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The effect of press temperature on properties of medium density fiberboard produced from *Eucalyptus camaldulensis* fibers

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Abstract

The target of this study was to investigate the possibility of MDF production from *Eucalyptus camaldulensis* wood. MDF fibers were produced applying three levels of steaming time. Laboratory MDF boards were produced using the generated fibers and different pressing temperature and time. Physical and mechanical properties of MDF panels were measured using relevant EU test methods and were statistically analyzed based on factorial experiment. The results indicated that at longer steaming time, MOR of boards was reduced and the lowest value (16.2 MPa.) were measured on boards produced from fibers generated applying 15 min steaming time. The press temperature imposed statistically significant effect on MOR, and increasing press temperature, increased MOR. Higher steaming time reduced the IB of boards as well as the thickness swelling and increasing steaming time from 7.5 to 15 min, decreased IB from 0.787 to 0.533 MPa. The results of this study indicated that, the MOR and MOE of boards produced from *Eucalyptus camaldulensis* fibers meet the requirements of Iran national standard values and the internal bonding and thickness swelling of boards are higher than the requirements.

Keywords: *Eucalyptus camaldulensis*, Medium density fiberboard, Press temperature, Press time, Steaming time.

1. Introduction

Medium density fiberboard (MDF), production has been expanding at very fast rate and new plants have been erected mainly in the developing regions. The unique specifications of MDF opened its way into various applications and generated interest among different consumer sectors especially cabinet and home furniture. High price and excellent return on investment enabled MDF producers to utilized good quality raw material to fulfill the requirements of the product and respond to consumer needs very well to their satisfaction. As a result, world MDF production was raised to almost 58.9 million m^3 in 2009 (Dehghani Firouzabadi and Ghorbannezhad, 2014, FAO, 2010).

Interest in production and consumption of MDF is not limited to industrial countries, and other regions are not exempt to such developments. Countries like China and Turkey have been able to expand their MDF production at very fast rates than industrial countries. However, these regions are faced with the severe shortage of wood as the main raw material and therefore these regions such as Iran have been searching alternative procedures to fulfill the needed wood, among them plantation of exotic fast growth species such as poplar and eucalyptus trees have been in the central point of research and developments.

Therefore MDF production must depend on lower quality raw material. In the era that countries around the world desire to implement local capacities for MDF production, the situation for MDF raw material supply is becoming tense, due to unavailability of raw material. In efforts to find alternative raw material for board production, different uncommon raw material including agricultural residues have been investigated and a good wealth of literature is seen (Akgul and Toslughu, 2008; Copur et al. 2008; Halvarsson, et al. 2010; Pan et al. 2010; Ciannamea et al. 2010). Fast growth, small diameter poplar and eucalyptus wood were the first candidates (Schneider et al., 2000). Roffael et al. (1992) investigated the potential of fast growth *P. trichocarpa* wood for the production of MDF and expressed that fibers produced using 16 years old trees produced stronger MDF boards than similar fibers from 5 years old trees. Zhang-Kang et al. (2000) used the wood fibers combined with bamboo fibers and wood reported that as the ratio of bamboo fibers increases in the MDF furnish, both MOE and MOR improves and the IB deteriorates. Pine fibers were studied for MDF production to find a way to reduce the density of the board (Eleoterio et al., 2000; Krzysik et al., 1999) expressed that MDF boards from *E. saligna* wood meets the minimum requirements of European and American standards and further study to improve the properties of the boards are suggested. De Compos et al. (2004) also investigated the application of *E. saligna* wood for the production of MDF.

Even though, Iran is operating four MDF plants, with total capacity of 1000 m^3/day in Northern Iran utilizing hardwoods and one, 400 m^3/day in Southern Iran based on bagasse, but it is still lacking sufficient production capacity to fulfill domestic requirements. This is due to unavailability and limitation on wood supply and other fiber sources. Consequently, attention must be concentrated on the application of uncommon and unconventional fiber supply especially plantation grown wood such as eucalyptus wood. The adaptation of such fast growth tree in different regions and limitations on fiber supply necessitated the investigation to identify its suitability for MDF production. This was the objective of our research.

2. Materials and methods

2.1. Fiber preparation

Three 17 years old plantation grown *Eucalyptus cameldulensis* trees were harvested from Dehnow eucalypt tree adaptation plantation in southern city of Mamasani, Fars province and then one bolt from each tree was cut at the breast height. The wood was transferred to wood and paper Research Laboratory at Research Institute of Forests and Rangelands located in Karadj. First, the bark was removed and the debarked logs were chipped using laboratory drum chipper, Pallmann PHT 120×430 to obtain suitable chips for fiber production. Chips were air dried and tored in polyethylene bags until used. The moisture content of chips prior to steaming was determined as 7%. For defiberation, chips were steamed at 180 °C for either 7.5 or 15 min using saturated steam in laboratory steaming system comprising of two vessel, one for saturated steam production and the other as steaming vessel. Softened chips were discharged in closed container and defibered immediately. Laboratory single disc refiner with the disc diameter of 25 cm and disc rotation of 1450 rpm was used and defiberation was performed in three passes. The fibers were manually dewatered and then air dried. Then a laboratory rotating drum dryer equipped with electrical heating elements was used for final drying of fiber to reach final moisture content of 3% (dry basis). Dry fibers were stored in polyethylene bags until used. Urea-formaldehyde resin at 63% solid, specific gravity, viscosity, gel time and pH of 1.26 g/cm^3, 69 s, 81 s and 8.15 respectively was supplied by local resin manufacturing plant. Reagent grade ammonium chloride was used as harder.

2.2. Board making and testing

Fibers were blended with 10% resin (dry basis) and 1% hardener (based on dry weight of resin) at the concentration of 50%, utilizing rotary drum blender and spray nozzle and then fibers were hand formed using wooden mold. Board target density and thickness was selected at 750 kg/cm^3 and 10 millimeters. Mats were pressed in laboratory press (Buerkle L100) applying 30 bar specific pressure, 5 mm/s closing speed. Three press temperatures of 170, 180 and 190 ºC and two press times of 3 and 4 min were used. Three boards for each combination of variables and based on the 3 factorial (2 steaming temperatures ×2 press times × 3 press temperatures) design total of 36 boards were produced. All boards were conditioned at 65% relative humidity and 21 °C for 15 days and then test samples were prepared from each board according to relevant EN standards. MOR and MOE were measured according to EN 310:1996, Internal bonding (IB), EN 319:1996 and dimensional changes, EN 317:1996 standards. Factorial experimental design based on completely randomized block design was used for statistical analysis of the generated data and in case the effect of variable(s) on the measured properties was significant at 99% or 95% level, then the averages were grouped based on DMRT.

3. Results and discussion

The results of strength and thickness swelling measurement on MDF boards produced from *Eucalyptus camaldulensis* plantation grown wood applying different press temperatures, press time and chips steaming times are illustrated in Figures 1-5. Each value in figures 1-5 is the average of 12 measurements (three replicate boards for each combination of variables and four sets of samples from each board). The results of the statistical analysis showing the F-values and significance level are summarized in Table 1.

Table 1. Analysis of variance (ANOVA) of the results (F- value and significance level).

Source	MOR	MOE	IB	T.S (2h)	T.S (24h)
Steaming time	11.149 **	2.777 n.s	32.491**	8.823**	0.619 n.s
Press temperature	35.416 **	0.956 n.s	0.722 n.s	1.145 n.s	1.084 n.s
Press time	0.393 n.s	0.000 n.s	0.445 n.s	0.842 n.s	0.212 n.s
Steaming time * Press Temperature	3.399 *	4.621**	10.794**	5.256**	1.556 n.s
Steaming time * Press time	0.862 n.s	3.211*	0.435 n.s	0.053 n.s	1.828 n.s
Press temperature * Press time	1.759 n.s	1.015 n.s	3.378*	0.968 n.s	0.047 n.s
Steaming time * Press temperature * Press time	2.101 n.s	0.032 n.s	1.377 n.s	1.235 n.s	2.310 n.s

**significant at 99% confidence level, * significant at 95% confidence level, n.s no significant.

The results showed that at higher press temperature, the MOR of the boards increased which implies that as the pressing temperature increases, the more heat is transferred to the fibers on the surface layers of the mat causing the softening of these fibers. This phenomenon generates denser surface on the pressed boards (Figure. 1). This improved both MOR and MOE. Statistical analysis indicated that higher press temperature produced higher values of MOR or MOE, which indicates that the effect of press temperature on both MOR and MOE are significant at 99% level.

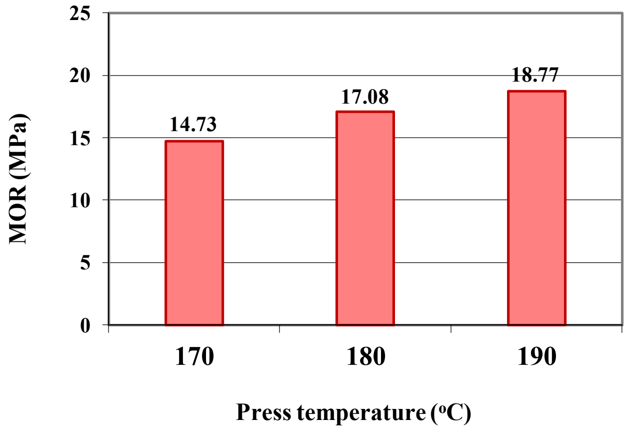

Figure 1. Illustration of the influence of the press temperature on MOR of the MDF boards.

The combined effect of increasing press temperature and steaming time is illustrated in Figure 2. Longer steaming time produced higher MOR but lower MOE except press temperature of 190 ºC. It can be anticipated that longer steaming time intiated the thermo-hydrolysis of the wood substances especially hemicelluloses and weakens the structure of the wood itself. The longer press time deteriorated the MOE of the boards and the boards pressed at 3 min showed higher MOE. The results indicates that either shorter press time or lower press temperature ought to be used for pressing urea formaldehyde bonded MDF borads. The combined effect of steaming time and press temperature on the MOE of the MDF boards was statistically significant at 95% confidence level. The interaction effect of press temperature and steaming time is observed from Figure 2. Higher MOR was observed for boards produced using fibers genetared apllyong 7.5 min steaming time (Figure 3). However, boards prodcued using fibers with 15 min steaming time showed higher MOE, but board pressed at 190 ºC also showed higher MOR. This finding initiates from the interaction of both factors which produces denser and brittle surfaces.

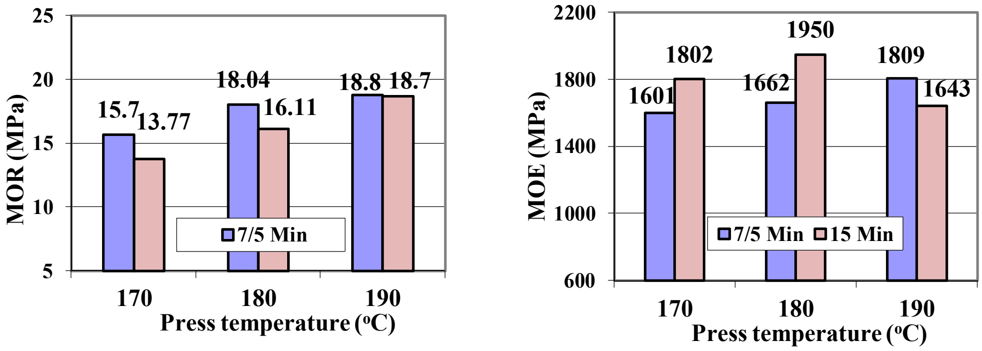

Figure 2. Illustration of the influence of press temperature and time on MOR and MOE of MDF boards.

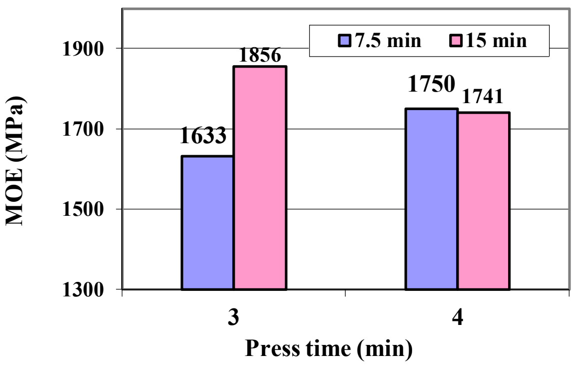

Figure 3. Illustration of the influence of the press temperature and steaming time on the MOE of the MDF boards.

The impact of pressing variables (press time and temperature) on IB of the boards showed that 190 °C press temperature generated higher IB than 180 **°C** press temperatures. However, at 170 or 180 °C press temperature, the press time of 4 min produced higher IB (Figure 4). Both 2 h thickness swelling showed that lower value are reached using fibers with 7.5 min steaming times and 170 °C press temperature (Figure 5).

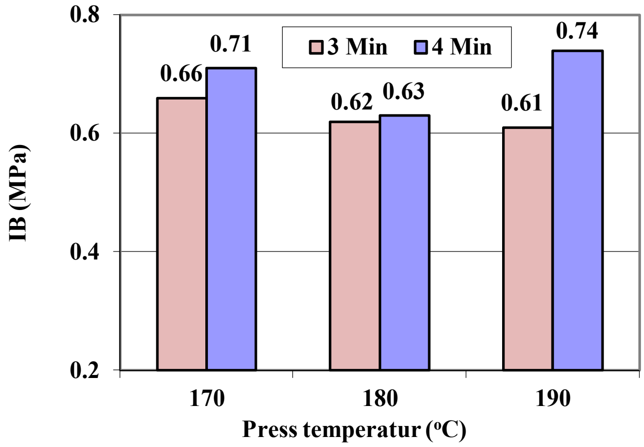

Figure 4. Illustration of the influence of the press temperature and steaming time on the internal bond (IB) of the MDF board.

Different press temperatures and times were studied to find the best combination of variables. Optimum combination was found as 4 min pressing at 190 ºC. Of course these values are valid for 10 mm thick board. It can be expressed that at lower press time and temperature, sufficient heat is not transferred to the board core and resin curing is not complete. Apparently, press temperature is more influential on all measured properties than press time. Even though, the strength of MDF from uncommon raw material such as eucalyptus wood does not compare with softwoods, but it can be utilized as raw material in fiber deficient countries.

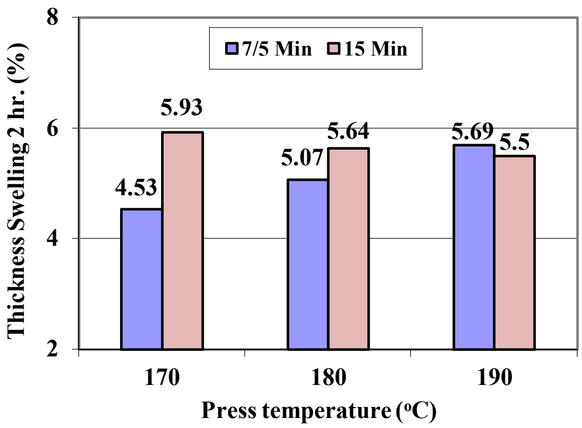

Figure 5. Illustration of the influence of the press temperature and steaming time on the thickness swelling after 2 h immersion in water of the MDF boards.

4. Conclusions

World is facing shortage of wood supply, and the situation in countries located in forest deficient areas which are willing to operate board production facilities is severe. The situation will be harder in the era that forest rich countries are intending to use wood and other lignocellulosic residues for energy. This indicates the need to look for alternative and fiber supplies, among them plantation grown wood such as eucalyptus wood which can be a potential source of fibers. MDF production utilizing such wood revealed that both strength and thickness swelling of the boards are at acceptable level.

The results of this study showed that, the MOR and MOE of boards produced from *Eucalyptus camaldulensis* fibers meet the requirements of Iran national standard requirements and the internal bonding and thickness swelling of boards are exceeds the requirements. Furthermore, to be able to produce fibers suitable for MDF production, both fiber preparation condition and pressing variables should be adjusted to reach the required quality of the fibers and boards.

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