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EFFICIENT UTILIZATION OF CORN STALK AND POPLAR PLANER SHAVINGS IN MANUFACTURING PARTICLEBOARD

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ABSTRACT

In this study, particleboards were manufactured using a mixture of corn stalks and poplar wood particles at different ratios utilizing 10 % urea-formaldehyde adhesive. Panels with a density of 0,70 g/cm^3 were manufactured using various amount of corn stalks and poplar wood from 100 to 25 %. Manufactured panels were tested the mechanical properties including modulus of rupture, modulus of elasticity and internal bond and the water absorption and thickness swelling. In addition, the chemical properties and fiber dimensions of poplar wood and corn stalks were also evaluated. Some properties of the manufactured panels increased with the content of poplar particles. The addition of wood poplar particles resulted in a significant increase of some properties of particleboards. From this study, it can be concluded that the combination of poplar particles and corn stalks resulted in particleboards acceptable for interior applications due to low water absorption and thickness swelling. The internal bond strength, the most serious deficiency of stalks, was upgraded sufficiently by increasing the content of wood poplar particles. This study demonstrate that corn stalks may be considered as a charger for wood poplar particleboards manufacturer in region where wood is not abundant. unusual to wood material in the production of particleboards.

Keywords: Mechanical properties, particleboard, physical properties, *Populus nigra*, *Zea mays indurata*.

INTRODUCTION

Particleboard is an important product of the composite industry and is manufactured from the wood particles. The world demand for wood composite production is increased with the growing of the world population and the expansion uses of applications that have major impact on resources of standing forest and the supply of wood for production of particleboards has been reduced due to the deforestation of natural forests (Nath and Mwchahary 2012). Increasing world demand contributes to the search of new raw materials of the manufacture of forest products or most efficient use of available raw material. Agricultural residues are renewable annually and abundant therefore became an excellent alternative source that can be used to replace wood and wood fibers if performance is acceptable (Rowell 1995, Nemli *et al.* 2009). The use of renewable biomass as a raw material can gain the environment and socioeconomic development as these residue materials are grown in the soil and often disposed through combustion with generation of undesirable volatile organic carbon-based products (Rowell 1995, Suleiman *et al.* 2013).

Several scientists have investigated reported on the characteristics of agrofibers. For decades literature cited and described particleboard manufactured using agricultural wastes and/or residues of annual plants such as; corn pith and wheat straws (Wang and Sun 2002) sunflower stalks (Bektas *et al.* 2005) kenaf stalks (Kalaycioglu and Nemli 2006) bamboo (Biswas *et al.* 2011) rice straw (Zhang and Hu 2014). Fibrous materials including straws were used for paper manufacturing about two centuries ago.

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Corn demand has been increased throughout the years to satisfy human consumption resulting in important lignocelluloses residues which could be utilized as raw material to manufacture particleboard and papers They are cheap, ready available, renewable lignocellulosic source, biodegradable from nature, excellent source of cellulose, hemicellulose and lignin and good fibers structure in terms of length and diameter (Azubuike *et al.* 2012). It is reported that hemicellulose content is higher and the lignin content lower in straw and stalks materials (Rowell *et al.* 2000, Guler *et al.* 2016). The morphological evaluation of straw and stalks revealed a higher content of nonfibrous thin wall cells, epidermal cells and parenchyma cells compared to that in wood particles (Liu *et al.* 2005).

Studies researches have been conducted on the uses of corn stalks in the production of composites (Guler *et al.* 2016), As Prasetiyo *et al.* (2019) and they reported that of particleboards made using corn stalk raw materials and urea formaldehyde or phenol formaldehyde was satisfactory. Quality varies with the level of resin uses.

In Kurdistan, corn, wheat, sunflower, rice and other crops are produced for food industries and vegetable oil production resulting in important fiber and residues available. These agriculture residues are used for heat production, animal feedstocks or fertilizers with little economic impact for the growers. Alternatives uses to add value on stalk residues will be beneficiary for the environment by production of VOC (volatile organic compounds) and a good source of income for a good and durable local economy.

The objective of this paper is to examine the feasibility of utilizing corn stalks grown and harvested in Kurdistan combined with local wood mills residues such as wood poplar in the manufacturing of particleboards for construction in interior application when moisture is not a threat. Particleboard will be laboratory manufacture using a combination of straws and wood poplar. Some physical, mechanical and chemical properties will be evaluated and compare to existing standards.

MATERIALS AND METHODS

In this study poplar wood (*Populus nigra*) and corn stalks (*Zea mays indurata* Sturt.) were utilized as a raw material for production of particleboard. Corn stalks were harvested from plantation fields in (Barderesh\ Duhok Provence). Straws and debris were separated. Dust and dirt were removed by water washing then chipped coarsely using a chipper machine and a ring flaker to produce small pieces of particles poplar wood particles were collected from a local mill located in Karzan Duhok province of Iraq.

Wood particles were dried and screened through a vibrated sieve. The mean particles size used in this study was 1,5 cm to 2 cm. screened selected particles were dried at 100 ºC - 105 ºC in an oven a moisture content of 3 % was reached. Table 1 contains the properties of urea-formaldehyde (UF) used in this UF was sprayed using a rotary drum blender equipped with a spray nozzle. the boards were manufactured at density of 0,70 g/cm^3 using with 10 % resin based on the oven dry weight of the materials. About 1 % of ammonium chloride (NH_4CL) as hardener was added to urea-formaldehyde resin through blender before spraying on the raw materials. The composition of raw materials in terms of ratio of wood to corn stalk are listed in Table 2. Materials were blended for 3 minutes with the resin and hardener for a better distribution on the particles. coated particles were weighted and placed in a wooden mold measuring (36 cm x 36 cm x 25 cm depth) on a 2 mm steel plate compressed manually after it was covered with an aluminum foil (Archanowicz *et al.* 2013).

Two experimental particleboards with dimensions of 31 cm x 31 cm x 1 cm were produced for each design. Boards were pressed at 25 MPa down to 10 mm at 150 ºC for 10 minutes using a hydraulic press (AS METAL - Ayhan Necipoglu, model SSP - 140). At the end of the pressure cycle, boards were conditioned at 28 °C and 45 % relative humidity, panels were put in conditioning room until the panels reached the moisture content at (10 %). After conditioning the boards were edge trimmed to 300 mm x 300 mm x 10 mm.

Table 1: The properties of urea-formaldehyde (UF) adhesive used in this study.

Properties	Value
Solid content %	55 ± 1
Density (g /cm^3)	1,22
Viscosity (cps)	185
Flowing time (25 °C, s)	20 - 40
Free formaldehyde %	0,7
NH4Cl content (max, 1%) Gel time (100 °C, s)	25 - 30
Storage time (25 °C, day)	90
pH	7,5 - 8,5

Table 2: Raw materials used.

Board Type	Corn Stalks	Poplar wood
A	0	100
B	25	75
C	50	50
D	75	25
E	100	0

Raw materials %

Physical and mechanical properties were evaluated and performed according to ASTM D1037-06 (2004). Tow samples from each board were prepared and used for the static bending to determine modulus of rupture (MOR) and modulus of elasticity (MOE) using the following dimensions: 30 cm x 5 cm x 1 cm, the dimensions for the internal bond testing (IB) were 5 cm x 5 cm x 1 cm. To determine water absorption (WA) and thickness swelling (TS) tests for 2 hours and 24 hours, two samples were taken from each board with dimensions of 5 cm x 10 cm x 1 cm. On computer control electronic universal testing machine (Model: WDW - 200E\200 KN\ Load accuracy, Class 0,5) the mechanical properties determination tests were completed.

Chemical properties

The chemical composition of both poplar wood and corn stalk were determined and samples processed following procedures described in TAPPI 257 cm 85 (1985). Holocellulose and alpha cellulose were estimated using the techniques for chloride (Wise and Karl 1962) and TAPPI 203 cm 99 (1999) respectively. The lignin and ash were additional processed by the methods of TAPPI 222 om 98 (1998) and TAPPI 211 om 93 (1993). Solubility properties were estimated based on alcohol benzene TAPPI 204 cm 97 (1997) cold and hot water TAPPI 207 om 99 (1999) and 1 % NaOH TAPPI 212 om 98 (1998).

Fibers properties

To determine fiber dimensions the particles of both poplar wood and corn stalks were cut and prepared for maceration process according to the modified franklin method (Franklin 1946). The samples in test tubes were cooked into pulp in the oven set at 60 °C for 24 h. After washing and rinsing with distilled water and shaking individual fibers were sampled appropriately for measuring. Fibers were spread over a glass slide and they were observed under light microscope according to method described by Jane (1970). A total of 100 fibers were used to measure length, diameter and cell wall for each type.

Statistical analysis

Data analysis were performed analysis of variance (SAS 2013) and significant differences between variables were determined by Duncan test at p < 0,01 level.

RESULTS AND DISCUSSION

The mechanical properties of produced particleboard are given in Table 3. The highest value of modulus of rupture MOR of 46,69 MPa was obtained with boards made of wood poplar particles made with 10 % UF (type A, 100 percent). The lowest MOR value of 29,67 MPa was achieved with the produced particleboards with corn stalks (type E, 100 %). Also, it appears from Table 3 that MOR values of particleboards decreased with increases of corn stalk content in the panels. This result is in accordance with Guler *et al.* (2016) and Prasetiyo *et al.* (2019) reporting on the possibilities of utilizing different agriculture residues Kalaycioglu (1992), Goker *et al.* (1993) and Kalaycioglu and Ors (1993). The addition of corn stalks reduces the MOR of particleboard made of UF.

Table 3: Mechanical properties, test results of ANOVA and Duncan's test of particleboards made from poplar wood and corn stalks particles.

Mechanical Properties	Board Type	Mean (MPa)	Standard Deviation	Standard Error	Minimum (MPa)	Maximum (MPa)
MOR (MPa)	A	46,69a[1]	67,77	21,43	31,30	53,66
	B	37,10b	87,62	27,71	27,86	50,31
	C	34,54bc	65,84	20,82	23,49	45,38
	D	32,48bc	63,79	20,17	20,91	40,92
	E	29,67c	73,17	23,14	16,50	37,89
MOE (MPa)	A	1642,61a	1788,02	565,42	1371,36	1847,57
	B	1454,22b	1741,1	550,58	1140,41	1639,57
	C	1071,08c	1682,26	531,98	9329	1439,02
	D	968,70c	1415,45	447,60	914,86	1121,39
	E	777,07d	1737,47	549,44	388,83	954,28
IB (MPa)	A	0,491a	1,13	0,533	0,372	0,692
	B	0,421b	0,793	0,251	0,355	0,570
	C	0,381b	0,536	0,169	0,253	0,417
	D	0,309c	0,516	0,163	0,219	0,380
	E	0,240d	0,496	0,157	0,188	0,336

Means with the same letters are not significantly different.

The highest of modulus of elasticity MOE value of 1642,61 MPa was observed in particleboard made using only poplar wood particles type A while the lowest MOE value of 777,07 MPa was noticed for type E panels including 100 % corn stalks particles. The values of MOE showed a similar trend to results of the MOR. MOE values of produced particleboards were decreased with increase of corn stalks content in the panels. Most panel types displayed a significant variation (p < 0,01) in their MOR and MOE properties, as well as the corn particles when used to produce particleboard reduced the MOE values greater than the MOR. These results are in agreement with Guler *et al.* (2016) and Prasetiyo *et al.* (2019) and the desired MOE values for multi-purpose particleboards also have been studied and reported as in the literature Goker *et al*. (1993) and Kalaycioglu and Ors (1993).

Many workers reported that the size of particles influences significantly the produced particleboard, hence the larger size of Particles produced panels has better MOR and MOE than any of those formed from small particles (Kasir 1979, Nazerian *et al*. 2011, Izekor *et al*. 2013, Chiman 2015). While in the current study, the poplar particles used are not standardized in the form of shaving residues that are often folded and not identical to the size of the corn stalks, and this folding may have interfered with the particle size and may ultimately have yielded different results. This is an explanation why panels produced from poplar particles have better MOR and MOE than those panels produced from pure corn stalks, as well as the lower structural properties of corn stalks. Furthermore the MOR and MOE panels produced from mixed poplar particles and corn stalks such as B, C and D have different mechanical properties of panel types A and E, the causes of such variation are due to the differences of particles geometry with regard to the influence of interacted amongst kind and particles size with resin content, as well as temperature and press time (Kasir 2006, Malanit *et al.* 2009, Chiman 2015, Barzani 2015).

Internal bond is a fundamental materials science test in which a sample is subjected to a controlled tension until failure) particleboard made from 100 % poplar wood displayed the maximum IB values of 0,491 MPa while particleboard manufactured from 100 % corn stalks had the minimum IB values of 0,240 MPa. in addition the IB of the particleboard was decreased with increase of corn stalks content in the panels. Study results have also been reported in other reports on corn stalk board (Akgul *et al*. 2010a, Prasetiyo *et al*. 2019).

Some studies have been reported that particleboard made utilizing different agricultural residues have lower mechanical properties than those made of wood particle (Bektas *et al*. 2005, Copur *et al*. 2007, Nemli *et al*. 2009, Buyuksari *et al*. 2010). However, the use of phenolic resins and diverse coatings on the particleboard surfaces can enhance some mechanical properties (Nemli 2003, Nemli *et al.* 2005).

The dimensional stability of particleboard is affected by different manufacturing factors such as panel density, amount of adhesive and distribution, moisture content, press duration, furnish types and chemical and structural properties of particles (Gertjejansen 1977, Chiman 2015, Akgul *et al.* 2010a).

The results of water absorption (WA) and thickness swelling (TS) for produced particleboards are listed in Table 4. The highest values of WA (210,33 % and 243,39 %) and TS (53,61 % and 61,94 %) were recorded in particleboard type E (100 % corn stalks) in a combination for water immersion times of 2 and 24 hours respectively. The mean of WA and TS in percentages for panels differed significantly in the duration of immersion in water ($p < 0,001$). Ratios of absorption and swelling were increased for all panel types with immersion duration from 2 to 24 h. Thus, increasing of corn stalks ratio in the panels resulted in a higher percentage of WA and TS in produced particleboards utilizing mixture of poplar wood and corn stalks (Figure 1 and Figure 2). From the tests, it is obvious that the majority of swelling in the direction of thickness occurred around test start times up to 2 h, of immersion. This rise relied on the amount of stalks of corn in the panels, which is similar to the results of Guler *et al.* (2016) and Guler (2016). The results indicated that the panel types E and D for 24 h was not differing insignificantly in WA and TS. This could be due to corn stalk particles which consist of higher amount of corn stalks and their core panels have softer parenchyma cells and hydroxyl groups that can attract more water because of corn stalk has higher hemicellulose compare to cellulose in wood.

Table 4: Water Absorption (WA) and Thickness Swelling (TS), test results of ANOVA and Duncan's test of particleboards produced from poplar wood and corn stalks particles.

Physical Properties	Board Type	Soaking time (minute)	Mean (%)	Standard Deviation	Standard Error	Minimum	Maximum
Water Absorption (WA)	A	2	97,51e	11,15	3,53	72,36	110,42
	B	2	127,39d	10,59	3,35	98,86	135,14
	C	2	145,17c	10,74	3,39	132,72	162,33
	D	2	183,91b	25,19	7,97	150,61	225,94
	E	2	210,33a	24,00	7,59	178,56	246,15
	A	24	115,28d	15,30	4,84	88,42	131,25
	B	24	136,36c	17,35	5,49	110,62	159,15
	C	24	162,17b	23,66	7,48	133,26	196,74
	D	24	224,71a	29,04	9,18	161,17	250,18
	E	24	243,39a	22,15	7,00	215,39	283,41
Thickness Swelling (TS)	A	2	43,6c	3,58	1,13	39,16	49,15
	B	2	44,28c	4,74	1,50	37,15	52,44
	C	2	48,13b	3,346	1,15	43,96	56,17
	D	2	50,57ab	3,70	1,17	44,19	56,93
	E	2	53,61a	4,82	1,52	47,56	61,02
	A	24	52,38b	3,41	1,08	48,73	57,19
	B	24	55,52ab	4,08	1,29	50,39	60,44
	C	24	57,19ab	4,88	1,54	49,66	64,56
	D	24	60,71a	8,82	2,79	53,57	78,39
	E	24	61,94a	9,65	3,05	55,21	85,52

Means with the same letters are not significantly different.

On the other hand, the lowest mean of WA and TS with more poplar wood content (A, B and C types for 2 h and 24 h). probably described by the furnishing consistency, particles properties and adhesive. The similar chemical structure of the corn stalks and poplar wood may explain the result. Corn stalks including a small amount of water-resistant compounds related to lignin and important amount of carbohydrates led to a higher amount of available OH groups, because of their higher cellulose content in wood compare to higher hemicellulose in stalk. and cellulose is stronger than hemicellulose due to its crystal form and it is more in wood a perennial species.

In general, the high values of some physical properties in this study could be attributed to the lack of wax or other hydrophobic substances not used through laboratory manufacturing of particleboard such as heat treatment, water repellent chemicals like paraffin, phenolic adhesives, acetylating of particles and coating of the particleboard surfaces can enhance the water repellence of the boards (Rowell and Norimoto 1988, Nemli *et al.* 2005, Guntekin *et al.* 2008, Buyuksari *et al.* 2010). WA and TS data obtained in this work are similar to data published by others scientists using different agriculture residues including hemps, sunflowers stalks, cotton stalks, pine wood and teas (Kalaycioglu 1992, Guler 2001, Bektas *et al.* 2006, Akgul *et al.* 2010a, Akgul *et al.* 2010b, Prasetiyo *et al.* 2019).

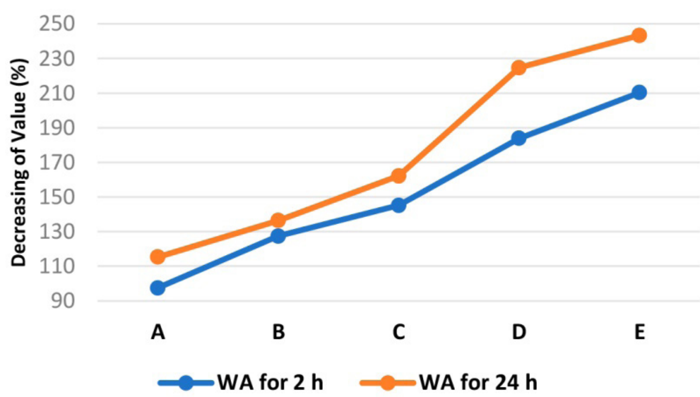

Figure 1: Average values of water absorption (WA) of panel types after 2 and 24 hours of treatment.

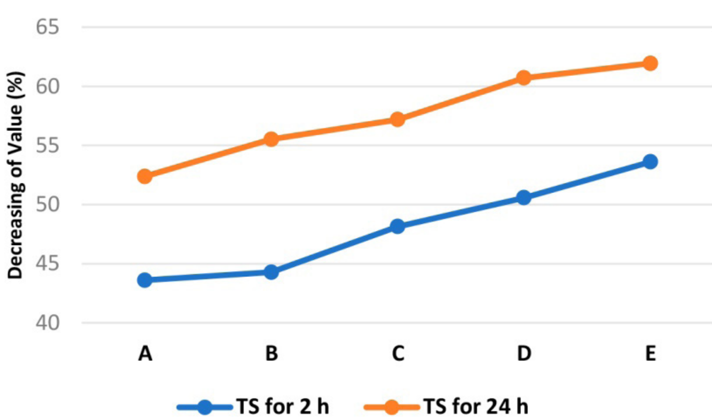

Figure 2: Average values of thickness swelling (TS) of panel types after 2 and 24 hours of treatment.

Chemical properties of the poplar wood and corn stalks are presented in Table 5. the corn stalks have a have a high content of holocellulose, cellulose and lignin. The chemical interaction between the resin and lignocellulosic materials present in corn stalks have a certain influence on the values of MOE and MOR (Prasetiyo *et al.* 2019). Chemical composition also impacts the dimensional stability of particleboard, corn stalks with lower water-resistant lignin and increased level of water attractive carbohydrates as mentioned earlier in literature (Akgul *et al*. 2010a, Akgul *et al*. 2010b). This finding is in agreement with earlier propositions in literature (Akgul *et al*. 2010b, Kargarfard and Jahan-Latibari 2011, Guler *et al.* 2016).

The strength of particleboard is influenced by both fiber geometry and chemical composition of the raw material. Fibers from agro- lignocellulose material is usually weak and the use of longer wood fibers produce stronger panel (Kargarfard and Jahan-Latibari 2011). The average dimensions of particle from corn stalks and poplar wood used to produce in this study particleboard are listed in Table 6 in agreement with data listed by Akgul *et al.* (2010b) and Kargarfard and Jahan- Latibari (2011).

Table 5: Chemical composition of poplar wood and corn stalks used in manufacture of particleboard.

Raw material	Holocellulose %	Cellulose %	Lignin %	Ash %	Alcohol - Benzene	1% NaOH	Hot Water	Cold Water
Poplar wood	70,2	46,73	22,56	2,19	2,73	15,22	6,20	5,19
Corn stalks	68,19	48,37	20,42	8,76	9,54	46,6	19,06	18,31

Table 6: Fiber dimensions of poplar wood and corn stalks used in manufacture of particleboard.

Raw Material	Particle length (mm)	particle diameter (µm)	Cell wall thickness (µm)	Fiber lumen diameter (µm)
Poplar wood	1,12	21,97	4,61	12,74
Corn stalk	1,02	19,4	4,62	19,30

CONCLUSIONS

From the results presented in the text it can be conclude that corn stalks and poplar particles can be utilized at various ratios to produced particleboards which may be utilized in interior applications due to water absorption and thickness swelling resultant. The low internal bond strength value using the adhesive type and level and the type of raw materials (corn stalks) can be upgraded sufficiently by increasing the proportion of wood particles. The results can demonstrate that corn stalks can be considered as an alternative to wood material in the production of particleboards.

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