

An attempt to use „Tetra Pak” waste material in particleboard technology

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Abstract: *An attempt to use „Tetra Pak” waste material in particleboard technology.* The study investigates the effect of addition Tetra Pak waste material in the core layer on physical and mechanical properties of chipboard. Three-layer chipboards with a thickness of 16 mm and a density of 650 kg / m³ were manufactured. The share of Tetra Pak waste material in the boards was varied: 0%, 5%, 10% and 25%. The density profile was measured to determine the impact of Tetra Pak share on the density distribution. In addition, the manufactured boards were tested for strength (MOR, MOE, IB), thickness swelling and water absorption after immersion in water for 2 and 24 hours. The tests revealed that Tetra Pak share does not affect significantly the value of static bending strength and modulus of elasticity of the chipboard, but it significantly decreases IB. Also, it has been found that Tetra Pak insignificantly decreases the value of swelling and water absorption of the chipboards.

Keywords: particleboard, Tetra Pak, waste raw materials

INTRODUCTION

In 2018 the world production of particleboard was 93.2 million cubic meters (FAOSTAT, 2020). High production is conditioned by the constantly growing demand for this type of boards. High value of the production is related to high demand for wood raw material. However, due to the limited possibilities of obtaining it from forests, more and more attention is paid to alternative raw materials that can be used in the particleboard industry.

In recent years, a number of scientific papers have been devoted to the applicability of lignocellulosic waste of agricultural origin (Adediran et al., 2019; Auriga et al., 2019; Borysiuk et al., 2019; Medved and Resnik, 2007; Taha et al., 2018; Wang and Sun, 2002) and the use of municipal waste such as waste paper, polymer materials like polyethylene, polystyrene, etc. (Borysiuk et al., 2008, 2004; Chen et al., 2006; Klyosov, 2007; Zbieć et al., 2010).

One of the most popular packaging used in the food industry is so-called ‘layered package’ for liquid food, commonly called Tetra Pak. The biggest disadvantage of this type of packaging is related to recovering raw materials after use. Worldwide, only 24.7% of Tetra Pak packaging is recycled (www.tetrapak.com).

The layered packaging for liquid food consists, depending on the manufacturer, in approximately of 75% paper, which ensures the rigidity, 20% polyethylene film, which protects the paper from moisture, and 5% aluminum foil, which protects the product against oxygen and light. This kind of structure hinders and increases the cost of separating the three materials from each other for reuse.

A commonly used method of recycling Tetra Pak packaging is the mechanical separation of paper from polyethylene and aluminum (Korniejenko et al., 2010). The level of complexity of the Tetra Pak packaging recycling process has contributed to the search for simpler and cheaper recycling methods. Also, there is conducted a research on the use of Tetra Pak as a raw material for the production of various types of composites (Bekhta et al., 2016; Korniejenko et al., 2009; Rhamin et al., 2013).

MATERIALS

Raw material

The tested particleboards were made of industrial pine particles and Tetra Pak packaging. Tetra Pak packages were collected from household waste sorting. The plastic upper part, including opening and closure elements, were removed from the packaging, and the remainings were mechanically shredded using a branch shredder. During shredding, partial delamination of this material occurred. The crushed material was sorted using a 40 mm sieve. Figure 1 illustrates the shredded Tetra Pak material.



Figure 1. The shredded Tetra Pak material

Adhesives

Particles were glued with urea-formaldehyde resin (Silekol 123). A 10% solution of ammonium sulfate $(\text{NH}_4)_2\text{SO}_4$ was used as the hardener. Units composition of the adhesive mass was 84 parts resin, 4 parts hardener, 12 parts water.

Manufacture of particleboards

As part of the research, three-layer particleboard with 0, 5, 10 and 25% share of waste Tetra Pak material in the core layer of boards, with a density of 650 kg/m^3 and a thickness of 16 mm were manufactured. The share at face layers was assumed at 35%. The binder content of the core layers was 8% and the face layers 10%, wherein the mixture of wood particles and Tetra Pak to was glued in the core layers. The pressing process was carried out on a single-shelf press with heated shelves, using a compression pressure of 2.5 MPa at 180°C . Pressing time was 288s.

The manufactured panels were seasoned for a period of seven days under normal conditions, i.e. at a temperature of $20 \pm 2^\circ\text{C}$ and relative humidity of $65 \pm 5\%$.

Mechanical and Physical properties

Static bending strength (MOR) and modulus of elasticity in static bending (MOE) were determined for the manufactured panels based on the PN-EN 310: 1994 standard and tensile strength perpendicular to the planes of the panel (IB) based on the PN-EN 319: 1999 standard. Mechanical properties have been examined on a universal testing machine. Swelling and water absorption were determined after immersion in water for 2 and 24 hours, according to PN-EN 317.

The determination of selected mechanical and physical properties was performed in 10 replicates for each of the tested particleboard variants.

The density of tested particleboards was determined according to EN 323 standard. Additionally, was determined density profile on a GreCon Da-X (x-ray) measuring instrument (Alfeld, Germany) with an incremental step of 0.02 mm. The profile designation was performed in triplicate for each of the tested board variants.

Statistical Analysis

Statistical analysis of the results obtained was carried out in the Statistica 13 program (TIBCO Software Inc.). To compare the significance of differences in individual values, homogeneous groups were used based on the Tukey test with 0.05 significance level.

RESULTS

Statistical analysis of static bending strength and modulus of elasticity did not indicate a significant impact of Tetra Pak share applied in the core layer of the produced particleboards (table 1). The particleboards were characterized by MOR in the range from 15.20 to 16.12 N / mm². It should be noted that all manufactured in this study particleboards met the requirements of the EN312 standard for general-purpose boards for use in dry conditions (10 N/mm²) regarding the range of static bending strength.

The share of Tetra Pak in the core layer of the particleboards had a significant effect on the value of tensile strength perpendicular to the planes of the board. A decrease in the value of IB was observed with the increase in the share of Tetra Pak. For boards with a 25% share of Tetra Pak was recorded a 70% decrease in value in respect to variant made entirely of industrial wood particles. The decrease in IB value could have been caused by the construction of Tetra Pak, which consists of materials with low surface adhesion or insufficient fragmentation of Tetra Pak particles.

Table 1. Mechanical properties of particleboards

Share of Tetra Pak	MOR (N/mm ²)		MOE (N/mm ²)		IB (N/mm ²)	
	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
0%	15,20 ^a	1,26	3166 ^{ab}	190	0,47 ^a	0,109
5%	15,62 ^a	1,46	3277 ^a	193	0,22 ^b	0,019
10%	16,12 ^a	1,25	3266 ^a	141	0,19 ^{bc}	0,019
25%	15,76 ^a	1,38	2985 ^b	188	0,14 ^c	0,020

a,b,c – homogenous groups

When analyzing the density profile of the manufactured particleboards (Figure 2), it can be seen that all the produced boards were characterized by a typical U-shaped density profile graph. It should be noted, however, that chipboards with Tetra Pak in the core layer showed some unevenness in the density distribution. At the same time, the density profile disorders in the core layer increase with the increase of Tetra Pak share. These disorders may explain the observed decrease in IB value while the share of Tetra Pak increases.

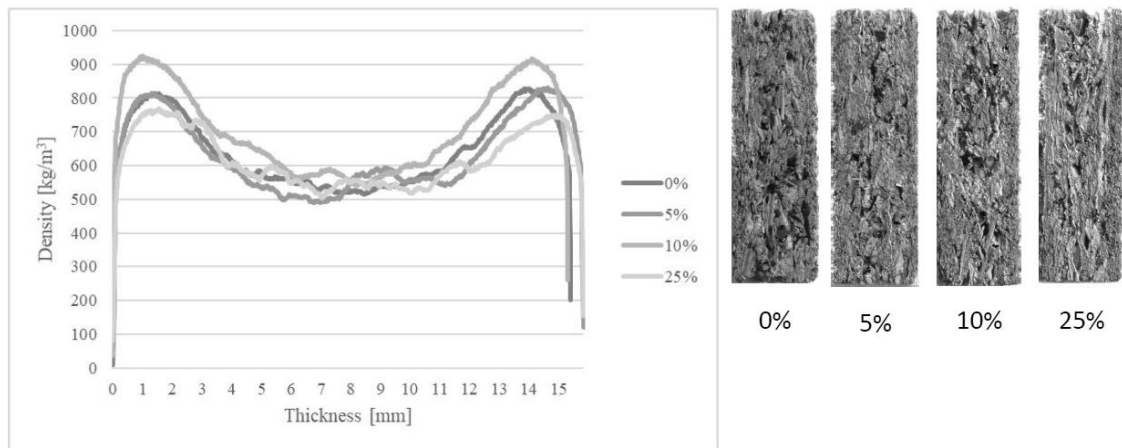


Figure 2. Density profile and cross-section photo of manufactured particleboards

Table 2. Physical properties of particleboards

Share of Tetra Pak	TS2H		TS24H		WA2H		WA24H	
	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.	Average	St. Dev.
0%	27,21 ^b	1,85	32,64 ^b	2,42	91,65 ^a	3,18	101,87 ^{ab}	4,34
5%	29,94 ^a	1,62	36,19 ^a	1,94	90,47 ^a	5,45	103,08 ^a	5,38
10%	26,62 ^b	2,21	32,27 ^b	3,03	87,51 ^{ab}	5,17	96,88 ^{bc}	6,26
25%	25,85 ^b	2,05	32,92 ^b	1,42	84,14 ^b	5,28	92,84 ^c	3,43

a,b,c – homogenous groups

Table 2 presents the average swelling and water absorption values after immersion in water for 2 and 24 hours. It should be noted that only particleboards with a 5% share of Tetra Pak were characterized by a significant increase in the swelling value after 2 and 24 hours soaking in water. However, there is visible a slight decrease in the swelling value on thickness as the share of Tetra Pak increases. In the case of absorbability, a decrease in its value can be seen with the increase of the share of Tetra Pak. This may be due to the construction of the Tetra Pak composite which contains hydrophobic materials that do not absorb water.

CONCLUSIONS

1. It is possible to manufacture chipboards with up to 25% Tetra Pak share in the core layer without reducing the static bending strength and modulus of elasticity of the boards.
2. An increase in the share of Tetra Pak in the core layer of particleboards results in a decrease in IB value
3. The increase in the share of Tetra Pak causes a slight decrease in swelling in thickness after 2 and 24 hours of soaking in water, but this decrease is insignificant
4. The absorbability value of particleboards decreases with the increase of Tetra Pak's share in the inner layer of the plates.

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Streszczenie: *Próba wykorzystania materiału odpadowego „Tetra Pak” w technologii płyt wiórowych. W ramach pracy zbadano wpływ udziału odpadowego materiału Tetra Pak w warstwie wewnętrznej płyt wiórowych na ich właściwości fizyczne i mechaniczne. Wytworzono trójwarstwowe płyty wiórowe o grubości 16 mm oraz gęstości 650 kg/m³ z 0%, 5%, 10% oraz 25% udziałem odpadowego materiału Tetra Pak. W celu określenia wpływu udziału Tetra Pak w płycie na rozkład gęstości zbadano profil gęstości. Ponadto wytworzone płyty zbadano pod kątem właściwości wytrzymałościowych (MOR, MOE, IB) oraz określono spęcznienie oraz nasiąkliwość po 2 i 24 godzinach moczenia w wodzie.*

Przeprowadzone badania wykazały, że udział Tetra Pak nie wpływa istotnie statystycznie na wartość wytrzymałości na zginanie statyczne oraz moduł sprężystości wytworzonych płyt wiórowych. Wpływa jednak w istotny statystycznie sposób na spadek IB wytworzonych płyt. Ponadto zaobserwowano, że udział Tetra Pak w nieznacznym stopniu powoduje spadek wartości spęcznienia oraz nasiąkliwości jednak obniżenie tych właściwości nie jest istotne statystycznie.

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