Production of Fiberboard Using Wood Fiber and Tetra Pak® Material and Evaluation of Some Physical and Mechanical Properties

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Composite boards were produced using Tetra Pak ground material and wood fiber, and the effects of the mixture ratio on the properties of the boards were determined. The main purpose of the study was to obtain a fiber board by bonding Tetra Pak material with wood fiber using phenol formaldehyde adhesive. For this purpose, waste Tetra Pak boxes were collected after domestic use and ground in a high-speed grinding machine. The obtained ground material (Tetra Pak material) was mixed with the wood fiber used in fiberboard production at different ratios of Tetra Pak material (0%, 33%, 66%, and 100%). These mixtures were glued using phenol formaldehyde. Each mixture was first formed into a sheet and then pressed in a hot press using a metal mold. After pressing, the physical (density, water absorption, and thickness swelling) and mechanical properties (modulus of rupture, modulus of elasticity, internal bond, and hardness) were determined. According to the data obtained, increasing the proportion of Tetra Pak material in the produced panels improved their physical properties while decreasing their mechanical properties. The modulus of rupture and modulus of elasticity values for group 1 and group 4 decreased from 32.1 to 10.4 N/mm² and from 2777 to 1019 N/mm², respectively.

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Keywords: Recycling; Waste Tetra Pak material; Wood fiber; Fiberboard; Composite board

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INTRODUCTION

Increased attention is being given to recycling some solid waste materials and using them in the production of new products. In particular, efforts of recycling plastic waste, metals, paper products, and glass materials and bringing them back into the economy are increasing. Efforts toward waste management have gained momentum both in Turkey and other countries of the world. Important steps have been taken within the scope of the *Zero Waste* project launched in Turkey in 2017.

Packaging containers from various manufacturers are used for liquid beverages. These beverage containers are marketed under the trade names Tetra Pak®, Pure Pak®, SIGNATURE EVO®, and Greatview® (Bal and Nasıroğlu 2024). A large number of packaging containers are produced worldwide each year, and because these containers are single-use, they become waste after being used. In 2023 alone, 179 billion boxes were produced by Tetra Pak (www.tetrapak.com/tr). This figure, when compared to the number of boxes produced by other manufacturers, amounts to a significant waste stream. Various methods have been developed for recycling this type of packaging waste; these include shredding and compressing these boxes under heat to produce sheets, hydropulping to extract paper fiber from them, producing pellets from the remaining polyethylene and aluminum, and incinerating the waste to generate energy (Enç *et al.* 2012).

There have been studies on the recycling of waste beverage cartons and their use in the production of different composites. For example, beverage packaging, originally designed and developed for milk, is widely used in the packaging of many foods and beverages. It has been stated that the recycling and recovery of beverage cartons, which contain approximately 70% paper, 25% polyethylene (PE), and 5% aluminum, is important, and research has been conducted on the separation and recovery of these materials (Martínez-López *et al.* 2016; Karaboyacı *et al.* 2017). In another study, Abreu (2007) reported that various items were produced from the PE and aluminum waste remaining after removing the paper portions from beverage cartons. Uner and Bülbül (2022) investigated some mechanical properties of beverage cartons and composite sheets produced from recycled PE using some fillers and binders.

Previous studies have used beverage boxes as filler in the production of composite materials using thermoplastic polymers. The majority of these studies focused on developing a new polymer-based composite using an extruder machine with a polymer matrix. In these studies, waste beverage boxes were used as filler, and the properties of composites produced with different types of polymers were evaluated (Lopes and Felisberti 2006; Hidalgo 2011; Kaymakçı *et al.* 2012; Ebadi *et al.* 2016; Ebadi *et al.* 2018; Bal 2022; Kuzmin *et al*. 2023; Bal and Nasıroğlu 2024; Bal 2025). In another study, boards were produced from beverage boxes bonded with different ratios of PE under high pressure in a press, without using an extruder machine. Some of their properties were determined and compared with those of oriented strand board and particleboard (Gok *et al.* 2017).

Previous studies have focused on composites with different properties obtained by bonding beverage boxes with thermoset polymers. For example, Rhamin *et al.* (2013) obtained 1-cm-thick panels by cutting beverage boxes into 5 cm × 5 cm pieces and then gluing them with MUF glue. Sujatha *et al.* (2021) investigated some mechanical properties of composite panels produced from glued and unglued beverage boxes and reported some positive results for the produced composite panels. In addition, Auriga *et al.* (2021) investigated some of the physical and mechanical properties of particleboard produced from beverage boxes using urea-formaldehyde resin. Some positive results were reported as a result of this study. However, apart from these three studies, to the best of the author's knowledge, no studies on the production of panels from waste beverage boxes using thermoset adhesive have been conducted.

Medium-density fiberboard (MDF) is produced using wood fibers obtained from different tree woods and thermoset polymers. MDF is used especially in furniture production and decoration. Previous studies have investigated the use of other annual plants and waste paper besides wood fiber in MDF production. These include the use of soybean stalks and wheat stalks with urea formaldehyde adhesive (Ye *et al.* 2007), peanut shells (Akgul and Tozluoglu 2008), wheat stalks and urea formaldehyde adhesive (Halvarsson *et al.* 2010), rice husks and soybean protein adhesives (Ciannomea *et al.* 2010), corn and cotton stalks, and urea formaldehyde adhesive (Kargarfard and Jahan-Latibari 2011), Rorippa stalks and wood fibers (Tozluoğlu 2016), waste from a kraft pulp mill and urea formaldehyde adhesive (Ustaömer *et al.* 2019), waste cement bags (Sales *et al.* 2021), waste newspaper and wood fibers (Engin and Konukçu 2024), palm tree leaves, beech and fir wood fiber and urea formaldehyde glue (Ustaömer *et al.* 2024), and waste MDF dust

(Güler and Doğan 2022). The physical and mechanical properties of these boards were investigated.

Many studies have been conducted to develop new products from recycled Tetra Pak boxes. Information on these previous studies has been provided in the literature summary. However, to the best of the author's knowledge, no previous study has examined a material produced by mixing waste Tetra Pak material with wood fiber and using phenol formaldehyde as an adhesive. Recycling such waste and producing new products are defined under the goals of "Responsible Consumption and Production" in the Sustainable Development Goals. Utilizing Tetra Pak materials in this way in MDF production will potentially lead to reductions in the amount of waste in landfills and in the consumption of virgin fibers. In line with these goals, the main aim of this study was to produce fiberboard using wood fiber and Tetra Pak material and then evaluate selected properties of the resulting boards.

EXPERIMENTAL

Materials

Wood fiber

The wood fibers used in this study were obtained from the Kastamonu Entegre Factory located in Adana province in Turkey. The wood fibers were derived from pine wood. The wood fibers were obtained without glue. The gluing process was carried out in a laboratory environment. In this study, the fibers were dried in the laboratory and then glued together before the panels were produced. An image of the fibers in their dry state before gluing is provided in Fig. 1-e.

Tetra Pak material

The Tetra Pak boxes, used in this study were collected by the author himself after household use. All the Tetra Pak boxes used in the study were milk boxes and were either half-liter or one-liter in size, as can be seen in Fig. 1-a. The Tetra Pak boxes contain approximately 70% paper, 25% polyethylene (PE), and 5% aluminum (www.tetrapak.com/tr). After use, the boxes were cut in half (Fig. 1-b), the insides were washed with water, and they were then dried and stored. During the laboratory work, these boxes were shredded (Fig. 1-c) and defibrated (Fig. 1-d) using a high-speed grinder (Brader 1500; Demsan, Balıkesir, Türkiye). The appearance of these Tetra Pak materials and wood fibers in their dry state before gluing is shown in Fig. 1-d and 1-e, respectively.

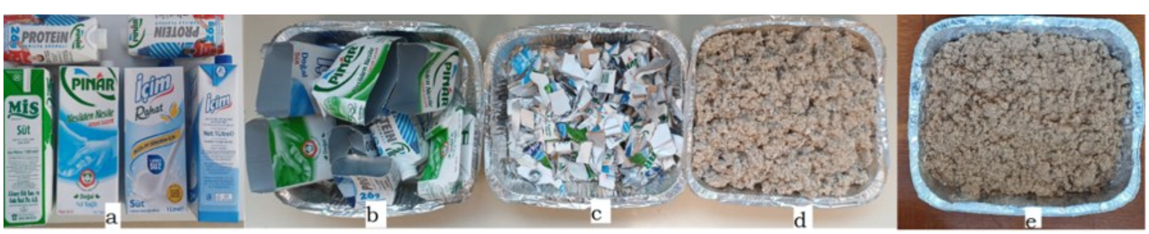

Fig. 1. Milk boxes (a), cleaned boxes (b), shredded boxes (c), Tetra Pak material (d), wood fiber (e)

Adhesive

This study used phenol formaldehyde (PF) adhesive, which is a product of Marmara Integrated Chemical Industry Inc. (İstanbul, Türkiye). Adhesive was obtained from Petek Plywood Inc. (Gaziantep, Türkiye). This glue has a solid content of 47%. Before applying the adhesive, a dilute adhesive solution was obtained by mixing 100 g of glue with 100 g of water. This diluted adhesive was applied to the fibers as a spray. For each sheet, 50 g of dilute glue solution was used for 80 g of completely dry fiber.

Gluing of fibers

In this study, the wood fibers and Tetra Pak materials were glued using the same method. The fibers used to produce the panels were first dried in a drying oven until completely dry at the temperature of 105 ±2°C. Then, 80 g of oven-dried fiber was taken for each panel and placed in a plastic bucket. Next, 50 g of the diluted phenol formaldehyde glue was sprayed onto it in a pulverized form. Then, the fiber and glue were mixed in a high-speed mixer for approximately 10 s. This mixing process ensured that all the fibers were thoroughly wetted with the glue solution. A total of 4 different groups of panels were produced in the study. The mixing ratios for these groups are given in Table 1.

Table 1. Compositions of the Groups (wt%)

	Groups			
Content (%)	1	2	3	4
Wood fiber	100	67	33	0
Tetra Pak material	0	33	67	100

Production of fiber board sheets

While the glued fibers were still wet, they were poured into a frame on a metal mold to form a fiber mat. At this stage, they were compressed using a wooden hammer. The mold was removed, and the fiber mat was formed (Fig. 2). No degassing was performed during the pressing stage. Instead, 40-mesh screens were placed above and below the fiber mat to prevent vapor entrapment. The fiber mat was placed in the press and pressed at 180 °C for 5 min under a pressure of 26 kg/cm². Then, the sheets were removed from the press and allowed to cool. Four sheets were produced for each group. The sheets were produced with dimensions of 3.8 mm × 175 mm × 175 mm (thickness × width × length).

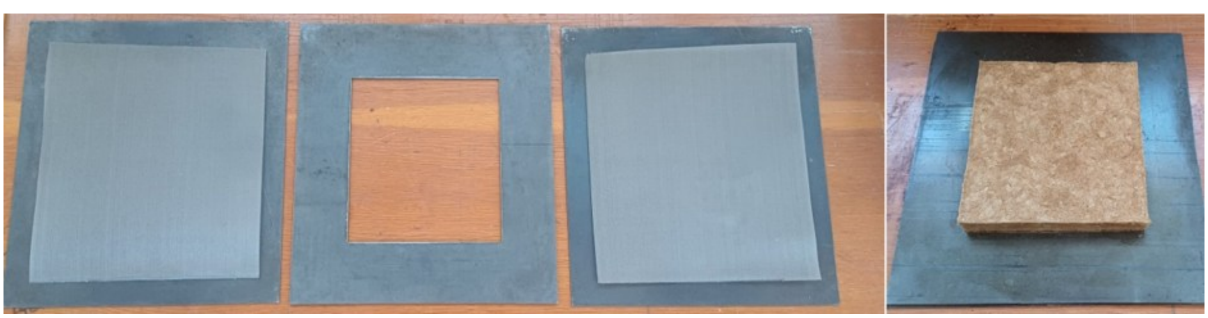

Fig. 2. Mat forming of the fiber board sheets

Methods

Test samples were prepared one week after the sheets were manufactured. Four test samples were prepared from each sheet for each test. Tests to determine the modulus of rupture, modulus of elasticity, internal bonding strength, thickness swelling-water absorption, density, and Janka hardness were performed according to TS EN 310 (1999), TS EN 317 (1999), TS EN 319 (1999), TS EN 323 (1999), and TS 2479 (1976), respectively.

Bending strength test specimens were prepared with dimensions of 3.8 mm × 40 mm × 90 mm (thickness × width × length). Tests were performed on a universal testing machine (EUTC 10 kN; Natek, Ankara, Türkiye) with a capacity of 10 kN. During testing, the support span was 76 mm, the preload was 5 N, and the test speed was 2 mm/min. The tests were performed 16 times.

For the internal bond strength test, test specimens measuring 3.8 mm × 40 mm × 40 mm were prepared. These test specimens were bonded to tensile apparatus using a two-component cyanoacrylate adhesive and placed in the testing machine. The test speed was set to 2 mm/min, and the preload was set to 5 N.

The static hardness was determined according to Janka's principle. During the test, the penetration depth of a steel sphere into the material was set at 2.82 mm. The test speed was set at 2 mm/min. All mechanical tests were performed 16 times.

Thickness-swelling and water-absorption tests were performed over 24 h periods. Sixteen test specimens were prepared for each group. After the test specimens were conditioned, their initial thickness and weight were measured, and then they were immersed in water. After 24 h, the test specimens were removed from the water, their surfaces were wiped with a dry cloth, and their thicknesses and weights were measured again.

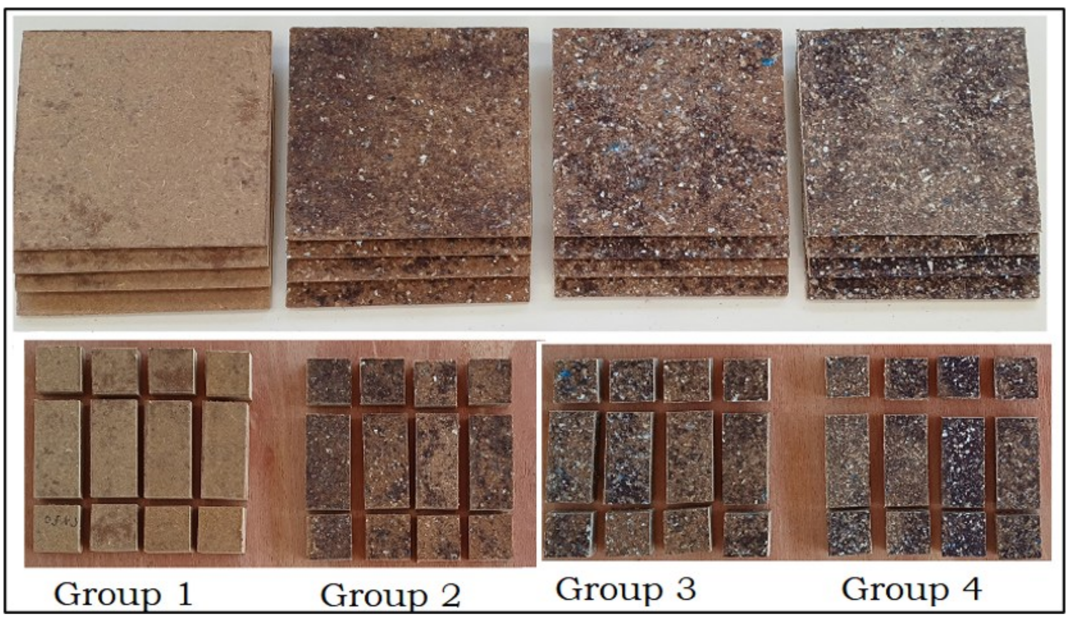

Fig. 3. Produced boards and test samples

Statistical analysis

The SPSS 13.0 (Sun Microsystems, Inc., Santa Clara, CA, USA) statistical package program was used. The data were analyzed using one-way analysis of variance (ANOVA), and significant differences among groups were determined by the Duncan multiple range test.

RESULTS AND DISCUSSION

The densities of the sheets produced within the scope of this study are listed in Table 2. As shown, the lowest density was measured in Group 4 (100% Tetra Pak material) at 698 kg/m³ and the highest density was measured in Group 1 (100% wood fiber) at 741 kg/m³. The densities of the other groups fell within this range. The differences in densities between the groups were statistically significant ($P < 0.01$). Group 4 had a lower density than the other groups, which is consistent with the fact that the PE in the Tetra Pak material had a lower density than the wood fiber. The density of the wood fiber cell walls was approximately 1500 kg/m³. The density of PE was approximately 920 kg/m³. Therefore, as the percentage of PE in the composite panel increased, the density of the composite panels decreased. Tetra Pak material contains approximately 5% aluminum. However, this amount did not have a significant effect on the density. Furthermore, even if the same pressure was applied equally to all the groups during pressing, the groups containing the Tetra Pak material had greater amounts of voids. Therefore, as the amount of Tetra Pak material in the composite increased, the density decreased.

Table 2. Densities of the Groups, ANOVA, and Duncan Test Results

Property		Group 1	Group 2	Group 3	Group 4	P value
Density (kg/m^3)	x̄	741 **C**	726 **BC**	716 **AB**	698 **A***	0.004
	sd	34	24	32	39	-

x̄: arithmetic mean, sd: standard deviation, *: lowest value; With different letters (*A, B, C) indicating significant differences in Duncan test results, Group 1: 100% wood fiber, Group 2: 67% wood fiber and 33% Tetra Pak material, Group 3: 33% wood fiber and 67% Tetra Pak material, Group 4: 100% Tetra Pak material

The percentages of water absorption and thickness swelling of the composites, as well as the Duncan test results, are given in Table 3. As shown, the highest percentages of thickness swelling and water absorption were measured in Group 1 (9.17% and 61.87%, respectively). The lowest values were measured in Group 4 (3.93% and 39.77%, respectively). The differences between the groups were statistically significant ($P < 0.001$). The percentages of thickness swelling and water absorption decreased as the amount of Tetra Pak material in the composite increased. The most important reason for this was that wood fiber is hygroscopic, while the PE and aluminum in the Tetra Pak material are not hygroscopic. As a result, as the percentage of Tetra Pak material in the composite increased, the water absorption and thickness swelling decreased. Similar results regarding the percentages of thickness swelling of sheets produced from Tetra Pak box parts were also reported in the study by Rhamin *et al*. (2013). The percentages of thickness swelling of all the groups were well below the values specified in the relevant standard. According to TS EN 622-5 (2011), for general-purpose panels intended for dry conditions, primarily for furniture and interior use, with thicknesses between 2 and 4 mm, the required maximum thickness swelling is 35%. Therefore, the swelling percentages in relation to the thickness of the panels produced within the scope of this study represent a positive result. The most effective factor in achieving this positive result was the adhesive used. Phenol formaldehyde adhesive is a much more water-resistant adhesive than urea formaldehyde. Phenol formaldehyde adhesive remains intact for a long time even in hot water, whereas urea formaldehyde adhesive rapidly deteriorates at the adhesive–wood fiber interface when it comes into contact with cold water (Pizzi 2004; Frihart 2005; Dunky 2017).

Table 3. Water Absorption, Thickness Swelling, ANOVA, and Duncan Test Results

Property		Group 1	Group 2	Group 3	Group 4	P value
Water absorption (%)	x̄	9.17 **C**	5.07 **B**	4.74 **B**	3.93 **A**	0.000
	sd	1.84	0.88	0.65	0.68	-
Thickness swelling (%)	x̄	61.87 **C**	47.14 **B**	44.05**AB**	39.77 **A**	0.000
	sd	11.46	3.53	4.34	3.18	-

x̄: Arithmetic mean, sd: standard deviation, *: lowest value, with different letters (*A, B, C) indicating significant differences in Duncan test results

The ANOVA test P-values and Duncan test results for the modulus of rupture and modulus of elasticity are given in Table 4. According to the data obtained, the composition of the board had a significant effect on the modulus of rupture and modulus of elasticity. The modulus of rupture values for the groups ranged from 10.4 to 32.1 N/mm². The modulus of elasticity values for the groups ranged from 1019 to 2777 N/mm². The smallest modulus of rupture value was in Group 4 and the largest was in Group 1. The differences between the groups in both the modulus of rupture and modulus of elasticity test results were statistically significant ($P < 0.001$). The modulus of rupture and modulus of elasticity values for the test samples from Group 1, which were produced using only wood fiber, were approximately 3 times higher than those of the test samples from Group 4, which were produced using only Tetra Pak material. According to these data, the strength and elasticity values of the boards produced with Tetra Pak material were considerably lower than those produced with wood fiber. In this case, producing boards with only Tetra Pak material under these conditions may not be suitable for most uses. However, the results obtained for Group 2 were promising. According to TS EN 622-5 (2011), for general-purpose panels intended for dry conditions, primarily for furniture and interior use, with thicknesses of 2 to 4 mm, the required bending strength is 23 N/mm², and the elasticity is not defined. According to this standard, the modulus of rupture and modulus of elasticity values for Group 2 were at acceptable levels for these applications. Furthermore, according to TS EN 622-5 (2011), for panels with a thickness of 2 to 4 mm, intended for use as rigid underlayment in roofs and walls, the required modulus of rupture is 14 N/mm² and the modulus of elasticity is 1600 N/mm². The modulus of rupture and modulus of elasticity values for Groups 2 and 3 were at acceptable levels for these applications. The Group 1 fiber board was made from wood fiber, while the other groups consisted of cardboard, PE, and aluminum. In fact, all of the groups were similar in terms of the fiber content. However, a significant difference in strength emerged between them. The most important reason for this result was that the wood fiber used in paper production undergoes significant change during the chemical cooking, mechanical grinding, and refining stages. In chemical paper production, lignin is chemically dissolved and separated from wood fibers, but the delignification process is not applied in fiberboard production. Therefore, the wood fiber used in fiber board production has a higher mechanical performance than the wood fiber used in cardboard production. As a result, as the percentage of Tetra Pak material increased, the modulus of rupture and modulus of elasticity values for the composite boards decreased. No previous study was found that produced composite boards using both wood fiber and Tetra Pak material. However, in some other studies, the mechanical properties of boards produced with wood fiber and another material generally decreased as the percentage of wood fiber decreased. For example, Akgül and Tozluoğlu (2008) produced fiberboards mixed with peanut shells and wood fiber. The modulus of rupture and modulus of elasticity values for the produced boards decreased as the percentage of peanut shells increased. Krzysik *et al*. (1993) produced fiberboard with wood fiber and waste newspaper fiber. The modulus of rupture and modulus of elasticity values for the boards they obtained decreased as the percentage of newspaper in the board increased. Suchorab *et al*. (2023) produced high-density fiberboards by adding upholstery fabric fibers at different contents (0, 5, 10, and 20% by weight relative to dry wood fibers) and reported that the modulus of elasticity and modulus of rupture decreased. Furthermore, assuming all other factors remain the same, as the density of the fiberboard decreases, its mechanical properties also decrease. In this present study, it was observed that as the Tetra Pak material ratio increased, the density of the boards decreased. This decrease in density led to a reduction in mechanical properties.

Table 4. Modulus of Rupture, Modulus of Elasticity, ANOVA, and Duncan Test Results

Property		Group 1	Group 2	Group 3	Group 4	P value
Modulus of rupture (N/mm^2)	x̄	32.1 **D**	23.9 **C**	17.5 **B**	10.4 **A***	0.000
	sd	3.9	2.9	3.3	1.7	-
Modulus of elasticity (N/mm^2)	x̄	2777 **D**	2278 **C**	1708 **B**	1019 **A**	0.000
	sd	335	339	318	161	-

x̄: Arithmetic mean, sd: standard deviation, *: lowest value, With different letters (*A, B, C, D) indicating significant differences in Duncan test results

The internal bond strength, ANOVA, and Duncan test results are given in Table 5. According to the data in the table, the internal bond strength decreased as the percentage of Tetra Pak material in the composite increased. The internal bond strength of Group 1, which was produced using only wood fiber, was 1.14 N/mm^2, while that of Group 4, which was produced using only Tetra Pak material, was 0.40 N/mm^2. The most important reason for this result, as mentioned when discussing the other mechanical properties, was the low adhesion performance of PE and aluminum in the Tetra Pak material with the phenol formaldehyde adhesive. Similar results have been reported in previous studies. Xu *et al*. (2025) produced MDF from virgin and secondary fibers, and they reported that compared to MDF with virgin fibers, the internal bond strength of recycled MDF statistically decreased at all substitution ratios. Ye *et al*. (2007) produced a board using different ratios of wheat, soybean stalks, and wood fiber. The mechanical properties of the resulting fiber board decreased with the percentage of wood fiber. In another study, Tozluoğlu (2016) produced fiber board using Rorippa stalks and wood fiber in different ratios and investigated some mechanical properties. He found that as the proportion of Rorippa stalks in the board increased, the mechanical properties of the board decreased. The results obtained in this study, as well as those obtained in previous studies, can be explained by the rule of mixtures principle. According to this principle, the properties of a composite material are similar to those of the components that make up the composite. This situation has also been reported in studies on thermoplastic composites (Kaymakçı *et al*. 2012; Çavuş 2020; Bal 2023; Narlıoğlu 2024). Furthermore, the internal bond strengths of all the groups were at an acceptable level for boards to be used as rigid subfloors in roofs and walls, according to the relevant standard. According to TS EN 622-5 (2011), for panels with a thickness of 2 to 4 mm, intended for use as rigid underlayment in roofs and walls, the required internal adhesion is 0.30 N/mm².

Table 5. Internal Bond Strength, ANOVA, and Duncan Test Results

Property		Group 1	Group 2	Group 3	Group 4	P value
Internal bond strength (N/mm^2)	x̄	1.14 **C**	0.59 **B**	0.51 **AB**	0.40 **A**	0.000
	sd	0.28	0.11	0.09	0.09	-

x̄: Arithmetic mean, sd: standard deviation, *: lowest value, with different letters (*A, B, C) indicating significant differences in Duncan test results

Data from the static hardness test (Janka hardness), ANOVA test P-values, and Duncan test results are given in Table 6. As seen, the hardness values of the composite panels ranged from 22 to 42 N/mm². As with other mechanical properties, the lowest hardness was obtained in Group 4 and the highest hardness in Group 1. The hardness value of the panels produced with only Tetra Pak material (Group 4) was approximately half that of panels produced with only wood fiber (Group 1). As the percentage of Tetra Pak material in the composite increased, the static hardness decreased. This was similar to the results obtained for the other mechanical properties given above. However, unlike the other mechanical properties, a high hardness value is not a desirable characteristic for every composite panel. Hardness is an important parameter, especially for materials that are subject to wear in their place of use such as wood-based flooring, stair treads, and workbench tops. In contrast, hardness is not a desired property in some finishing materials used in furniture production, some panels used for decoration, or some panels used for insulation purposes.

Table 6. Hardness, ANOVA, and Duncan Test Results

Property		Group 1	Group 2	Group 3	Group 4	P value
Hardness (N/mm^2)	x̄	42.38 **C**	39.74 **C**	34.23 **B**	22.05 **A***	0.000
	sd	8.12	4.60	4.14	3.52	-

x̄: Arithmetic mean, sd: standard deviation, *: lowest value, with different letters (*A, B, C) indicating significant differences in Duncan test results

Morphology of Composite Panels

SEM images were obtained from the fracture surfaces of the bending test specimens. The SEM images of the groups are given in Fig. 4. The SEM image obtained from the Group 1 test specimen is given in Figs. 4-A and B. When these images are examined, wood fibers and even the cell lumens of the wood fibers are visible. Apart from the wood fibers, another object is not visualized in Figs. 4-A and 4-B. The SEM images obtained from the Group 4 test specimens are given in Figs. 4-C, D, E, and F. When these images are examined, Tetra Pak materials and PE particles can be seen. In addition, in Figs. 4-E and F, it can be seen that Tetra Pak materials were mixed with PE particles in a molten state. Aluminum particles, which are present in the Tetra Pak can contents, were not detected in the SEM images. However, aluminum particles can be seen with the naked eye in Fig. 3.

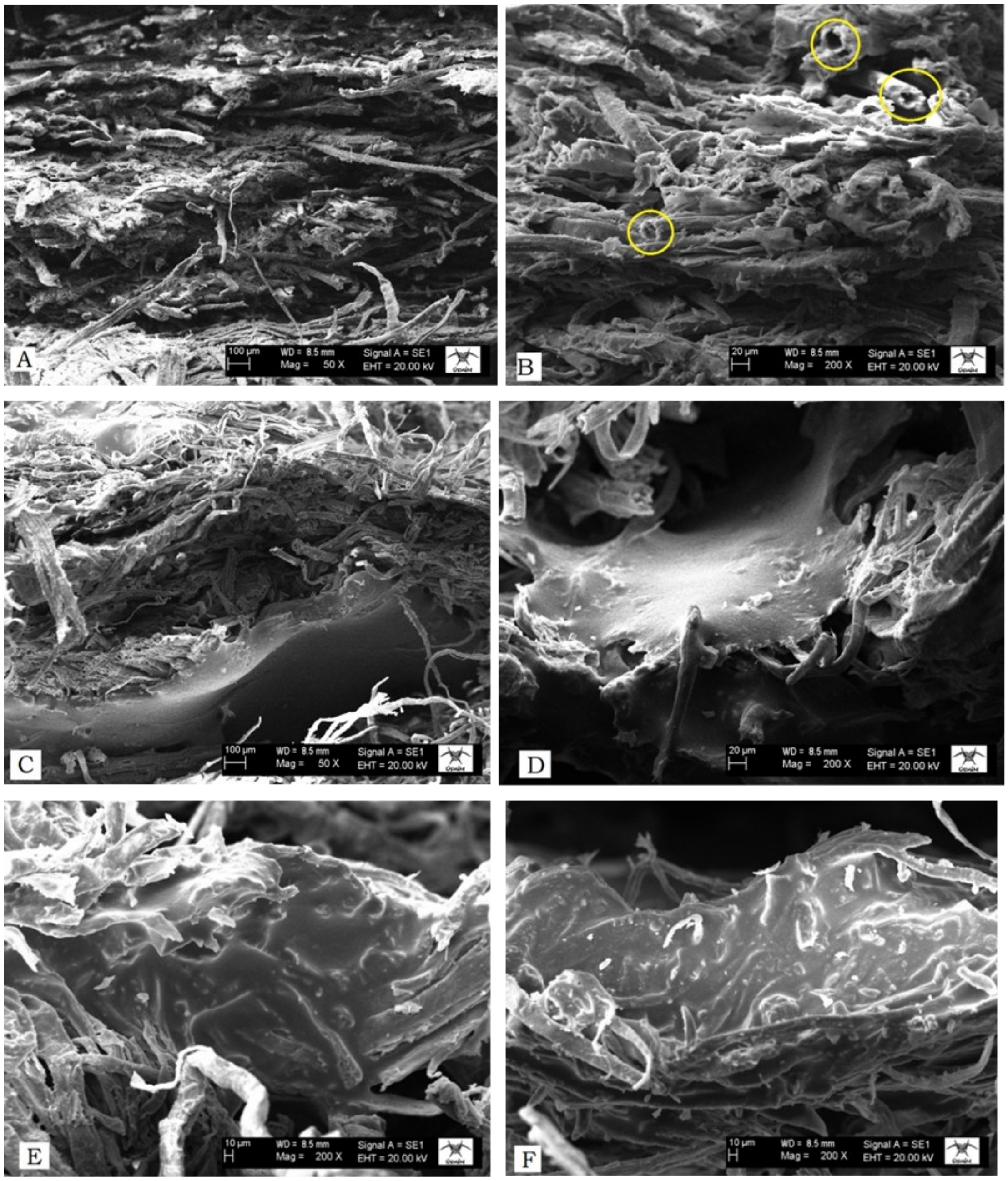

Fig. 4. SEM images of the composite boards, A) Group 1-50 X, B) Group 1-200 X, C) Group 4-50 X, D) Group 4-200 X, E) Group 4-200 X, and F) Group 4-200 X

CONCLUSIONS

In this study, fiberboard specimens were produced by mixing wood fiber obtained from a fiber board factory with fiber obtained by grinding waste Tetra Pak boxes in different ratios and bonding them using phenol formaldehyde glue. Some physical and mechanical properties of the resulting boards were investigated, and the following results were obtained.

1. Within the scope of the study, the wood fiber and Tetra Pak material were successfully glued with dilute phenol formaldehyde glue. Mixing the fiber–glue mixture in a high-speed mixer after glue spraying ensured that the fibers were thoroughly glued together. Thus, no problems occurred during the gluing process. The sieves placed above and below the board mat during hot pressing allowed for smooth boards to be obtained without any problems. This method eliminated the problem of boards bursting after pressing, which has been experienced in fiberboard production in laboratory environments.
2. As the percentage of Tetra Pak material in the board increased, the density, water absorption, and thickness swelling values decreased. This was a positive result for the applications of wood-based boards.
3. All of the mechanical properties decreased as the percentage of Tetra Pak material in the board increased. This situation is a negative consequence for applications where the mechanical performance of this type of panel is important.
4. However, it can be said that this situation will not pose a problem for some applications where the mechanical performance is not critical. According to the mechanical performance classes required for the application of fiber boards, the physical and mechanical performances of all the panels met the necessary conditions for panels to be used as rigid underlayment in roofs and walls.
5. Panels produced with Tetra Pak materials can be used in insulation boards, packaging boards, wall coverings, and non-structural interior applications.

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Conflict of Interest

The author declares that he has no conflict of interest.

Use of Generative AI

Absolutely no Artificial Intelligence (AI) tools (*e.g.*, writing, editing, data analysis, figure generation, *etc.*) were used in any part of this article.

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