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Investigating Some Physical Properties of Composite Board, Produced from Sunflower Stalks, Designed Horizontally

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Abstract
The aim of this study was to investigate the usage possibilities of sunflower stalks in the manufacturing of alternative insulation board, which are left as waste (agro-fiber wastes), in the fields and are useless except for firing like a lot of agricultural wastes in Turkey and in the world every year. The sunflower stalks were designed horizontally to produce the board, and its physical properties were compared to the honeycomb-shaped composite board filled with kraft paper (Control board). Urea formaldehyde (UF) resin, Melamine Urea Formaldehyde (MUF) resin, and the D2 (PVA based) adhesives were employed for producing the composite boards. The physical properties [Chemical analysis, specific gravity, SEM, TGA, sound and heat insulations, ultrasonic pulse, LOI (limiting oxygen index), and combustion characteristics] of all the insulation boards were studied.
The average specific gravity value, weight loss determined by TGA, heat insulation ratio, heat conductivity coefficient, sound insulation ratio, ultrasonic transmission speed value, LOI values (for the wooden part + core and wooden part), and weight loss ratio found by the combustion test were 0.29 g/cm^3, 90.40%, 51%, 0.045 W/mK, 24.03%, 0.46 mm/μs, (28 and 30.5), and 91.72%, respectively.
As a result, the composite insulation board was observed to be better than the control board since it presented a higher specific gravity value, higher insulation ratio, lower heat conductivity coefficient, higher sound insulation ratio, lower ultrasonic transmission speed value, and better combustion characteristics with respect to the control board.
Keywords: Agro-fiber wastes, composite, insulation, sunflower stalk.

Ayçiçeği Saplarından Yatay Tasarımla Üretilen Kompozit Levhanın Bazı Fiziksel Özelliklerinin Araştırılması

Özet
Bu çalışmanın amacı, her yıl Türkiye'de ve dünyada birçok tarımsal atık gibi hasat sonrası tarlalarda atıl olarak bırakılan ve yakma dışında bir işe yaramayan tonlarca ayçiçeği bitkisi sapının alternatif izolasyon levhası üretiminde kullanılma imkânlarını araştırmaktır. Çalışmada ayçiçeği bitkisi sapları yatay dizayn edilerek üretildi ve fiziksel özellikleri bal peteği görünümlü kraft kâğıt dolgulu kompozit levhalarla (Kontrol levhası) kıyaslanmıştır. Kompozit levhaların üretiminde Üre Formaldehit (UF) tutkalı, Melamin Üre Formaldehit (MUF) tutkalı ve PVA esaslı D2 tutkalı kullanıldı. Üretilen kompozit levhaların fiziksel [Kimyasal analiz, özgül ağırlık, SEM-Taramalı elektron mikroskop görüntüleme, TGA-Termogravimetrik analiz, ses ve ısı izolasyon oranı, ultrasonik ses iletim hızı, LOI (limit oksijen indeksi) ve yanma karakteristikleri] özellikleri araştırıldı. Özgül ağırlığı, TGA sonucu ağırlık kaybı, ısı izolasyon oranı, ısı iletim katsayısı, ses izolasyon oranı, ultrasonik ses iletim hızı, LOI değeri (odunsu dış kısım+süngerimsi öz kısım ve odunsu dış kısım) ve yanma testi sonucu meydana gelen ağırlık kaybı sırasıyla 0.29 g/cm3, %90.40, %51, 0.045 W/mK, %24.03, 0.46 mm/μs, (28 ve 30.5) ve %91.72 olarak tespit edilmiştir.
Sonuç olarak, kompozit izolasyon levhasının kontrol levhasına göre özgül ağırlığının daha yüksek, ısı izolasyon oranının daha yüksek, ısı iletim katsayısının daha düşük, ses izolasyon oranının daha yüksek, ultrasonik ses iletim hızının daha düşük ve yanma karakteristiklerinin daha iyi olduğu gözlenmiştir.
Anahtar Kelimeler: Ayçiçeği sapı, izolasyon, kompozit, tarımsal lifsel atıklar.

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INTRODUCTION

Dependant on the population growth in the world, there has been a significant increase in the demand of wood and other biomass based particleboard production materials recently. The world population increases by approximately 90 million per year. Moreover, according to today's data, the world's average use of forest resources as

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fuel is known to be approximately 0.7 tons per person while the whole world consumption is over 3.5 billion tons. Therefore, it is crucial to recycle agricultural fibers and its alternatives such as other vegetative fibers so that they can be utilized more effectively (Rowell 1995, Cooper et al. 1999).

The world's annual vegetative and agricultural waste potential is 4,033,080,000 tons. In Turkey, an average of 36,940,000 tons of agricultural waste occurs every year. This waste is composed of approximately 18 million tons of straw, 8 million tons of barley stalk, 2.5 million tons of corn stalk, 3 million tons of cotton stalk, 2.5 million tons of sunflower stalk, 200,000 tons of rice stalk, 240,000 tons of rye stalk, 300,000 tons of tobacco stalk, 2 million tons of hemp stalk, and 200,000 tons of lake stalk (Güler et al. 2001).

The most researched agricultural waste in the world belongs to the plants of hemp, sugar cane, bamboo, jute, kapok, ramie, kenaf, *Poaceae*, cane and sisal. The most important of them is considered sugar cane. Before the early 90's, there were only 30 establishments in all over the world producing particleboard using sugar cane (Kalaycıoğlu 1992).

Annual plant fibers, specifically cereal stalks and products play an important role in the forest industry and various energy branches in the cereal producing countries. Due to the fact that forests are under the risk of extinction, the forest industry has headed to the utilization of substitution raw material instead. Nowadays, in the Far East countries, primarily in China and India, the use of annual plants in this sector has attracted great attention and thus big-sized establishments to process forest products were founded. Due to the inadequacy of wooden raw material, the use of wood in the forest production sector has decreased progressively (Tutuş et al. 2000). The average sunflower production in Turkey is 850,000 tons per year. However, considering the fact that the amount of the stalk left after the production as a waste is approximately 2.5 times more than the amount of sunflower itself in weight, the average production size appears to be 212,500 tons per year in Turkey while it is approximately 65 million tons in the world (Atchison 1991).

The English Patent Office registered a patent that defines the production of construction material of two or more layers, which are in the structure of a honeycomb, either parallel to each other or whose axes are perpendicular (between 0°-90° degrees), by being pressed either cold or hot with straw, sugar cane, bamboo, various stalks, or such tubular natural material as adhesive; adhesives that contain rubber, bituminous gluing material, synthetic adhesives, and synthetic resin adhesive (Leon 1942).

It is also reported that various studies that investigate the properties of particleboard that contain sunflower stalk and shell exist at the University of Minnesota. In one of these studies, a particleboard was produced by making a mixture of 50% Populus tremula and 50% sunflower seed shells. In another such study, researchers focused on the sunflower stalk. The stalks were prepared; its pith was removed by use of various methods and it was mixed with *Populus tremula* particleboard. As a result, it was observed that the physical and mechanical properties of the board were enhanced by the inclusion of sunflower stalks fiber structure (Gertjejansen 1977).

In this study, a new wall plaster product was generated using 0-5% perlite, 0-2.5% waste paper, and 3.5-17.7% waste calcined borax. The optimum ratios for the additives were 3% perlite, 1.5% waste paper, and 7.1% waste calcined borax. The new plaster was subjected to mechanical strength and thermal transmittance measurements using TS 825 and TS 12808-3 Turkish standards. Under the optimal mixing ratios, the plaster had a thermal conductivity of 0.17 W/m2K and a mechanical strength (bending) of 61.44kg/cm^2. The required standards by TSE 825 are 0.13 W/m2K. When the new product was compared with the existing plasters on the market, it was observed that thermal transmittance and mechanical strength both increased by 26% and 31%, respectively (Batar et al. 2009).

In this study, utilizing the wastes of valonia oak (*Quercus ithaburensis* Decne subsp *macrolepis*) in *P. ostreatus* cultivation was investigated. The tannin obtained from Valonia oak is mostly utilized in the leather industry. After extracting the tannin, the waste has no industrial utilization in Turkey. Milled valonia oak wastes composed of acorn cup hold high humidity; therefore, it has a high drying cost for transporting as well as storage problems for the mills. Valonia oak wastes were used as compost to cultivate *P. ostreatus*. The results indicated that the mycelia development on the oak wastes were realized after 45 days with a yield of 24.5%

(weight/weight) which is to be considered as a potential substrate for *P. ostreatus* cultivation (Şen and Yalçın, 2011).

In our country, waste of the forest industry and annual plants has not been utilized under mass-production by any of the relevant industry branches yet. In Turkey and the world, the fibrous agricultural waste has a great potential for board production. The application of this study is for industry which could increase the value of the sunflower stalk and make tons of sunflower stalks useful thus increasing the economy. Moreover, the aim of this study is to contribute to the achievement of many goals including increasing employment in the agricultural regions, utilizing sunflower stalks with its great insulation properties as an alternative insulation material in the construction sector, decreasing the consumption of forests primarily in Turkey, contributing to energy savings, and efforts to prevent global warming.

MATERIAL AND METHODS

This study which was started in August, 2009 was completed in one year. The sunflower plant (*Helianthus annuus* L.) to be used in the board production was picked in Kılılı, a town in the Türkoğlu district of Kahramanmaraş. The board was produced with a horizontal design and honeycomb shaped and Kraft paper filled composite boards were utilized as the control board.

The fibrous outer layer of the stalk constitutes 90% of the dry stalk in total weight. The fibers are long and brown while the white part can easily be separated from the pith (despite the density of the fibers is 0.430 g/cm^3, the density of the pith is 0.035 g/cm^3 and the average specific weight of the stalk is 0.330 g/cm^3). The pith in the stalk visually looks like a honeycomb.

In the production of both the horizontally designed boards and the control board, we used MDF boards from the Yıldız MDF Corp. which were prepared in the size of 2100 x 2800 x 4 mm with the specific weight of 0.85 g/cm^3.

In this study, the adhesives used were urea formaldehyde (UF), melamine urea formaldehyde (MUF), and the D2 glue composed of PVA. The technical specifications of the adhesives are given in Table 1.

The specifications of the honeycomb-shaped paper filling are given in Table 2.

The sunflower stalks of the study were picked in September, 2009 after the harvesting time from village of Kılılı a town in the Türkoğlu district of Kahramanmaraş. Dirt on the stalks such as mud, root, and leaf were removed roughly while the stalks were still in the field. The picked stalks were gathered and taken to an enclosed area. Then, they were cut with the use of a template to make them equal in size. Subsequently, they were classified with the consideration of being homogenous in terms of length and diameter in order to make them into uniform bunches (Efe 2011).

Afterwards, the stalks were aligned according to the small diameter-big diameter method so that their thin and thick ends balance each other. By use of a packing needle, they were bundled with cotton yarn by connecting the ends from points 100 mm from the end. The bundling is accomplished, with a yarn being threaded from one end to the other by passing it from the top of a stalk to the bottom of the next. In return, this process is repeated, but this time in reverse order in order to make the stalks compose a layer. In the hydraulic hot press, these stalk layers were pressed between MDF boards which had been prepared beforehand in the size of 500 x 1100 mm with a 4mm thickness. Therefore, the horizontally-designed insulation board was produced. Figure 1 depicts the general layout of the production flow of the board (Efe 2011).

Samples of the board produced with the procedure depicted in Figure 2 were prepared in different size and number according to the different

Table 1. The specific features of glues

Features	Glue		
	UF[1]	MUF[2]	D2[3]
Dry mass ratio (%)	65 ±1	55 ±1	-
Spesific gravity (g/cm^3) (20° C)	1.25-1.27	1.25	-
Viscosity (cps) (20° C)	120-200	200	15.000 +/- 6.000 (MPa.s)
pH	7.5-8.5	8.5	6-8
Gelation time(100° C'de) (s)	25-35	50-60	-
Free formaldehyde (%)	0.17 (max.)	0.16 (max.)	-
Minimum film making temperature (°C)	-	-	3 °C
Vitrification point	18 °C		

(1)Urea formaldehyde glue, (2)Melamine urea formaldehyde glue, and (3)D2 glue

Table 2. The features of honeycomb paper filling material.

Features	Values
Cell diameter (mm)	28
Density (g/m^2)	175
Compressive strength (MPa)	1.3
Cutting strength (MPa)	0.5
Usage temperature (°C)	(-30)-(+80)
Expansion measure (mm)	2400x1200
Spesific gravity (kg/m^3)	80-90

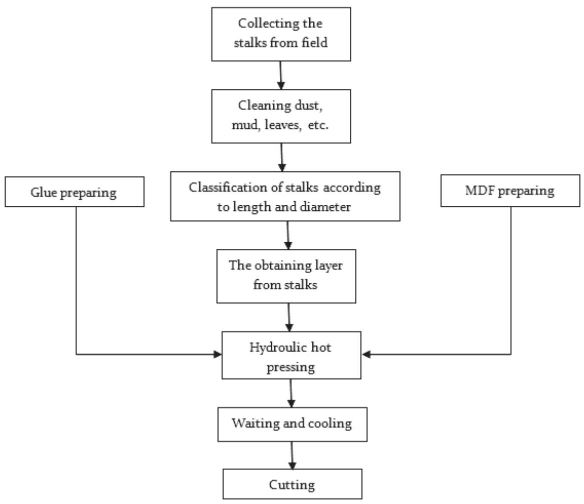

Fig. 1. The production schematic of the horizontally designed board.

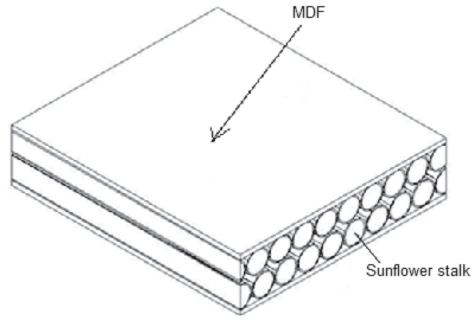

Fig. 2. The horizontally designed board sample.

Table 3. Production conditions according to glues.

Glues	Pres pressure (N/mm^2)	Pressure temperature (^0C)	Pressure time (dk)
Urea formaldehyde	0.05	110	10
Melamine urea formaldehyde	0.05	110	10
D2	0.05	25	55

test standards so that the respective tests could be done. Table 3 presents the application conditions depending on the utilized adhesive type.

The chemical analysis of the sunflower stalks was accomplished using the following method: The sunflower particles the size of a matchstick were first ground in a Wiley mill and then sifted in sieves of 40 mesh and 60 mesh, respectively. The remaining samples on the sieve of 60 mesh (250 μ) were stored in a closed glass jar and subjected to the chemical analysis procedures using the following references: TAPPI T 13 om-54 standard for the determination of cellulose, TAPPI T 203 os-71 standard for the determination of holocellulose (Wise and Karl 1962, Gümüşkaya and Usta 2002), TAPPI T 222 om-88 standard for the determination of lignin, TAPPI T 203 os-71 standard for the determination of alpha cellulose, TAPPI T 211 om–85 standard for the determination of ash, TAPPI T 207 om-88 standard for the determination of resolution in cold water, and TAPPI T 207 om-88 standard for the determination of resolution in a 1% solution of NaOH.

The specific gravity test was accomplished according to the TS EN 323, Anonymous (1999) standard, the determination of moisture was according to the TS EN 322, Anonymous (1999) standard, the SEM-Scanning Electron Microscope screening was accomplished with a SEM device, "Jel JSM-5500LV", by magnifying 100 μm of the area by 170 and 200 times, the thermo gravimetric analysis (TGA) was accomplished using a Shimadzu TGA-50" device, the sound insulation test was according to the "Box Model" which is a modified version of the TS EN ISO 140-3/A1:2006 standard, the ultrasonic sound transfer speed test was according to the ASTM C 597 standard with a PUNDIT (Portable Ultrasonic Non-Destructive Digital Indicating Tester) device, the heat insulation ratio with the box model, the determination of heat transfer coefficient was with the TD-8561 model heat transfer coefficient measurement device (method A) of the PASCO Scientific company and with a device called the Quick Thermal Conductivity Meter, QTM-500 Kyoto (method B) according to the ASTM C1113-99 (2004) standard, the determination of the LOI (Limit oxygen index) was according to the ASTM D2863-09 standard, and the combustion test was according to the ASTM-E 69 standard were accomplished.

RESULTS AND DISCUSSION

As a result of the chemical analysis of the woody outer layer of the sunflower stalk, we discovered that it contains 82.69% holocellulose, 18.2% lignin, 41.86% cellulose, 39.22% alpha-cellulose, and 13% ash. Also, it was observed that its resolution ratio in a 1% of NaOH solution, ether, and cold water occurs at the ratio of 25.14%, 10.59%, and 12.06%, respectively.

Moreover, as a result of the chemical analysis of the cancellous pith part of the sunflower stalk, we discovered that unlike the woody outer part, it contains 69.70% holocellulose, 3.2% lignin, 45.4% cellulose, 36.20% alpha-cellulose, and 7% ash. Also, it was observed that its resolution ratio in a 1% NaOH solution, ether, and cold water occurs at the ratio of 26.17%, 13.45%, and 11.18%, respectively.

The average values of the specific gravity of the horizontally designed boards and the control board were determined to be 0.29 g/cm3 and 0.18 g/cm^3 respectively. As reported in the study of (Bektaş et al. 2002), entitled “Particleboard production by use of sunflower stalks with urea formaldehyde glue”, the specific gravity value of the particleboards produced using urea formaldehyde glue from sunflower stalks, which were chipped in laboratory conditions for general purposes, were observed to be 700 kg/m^3 (Bektaş et al. 2002).

In order to utilize wheat and rice straws, boards made up of wheat straw and rice straw with specific gravity values of 0.770 gr/cm^3 and 0.750 gr/cm^3, respectively, were produced with the use of UF glue (Mantanis et al. 2000).

In the study entitled “Particleboard Production from the Sunflower (*Helianthus annuus* L.) Using Urea Formaldehyde Glue”, the technical properties of the particleboards (700 kg/m^3), which were produced using urea formaldehyde glue from sunflower stalks (100%) chipped for general purposes in laboratory conditions, were examined (Bektaş et al. 2002).

In another study, it was observed that the boards produced from peanut shells by using different glues with the application of a pressure of 6 kg/cm^2 had a specific gravity between of 0.59-0.80 gr/cm^3 (Batalla et al. 2005).

In a relevant study about utilizing and evaluating cotton carpel, the urea formaldehyde and the melamine urea formaldehyde glues were used in a proportion between 9% and 11% for particleboard production. The three-layer boards were produced with the specific conditions of a maximum pressure at 2.65 N/mm^2 and a temperature of 150°C for 7 minutes. As a result, the swelling ratio in the thickness of all boards was observed to be higher than 14%, the baseline value mentioned in the relevant standard, TS EN 312, except that of boards which were produced by using MUF with the specific gravity of 0.471 gr/cm^3. Furthermore, it was determined that the swelling ratio in the thickness of the boards made up of cotton carpels were lower than that in boards made from the sunflower stalk, hemp or cotton stalk. The bending strength values were observed to be between 9.4 and 13.1 N/mm^2 while the highest bending strength value belonged to the boards which were produced by using MUF adhesive that had a specific gravity of 0.651 gr/cm^3. The lowest bending strength value was obtained from the boards which were produced using MUF adhesive that had a specific gravity of 0.471 gr/cm^3. Also, the highest and the lowest values of internal bond strength were obtained while examining these boards (Alma et al. 2005).

Güler et al. (2006) produced particleboards with three layers and specific gravity of 0.700 g/cm^3 by mixing various ratios of AS (Sunflower Stalk) and chips of Calabrian Pine.

The images in Fig. 3 were obtained as a result of a SEM inspection of the sunflower stalk. According to the figure, the lumens of the long fibers of woody stalk which support the stalk are shown in Fig. 3(a) and also the pith of the stalk which is similar to a honeycomb is shown in Fig. 3(b). These SEM images are highly similar to those which were obtained in previous studies (Ashori and Nourbakhsh 2010).

The TGA graphics with the outer, inner and both the outer and inner parts of the sunflower stalk are shown in Fig.4.

At the end of the TGA, the wooden outer part of the sample started to decompose at 278.8°C and quickly lost weight until approximately 325°C. After this point, the weight loss continued more slowly until approximately 650°C was reached and the loss was observed to be more stable from 650°C to 800°C which is the maximum temperature. The total weight loss was measured to be 92.17%. The spongiform inner part of the sample started to decompose at 265.8°C and lost weight quickly until approximately 340°C. After this point, the sample continued to lose weight but this time more slowly until approximately 550°C and finally, the weight loss became more stable from 550°C to 800°C which is the maximum temperature. Total weight loss was measured to be 82.49%. The sample including both the outer and inner parts started to decompose at 275.9°C and lost weight quickly until approximately 325°C was reached. Then, a slower weight loss was observed until the point of 430°C. Subsequently, the weight loss increased a little between the points of 430°C and 550°C. Finally, a constant weight loss was observed from the point of 500°C to the maximum temperature 0f 800°C. The total weight loss was measured to be 90.40%.

According to the results of the sound insulation tests, the sound insulation ratio of the box models

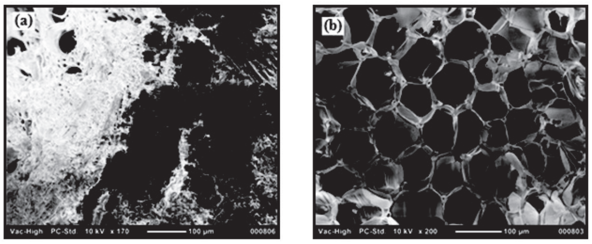

Fig. 3. The SEM images of the (a) wooden part and (b) pith part of the sunflower stalk.

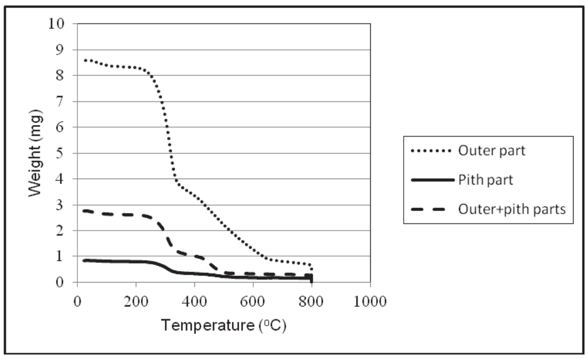

Fig. 4. TGA graph of the sunflower stalk samples.

made from the horizontally designed board and the control board were measured to be 19.37% and 16.77%, respectively. The ultrasonic pulse test values of the control board and the horizontally designed board were 1.82 mm/μs and 0.46 mm/μs, respectively. These values have proven that the horizontally designed board is superior to the control board in terms of insulation abilities.

In the heat insulation test, as can be seen in Fig. 5, the time to reach the target temperature degree, which was 60°C, was 15 minutes for the horizontally designed board and 16 minutes for the control board, respectively. As for the cooling test, the time to cool down the horizontally designed board and the control board to 25°C was 314 minutes and 160 minutes, respectively. It is obvious that while both boards took almost the same time to be warmed up to a specific temperature; the horizontally designed board took 154 minutes more for cooling when compared to the control board and thus provided heat conservation for a longer period of time. The test mechanism is shown in Figure 6.

The average heat transfer coefficients of the horizontally designed board and the control board were determined to be 0.045 W/mK and 0.059 W/mK, respectively, according to the A method. As for the measurements done with the B method, the heat transfer coefficient values were determined to be 0.060 W/mK and 0.065 W/mK, respectively. Corresponding heat transfer coefficient values of the horizontally designed insulation board and the control board are presented in Table 4.

The sorghum and the sunflower plants were used together in a board which was developed and produced by the Koyo Sangyo Company. In this sandwich shaped board, the sunflower stalks were used in the core and the sorghum stalks were used at the outer layers while both sides were covered with jute. The specific gravity, heat transmission coefficient, modulus of elasticity, and bending strength values of this board were approximately 0.22 g/cm^3, 0.060 W/mK, 2.815 N/mm^2, and 0.22 GPa, respectively (Anonymous 2007).

The particleboard production using a mixture of sunflower stalk (AS) chips, and poplar wood (*Populus alba* L.) chips in various proportions were studied. It was found that the highest modulus of rupture (25.3 N/mm^2) and the modulus of elasticity (2963.3 N/mm^2) values were obtained from the particleboards made only by using poplar wood whereas the lowest modulus of rupture (14.65 N/mm^2) and the modulus of elasticity (1800.2 N/mm^2) values were obtained from the particleboards made only by using sunflower stalks. Accordingly, it was reported that the mechanical properties of the particleboard diminish while the ratio of sunflower stalks in the structure of particleboard increases (Bektaş et al. 2005).

Particleboards of specific gravity of 0.700 g/cm^3 were produced from various ratio mixtures of sunflower stalk chips and the calabrian pine chips. The highest modulus of rupture, the modulus of elasticity, and internal bond were obtained from the particleboard which was produced with a mixture of 75% sunflower stalk chips and 25% calabrian pine while the lowest modulus of rupture, the modulus of elasticity, and internal bond were obtained from the particleboard produced with only sunflower stalk chips. The lowest water absorption ratio and swelling ratio in the thickness was obtained as 74.6% and 21.1%, respectively, from the particleboards which were produced with a mixture of 75% sunflower stalk chips and 25% calabrian pine chips. The highest water absorption and swelling in thickness ratios was obtained as 82% and 25%, respectively, from the particleboards produced with only sunflower stalk chips. These boards had higher hygroscopic properties because of their highly

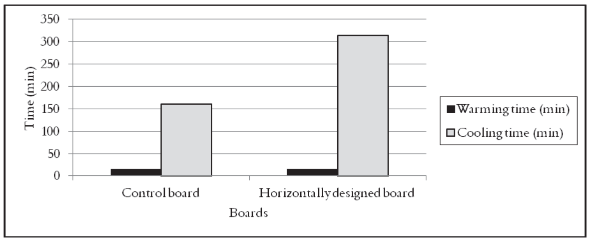

Fig. 5. The heat retention times of the boards.

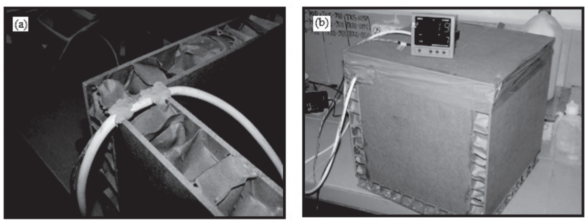

Fig. 6. (a) The fitting of the thermo couple to the test box and (b) the monitoring of heat changing on the digital thermometer.

Table 4. The heat transmission coefficients.

Features	Glue		
	UF[1]	MUF[2]	D2[3]
Dry mass ratio (%)	65 ±1	55 ±1	-
Spesific gravity (g/cm^3) (20° C)	1.25-1.27	1.25	-
Viscosity (cps) (20° C)	120-200	200	15.000 +/- 6.000 (MPa.s)
pH	7.5-8.5	8.5	6-8
Gelation time(100° C'de) (s)	25-35	50-60	-
Free formaldehyde (%)	0.17 (max.)	0.16 (max.)	-
Minimum film making temperature (°C)	-	-	3 °C
Vitrification point	18 °C		

(1)The result of measurements by a TD-8561 ınstrument of the PASCO Scientific company and (2)The result of measurements suitable to the ASTM C1113-99 (2004) standard.

porous structure (Güler et al. 2006).

Particleboards of the specific gravity value of 0.700 g/cm^3 were produced from various ratio mixtures of sunflower stalk chips and the calabrian pine chips. In these mixtures, the urea formaldehyde glue was used with a ratio of 9% in the middle layer and 11% in the outer layer of the board. It was pressed at a temperature of 150°C for 7 minutes. As a result, the best mechanical properties were obtained from the particleboards produced with a mixture of 50% of sunflower stalk chips and 50% of calabrian pine chips (Güler et al. 2006).

The LOI value of the wooden outer part together with the cancellous pith part was measured to be 28% in the LOI test while the test result was 30.5% for the wooden outer part only. These results show that the sunflower stalk is a low flammable biomass. Additionally, in accordance with the conclusion of previous studies in relevant literature (Fenimore 1975, Horrocks et al. 1988, Chen et al. 2006), which was "Materials with a LOI value higher than 28% are hardly flammable and thus classified as self-extinguishing materials, and materials with a LOI value between 21% and 28% are classified as slowly flammable", it was determined that the sunflower stalk, specifically its wooden outer part, was a self-distinguishing material.

According to the combustion test, the amount of ash was observed to be 4.694 g for the horizontally designed board and 4.541 g for the control board. In the same test, the amount of weight loss was measured to be 52.218 g and 33.906 g for each board respectively.

Flaming combustion lasted 163 s on the horizontally designed board and 174 s on the control board. Also, the self-combustion time was 611 s for the horizontally designed board and 337 s for the control board.

CONCLUSION

It was observed that the chemical composition of the sunflower stalk and its SEM images were in accordance with the findings of previous studies from literature. Although the specific gravity of the horizontally designed composite insulation board was higher than that of the control board, the board was nonetheless lighter than many similar boards in literature which were produced from agro-fibrous materials (Efe 2011).

As a result of the TGA, it was observed that there was a difference of 9.68% in weight loss between the outer layer and pith of the sunflower. In the same test, the average weight loss in the mixture of both the outer and the pith of the stalk was 90.40%. On the other hand, it was observed that all three parts of the sunflower stalk started degradation at close temperature values.

Owing to higher sound insulation ratio and lower ultrasonic transmission speed, the horizontally designed composite insulation board was superior to the control board in terms of insulation properties (Efe 2011).

Heat transmission coefficients of some of the most utilized insulation materials nowadays including glass wool/rock wool, XPS, EPS, wood dust board, and cork sheet are known to be 0.040 W/mK, 0.028-0.031 W/mK, 0.040 W/mK, 0.090-0.150 W/mK, and 0.040-0.055 W/mK, respectively. When these materials are compared to the horizontally designed board, it can be clearly seen that the board is similar to them in terms of the heat transmission coefficient.

In the heat insulation test, it was observed that the horizontally designed board kept the heat for a longer time than the control board did. Also, it was determined that its heat transmission coefficient was lower than that of the control board in both measurement methods (A and B) (Efe 2011).

Due to its high LOI value and short flaming combustion time, the composite insulation board was proven to be a low flammable material. Therefore, widespread utilization of this board has the potential to play an important role in retarding possible fires that occur in buildings (Efe 2011).

In the literature, in addition to utilization of sunflower stalk, there are several studies that also utilize various types of agricultural waste for particleboard production. In such works that utilize sunflower stalk, it was observed that generally this agricultural waste is chipped and combined with different natural materials in order to develop boards that are to be examined mainly in terms of mechanical properties. In our study, less commonly investigated subjects in the literature such as physical properties of the board especially insulation related ones were investigated. As a result, it was found that the sunflower stalks are suitable materials for the production of composite boards for insulation purposes.

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