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ARTÍCULO

Some physical and mechanical properties of particle boards produced with hazelnut husk and astragalus (*Astragalus membranaceus*) plant

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Abstract:
In this study, under laboratory conditions, hazelnut husk and astragalus plant were mixed separately into black pine wood chips, and multi-purpose boards were produced from the obtained chips with urea formaldehyde glue. After the hazelnut husk and astragalus plant were dried and ground, they were added to the chip and glue mixture in certain proportions. Hazelnut husk mixture ratios were applied as 100 %; 0 %, 75 %; 25 %, 50 %; 50 %, 25 %; 75 %, 0 %; 100 % to black pine wood chip in the particle board mixture. These ratios were made in the same way for the astragalus plant. From these mixtures, chipboard blanks of 16 mm thickness and densities between 0,68 g/cm^3 and 0,72 g/cm^3 were produced. Density, moisture content, thickness increase, water intake, bending strength, modulus of elasticity in bending and tensile strength perpendicular to the surface were tested in physical and mechanical experiments. According to the results obtained, as the participation rate of hazelnut shells and astragalus increased, the durability properties of the panels decreased. At the same time, it shows that the technological properties of the panels produced by adding up to 25 % astragalus plant and hazelnut shells to the mixture comply with the standards.

Keywords: Astragalus plant, black pine wood chip, hazelnut husk, mechanical properties, particle board, physical properties.

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Introduction

The problem of raw material supply in the particleboard industry is growing over time. Many countries are trying to find different sources of raw materials. In addition to the increase in consumption in parallel with the world population, the scarce and insufficient raw material resources cause an increase in costs. It has become imperative to evaluate resources economically and rationally. All kinds of raw materials with lignocellulosic structure are tried to be evaluated in the production of boards.

Many particle board factories in the world use annual plant waste in their production as a raw material source. For this purpose, it makes it possible to produce particleboard from plant-derived materials such as flax, hemp, cotton stalks, sugarcane, cotton straw, peanut shells, straw, sunflower seed shells or their wastes (Mobarak and Nada 1975, Guler 2015a).

The protection of forest resources and the environment, as well as the development of environmentally friendly technologies, have gained importance today. For the particle board industry, the suitability of various raw material sources for board production continues to be investigated.

Approximately 75 % of the world hazelnut (*Corylus avellana* L.) production and between 70 % and 75 % of its export is carried out by Turkey. 4 million people are directly or indirectly interested in hazelnut, which has a share of approximately 500 million dollars in total exports in Turkey. Hazelnut production, which is harvested on an area of 337 thousand hectares in Turkey, is between 650 and 700 thousand tons/year in shell, and 400 and 450 thousand tons of this is exported. About 400 thousand tons/year of husk and bark are produced as waste (Guler *et al.* 2009).

Camlibel (2023), according to the test results of particleboards produced using poplar waste in two different press types; thickness (0,63 %), bending strength (1,27 %), moisture content (0,47 %), thickness swelling (37 %), water absorption (39,9 %), modulus of elasticity (11,35 %), the inner bond (7,22 %) increased according to hot pressure. On the other hand, it was reported that density (2,7 %), surface strength (18,81 %), screw withdrawal resistance (14 %) and formaldehyde (57,12 %) decreased.

Kristak *et al.* (2023), It has been said that further research is needed to identify factors to formulate new ultra-low formaldehyde emission wood adhesives with optimum properties and expand their applications in the wood-based panel industry. They also reported that another viable option to reduce harmful formaldehyde emissions from finished wood composites is the addition of formaldehyde scavengers to the adhesive systems used in the production of wood-based panels.

Giudice *et.al.* (2023), Thermo-vacuum modification has been conducted on the siberian larch (*Larix sibirica* L.) wood. They reported that TVT (thermo vacuum-treatment) using PVP had a significant effect on the chemical and physical properties of larch wood. On the other hand, they reported that the compressive strength of larch wood samples was not affected and there was a slight decrease in MOE.

Bal and Ayata (2020) reported that the sapwood of the black pine (*Pinus nigra* J.F.Arnold) tree is wide, its heartwood is narrow and very resinous. On the other hand, they stated that the appearance of annual rings was clear and soft. It has been reported that the radial expansion of larch wood is 6,57 %, its volumetric expansion is 14,23 %, its tangential expansion is 7,19 %, while its radial contraction is 5,69 %, its tangential contraction is 7,12 % and its volumetric contraction is 12,40 %. They reported that cellulose in larch wood was 48,27 %, extractive substance content 8,71 %, holocellulose 64,27 %, α-cellulose 40,10 % and lignin 34,32 %. On the other hand, they reported that hot water solubility was 8,68 %, cold water solubility was 7,42 %, ash content was 0,60 % and 1 % NaOH solubility was 19,75 % (Sanıvar and Zorlu 1980, Kardas 2014, Akyurek 2019, Var and Kardas 2017, Cavuş *et al.* 2019).

Bal and Ayata (2020), in her study on the mechanical properties of black pine wood, They determined the humidity as 9,77 %, the air-dry density as 508 kg/m^3, the bending strength as 118,7 N/mm^2 and the modulus of elasticity as 97,89 N/mm^2.

Morrell (2019), It states that wood is one of our most important renewable building materials, that it is resistant to adverse conditions and biological and physical damage, and that its lifespan can be extended with preservatives.

Guler *et al.* (2009), investigated the technological properties of the boards they produced by using urea formaldehyde, melamine formaldehyde and phenol formaldehyde glue (between 8 % and 9 % in the middle layer, between 10 % and 11 % in the outer layer) in a study on hazelnut husk. The bending strength of the produced particle boards was determined as 0,70 g/cm^3 and a density value of 12 N/mm^2 (Guler *et al.* 2009). Alternative sources used by some researchers for particle board production are given in Table 1.

Table 1: Alternative sources used by some researchers for particle board production.

Alternative Sources	Researchers
Sunflower stalk, wheat stalk, pepper stalk Cotton stalk, corn stalk	Bektas *et al.* 2020; Oh and Yoo 2011; Guler *et al.* 2006; Alma *et al.* 2005; Bektas *et al.* 2005; Guler and Özen 2004
Peanut shell, hazelnut husk, peanut	Guler and Buyuksari 2011; Guler *et al.* 2009; Mańkowski and Laskowska 2021
Kenaf, hemp, flax, hemp grass, sugarcane	Kalaycıoglu and Nemli 2006; Xu *et al.* 2003
Rice pad, licorice root	Guler 2015b; Yang *et al.* 2003
Coconut skin and fiber	Khedari *et al.* 2004; Khedari *et al.* 2003
Pine cones, needle leaves	Buyuksari *et al.* 2010; Nemli and Aydın 2007
Vine waste, tea waste, grass waste, kiwi pruning waste	Nemli *et al.* 2009; Nemli *et al.* 2003

In this study, some technological properties of the boards obtained by adding certain proportions of industrial black pine wood chips to mixtures of hazelnut husk and astragalus plant as raw material were examined.

Materials and methods

In panels production, larch shavings obtained from the market, hazelnut shell waste from the Trabzon region and astragalus plants from the Bayburt countryside were provided. After the astragalus plant and hazelnut husk were dried, fine chipping was done in the chipping machine. Later, black pine wood chips were added to this process with two different chipping. In the first chipping process, from 0,8 mm to 1,5 mm for the outer layers of the board and from 1,5 to 3 mm average thickness for the middle layer in the second chipping process were done.

The mixture obtained by blending astragalus plant, hazelnut husk and black pine wood chips in certain proportions is given in Table 2. All the chips were dried in the drying oven at 70 °C and the humidity was maintained between 1 % and 3 %. The amount of chip mixture and glue used for the production of the board was calculated separately for the outer and middle layers. The amount of chips determined for each layer was weighed and the gluing stage was started.

Table 2: Test panels.

Panels type	Industrial wood chips (%)	Hazelnut husk (%)	Panels type	Industrial wood chips (%)	Astragalus Plant (%)
A	100	0	A	100	0
B	75	25	M	75	25
C	50	50	N	50	50
D	25	75	O	25	75
E	0	100	P	0	100

The production of the panels was carried out in Duzce University Faculty of Forestry. 40 cm x 40 cm forming frame and 16 mm thick wedges were used in the preparation of the board draft. The targeted density on the panels were determined as 730 kg/m^3. Urea formaldehyde glue was used 10 % in proportion to the dry chip weight.

A total of 10 boards were produced, 2 from each board mix group. Single-layer panels were produced with a press temperature of 150 °C, a pressing time of 7 minutes, a press pressure between 2,4 N/mm^2 and 2,6 N/mm^2, and a panels thickness of 16 mm. The produced boards were kept in the air-conditioning room at 20 °C and 65 % relative humidity in accordance with the TS 642-ISO 554 (1997) standard for three weeks, and the necessary samples were prepared for the trials from these air-conditioned boards TS EN 326-1 (1999). The properties of urea formaldehyde glue are given in Table 3.

Table 3: Properties of the urea formaldehyde.

Properties	UF
Solid (%)	55 ± 1
Density (g/cm^3)	1,2
pH	8,5
Viscosity (cps)	160
Ratio of water tolerance	10/27
Reactivity	35
Free Formaldehyd (%)	0,15
33% NH_4CI content (max, %)	1
Gel point (100 °C)	25-30
Storage time (25 °C, max day)	90
Flowing point (25 °C)	20-40

In the study, TS EN 312-2 (1999) standard (particle boards-properties) was used for physical and mechanical tests. The physical properties of the produced boards are density TS EN 323 (1999), humidity amount TS EN 322 (1999), 2 h and 24 h thickness increase rate and water intake amount TS EN 317 (1999). Modulus of rupture and modulus of elasticity in bending of the mechanical properties of the boards were determined in accordance with TS EN 310 (1999) and internal bond strength to the surface TS EN 319 (1999).

20 test samples were tested in determining the physical properties and 10 test samples were tested in determining the mechanical properties. All the data were statistically analyzed by using the analysis of variance (ANOVA) and Duncan's mean seperation tests.

Results and discussions

2-hour and 24-hour average data, standard deviation and homogeneous groups of the density, moisture rates, swelling (TS) and water absorption (WA) properties of the test panels were determined. The data obtained are given in Table 4.

In the analysis of variance of the findings obtained in laboratory experiments on particle boards, it was determined that the production conditions had effects on water uptake and thickness increase. The data obtained are given in Table 4.

In Table 4, the average specific mass values vary between 0,68 g/cm^3 and 0,72 g/cm^3, and it is seen that these values comply with the TS EN 312-2 (1999) standard in terms of the 0,70 g/cm^3 density values aimed to be produced in the study. If the density change in particle boards is more than 10 %, it means that it is not in accordance with the standards.

Table 4: Average values and similarity groups of the physical properties of the test panels.

Panel groups			Moisture (%)	Intensity (g/cm^3)	Thickness swelling (TS) (%)		Water absorption (WA) (%)	
					2 h	24 h	2 h	24 h
A	0	X	6,7	0,713	27,69c	30,24d	53,20c	61,42d
		±sd	0,15	0,09	6,49	5,87	6,12	7,15
B	25	X	6,24	0,707	31,33abc	32,00cd	68,76a	71,50ab
		±sd	0,14	0,07	5,18	5,99	8,24	7,11
C	50	X	6,20	0,680	29,24bc	30,35d	62,63b	68,68bc

		±sd	0,08	0,708	5,02	5,74	7,29	6,47
D	75	X	6,21	0,716	32,42abc	33,80bcd	58,71b	62,71d
		±sd	0,09	0,08	7,54	6,01	8,68	7,27
E	100	X	6,30	0,723	34,55a	36,45abc	61,47b	65,77cd
		±sd	0,12	0,09	7,06	4,61	4,04	4,37
A	0	X	6,68	0,713	27,69c	30,24d	53,20c	61,42d
		±sd	0,15	0,09	6,79	5,87	8,17	7,15
M	25	X	6,80	0,714	31,24abc	34,04bcd	53,20c	64,22d
		±sd	0,28	0,05	5,92	4,11	6,12	3,47
N	50	X	6,71	0,706	34,21ab	36,13abc	69,29a	72,68ab
		±sd	0,13	0,06	4,55	3,96	7,44	6,82
O	75	X	6,54	0,718	34,98a	37,58ab	52,69c	66,28cd
		±sd	0,14	0,09	5,42	5,01	6,54	5,87
P	100	X	6,90	0,694	35,54a	38,65a	71,48a	75,59a
		±sd	0,17	0,08	8,35	7,32	9,64	5,98

X: average, sd: standard deviation, the same weeks in the same column (a,b,c,d,e) mean that there is no statistically significant difference.

It was determined that the deviation from the targeted specific mass value was between 1 % and 2 % at most and the equilibrium humidity of the panels was between 6 % and 8 %. It is stated that the humidity change of the test panels should be in the humidity range between 5 % and 13 %, which is required in the TS EN 312-2 (1999) standard.

The increase in thickness was determined as 36,45 % for 24 h in E group boards, which is the highest, and 30,35 % in the lowest C group boards, in the panels groups produced with husk. Compared to the boards made of black pine wood chips, the swelling increased with increasing hazelnut husk ratio. In the panels with astragalus plant, it was determined as 38,65 % in the highest P group panels and 34,04 % in the lowest M group panels. Swelling increased with the addition of astragalus to the chips.

It has been determined that there are significant differences between the panels groups in the amount of water intake, and it generally varies between 62,71 % and 71,5 % in the hazelnut husk for 24 h. In astragalus plant, it varies between 64,22 % and 75,59 %. The thickness increase is given as 14 h % for 24 h in TS EN 312-2 (1999) in the standards. In general, the increase in thickness of the panels produced from annual plant and agricultural wastes is higher than the predicted values.

Kalaycıoglu (1992), in his studies with tobacco stem and tea factory waste, determined that the water intake of the panels was between 60 % and 71 % for 24 h, and the thickness increase was between 22 % and 37 %. In another study it was determined that the amount of water intake was between 37 % and 93 %, and the thickness increase was between 13 % and 31 % for 24 h in panels made from hazelnut husk, peanut shell, cotton stalk and corn stalk residues (Guler 2015a, Bektas *et al.* 2021). Filiz *et al.* (2011) determined that the low density particle boards produced from tea plant wastes are between 17 % and 34,8 %. In another study, it was stated that the swelling values of medium density board groups obtained from lavender plant and red pine chips were between 34,36 % and 76,98 % (Sevincli 2014).

Data on the rupture modulus, elastic modulus and internal adhesion strength of the surface of the test panels were determined. The data obtained are given in Table 5.

In the analysis of variance of the findings obtained in laboratory experiments on particle boards, it was determined that the production conditions had effects on modulus of rupture, modulus of elasticity and internal bond strength to the surface. The data obtained are given in Table 5.

When the mean MOR and MOE values of the panel groups were examined, MOR 13,12 MPa was obtained in the control group (A) panels. The lowest MOR value was determined as 3,92 N/mm^2 in E group panels and 4,95 N/mm^2 in P group panels. As the husk and geven participation rate in the panel increased, the strength values decreased. As with the MOR values, the MOE values decreased in the mechanical values with the increase of plant materials.

It was determined that there were statistically significant differences between all data obtained in EM with 95 % confidence ($p<0,05$). Aras *et al.* (2014) determined the modulus of elasticity as 970 N/mm^2 in the boards produced from 100 % pine nut cones with a density of 0,70 g/cm^3.

Table 5: Mean values and similarity groups of the mechanical properties of the test panels.

Panels group		MOR (MPa)	MOE (MPa)	IB (MPa)
A	X	13,12a	2179,71a	0,55a
	±sd	1,99	268,00	0,09
B	X	11,05b	1876,85b	0,44bc
	±sd	1,09	128,49	0,07
C	X	6,08d	1192,57d	0,24e
	±sd	2,07	56,41	0,02
D	X	5,16de	802,85ef	0,23e
	±sd	1,54	132,65	0,10
E	X	3,92e	605,28g	0,20e
	±sd	2,41	201,51	0,06
A	X	13,12a	2179,71a	0,55a
	±sd	1,99	268,00	0,04
M	X	10,79b	1934,83b	0,41bc
	±sd	1,40	270,83	0,08
N	X	7,55c	1438,14c	0,48b
	±sd	2,33	253,41	0,09
O	X	4,09e	819,00e	0,30d
	±sd	1,01	220,11	0,02
P	X	4,95de	654,28fg	0,12f
	±sd	1,40	185,44	0,02

MOR= modulus of rupture; MOE= modulus of elasticity; IB= internal bond strength

X: average, sd: standard deviation, same weeks in the same column (a,b,c,d,e) statistically show significant differences.

According to the TS EN 312-2 (1999) standard, the panels with 13,12 N/mm^2, 11,05 N/mm^2 and 10,79 N/mm^2 values obtained in the A, B and M group panel groups for the MOR value can meet the Type P1 and P2 panel class requirements. MOE on the other hand, meets the values specified in the TS EN 312-2 (1999) standard again for A group (control samples), B group (25 % hazelnut husk addition) and M group (25 % hazelnut husk addition) panels. The panels obtained by using these wastes more than these rates do not comply with the values in the standards.

When Table 5 is examined, the highest IB strength to the surface was measured as 0,55 MPa in the control group panels (A), while the lowest E group (100 % hazelnut husk) was 0,20 MPa and the P group (100 % astragalus) 0,12 the N/mm^2 group was detected in the panels. As the ratio of hazelnut husk and astragalus plant in the panel increases, the tensile strength values decrease. However, it is seen that the addition of wastes up to 50 % meets the tensile strength values standards.

When the results obtained are compared with the TS EN 312-2 (1999) standards, the 0,24 MPa value specified in the properties (Type P1) standard for general purpose boards used in dry conditions in terms of IB strength is A (control), B, C, M, N and O. group panels are seen to be met. When evaluated for Type P2 (Properties for boards used in interior applications (including furniture) in dry conditions), A, B, M and N group boards meet 0,35 MPa.

Conclusions

As a result of the statistical evaluations obtained from the test panels, it was seen that the technological properties of the panels comply with the standards used in hazelnut shells and astragalus plants at a rate of 25 %.

On the other hand, coating the particleboard surface with laminated and wood veneer boards will have a positive effect on the strength properties of the board (Chow *et al.*1986). Accordingly, as a result of covering the boards produced with raw material sources such as astragalus plant and hazelnut husk with wood or laminated boards, the physical and mechanical properties of the board will improve.

Panels produced with hazelnut husk, astragalus plant and similar raw material sources cannot be used in places where high strength properties are required. However, if it is produced with light weight and sufficient strength properties, it can be considered as an insulation material indoors. As a result, it can be evaluated in production to a certain extent in the production of particleboards to be used for general purpose and indoor environments.

Authorship contributions

S.K.: Conceptualization, data curation, formal analysis, investigation, methodology, resources, software, supervision, validation, visualization, writing - original draft, writing - review & editing. C.G.: Conceptualization, data curation, methodology, resources.

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