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ARAŞTIRMA MAKALESİ RESEARCH PAPER

Some Properties of Fiberboard Manufactured with Wastes of Kraft Pulp Mill [*]

Derya USTAÖMER*[1] Evren ERSOY KALYONCU[2] Hüseyin KIRCI[1]

[1]*Karadeniz Technical University, Department of Forest Industry Engineering, Trabzon, Turkey.*
[2] *Karadeniz Technical University, Arsin Vocational Scholl of Higher Education, Material and Material Processing Technologies, Trabzon, Turkey.*

*: https://orcid.org/0000-0003-0102-818X, : https://orcid.org/0000-0002-4538-7187, : https://orcid.org/0000-0002-3529-776X

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Abstract: In this study, it was aimed to investigate the usability of some wastes such as wood chip screening rejects and kraft pulp screening rejects as fibrous materials in the manufacture of medium density fiberboard (MDF). Chip screening rejects were refined with a laboratory type refiner; however, pulp screening rejects were not refined. These materials were added to commercial fibers with the rates of 10%, 30%. Fiberboards were manufactured using urea formaldehyde (UF) adhesive. Some properties of these fiberboards such as water absorption (WA), thickness swelling (TS), surface roughness parameters, color change, modulus of rupture (MOR) and modulus of elasticity (MOE) values were determined. As a result of these, it was found that all values showed different trend depending on rates and types of Kraft mill wastes. Generally, the use of these materials had positive effects on the panel properties.

Keywords: Fiberboard, kraft process, pulp fiber, screening rejects, wood chips.

Kraft Hamuru Fabrika Atıkları ile Üretilen Lif levhaların Bazı Özellikleri

Öz: Bu çalışmada, odun yonga eleme atıklarının ve kraft hamuru elek atıklarının lifsel materyaller olarak orta yoğunlukta lif levha (MDF) üretiminde kullanımının uygunluğu araştırılmıştır. Yonga eleme atıkları, laboratuvar tipi bir rafinörde liflendirilirken; hamur eleme atıkları ise rafinör işlemine uğratılmadan kullanılmıştır. Elde edilen lifsel materyaller ticari liflere %10 ve %30 oranlarında ilave edilmiş ve üre formaldehit (UF) tutkalı kullanılarak lif levha üretimleri gerçekleştirilmiştir. Üretilen bu levhaların su alma (SA), kalınlığına şişme (KŞ) değerleri, yüzey pürüzlülük parametreleri, renk değişim değerleri, eğilme direnci (MOR) ve eğilmede elastikiyet modülü (MOE) gibi bazı özellikleri belirlenmiştir. Bu çalışmanın sonucu olarak, tüm değerlerin, kraft fabrika atıklarının türü ve kullanım oranına bağlı olarak değişim gösterdiği belirlenmiştir. Genel olarak, bu atık materyallerin kullanımının levha özellikleri üzerinde olumlu yönde etkisinin olduğu tespit edilmiştir.

Anahtar sözcükler: Eleme atıkları, hamur lifi, kraft prosesi, liflevha, odun yongaları.

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INTRODUCTION

The growing scarcity of raw materials and disruptions of industrial waste management are some of the main problems that cause inevitable negative effects for all industries and need to be solved with economically and reasonably.

Like other industries, the MDF industry faces the same problems and is also negatively affected by the decrease in the availability of raw materials (Akgül & Tozluoğlu, 2008). This important problem has led researchers to search alternative sources. Residues or by-products of forest, wood or paper products such as annual plants, harvesting residues, agricultural wastes, lumber plant wastes, furniture plant wastes, wood shavings or shreds of paper etc. can reuse as raw material (Akgül & Çamlibel, 2008).

Kraft is the most common chemical pulping method used in the worldwide (Vaaler & Moe, 2001; Enqvist, 2006). Plenty of wastes such as barks, pins, fines, oversize and overthick wood chips of screening, pulp and paper sludge, pulp screening reject, black liquor, etc. occur during all stages of this process (Gavrilescu, 2004; Bajpai, 2015). Although these wastes are considered as a problem, they could be useful for many industries as resources.

The size and shape of wood chips are very important in chemical pulping and especially in kraft pulping (Gullichsen, 1999). Unsuitable wood chips cause some problems such as pulping chemical penetration and lower pulp yield (Gullichsen, 1999; Eriksen et al., 1981; Tian, 2017). Acceptable sizes of wood chips in kraft process are approximately 15-25 mm length, a width of 20 mm and 3-5 mm thickness (Gerald, 2006). In kraft pulping process, the oversized wood chips are rejected for pulping and sent to re-chipping while the fines are sent to burn for heat production (Bajpai, 2010). It is possible to produce refiner mechanical pulp (RMP) with small size of wood chips such as sawdust and shavings which are less suitable for kraft pulping due to their bulk (Lewis, 1971). Low cost, high values of yield (range of 85-95%), brightness, light scattering properties, smoothness, bulk and good formation are the major advantages of mechanical pulps (Bierman, 1996; Sundholm, 1999).

The pulp screening reject is another waste of the kraft pulping process. After separation of black liquor from the fiber, pulp screening performs to separate the undercooked, the coarser and non fibrilized fiber and fiber bundles from the pulp to produce accepted high-value pulp (Tikka et al., 1993; Kırcı, 2000; Hart, 2011). Rejects from the pulp screening process are usually refined, screened and the final rejects are thickened and burned (Tikka et al., 1993; Bierman, 1996; Hart, 2011).

The objective of this study was to evaluate the usability of small size of wood chips, which are not suitable in sizes for pulping standards and pulp screening rejects obtained from kraft process, for the manufacture of medium density fiberboard (MDF) and determine the some properties such as water absorption (WA), thickness swelling (TS), surface roughness parameters, color change, modulus of rupture (MOR), modulus of elasticity for these MDF panels.

MATERIAL and METHODS

In this study, commercial fibers (mixture of pine and beech) were used as raw material. Also, refiner mechanical pulp (RMP) fibers produced from wood chip screening rejects (the pin-chips) and kraft pulp screening rejects (PSR) obtained from Kraft pulp mill were taken as additive raw materials to commercial fibers.

Wood chip screening rejects (pin-chips) were refined by using disc refiner in a laboratory scale for refiner mechanical pulp (RMP) fibers. These fibers were air-dried and separated using laboratory mixer with 18.000 rpm speed for 2 minutes. Refiner mechanical pulp (RMP) fibers and pulp screening reject (PSR) fibers were mixed into commercial fibers with the additional rates of 10% and 30% for panel manufacturing. Fibers were dried to 2-3% moisture content. Urea formaldehyde (UF) at 12% rate was used as an adhesive. Paraffin emulsion as water repellent and ammonium chloride as hardener at 1% rates were added to UF adhesive. After the application of the adhesive, manually formed fiber mats were pressed at the hot press at 180 ºC temperature for 7 min. Fiberboards were manufactured with 8 mm thickness and 750 kg/m^3 target density. These MDF panels were conditioned at 65 ± 5% RH and 20 ± 1 °C, in accordance with TS-642-ISO 554 (1997) and dimensioned for the tests according to TS-EN 326-1 (1999). Panel types and contents were represented in Table 1.

Table 1. Panel types and contents.

Panel type	Content
A1	90% fiber +10 %RMP*
A2	70% fiber +30 % RMP*
B1	90% fiber +10 %PSR**
B2	70% fiber +30 %PSR**
Control	100% fiber

*RMP: Refiner mechanical pulp, **PSR: Pulp screening rejec.

***Water Absorption and Thickness Swelling*: The** water absorption (WA) and thickness swelling (TS) values of MDF samples for 2h-24h were determined according to EN 317 (1993) standard.

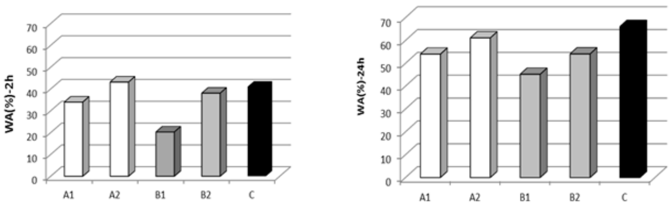
Modulus of Rupture and Modulus of Elasticity: The modulus of rupture (MOR) and modulus of elasticity (MOE) values of MDF samples were determined according to EN 310 (1993) standard.

Surface Roughness Parameters: The surface roughness parameters such as *R*a, *Rq* and *R*z of MDF samples were measured using Mitutoya Surftest SJ-210 instrument according to DIN 4768 (1990) standart.

Color Measurements: The color measurements of the MDF samples were carried out by using Konica Minolta CM-2600d spectrophotometer according to the CIE $L^*a^*b^*$ system (HunterLab, 2008). The Δa^*, Δb^*, ΔL^* and total color change (ΔE^*) of the MDF samples were determined.

RESULTS and DISCUSSION

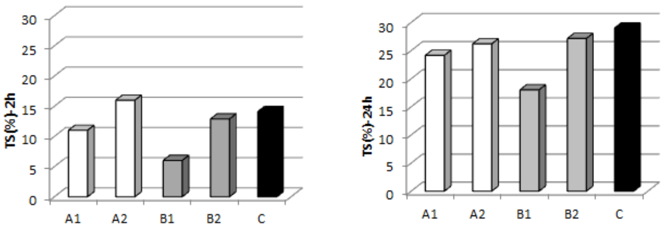
Water Absorption and Thickness Swelling: The water absorption (WA) and thickness swelling (TS) values of MDF samples after water immersion for 2 and 24 h are represented in Figure 1 and 2, respectively.



(a) (b)

Figure 1. (a)-WA values of MDF samples for 2h, (b)- WA values of MDF samples for 24h.

As can be seen in Figure 1a and 1b, average WA values changed depend on the type and rate of fibers. WA values of MDF samples for 2-24 h were found lower than WA values of control samples except for A2 group (2h) manufactured with rate of 30% RMP fibers. This group had slightly higher value. B1 group was found having the lowest WA values for both 2-24h. The best results were obtained with B group manufactured with PSR fibers compared to A group manufactured with RMP fibers. This situation could be reasoned because of fiber properties. The pulping process has an important effect on fiber properties (Clark, 1985; Smook, 2002; Migneault et.al., 2010). According to Luukko and Maloney (1996), mechanical pulp fibers are prone to swelling because of beaten fines.



(a) (b)

Figure 2. (a)-TS values of MDF samples for 2h (b) - TS values of MDF samples for 24h

As can be seen in Figure 2a and 2b, average TS values of MDF samples showed similar trend with WA values of MDF samples. These values also changed depend on the type and rate of fibers. TS values(2-24h) of A and B groups manufactured with RMP and PSR fibers were found more lower than those of control samples except for A2 group manufactured with rate of 30% RMP fiber (2h). A notable decrease was observed on the TS values (2-24h) of B1 groups manufactured with 10% addition of PSR fibers. Generally, higher TS values were obtained with RMP fibers. This could be attributed to the increased amount of fine in mechanical pulp.

Modulus of Rupture and Modulus of Elasticity: The modulus of rupture (MOR) and modulus of elasticity (MOE) values of MDF samples are represented in Figure 3 and 4, respectively.

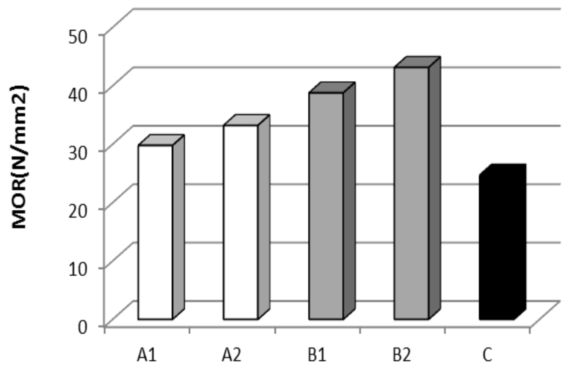


Figure 3. MOR values of MDF samples.

As represented in Figure 3, the type and rate of raw material showed notable effect on the MOR values of MDF samples. All MOR values were recorded to be higher than control values. These values increased with increasing rate of RMP and PSR fibers. The better results were recorded with B group compared to A group. The highest MOR value of MDF samples was obtained from B2 group manufactured with rate of 30% PSR fibers. The addition of PSR fibers provided more improvement than the addition of RMP fibers on the MOR values of MDF samples.

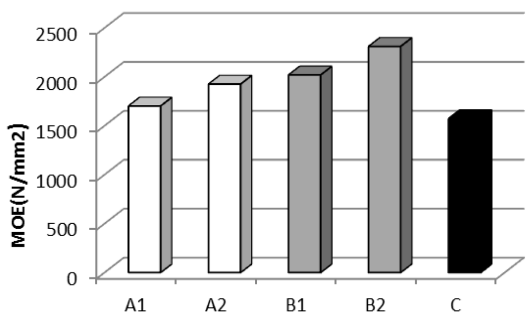


Figure 4. MOE values of MDF samples.

As can be seen in Figure 4, MOE values showed similar tendency with MOR values of MDF samples. All MOE values of the samples clearly improved as rates of RMP and PSR fibers were increased from 10% to 30%. The highest MOE value of MDF samples was obtained from B2 group manufactured with rate of 30% PSR fibers.

Evaluating both MOR and MOE values together; it is clearly seen that the rate and type of fibers had an important effect on these values. All MOR and MOE values of A and B groups were found higher than those of control groups. PSR fibers provided better results. These results could be attributed to the structural properties of the fibers. PSR fibers are longer than RMP fibers because of their production process. It is well known that fiber length is a crucial parameter. Long fiber can have more fiber joints and therefore this could affect the strength properties of the final material. Also, chemical pulp fibers are more flexible compared to mechanical pulp fibers (Johansonn, 2011). Similar trend was observed by Nourbakhsh & Ashori (2009). According to their study, the usage of long fibers with high aspect ratio is one of the considerable parameters controlling the mechanical properties of composites.

Surface Roughness Parameters

The changes in surface roughness parameters such as *R*a, *Rq* and *R*z of MDF samples are represented in Figure 5, 6 and 7, respectively.

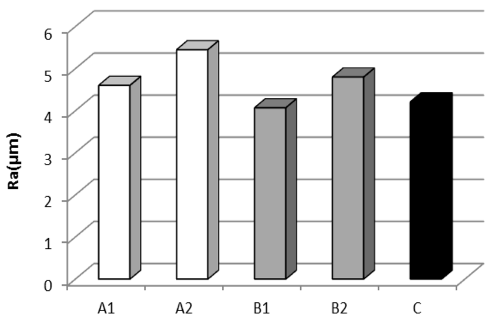


Figure 5. Ra values of MDF samples.

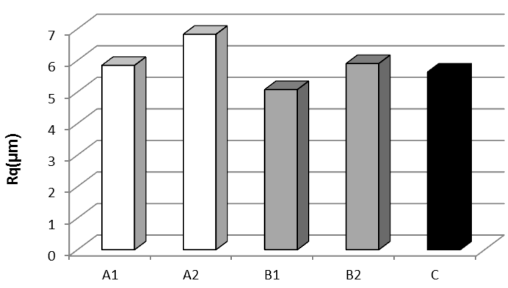


Figure 6. Rq values of MDF samples.

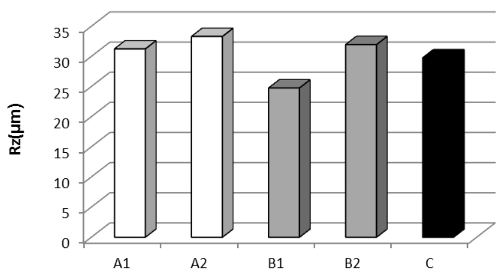


Figure 7. Rz values of MDF samples.

As can be seen in Figure 5, 6 and 7, generally, all surface roughness parameters (R_a, R_q, R_z) of A and B groups showed differences depend on the rate and type of fibers used for MDF manufacturing. These values of A and B groups were generally found to be higher than those of control groups except for B1 group manufactured with rate of 10% PSR fibers. The higher surface roughness parameters (R_a, R_q, R_z) were obtained with A2 and B2 groups. The B1 group resulted in the smoothest surfaces with the Ra value of 4.07 µm, Rq value of 5.08 µm and an Rz value of 25.14 µm, while corresponding R_a, R_q and R_z values for the control samples were 4.21µm, 5.63 and 28.98 µm, respectively.

Especially, R_a, R_q, R_z were found higher for A group. As the additive rate of RMP was increased, surface roughness values might be increased due to the more fines and small fibers. The changes on the surface roughness parameters of samples could be reasoned from the structural properties of RMP and PSR fibers. It is clear to say that, structural properties of raw materials might cause some irregularities on the material surface, and these irregularities also affect surface parameters of final material. It is reported that the surface roughness degree is a function of production parameters and raw material properties (Hiziroglu & Kosonkorn, 2006).

Color Measurements: The color measurement parameters (ΔL^*, Δa^*, Δb^*, ΔE^*) of MDF samples are given in Table 2, and Figure 8. The pictures of color changes occurred on the surfaces of MDF samples are presented in Figure 9.

Table 2. Color measurement parameters (ΔL^*, Δa^*, Δb^*)

Panel type	ΔL^*	Δa^*	Δb^*
A1	6.30	-1.60	-2.65
A2	8.48	-2.19	-0.53
B1	-1.68	-0.65	-2.11
B2	5.32	-0.98	-0.20

Control values were taken as references

Referring to the results in Table 2, positive and negative ΔL^* values were recorded for MDF samples. ΔL^* value represents difference in darkness and lightness; positive "+" value of ΔL^* indicates lighter and negative "-" value of ΔL^* indicates darker (Konica Minolta, 2018). According to results in Table 2, the ΔL^* values increased with increasing rates of RMP and PSR fibers. While the highest positive ΔL^* value was found to be 8.48 for A2 group manufactured with rate of 30% RMP fibers, the lowest value was found to be -1.68 for B1 group manufactured with rate of 10% PSR fibers. ΔL^* values indicated that all MDF samples turned to lighter color except for B1 group. These differences between lightness or darkness of MDF panel groups can be clearly observed from Figure 9.

All Δa^* values of MDF samples were found as negative and ranged from -0.65 to -2.19. This means that MDF samples had a tendency to green direction. Similarly, Δb^* values were also found as negative and ranged from -0.20 to -2.65. These values were found in blue direction. In the color scale, + a* and - a* represent red and green directions; +b* and –b* represent yellow and blue directions, respectively (HunterLab, 2008).

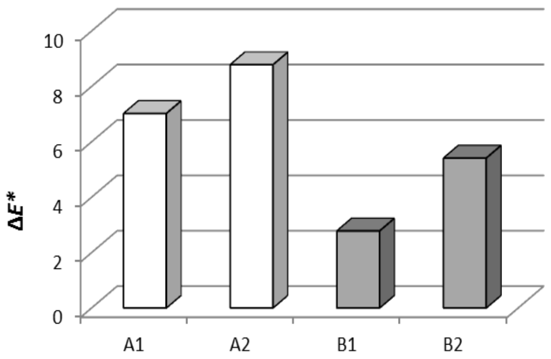


Figure 8. Δ*E**values of MDF samples.

As represented in Figure 8, it was found that the type and rate of raw material for panel manufacturing had effect on the total color change values of MDF samples. Especially, Δ*E** values increased with the increasing rates of RMP and PSR fibers. The highest Δ*E** value was determined to be 8.72 from A2 group manufactured with rate of 30% RMP fibers. The lowest Δ*E** value was recorded to be 2.78 from B1 group manufactured with rate of 10% PSR fibers. The highest color changes were obtained from A group manufactured with RMP fibers compared to B group manufactured with PSR fibers.

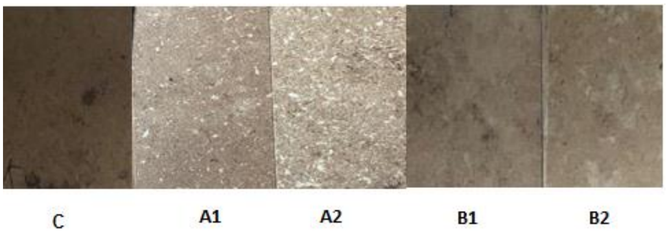


Figure 9. Pictures of control and MDF samples manufactured with RMP and PSR fibers

The color changes of panel groups were cleary seen in Figure 9. A1 and A2 groups had higher color change than B1, B2 groups and control group. This could be probably due to the differences in the structural properties of fibers. Mechanically produced pulp have some optical advantages such as brightness, light scattering properties (Sundholm, 1999). However, in kraft pulp production, chemical reactions of residual lignin with pulping chemicals cause dark brown color of pulp (Twede et al., 2014).

CONCLUSIONS

The fiber of refined chip screening rejects and pulp screening rejects obtained from kraft pulping process had positive effects on the MDF panel properties. In general, WA and TS values of each group for 2-24 h were found lower than those of control groups except for MDF panel manufactured with rate of 30% RMP. A considerable decrease was recorded on the WA and TS values (2-24h) of MDF panels manufactured with the rate of 10 % PSR fibers. All MOR and MOE values of each group were found higher than those of control groups and these values improved increasing rate of RMP and PSR fiber. The highest MOR and MOE values were obtained with rate of 30% PSR fibers. Surface roughness parameters of each group were generally found to be higher than those of control groups except for MDF panel manufactured with rate of 10% PSR fibers. The rougher surfaces were obtained with increasing rate of RMP and PSR fibers. The highest color changes were observed with the additive rates of RMP fibers. Generally, the best results for all tests were recorded from MDF panels manufactured with PSR fibers. Results indicated that, some wastes of Kraft pulping process such as wood chip screening rejects and kraft pulp screening rejects as fibrous materials have potential for reuse as raw materials for medium density fiberboard (MDF) manufacturing.

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***Corresponding author's:**
Derya USTAÖMER
Karadeniz Technical University, Department of Forest Industry Engineering, Kanuni Campus, 61080, Trabzon, Turkey.
E-mail : uderya@ktu.edu.tr
ORCID : https://orcid.org/0000-0003-0102-818X
Phone : +90 (462) 377 15 34
Fax : +90 (462) 325 74 99
GSM : +90 (546) 227 87 27