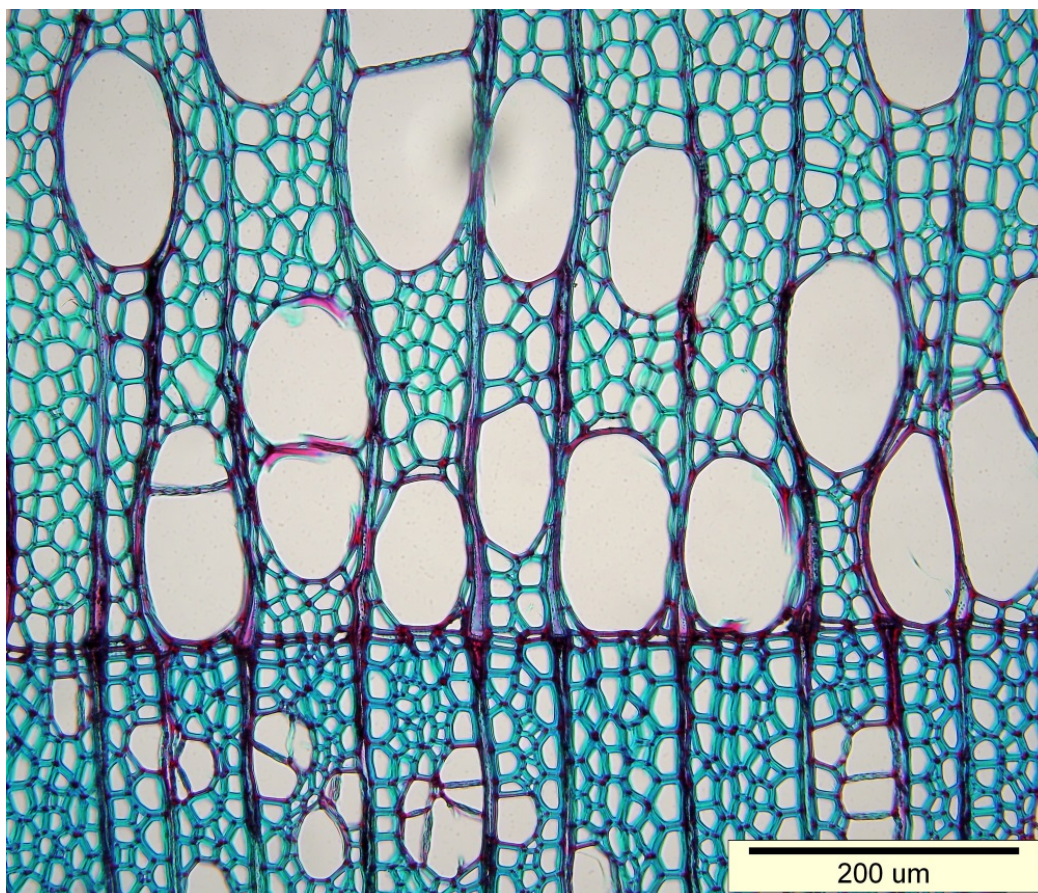


**Fig. 1.**

*Light micrographs of untreated wood in different magnifications (cross sections)*

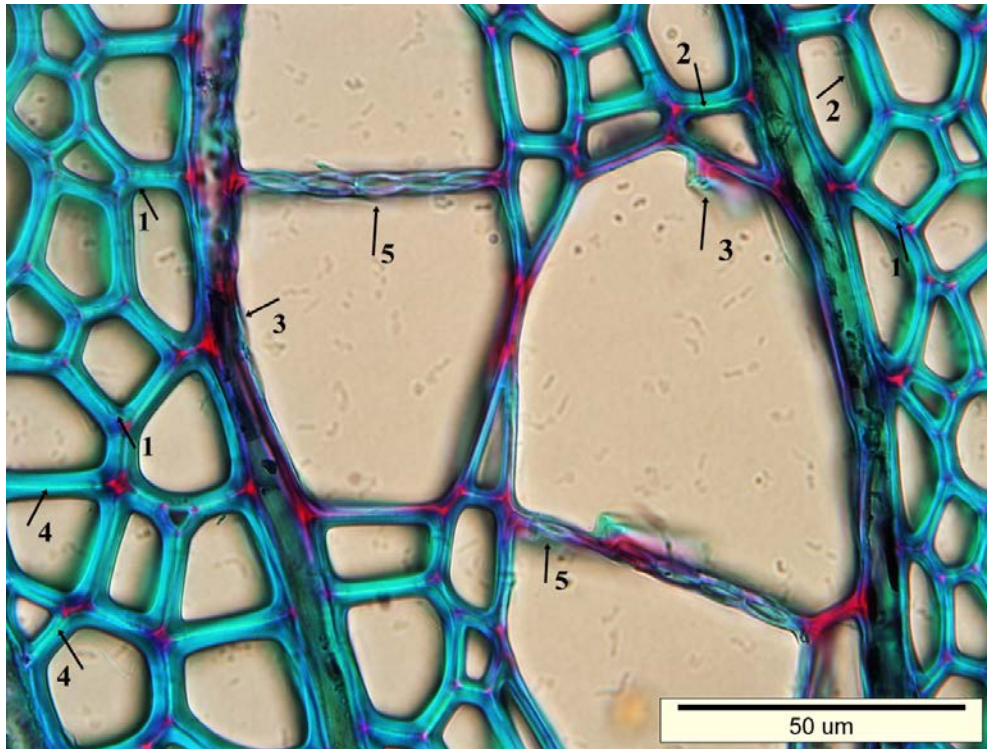
**Group A (150°C – 1MPa)**

Group A showed minimum structural damage and no visible distortion in the plane of growth rings was observed in cross sections (Fig. 2). The vessels and the fiber cells were also in their natural shapes considerably (Fig. 2). Minute cracks and low degree degradation were observed particularly in the cell wall of fibers located in the beginning and the last part of the growth rings (Fig. 3 and Fig. 4). Slight separations between compound middle lamella in fiber cells were noticed. Both damaged and undamaged bordered pits were also found in the cell walls of vessels arranged in the radial rows of 2 to 3 multiples.



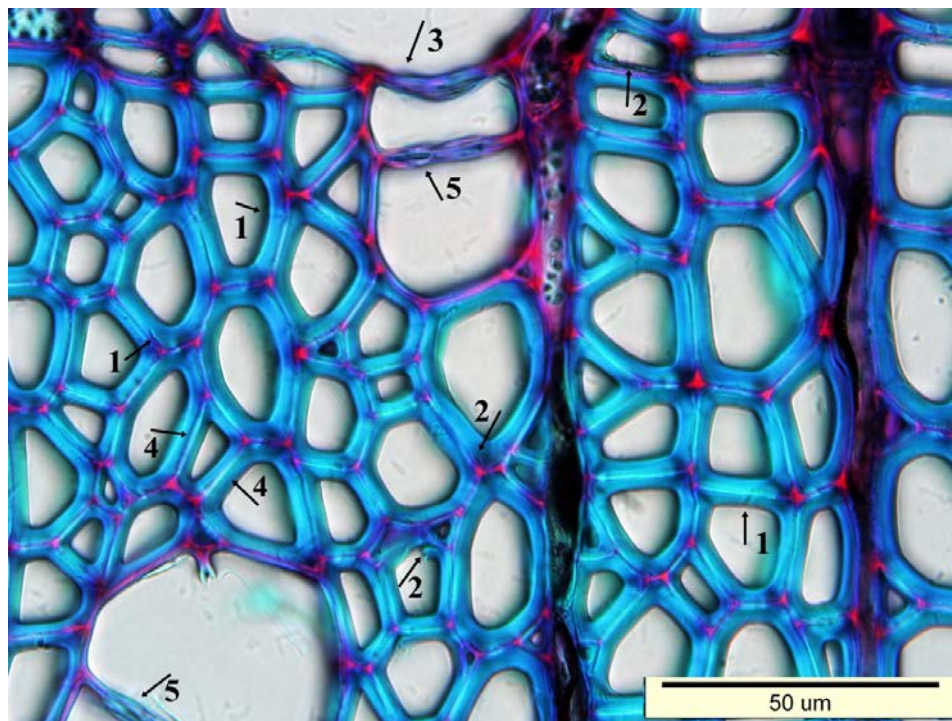
**Fig. 2.**

*No visible distortion in the plane of growth rings in Group A (cross sections)*



**Fig. 3.**

*Minute cracks in the fiber cell walls (arrow 1) and low degree cell wall degradation in the fibers (arrow 2) and the vessels (arrow 3) in the beginning part of the growth ring, slight separations between compound middle lamella in fiber cells (arrow 4) damaged bordered pits in the vessel cell walls (arrow 5) in Group A (cross section)*

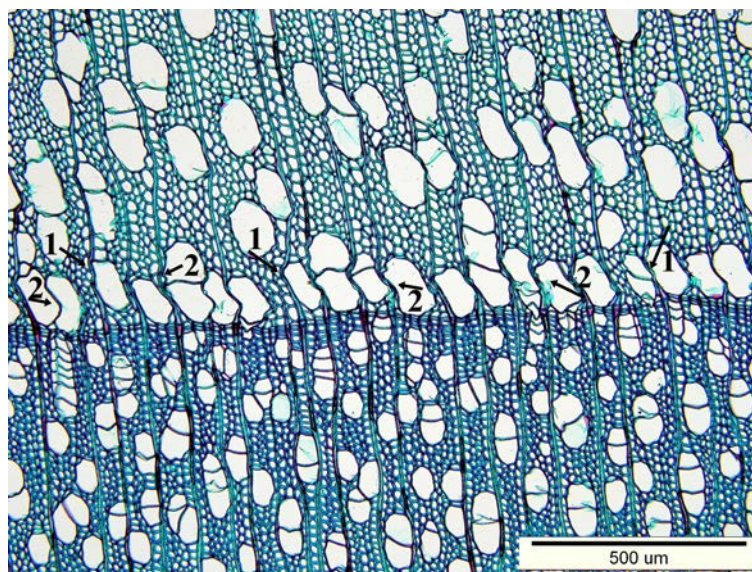


**Fig. 4.**

*Minute cracks in the fiber cell walls (arrow 1) and low degree cell wall degradation in the fibers (arrow 2) and the vessels (arrow 3) in the beginning part of the growth ring, slight separations between compound middle lamella in fiber cells (arrow 4) damaged bordered pits in the vessel cell walls (arrow 5) in Group A (cross section)*

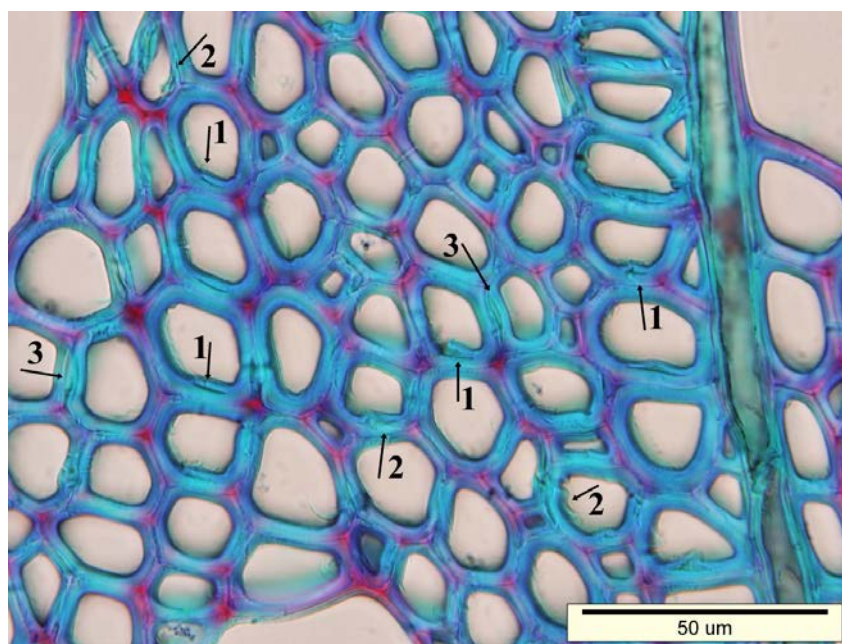
**Group B (170°C – 2MPa)**

Depending on the process condition, more damages were observed in the microstructure of Group B than in that of Group A. Buckling on the radial cell walls of the vessels were found clearly in the initial part of earlywood region. These structural alterations on vessels resulted in a slight wavy pattern in the relevant regions and in the rays (Fig. 5) On the other hand, collapse was not observed in all cell types. It was thought that the buckling on the radial cell walls of vessels was an indication that abrupt fractures would occur. Ruptures were also seen in the vessel cell walls. Distinct cracks and severe degradation were observed in the fiber cell walls located at the beginning and the last part of the growth rings. It was also seen distinct separations between compound middle lamella in the fiber cells (Fig. 6 and Fig.7). A great number of ruptured bordered pits were detected in the tangential cell walls of vessels arranged in the radial rows of 2 to 3 multiples.



**Fig. 5.**

***Slight wavy pattern at the initial part of earlywood region and in the rays (arrow 1) caused by buckling on the radial cell walls of the vessels (arrow 2) in Group B (cross section)***



**Fig. 6.**

***Distinct cracks (arrow 1) and severe degradation (arrow 2) in the fiber cell walls, distinct separations between compound middle lamella in fiber cells (arrow 3) in Group B (cross section)***

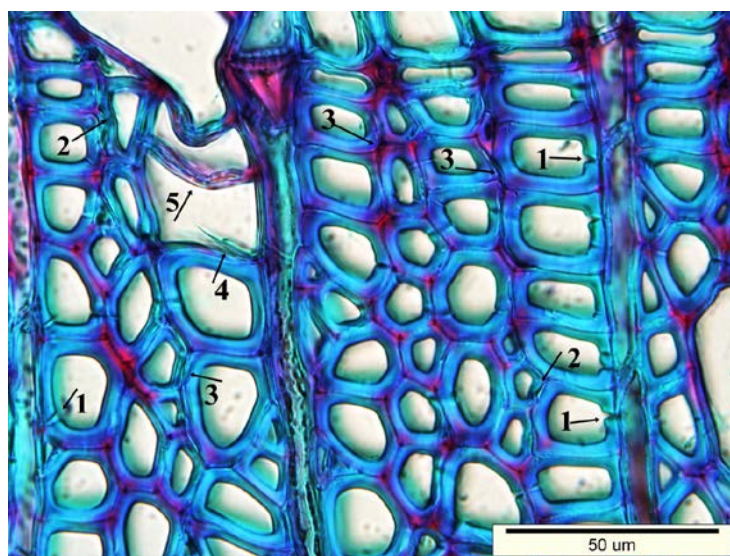


Fig. 7.

**Distinct cracks (arrow 1) and severe degradations (arrow 2) in the fiber cell walls, distinct separations between compound middle lamella in fiber cells (arrow 3), ruptures in the vessel cell walls (arrow 4), damaged bordered pits in the vessel cell walls (arrow 5) in Group B (cross section)**

This study showed that much more degradation in Group B panels (170°C – 2MPa) was seen when compared to the other panel samples and the distribution of deformation was not uniform in the growth rings of two treatment groups. All deformation in cell structure was quite distinct at the beginning and the last part of the growth rings. The similar findings were obtained in densified White ash (Tabarsa and Chui 2001) and *Populus ussuriensis* Kom (Ou *et al.* 2014). On the other hand, some authors reported that morphological changes between the earlywood and the latewood regions of *Populus* spp. were not different under densification process (Tabarsa and Chui 2001, Kutnar *et al.* 2009, Tu *et al.* 2014). The contradiction among the results of studies may be based on the process conditions, usage of different wood species and the wood properties such as different growth ring structure and different amount of latewood and earlywood. Tu *et al.* (2014) mentioned that a high densification ratio will lead to a higher rate of deformation in the wood cells, as well as uniform distribution throughout the growth ring in *Populus tomentosa*. Candan *et al.* (2013b) indicated that the percentage of maximum increase in density was 18%, in Group B. Kutnar and Šernek (2007) indicated that the increase in density was in the range of about 25% to about 500%, though preferably in the range of about 100% to about 200% in the densified wood. In this context, the maximum density did not reach to preferred initial value of 100%. On the other hand, the wood is diffuse - to semi-ring - porous in the current study and the vessels in the earlywood are larger than those in the latewood of the previous and of the same growth ring.

## CONCLUSIONS

The influences of varying temperature (150°C and 170°C) and press pressures (1MPa and 2MPa) on the anatomical structure on thermally compressed solid-wood panels produced by using European poplar (*Populus tremula* L.) wood were investigated. Microscopic investigations showed that changes in anatomical structures were not uniform in the growth rings for the two treatment groups.

The contradiction among the results of different studies suggests that further studies on the anatomical structure of wood subjected to different wood modification methods are needed.

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