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The Effects of Alkali Modification on Some Properties of Particleboard Produced from Corn Stalks*

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Abstract

The aim of this study is to recycle the corn stalks into the production cycle, which are used as animal feed, compost material or left as waste in the field without any use after harvest. For this purpose, it is planned to use corn stalks in particleboard production by modifying them. Lignocellulosic material obtained from corn (*Zea mays indurate* Sturt.) stalks was modified with 1, 3 and 5% NaOH solution. These modified parts were used in particleboard production. Some physical and mechanical properties of the obtained particle boards were investigated. At the end of the study, water absorption (WA) and thickness swelling (TS) analysis showed that alkali treatments also decreased the water resistance of the produced particleboards. Using modulus of elasticity (MOE), modulus of rupture (MOR), and internal bond (IB) strength analysis, the mechanical properties of produced particleboards were evaluated. It was observed that the mechanical properties were improved by 1% alkali treatment, but the increasing alkali content decreased the mechanical properties.

Keywords: Particleboard, modification, properties, corn.

Introduction

Throughout history, wood material has been one of mankind's oldest friends. Humans has been with it in every aspect of life, step by step, since the early ages. Mankind has used it in hunting and built a shelter. Over the ages, it has been used for places of worship and shelter. Today, we still see it in more than ten thousand forms, both massive and composite form, in all areas of life. When this is the case, human beings have tried to develop wood materials with the developing technology in every age.

There are many studies in the literature on the processes applied to increase the usage areas of lignocellulosic materials and to obtain higher quality products. Among the studies, methods such as acetylation (Chow et al., 1996; Khalil et al., 2007), enzymatic treatment (Zhang et al., 2003), heat treatment (Ates et al., 2010; Timar et al., 2016), treatment with alkali (Ndazi et al., 200; Beram and Yasar, 2020) were used.

Alkali treatment is one of the preferred methods to improve the surface properties of cellulosic fibers and chips and to increase the amount of reactive OH groups. It is known that the surface roughness and the number of reactive OH groups increase after alkali treatment and provide better adhesion. All these processes have significant effects on the physical, mechanical, and chemical properties of the boards.

Corn is widely produced in our country because its growing period is short, and its product range is wide (Guzel, 2002). Corn plant is an annual, monoecious culture and

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cereal plant, 1-2 meters high, blooming between June and August (Sezer, 2005). Corn is one of the important staple foods in developing countries, along with wheat and rice. It is consumed in large quantities in sub-Saharan Africa and Latin America. It is preferred by 900 million people worldwide. Corn is also preferred as animal feed all over the world (Peşkircioğlu et al., 2016).

Corn is also used in many areas in industry. The importance of corn has increased even more with its use in the production of bioethanol, an alcohol derivative produced from starch and sugar that can be added to fuels (Peşkircioğlu et al., 2016). Corn stalks are used in feed, fertilizer, furniture production areas. As it is known, the main components of product stalks are cellulose, hemicellulose and lignin (Haitao et al., 2016).

Almost all of Turkey's lands are suitable for growing corn plants. Considering the climatic conditions for corn cultivation in Turkey, the most favorable region is the Black Sea Region. Corn cultivation areas are located towards the inner parts of Marmara and Aegean regions in other regions (Şahin, 2001).

Corn production in Turkey reached 6.4 million tons in 2015. There is an annual plant stem potential of 2.5 million tons in our country (Güler, 2015; Bektas at al. 2020).

Figure 1: Corn cultivation in Turkey (URL3, 2022)

In this study, particles from corn stalks were soaked with NaOH solutions. Particleboards were produced from treated particles. The surface roughness properties of the boards were evaluated. It is aimed to evaluate how corn stalks can be better evaluated. Evaluation of lignocellulosic products in different fields has a serious importance in the last hundred years.

Material and Method

Material

Corn stalks were collected from Acıpayam-Denizli region of Turkey. The stalks were ground in a hammer mill and sieved through 1-3 mm sieves. The resulting particles were laid out and air-dried for 30 days. The hardener (Ammonium chloride) and glue (Urea formaldehyde) used in the study were supplied from the AGT-Antalya factory. The properties of the resin used are indicated in Table 1.

Table 1. Properties of urea formaldehyde resin

Properties	UF Resin
Solid content (%)	65±1
Density (g/cm3)	1.27 - 1.29
pH (25ºC)	7.5 - 8.5
Viscosity (cps, 25ºC)	150 - 200
Gel time (s, 100ºC)	25 - 30
Storage time (day, at 25ºC)	60
Flowing time (s, 25ºC)	20-30
Free formaldehyde (max.) (%)	0.19

2.1.1. NaOH treatment of particles from corn stalks

The particles obtained from corn stalks were treated with 1, 3% and 5% w/v NaOH solutions at room conditions for 24 hours in separate containers at certain time intervals. The particles were then sieved and the meat was washed with plenty of water by adding 10% CH3COOH to remove excess sodium hydroxide. The washed treated particles were dried for 20 days until they became air-dry (TS EN 319 (1999).

Method

Particleboard production

Corn stalk particles, which became air-dried, were dried until oven dry to 3% moisture at (102±3 °C) before board production. The particles were weighed for each board so that the density of the boards was 0.65 g/cm^3. The boards were made by spraying resin onto the particles in a drum mixer with an air system. According to the oven-dried particles weight, 10% of the resin and 1% of the hardener were used at a concentration of 35%. After bonding, the particles were laid out on a 1.2 cm thick slab of 50 x 50 cm. It was pressed for 6 minutes at 160 ± 5 °C under a pressure of 3-3.5 N/mm^2. Particleboards were kept at 20 °C and 65% humidity for 20 days (TS-EN 312 (2012).

Physical and mechanical tests

Thickness swelling (TS), and water absorption (WA) for physical properties, internal bond strength (IB), the modulus of elasticity (MOE), the modulus of rupture (MOR) for mechanical properties of the fiberboards were determined according to standards TSEN 310 (1999), TS-EN 317 (1999), and TS-EN 319 (1999).

Statistical Analysis

The results of the study were assessed using Minitab 16 statistics software. First, an analysis of variance (ANOVA Test) was carried out on the data. In the case of statistical differences according to the ANOVA test, a Duncan test was applied to determine different groups.

Results and Discussion

The physical and mechanical properties of boards produced from corn stalk particles are presented in Table 2 and Table 3. There was a statistical difference between the values of physical properties according to ANOVA (P < 0.001). The different groups were identified according to Duncan's test and are shown by different letters in each column of the tables.

Table 2. Physical properties of boards produced from corn stalk particles

Board type	**N**	**Density (g/cm³)**	**TS – 2h**	**TS – 24h**	**WA – 2h**	**WA – 24h**
Control	30	0.66	26.85 (3.12)[1] a[2]	30.86 (2.76) a	55.63 (4.96) a	81.42 (6.08) a
1% NaOH	30	0.67	29.21 (2.44) ab	33.48 (2.48) b	60.84 (3.67) ab	86.39 (7.26) ab
3% NaOH	30	0.65	32.86 (2.86) b	40.22 (3.82) c	68.15 (5.23) b	97.33 (8.43) b
5% NaOH	30	0.68	34.59 (3.21) bc	46.71 (3.26) d	84.52 (7.93) c	126.64 (9.57) c

1: Standard deviation, 2: Groups groups by Duncan test (p<0.001).

Table 3. Mechanical properties of boards produced from corn stalk particles

Board type	**N**	**MOE (N/mm²)**	**MOR (N/mm²)**	**IB (N/mm²)**
Control	10	1685 (46) a	9.86 (0.30) a	0.46 (0.04) a
1% NaOH	10	1834 (29) b	13.12 (0.74) b	0.34 (0.03) b
3% NaOH	10	1566 (23) c	9.26 (0.62) a	0.23 (0.02) d
5% NaOH	10	1138 (17) d	6.69 (0.37) e	0.19 (0.01) e

1: Standard deviation, 2: Groups groups by Duncan test (p<0.001).

The WA and TS values of particleboards produced with particles treated with NaOH increased compared to the control groups. The increase in NaOH concentration caused these values to increase. Not all groups reached the maximum 16% value specified in the TS-EN 312 standard for these physical properties. Swelling of the crystalline structure in cellulose during alkali treatment may facilitate water entry into the boards (Gwon et al., 2010). During the alkali treatment, the wax and oil components, which are the source of the water repellent feature of the wood material, were removed (Bekhta and Hıziroğlu, 2002). Thus, the poor resistance to WA and TS in sheets subjected to alkali treatment can be attributed, in part, to the low concentrations of lignin, which exhibits a hydrophobic property. The proportional increase in cellulose during alkali treatment caused this situation (Fengel and Wegener, 1984).

Boards produced from particles treated with 1% NaOH have higher MOE and MOR values than the control group. These values of the boards produced from boards treated with 3% and 5% NaOH have decreased. According to TS-EN 312 standard, MOE and MOR values are required as minimum 1800 N/mm^2 and 10.5 N/mm^2 for indoor installation (including furniture) and general-purpose applications in dry environments. In the study, only the 1% group met all the desired mechanical values. Boards made from chips treated with control and 3-5% sodium hydroxide failed to meet the minimum value for MOR. Alkali treatment has been observed to reduce the internal bond strength (IB). The decrease in IB strength can be explained by the decrease in lignin ratios during alkali treatment (Joseleau et al., 2004; Güler, 2019). It is mentioned in many studies in the literature that more than 1% sodium hydroxide application during alkali treatment application weakens the fibers and particles and causes low strength performance (Yasar and Icel, 2016; Güler, 2019).

4. Conclusions

In our country, corn production is carried out in almost all regions. Therefore, from a biomass point of view, corn stalks can be used in particleboard production. This study showed that corn stalks should be modified by some methods to improve the mechanical properties of particle boards. The MOE and MOR values of the boards produced with 1% NaOH-treated particles were improved compared to the control group boards. Lower MOE and MOR values were obtained at other ratios. Boards produced with particles treated with only 1% NaOH meet the TS-EN 312 standard in terms of mechanical properties. As a result, it is seen that if boards are to be produced from corn stalks, it should be treated with a maximum of 1% sodium hydroxide before the production of boards for general use in dry conditions.

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