Turkish Journal of Forestry | Türkiye Ormancılık Dergisi
2024, 25(4): 530-533 | Research article (Araştırma makalesi)

Investigation of the effects of heat treatment on medium density fiberboard (MDF)

Hikmet Yazıcı[a,*], Hüseyin Peker[b], Murat Özalp[c]

Abstract: In particular, materials such as medium density fiberboard (MDF) have advantages such as high strength, homogeneous structure and easy processability, but disadvantages such as sensitivity to water and formaldehyde emission. To minimize these disadvantages and increase the durability of the material, methods such as heat treatment are used. This study was carried out to determine the effect of heat treatment at different temperatures on water swelling and formaldehyde emission values of MDF samples. Fiberboards with a thickness of 18 mm were used in the experiments. The fiberboard samples used in this study were kept at 120 °C, 150 °C and 180 °C for 2, 4 and 6 hours respectively. It was observed that water swelling and formaldehyde emission values decreased with increasing time and temperature in heat treatment.
Keywords: Heat treatment; MDF, Screw withdrawal, Swelling in water, Formaldehyde emission

Isıl işlemin orta yoğunlukta lif levha (MDF) üzerindeki etkilerinin araştırılması

Öz: Özellikle orta yoğunlukta lif levha (MDF) gibi malzemeler yüksek mukavemet, homojen yapı ve kolay işlenebilirlik gibi avantajlara sahip olmakla birlikte suya karşı hassasiyet ve formaldehit emisyonu gibi dezavantajlara sahiptir. Bu dezavantajları en aza indirmek ve malzemenin dayanıklılığını artırmak için ısıl işlem gibi yöntemler kullanılmaktadır. Bu çalışma, farklı sıcaklıklarda ısıl işlemin MDF numunelerinin suda şişme ve formaldehit emisyonu değerleri üzerindeki etkisini belirlemek amacıyla gerçekleştirilmiştir. Deneylerde 18 mm kalınlığında lif levhalar kullanılmıştır. Bu çalışmada kullanılan lif levha numuneleri 120 °C, 150 °C ve 180 °C'de sırasıyla 2, 4 ve 6 saat bekletilmiştir. Isıl işlemde artan süre ve sıcaklıkla birlikte suda şişme ve formaldehit emisyon değerlerinin azaldığı gözlemlenmiştir.
Anahtar kelimeler: Isıl işlem, MDF, Vida çekme, Suda şişme, Formaldehit emisyonu

1. Introduction

Polymer bio-composites have garnered increasing research interest due to the utilization of naturally occurring lignocellulosic fibers and bio-based polymer matrices. The term "natural fiber" broadly refers to a variety of plant, animal, and mineral fibers (Clemons and Caulfield, 2010). Common natural fibers in the polymer composite industry include wood fibers and agro-based fibers such as bast fibers (e.g., hemp, jute, kenaf), leaf fibers (e.g., banana, pineapple, sisal), and seed fibers (e.g., oil palm, cotton) (Jawaid and Khalil, 2011). Medium-density fiberboard (MDF) is a wood-based material produced by pressing wood fibers combined with synthetic resin under high frequency and heat. The fibers are uniformly distributed, creating a hard, dense, and homogeneous board with smooth surfaces on both sides. MDF offers advantages in mass production due to its ergonomic properties compared to laminated boards, which reduces labor and time. MDF can be easily painted, coated with PVC paper, or printed with figures. It also holds screws and glue effectively. Specialized types of MDF, such as MDF-X (low formaldehyde content), MDF-H (water and moisture resistant), and MDF-I (fire resistant), are available for applications requiring specific technical properties. Despite its advantages, the MDF industry has faced economic challenges, including fluctuations in the construction sector and difficulties in furniture production (Örs and Keskin, 2003). Research has investigated the hydrolysis of urea-formaldehyde (UF) resins to understand the mechanisms of formaldehyde release from cured UF resins and UF resin-bonded wood panels (Nessuer and Schall, 1970; Robitschek and Christensen, 1976; Myers and Koutsky, 1990; Elbert, 1995; Ringena et al., 2006). The use of different amine solutions in UF resins as formaldehyde scavengers has improved the physical and mechanical properties of MDF panels and reduced formaldehyde emissions (Boran et al., 2011). Studies have shown that MDF produced from black pine exhibits better physical and mechanical properties compared to MDF produced from European oak, Oriental beech, or a mixture of these species (Ayrilmis, 2000). MDF samples manufactured from 100 % beech and 100 % pine fibers, at various adhesive levels and densities, demonstrated that wood species, fiberboard density, and adhesive ratio significantly affect properties such as modulus of rupture,

[a] Zonguldak Bülent Ecevit Üniversitesi, Çaycuma Meslek Yüksekokulu, Tasarım Bölümü, 67900, Zonguldak, Türkiye
[b] Artvin Çoruh Üniversitesi, Orman Fakültesi, Orman Endüstrisi Mühendisliği Bölümü, 08000 Artvin, Türkiye
[c] Kütahya Dumlupınar Üniversitesi, Simav Teknoloji Fakültesi, Ağaç İşleri Endüstri Mühendisliği 43500, Simav, Kütahya
[*] **Corresponding author** (İletişim yazarı): hikmet.yazici@beun.edu.tr
Received (Geliş tarihi): 02.06.2024, **Accepted** (Kabul tarihi): 21.08.2024

Citation (Atıf)**:** Yazıcı, H., Peker, H., Özalp, M., 2024. Investigation of the effects of heat treatment on medium density fiberboard (MDF). Turkish Journal of Forestry, 25(4): 530-533.
DOI: 10.18182/tjf.1494660

screw withdrawal resistance, and thickness swelling. The highest resistance was observed in MDF produced from beech fiber at a density of 720 kg/m³ and an adhesive level of 190 kg/m³, while the lowest resistance was found in pine fiber MDF at a density of 700 kg/m³ and an adhesive level of 180 kg/m³ (Kara and Ateş, 2015). Natural fibers often require modification to improve their bonding with polymer matrices. Various methods, including physical, chemical, and biological treatments, have been explored for fiber modification (Kaddami et al., 2006; Ishak et al., 2009; Asumani et al., 2012). However, these methods often face environmental and economic limitations. Recently, borax (BR) has been used as a green chemical treatment technique, either as a filler or through impregnation (Widiarto, 2005; Özalp, 2010; Cavdar et al., 2015). Moezzipour et al. (2018) found that electrical heating could reduce the negative effects on fibers compared to hydrothermal treatments, leading to improved mechanical properties of the newly produced MDF (Moezzipour et al., 2018). This study highlights the benefits of using recycled fibers to reduce formaldehyde emissions, which is advantageous for both environmental and human health concerns.

In this study, we investigated the effects of heat treatment on water swelling and formaldehyde emission in MDF. The results were compared with non-heat-treated fiberboards to evaluate both positive and negative changes.

2. Material and method

2.1. Material

Medium density fiberboard (MDF) with a thickness of 18 mm was used in all experimental studies.

2.2. Method

2.2.1. Heat treatment

Fiberboards with a thickness of 18 mm, sourced from two different companies, were subjected to heat treatment in a drying oven at temperatures of 120 °C, 150 °C, and 180 °C for durations of 2, 4, and 6 hours.

2.2.2. Thickness swelling

Experiment and control samples, cut to a size of 75 x 75 ±1 mm in accordance with TS EN 317 standards, were subjected to heat treatment at 120 °C, 150 °C, and 180 °C for 2, 4, and 6 hours. After heat treatment, the samples were immersed in water for 2 and 24 hours. The increase in thickness of the samples was measured, and the thickness swelling rate was calculated. Prior to the experiment, specimens were conditioned in an acclimatized chamber at 20 ± 2 °C and 65 ± 5% relative humidity until they reached a constant mass (TS EN 317, 1996). The immersion process was carried out in clean, static water with a pH of 7 ± 1 and a temperature of 20 ± 1 °C, ensuring that the samples did not come into contact with each other and that the base and edges of the water tank were vertical. Water was changed after each experiment. After the immersion process, the samples were removed from the water, excess water was drained, and thicknesses were re-measured from the initial measurement point. Thickness swelling was calculated using the following equation:

$$G_t = \frac{t_2 - t_1}{t_1} \times 100 \quad (1)$$

Where;

Gt: Thickness increase (%)

t1 : Thickness of experiment sample before immersing to water as mm

t2 : Thickness of experiment sample after immersing to water as mm

2.2.3. Formaldehyde emission

Formaldehyde emission measurements were conducted in the laboratory at Gebze Polisan Chemistry. The heat treatment of specimens was performed at temperatures of 120 °C, 150 °C, and 180 °C for durations of 2, 4, and 6 hours. Formaldehyde emission was measured using the perforator method according to TS 4894 EN 120 standards (TS EN 4894 120, 1999). This method involves extracting free formaldehyde from the board samples, which are boiled in toluene. The free formaldehyde is then transferred to distilled water, and its concentration in the aqueous solution is measured. The emission amount is expressed as a proportion of the dry board weight. The formaldehyde emission was calculated using the following formula:

$$F = \frac{(As - Ab).f.(100 + R.V)}{M} \text{ (mg/100 g complete dry board)} \quad (2)$$

Here;

As : Absorbance of extraction solution (nm), Ab : Absorbance of blank test (nm)

f : Calibration Curve Factor, R : Humidity amount of board (%)

M : Sample Weight (g), V : Volume of flask (cm^3)

The perforator test device used for measuring formaldehyde emissions is shown in Figure 1.

Figure 1. Perferator test device

3. Result and discussion

3.1. Thickness swelling results

At the end of a 2-hour water immersion period, the swelling results for specimens from Companies A and B, which were heat-treated at 120 °C, 150 °C, and 180 °C for 2, 4, and 6 hours, are presented in Table 1.

When these results were discussed, it was seen increase in thickness swelling in all heat-treated samples of fiber boards produced by A company compared with control value. At the end of waiting time of 24 hours, swelling in water results of specimens, which were waited at 120- 150- 180 ºC for 2- 4- 6 hours, were given in Table 2.

The results show an increase in thickness swelling for all heat-treated fiber board samples from both companies compared to the control values.

3.2. Formaldehyde emission values

Effects of heat treatment on formaldehyde emission values were given in Table 3.

Table 1. Swelling results at the end of waiting for 2 hours in water (%)

Heat treatment (°C)	Time (Hours)	Non-heat treated	Standard deviation	Max. value	Min. value	Average value (%)
120	2	18.7	1.11	6.5	3.72	4.72
	4		0.64	6.11	4.61	5.42
	6		0.46	5.72	4.55	5.23
150	2		0.35	5.61	4.72	5.21
	4		0.26	5.77	5.16	5.53
	6		0.27	5.44	4.72	5.01
180	2		0.30	5.70	5.11	5.38
	4		0.34	4.88	4.05	4.27
	6		0.67	5.11	3.61	4.37

Table 2. Swelling results at the end of waiting for 24 hours in water (%)

Heat treatment (^{0}C)	Time (hours)	Non-heat treated	Standard deviation	Max. value	Min. value	Average value (%)
120	2	18.47	1.18	21.83	18.77	20.15
	4		0.70	22.88	21.11	22.13
	6		0.52	20.77	19.61	20.15
150	2		0.65	23.27	21.44	22.3
	4		0.40	22.88	22.00	22.44
	6		0.22	22.05	21.44	21.68
180	2		0.54	24.11	22.61	23.26
	4		1.85	23.33	18.77	21.14
	6		1.99	23.5	18.27	21.58

Table 3. Formaldehyde emission results (mg/100g)

Heat treatment (°C)	Time (hour)	Standard deviation	Max. value (%)	Min. value (%)	Average value
120	2	0.56	19.20	18.03	18.75
	4	0.60	19.17	18.00	18.68
	6	0.38	18.40	17.45	18.05
150	2	0.29	17.57	16.90	17.18
	4	0.40	17.27	16.43	16.81
	6	0.35	17.17	16.25	16.71
180	2	0.45	16.75	15.48	16.08
	4	0.41	15.75	14.72	15.29
	6	0.53	16.40	15.06	15.54

The formaldehyde emission values of specimens heat-treated at 120 °C did not show significant reductions on average, and the heat treatment at 120 °C had minimal effect on formaldehyde emission. However, specimens heat-treated at 150 °C exhibited a noticeable decrease in formaldehyde emission, with the reduction becoming more pronounced with increased treatment time. Similarly, heat-treated specimens at 180 °C also showed decreased formaldehyde emissions, with a significant effect observed with increased heat treatment time. Overall, increasing the temperature and duration of heat treatment led to a reduction in formaldehyde emissions. The optimal temperature for minimizing formaldehyde emissions was found to be 180 °C, with increasing treatment time resulting in further reductions in formaldehyde levels.

To minimize formaldehyde emissions, the maximum temperature is 180 °C. Data collected at 120 °C and 180 °C show that formaldehyde emissions decrease with increasing heat treatment temperature and time.

4. Conclusions

In this study, we investigated the effects of heat treatment on Medium Density Fiberboard (MDF) samples, focusing on their swelling behavior in water and formaldehyde emission levels. The heat-treated MDF samples were subjected to different temperatures and durations to assess their performance. Specifically, the samples were treated at temperatures of 120 °C, 150 °C, and 180 °C for periods of 2, 4, and 6 hours.

The swelling experiments revealed that, after 2 and 24 hours of immersion in water, all heat-treated MDF samples exhibited increased thickness swelling compared to the control samples that were not heat-treated. This suggests that while heat treatment may enhance some properties, it also adversely affects the dimensional stability of MDF in water.

Regarding formaldehyde emissions, the results were more favorable. The MDF samples heat-treated at 120 °C, 150 °C, and 180 °C for varying durations (2, 4, and 6 hours) all met the relevant standards for formaldehyde emissions. Importantly, the heat treatment led to a reduction in formaldehyde emissions compared to the untreated control samples. This reduction is significant because formaldehyde is a well-known health hazard, and its decreased presence in the treated samples indicates an improvement in air quality and safety.

The technological properties of MDF, which consists of at least 80% vegetable fibers, are generally comparable to those of solid wood. However, the study highlights a trade-off between the benefits and drawbacks of heat treatment. While heat treatment was effective in reducing formaldehyde emissions—thereby mitigating a health risk—it also negatively impacted the swelling behavior of the MDF. This indicates that while higher temperatures and longer treatment times can be beneficial for reducing formaldehyde, they may simultaneously compromise the material's water resistance and dimensional stability.

Overall, the findings suggest that heat treatment can improve the safety profile of MDF by reducing harmful formaldehyde emissions, but careful consideration must be given to its effects on the material's physical properties.

References

Asumani, O. M. L., Reid, R.G., Paskaramoorthy, R., 2012. The effects of alkali–silane treatment on the tensile and flexural properties of short fibre non-woven kenaf reinforced polypropylene composites. Composites Part A: Applied Science and Manufacturing, 43(9): 1431–1440.

Ayrilmis, N., 2000. The effect of tree species on technological properties of MDF. MSc Thesis, Istanbul University, Institute of Natural Sciences, Turkey.

Boran, S., Usta, M., Gümüşkaya, E., 2011. Decreasing formaldehyde emission from medium density fiberboard panels produced by adding different amine compounds to urea formaldehyde resin. International Journal of Adhesion and Adhesives, 31(7): 674–678.

Cavdar, A. D., Mengeloğlu, F., Karakus, K., 2015. Effect of boric acid and borax on mechanical, fire and thermal properties of wood flour filled high density polyethylene composites. Measurement, 60: 6–12.

Clemons, C.M., Caulfield, D.F., 2010. Functional fillers for plastics. In: Natural Fibers, John Wiley & Sons, Weinheim, pp. 150-556.

Elbert, A. A., 1995. Influence of hardener systems and wood on the formaldehyde emission from urea-formaldehyde resin and particleboards. Holzforschung, 49(4):358-362.

Ishak, M. R., Leman, Z., Sapuan, S. M., Salleh, M. Y., Misri, S., 2009. The effect of sea water treatment on the impact and flexural strength of sugar palm fibre reinforced epoxy composites. International Journal of Mechanical and Materials Engineering. 4(3): 316–320.

Jawaid, M., Khalil, H.P.S.A., 2011. Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review. Carbohydrate Polymers, 86(1): 1–18.

Kaddami, H., Dufresne, A., Khelifi, B., Bendahou, A., Taourirte, M., Raihane, M., Issartel, N., Sautereau, H., Gerard, J-F, Sami, N., 2006. Short palm tree fibers–Thermoset matrices composites. Composites Part A: Applied Science and Manufacturing, 37(9): 1413–1422.

Kara, M.E., Ateş, S., 2015. Effects of Some Production Variables on MDF qualİty. In: XXVIIth International Conference Resarch Furniture Industry, 17-20 September, s.74-80 Ankara.

Moezzipour, B., Abdolkhani, A., Doost-hoseini, K., Ahmad Ramazani, S. A., Tarmian, A., 2018. Practical properties and formaldehyde emission of medium density fiberboards (MDFs) recycled by electrical method. European Journal of Wood and Wood Products, 76: 1287–1294.

Myers, G.E., Koutsky, J.A., 1990. Formaldehyde liberation and cure behavior of urea-formaldehyde resins. Holzforschung, 44(2), 117–126.

Nessuer, H., Schall, W. 1970. Experiments for the determination of hydrolysis phenomena in particleboards. Holzforschung Holzverwert, 22(6), 116-120.

Örs, Y., Keskin, H., 2003. Ağaç Malzeme Teknolojisi. Gazi Yayınevi, Ankara.

Özalp, M., 2010. The effect of borax pentahydrate addition to urea formaldehyde on the mechanical characteristics and free formaldehyde content of medium density fiberboard (MDF). European Journal of Wood and Wood Products, 68: 117–119.

Ringena, O., Janzon, R., Pfizenmayer, G., Schulte, M., Lehnen, R., 2006. Estimating the hydrolytic durability of cured wood adhesives by measuring formaldehyde liberation and structural stability. Holz als Roh-und Werkst., 64(4): 321–326.

Robitschek, P., Christensen, R. L., 1976. Degradation phenomena in urea-formaldehyde resin-bonded particleboard. Forest Products Journal, 26(2): 43-46.

TS EN 317, 1999. Particleboards and fibreboards determination of swelling in thickness after immersion in water. TSE, Ankara.

TS 4894 EN 120, 1999. Wood based sheets boards determination of formaldehyde content, TSE, Ankara.

Widiarto, S., 2005. Effect of borax on mechanical properties and biodegradability of sago starch—poly (vinylalcohol) blend films. Jurnal Sains and Teknologi, 2: 151–157.