

Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Production of Fire-Resistant Particle Boards from some Agricultural Residues

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ABSTRACT

The research aims producing fire-resistant particle boards using different types of highly combustible agricultural residues. The some mechanical properties parameters included modulus of rupture and modulus of elasticity while physical properties were water absorption, swelling thickness, mass loss, ignition, glowing time, width and length of the burnt area. Particleboards variables were adhesives (urea formaldehyde ratio of 10%, sodium silicates and paraffin wax ratio of 5%, hardener (ammonium chloride) and fire-retardant (a mixture of diammonium phosphate and boric acid is nontoxic ratio of 0, 5, 10, 15 and 20 %). All above carried out under four press temperature (100,120,140,160 °C), four thicknesses of 14,16,18 and 20mm and four agricultural residues cotton stalks, corn stalks, rice straw and sawdust. The manufactured boards were tested according to TS-EN standards. The results recorded that the maximum modulus of elasticity and modulus of rupture of 4750 and 28.5 N/mm² respectively were obtained using cotton-stalk particle boards, pressing temperature of 140 °C and particle board thickness of 14 mm. The maximum averages water absorption percentage after 2 and 24 h was 28 and 73% respectively and the maximum averages swelling percentage after 2 and 24 h was 22.3 and 33.7 % respectively, were obtained using rice-straw particle boards under pressing temperature of 100 °C and particle board thickness of 20 mm. The most fire-retarding properties were improved with the increase in fire-retarding-content up-to 15 %. Higher amounts resulted in decreasing of the fire-retarding properties.

Keywords: Particle board, fire-retarding, cotton stalks, corn stalks, rice straw, sawdust, mechanical, physical properties.

INTRODUCTION

Utilization of surplus and residual biomass has proven to be an effective management option for reducing environmental impacts arising from the disposal agricultural residues. Such utilization often removes potential health risks owing to burning the agricultural wastes in open fields. The increase in the intensive using of production elements and what associates it of horizontal and vertical expansion has been reflected on the increase of the amount of agricultural wastes on farmers, the misuse of these agricultural wastes represents a dangerous environmental damage and a waste of economic resource. The volume of the agricultural wastes is estimated by about 35 million tons per year, of which, about 12 million tons are left without avail. The production wood from nature forests is expected to decline while as, the use of fiber from residues is expected to mainly increase in order to both meet societies demands for building and engineering materials and to help in solving from disposal the agricultural wastes. Producing Particle board was the most suitable means to convert these wastes into materials with economic value that contribute to improve the environment and increase the self-sufficiency, Hassan *et al.*, (2014). On the other hand Guler (2015) said that the panel products using wheat straw and other crop residues are being commercially manufactured in a number of countries. Several countries utilized agro fibers for the production of particle board or other composite panels. So far there are at least 30 plants that utilize agricultural waste materials in the production of particle boards around the world. On the other hand Alexandru (2002) sawdust is generally considered as a timber-industrial waste that pollutes the environment, but can become a valuable commodity either as a raw material in manufacturing industries for wood boards, light

construction materials such as shelves, wall and roof sheeting. Moreover, Rofii *et al.* (2013) studied the use of furniture mill residues containing high density raw materials in particle board production and to evaluate the effect of mixing several types of furnish on board performance. Resin was applied at 6 % content in mat preparation. The pressing conditions were temperature of 180 °C, initial pressure of 3 MPa, and pressing time of 5 minutes. They found that all residues from furniture mills have the potential to be used for particle board production. Furthermore, Hamid (2007 and 2008) fresh wood and urea-formaldehyde are needed as a synthetic adhesive system and other fossil-based adhesive systems. Research related to this focused on the manufacture of granular panels from agricultural waste bonded by urea formaldehyde. Manufacture granular panels from cotton stalks as well as medium density fiberboard (MDF) sheets with urea-formaldehyde. Okai *et al.* (2015) determined that the potential of utilizing agricultural residues such as corn stalk for particle board manufacturing with the aim of reducing pressure on tropical forests. The corn stalk particle boards are denser than some medium- density particle boards produced from timber species. ECA, (2000) and Gelbke, (2008) reported that adhesives based on urea-formaldehyde (UF) are the most commonly used resins for conventional particle board production in Europe. Emissions of formaldehyde are a concern from a health perspective. Therefore, produce boards with low formaldehyde emissions decrease the input of binders with a fossil origin. Also, particle board production technology has developed greatly, particularly with the introduction of constant pressure, providing new levels of product standardization Walker (2006). Kúdela *et al.* (2017) studied that moisture content in beech wood before pressing was 17 to 20 %, the suitable pressing temperature was

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DOI: 10.21608/jssae.2021.158667

180 to 200 °C, and the suitable pressing time was at least 10 min. Better results were attained with 40 % compression. The hardness of samples was increased by 2.4 to 3.4 times the hardness of the original wood. The increased compression also noticeably reduced the wood surface roughness. Chibudike *et al.* (2019) studied that decrease in the percentage of agro-waste increased the hardness of the board which is the property of a material that enables it to resist plastic deformation, usually by penetration. This was observed in R2 and D1 with 20 % and 10 % agro-waste content respectively, higher strength properties compared to POP and Fiber with 40 % and 30 % agro-waste content. Also Attia *et al.* (2017) said that any increase in pressing straw particle boards temperature of more than 180 up to 210 °C, modulus of rupture decreased by about 14.3, 7.8, 7 and 6.4% under the same mentioned sample thicknesses. The same behavior was noticed with wood sawdust particle boards. It is that high pressing temperatures changed the color of particle board to be darker. Moreover, the (Sundqvist, 2002 and Ayadi *et al.*, 2003) said that thermal treatment results in darkening of the wood. High pressing temperatures decrease strength of particle board mainly due to de polymerization reactions of wood polymers. Catherine *et al.* (1996) Also it was found that the presence of boron compounds decreases water absorption by 50 - 80% for different samples. Guler and Ozen (2004) reported that high thickness swelling values (TS) for the particle boards that are produced using agricultural residues such as 35% for cotton stalks after 24 h water soaking. Guler and Buyuksari (2011) reported that the findings in this study showed that only Type H (density 0.8 g/cm³) and adhesive ratios & the urea formaldehyde (UF) resin at 9 % and 11% levels were used for the core and outer layers particle boards met the minimum requirements. The required MOR and MOE values of 11.5 N/mm² and 1600 N/mm² are for general purpose and for interior fitments particle boards (including furniture) applications, respectively. Khozeini *et al.* (2014) reported that mechanical properties including fire resistance, tensile and flexural strengths of composites were enhanced by adding fire retardant. However, fire retardant increasing led to a decrease in impact strength. Also, Medved *et al.* (2019) reported that increased fire resistance is achieved through fire retardant addition during panel production or by spraying fire-retardant on already finished panels. The downside of fire-retardant addition during panel production is related to decrease mechanical properties. It is found this that increasing concentrations of fire retardants from 0 % to 5 % decreases the bending strength of finished board from 12.5 N/mm² to 5.049 N/mm². Addition of traces of paraffin wax and boron compounds gives excellent water-repellent surface which creates a hydrophobic surface towards composites, Nagieb *et al.* (2011).

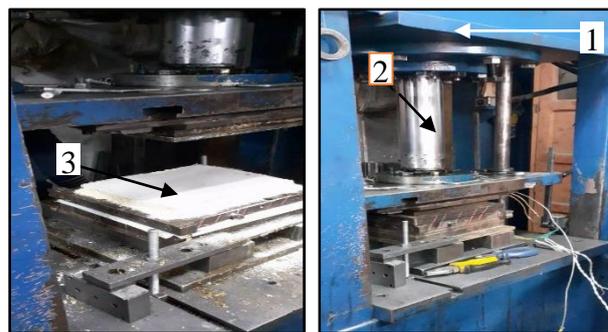
The objective of this research is to produce fire-resistant particle boards using different types of highly combustible agricultural residues (cotton stalks, corn stalks, rice straw and sawdust)

MATERIALS AND METHODS

The particle board production machines line are dry technical oven, Turkish chopper machine, grading machine, mixer and hydraulic press-machine.

The hydraulic press

The hydraulic press was used to press the raw materials to produce pressed wood, shows in Fig. 1.



1-main frame, 2-piston, 3- particle board under the manufacturing
Fig. 1. The hydraulic press during manufacture particle boards

It consists of the following main parts:

- Main frame with 230 cm length, 125 cm width and 48 cm thickness.
- Piston with 21 cm diameter and 40 cm length.
- Control panel, which contains two contactors (relay and over load).
- Oil pump with a disposal of 11 l/min.
- Pressure gauge that gave a pressure of 250 bar with accuracy of 1.0 bar, it was powered by an electric motor of 7.35 kW(10 hp).

Tested materials: The agricultural residues were collected from local farm but, wood sawdust was collected from local carpentry workshop in Zagazig City, Sharkia Governorate. Cotton stalks, corn stalks, rice straw and sawdust were tested in this study.

The following steps were done to produce particle boards:-

Material preparing:

Agricultural residues were cleaned by sieving and then all particles were dried at 100 - 110°C until 3 % moisture content. The chopping and grinding process was used to produce diameter agricultural residues of the final products of 3 - 20 mm. The products were graded to smooth grades less than >5 cm. Then, the agricultural residues components are mixed with soft sawdust (as filler) at mixing machine with ratio of 1:1.

The developed mixing machine was fabricated and tested is shown in Fig. 2. The overall dimensions are: total length of 900 mm, diameter of 400 mm, the A stainless steel mixing chamber was length of 500 mm. The main parts:

- 1-The mixing chamber;
- 2-stirring auger with fingers made of rubber;
- 3-Electric motor; 4- Switch operating; 5- base stand.

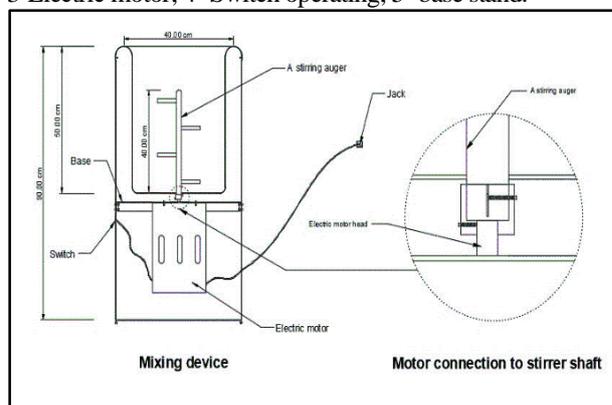


Fig. 2. The schematic diagram of the main parts of a mixing machine

Materials Adhesive was added: The urea-formaldehyde resin (UF) (the pH is 7.5 – 8.0, 66 % solid content) was mixed with agricultural residues (raw materials) with percentage ratio of 10 %, sodium silicates, paraffin wax and Hardener: ammonium chloride were mixed with agricultural residues with percentage ratio of 5 %. Fire-retardant (Flame retardant): A mixture of diammonium phosphate (NH₄)₂HPO₄ and boric acid (burnblock) is non-toxic, made from ingredients that occur naturally in wood and cotton such as (cellulose) are used as an effective flame repellent, and the materials were purchased from Kaimei Chemical Technology Co., Ltd. Fire-retardant ratio were as follows: 0, 5, 10, 15 and 20 %. Fire retardant was mixed with only to upper and lower layers particles before the compression process. A stainless steel hollow mold was made with dimensions of 25 x 20 x 5 cm and a frame of 2.5 cm in all directions, show in fig. 3.



Fig. 3. Photograph of hollow mold

The material was placed in the mold to perform the pressing operations, the Thermo mold is attached to a thermometer that is used to measure and control the temperature. Then, samples were dried at 20 ° C ± 2 ° C and 18 % ± 5% relative humidity until a stable mass was obtained in Fig. 4 show manufactured particle boards.



Fig. 4. Manufactured particle boards

The particle board dimensions were length of 250 mm, width of 200 mm, and All above carried out under four thicknesses of 14, 16, 18 and 20 mm. The pressing conditions were as follows; press temperature: 100, 120, 140, 160 C°. Press time: 10-15 min and pressure: 7 - 8 N/mm². A comprehensive test device was used to evaluate the mechanical properties of particle board. Values represent the average of 15 samples and for determine fire resistance: Test specimens with dimensions of 250 × 200 × (14, 16, 18 and 20) mm were prepared and fixed fire testing device was used to determine fire resistance values represent the mean of 5 specimens at all tested parameters.

Mechanical properties

Bending strength conducted to calculate module of rupture and module of elasticity. There were measured using Particle board load testing device in the Laboratory at the Faculty of Engineering, Cairo University. Pressure gauge that gave a pressure configurations 500 kN. The load was applied at the center of the tested specimens at material resistance equipment until the maximum load was reached and crosshead speed of the load was set at 9 mm.min⁻¹.

The module of rupture was calculated from Equ. 1 while, the module of elasticity computed from Equ. 2.

$$MOR = (3 P L) / (2 a e^2) , (N/mm^2) \dots\dots\dots (1)$$

Where:

“MOR” Module of elasticity (N/mm²), “P” was the applied load, (N), “L” distance between supports (mm), “a” the width of the specimen, (mm) and “e” nominal thickness of the specimen, (mm),

$$MOE = (P_1 L^3) / (4 a e^3 y_i) , (N/mm^2) \dots\dots\dots (2)$$

Where:

“MOE” Module of rupture, “P₁” was the proportional limit load, (N), “y_i” the deflection in the proportional limit, (mm), “e” nominal thickness of the specimen, (mm), “a” width of the specimen, (mm) and “L” distance between the supports, (mm).

Physical properties

Physical properties were tested according to the Colombian technical standard (NTC) 2261.

The water absorption and thickness swelling for particle boards were conducted under particle boards dimensions of 50 x 50 mm for different thicknesses of 14, 16, 18 and 20 mm. But, start time to ignition, time of ignition glowing, mass loss and ratio of width to length burnt area were evaluation for particle boards dimensions of 250 x 200 mm under different thicknesses of 14, 16, 18 and 20 mm. in accordance to ISO 11925-3 (1997).

Water absorption and swelling thickness properties

The particle boards were soaked in water with pH of 6 ± 1 for 2 and 24 hours. Board thickness and mass were measured before and after the immersion determined according to the following formula (Unsal *et al.*, 2009):

$$WA(\%) = \frac{WA_2 - WA_1}{WA_1} \times 100 \dots\dots\dots (3)$$

Where: WA is the water absorption rate %, WA₂ is the particle board mass after immersion 2 and 24 hours, g,

WA₁ is particle board mass before immersion in water, g,

$$TS(\%) = \frac{TS_2 - TS_1}{TS_1} \times 100 \dots\dots\dots (4)$$

Where: TS is the swelling-thickness rate,

TS₂ is the particle board thickness after immersion in water for 2 and 24 hours, mm,

TS₁ is particle board thickness before immersion in water, mm.

Fire retardant test

The tests were conducted for number of panels according to the Japanese Industrial Standard JISA 1322 (1982). The fixed fire testing device was used as shown in Fig. 5 which particle board was put at a 45° angle. The heating flame was adjusted to a height of 27 mm and was applied for 10 min. Sample thickness and lengths were measured using a digital micrometer having 0.01mm gradients. The recorded values represent the mean of 5 samples per each treatment.

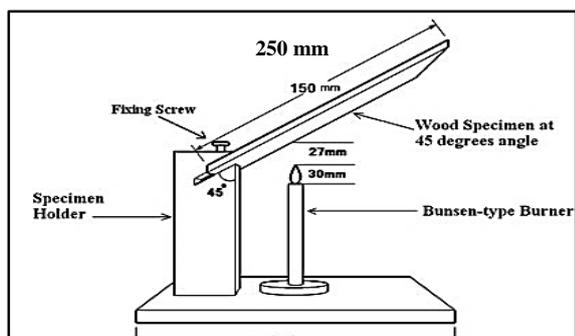


Fig. 5. Schematic of fixed fire testing device

RESULTS AND DISCUSSION

1. Particle boards mechanical properties

Fig. 6 (A and B) shows the effect of particle board thickness, pressing temperature and crop-residues type each of modulus of elasticity and modulus of rupture for particle boards. Data in Fig. 6 (A) show that the maximum modulus of elasticity of 4750 N/mm² was obtained using cotton-stalk particle boards, pressing temperature of 140 °C and particle board thickness of 14 mm. Meanwhile, the minimum modulus of elasticity of 1735 N/mm² was obtained using rice straw, pressing temperature of 100 °C and particle board thickness of 20 mm. On the other side in Fig. 6 (B) show, whereas, the maximum modulus of rupture of 36.3 N/mm² was obtained using cotton stalk particle boards, pressing temperature of 140 °C and particle board thickness of 14 mm. Meanwhile, the minimum modulus of rupture of 13.1 N/mm² was obtained using rice straw particle boards, pressing temperature of 100 °C and particle board thickness of 20 mm. All tested particle board using cotton stalk, corn stalk, rice straw and sawdust at all tested thickness and pressing temperature fulfill the minimum requirements in standards for general grade of particle boards. On the other side, the properties based on TS-EN 312 standard, 11.5 N/mm² and 1600 N/mm² are the minimum requirement for modulus of rupture and modulus of elasticity of particle board panels for general uses (TS-EN 319, 1996) and (TS-EN 312, 2005). According the utilization of residues of tested crops cotton stalk, corn stalk, rice straw and sawdust for manufacturing of particle boards with thickness of until 20 mm.

2. Particle boards physical properties

The water absorption.

Fig. 7 (A and B) shows the effect of particle board thickness, pressing temperature and crop-residues types on the water absorption percentage after 2 and 24 h for particle boards. Results showed the maximum averages of water absorption percentage after 2 and 24 h of 28 and 73 % respectively under using rice straw particle boards, pressing temperature of 100 °C and particle board thickness of 20 mm. Meanwhile, the minimum averages water absorption after 2 and 24 h were 17 and 41.4 % using cotton stalks particle boards under pressing temperature of 160 °C and particle board thickness of 14 mm. It is found that by decreasing particle board thickness the percent of water absorption decreases on abnormally by increasing of pressing temperature the percentage of water absorption decreases.

Swelling thickness.

Fig. 8 (A and B) shows the effect of particle board thickness, pressing temperature and crop-residues type on swelling thickness percentage after 2 and 24 h. Results show

that the maximum averages swelling percentage after 2 and 24 h recorded 22.3 and 33.7 % respectively under using rice straw particle boards under pressing temperature of 100 °C and particle board thickness of 20 mm. Meanwhile, the minimum averages swelling percentage after 2 and 24 h were 11.5 and 24 % respectively, were obtained using cotton stalks particle boards, pressing temperature of 160 °C and particle board thickness of 14 mm.

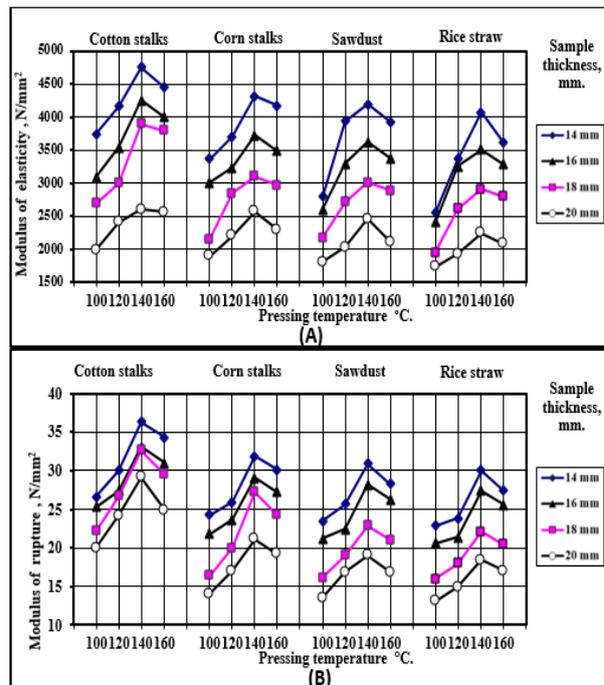


Fig. 6. Effect of particle board thickness, pressing temperature and crop-residues type on modulus of elasticity (A) and modulus of rupture (B) of the particle boards

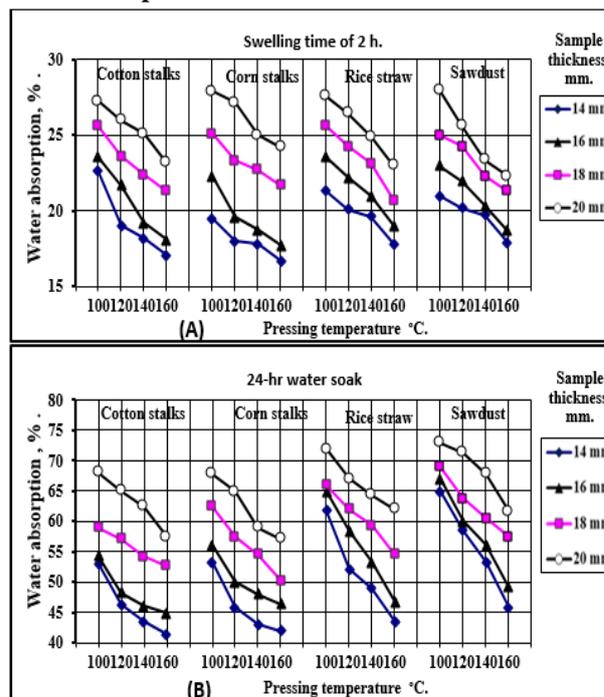


Fig. 7. A and B. Effect of particle board thickness, pressing temperature and crop residues type on the water absorption percentage after 2 and 24 h.

The increasing of water absorption by increasing particle board thickness is due to increasing of particle board volume. Meanwhile, the decreasing of water absorption by increasing pressing temperature is due to decreasing of particle board porosity. (TS-EN 312, 1996).

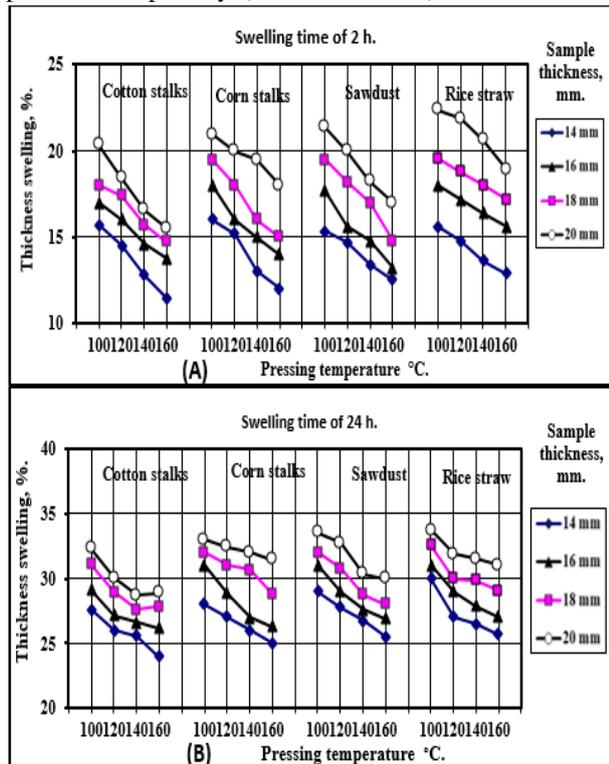


Fig. 8. A and B. Effect of particle board thickness, pressing temperature and crop residues type on the swelling thickness after 2 and 24 h

The Time to onset of ignition.

Fig. 9 shows the effect of particle board thickness, crop-residues type and fire retardant percentage on the time to ignition for the particle boards.

Results show that the maximum average of the time to ignition is 248 s at using cotton-stalk particle boards and fire retardant of 15 % under particle board thickness of 20 mm. Meanwhile, the minimum average of the time of ignition of 28.1 s under using rice straw particle boards under fire retardant of 0 % and particle board thickness of 14 mm. This is in an agreement with Hume (1992) which, stated that the time of ignition increases with the increase of the testing material thickness.

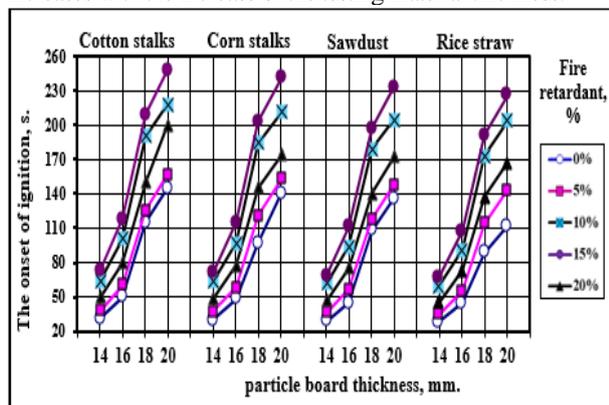


Fig. 9. Effect of particle board thickness, crop-residues type and fire retardant percentage on the onset of ignition.

The time to onset of ignition glowing.

Fig. 10 shows the effect of particle board thickness, crop-residues type and fire retardant percentage on the time to ignition of glowing for the particle boards.

Results show that the maximum average of the time to onset of ignition glowing of 158 s under using cotton-stalk particle boards, under fire retardant of 15 % and particle board thickness of 20 mm. Meanwhile, the minimum average of the time to ignition of 93 s under using rice straw particle boards, fire retardant of 0 % and particle board thickness of 14 mm.

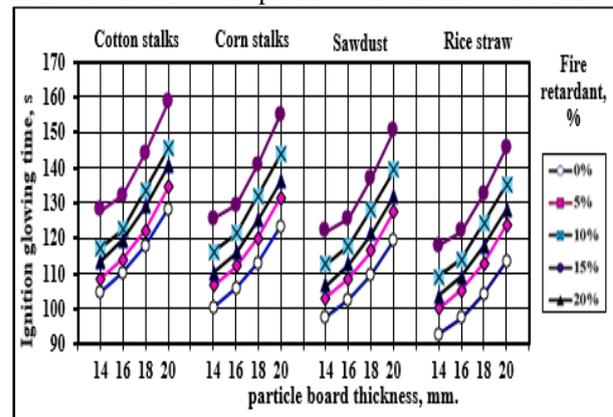


Fig. 10. Effect of particle board thickness, crop-residues type and fire retardant percentage on the onset of ignition glowing

Increasing the percentage of fire retardants on particle boards surface layer which increasing the times to onset of glowing.

Mass loss.

The data presented in Fig. 11 shows the effect of particle board thickness, crop-residues type and fire retardant percentage on the mass loss of particle boards. It is found that the maximum average of mass loss of 33.2 % was obtained using rice straw particle boards, under fire retardant of 0 % and particle board thickness of 20 mm. Meanwhile, the minimum average of mass loss is 7.6 % under using cotton-stalk particle boards, fire retardant of 15 % and particle board thickness of 14 mm.

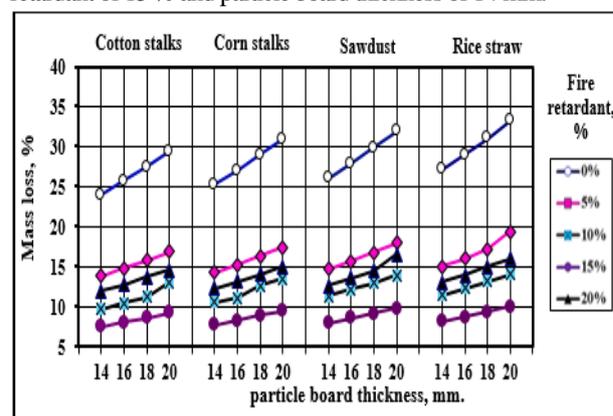


Fig. 11. Effect of particle board thickness, crop-residues type and fire retardant percentage on the mass loss

Width and length of the burnt area.

Fig. 12 (A and B) shows the effect of particle board thickness and fire retardant percentage on the burnt area for the particle boards. Data in Fig. 12 (A) show that the maximum average the width of 120.07 mm under using rice straw particle boards, fire retardant of 0 % and particle board thickness of 20 mm. Meanwhile, the minimum average the

width of 85.1 mm recorded using cotton-stalk particle boards under fire retardant of 15 % and particle board thickness of 14 mm. on the other side in Fig. 12 (B) show, whereas, the maximum average the length of 130 mm was obtained using rice straw particle boards, fire retardant of 0 % and particle board thickness of 20 mm. Meanwhile, the minimum average of the length of 86 mm was obtained using cotton-stalk particle boards, fire retardant of 15 % and particle board thickness of 14 mm.

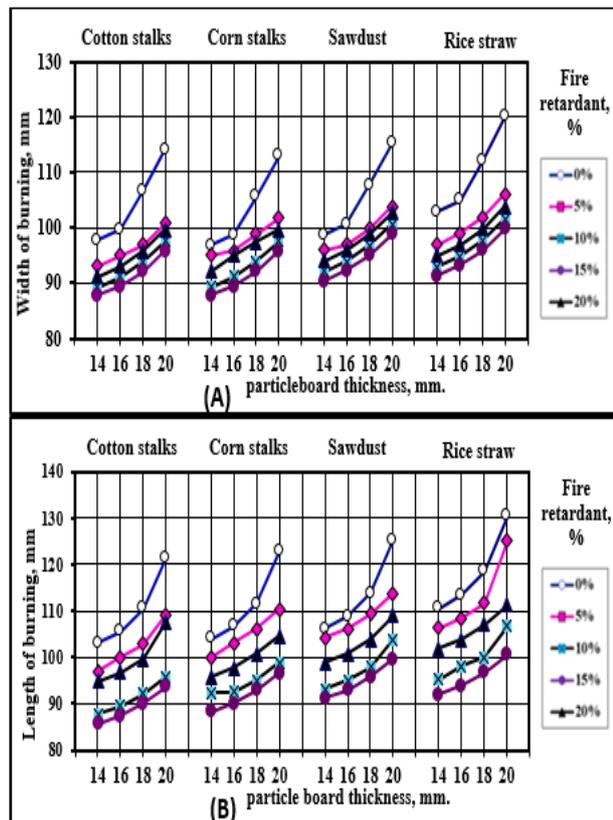


Fig. 12. A and B. Effect of particle board thickness, crop-residues type and fire retardant percentage on width and length the burnt area

CONCLUSION

The optimum conditions to produce particle board using cotton stalks, corn stalks, sawdust and rice straw were: pressing temperature of 140 °C, swelling time of 2 h, particle board thickness of 14 mm and fire-retarding content of 15 %. According to European and Turkish standards of TS-EN 319 & TS-EN 312. Mechanical and physical properties particle board under the previous the optimum conditions were: modulus of elasticity of 4750, 4323, 4193 and 4067 N/mm² and modulus of rupture of 36.3, 31.9, 30.9 and 30 N/mm². Averages of water absorption percentage of 18.2, 17.8, 19.6 and 19.7 % and averages swelling percentage of 12.8, 13, 13.4 and 13.6 % for 2 h. The time to ignition of 73, 70.8, 68.7 and 66.6 s, ignition glowing time of 128, 125.5, 121.7 and 118 s, mass loss of 8.2, 8, 7.79 and 7.56 %, width of the burnt area of 87.72, 88.6, 90.4 and 91.4 mm and length of the burnt area of 85.7, 88.4, 91.1 and 92 mm for cotton stalks, corn stalks, sawdust and rice straw respectively. Cotton stalks and rice straw produce 2.00 and 3.5 Mt available annually. The utilization of these residues in particle board would add economic value.

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إنتاج ألواح خشبية غير القابلة للاحتراق من المخلفات الزراعية جمال حسن السيد، ميرفت محمد عطالله* و محمد ابراهيم محمد أحمد قسم الهندسة الزراعية – مركز البحوث الزراعية – الدقى – الجيزة

إن الزيادة في الاستخدام المكثف لعناصر الإنتاج وما يرتبط بها من التوسع الأفقي والرأسي انعكست على زيادة كمية المخلفات الزراعية على المزارعين ، وإساءة استخدام هذه المخلفات الزراعية يمثل ضرراً بيئياً خطيراً وإهداراً للموارد الاقتصادية. ويقدر حجم المخلفات الزراعية بنحو 35 مليون طن سنوياً ، منها ما يقرب من 12 مليون طن متبقية دون جدوى. كان إنتاج ألواح خشب مضغوط أنسب وسيلة لتحويل هذه النفايات إلى مواد بديلة للأخشاب الطبيعية ذات قيمة اقتصادية تساهم في تحسين البيئة وزيادة الاكتفاء الذاتي من زيادة الطلب على صناعة الأخشاب. الهدف من هذه الدراسة إعادة تدوير المخلفات الزراعية لإنتاج ألواح خشب مقاومة للحريق عالية الجودة باستخدام أنواع مختلفة من المخلفات الزراعية شديدة الاشتعال (سيقان القطن ، سيقان الذرة ، قش الأرز ، نشارة الخشب). تم إجراء عمليات التقطيع والفرم. تم خلط مكونات المخلفات مع نشارة الخشب الناعمة (مادة مالئة) باستخدام آلة خلط بنسبة 1:1 - تم خلط راتنج اليوريا فورمالدهيد كمادة لاصقة بنسبة 10٪. إضافة سيليكات الصوديوم وشمع البارافين كمادة لاصقة وكلوريد الأمونيوم كمادة مصلدة بنسبة 5٪، تم خلط الإضافات مع المخلفات الزراعية (المواد الخام). تم وضع المادة في قالب مجوف بأبعاد 30 × 20 × 5 سم لإجراء عمليات الكبس- تم إرفاق القالب بنظام حراري يستخدم لقياس والتحكم في درجة الحرارة. تمت الدراسة على أربع أنواع من المخلفات (سيقان القطن ، سيقان الذرة ، قش الأرز ، نشارة الخشب) وتم ضغط هذه المخلفات على أربع درجات حرارة ضغط (140، 120، 100، 160) درجة مئوية مع استخدام مثبطات الحريق (خليط من فوسفات الأمونيوم الثنائي وحمض البوريك وهي مواد مقاومة للحريق) ، تم خلطهم فقط بجزئيات الطبقات العليا والسفلى قبل عملية الضغط بأربع نسب (صفر ، 5 ، 10 ، 15 ، 20٪) لإنتاج أربعة عينات مختلفة السمك (14 ، 16 ، 18 و 20 مم) تحت ضغط: 7-8 نيوتن/مم² وقت الضغط: 10-15 دقيقة. تضمنت المتغيرات المدروسة الخصائص الميكانيكية: معامل التمزق ومعامل المرونة. وتشمل الخصائص الفيزيائية: إمتصاص الماء، وسمك الإنتفاخ ، وفقدان الوزن ، والاشتعال ، ووقت التوهج، وعرض وطول المنطقة المحترقة. النتائج التي تم الحصول عليها: الحد الأقصى لمعامل المرونة ومعامل التمزق بنسبة 4750 و 28,5 نيوتن/مم² على التوالي باستخدام ألواح الخشب المصنوعة من حطب القطن ودرجة حرارة الضغط تبلغ 140 درجة مئوية وسمك لوح الخشب المضغوط 14 مم. الحد الأقصى لمتوسط نسبة إمتصاص الماء بعد 2 و 24 ساعة 16,3 و 28,7٪ على التوالي، باستخدام درجة حرارة الضغط 100 درجة مئوية. وسمك لوح الخشب المضغوط 20 مم. أشارت النتائج إلى أن جميع الألواح المنتجة تفي بالمتطلبات الدنيا وفقاً لمعيار TS-EN 319 and TS-EN 312. الحد الأقصى لمتوسط الوقت اللازم للاشتعال هو 248 ثانية باستخدام ألواح الخشب المصنوعة من حطب القطن نسبة المواد المقاومة للاحتراق 15٪ وسمك لوح الخشب المضغوط 20 مم. أشارت النتائج أن معظم خصائص تثبيط الحريق قد تحسنت مع زيادة نسبة المواد المقاومة للاحتراق إلى 15٪. أدت الكميات المرتفعة إلى تقليل خصائص تثبيط الحريق. لذلك، يوصى باستخدام 15٪ من محتوى المواد المقاومة للحريق كمستوى مثالي للاستهلاك. وأن حطب القطن ، سيقان الذرة ، قش الأرز ونشارة الخشب يمكن استخدامها كمادة خام في صناعة الخشب المضغوط الغير قابل للاحتراق. إن استخدام هذه المخلفات في إنتاج ألواح الحبيبات سيضيف قيمة اقتصادية.