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RECYCLING OF AGRICULTURAL RESIDUES FOR PRODUCING HIGH QUALITY PRESSED WOOD

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ABSTRACT: The present research was carried out to study the suitability of using agricultural residues as a raw material for producing pressed wood. Two types of agricultural residues (Rice straw and wood sawdust) were used. Experiments were conducted to study some different operating parameters (pressing temperature, sample thickness and resin ratio) affecting the pressing process. The produced particleboards were evaluated in terms of static bending strength (modulus of rupture and modulus of elasticity) and thickness swelling. Final quality of the produced particleboards was compared with the particleboard standard quality guidelines. The experimental results reveal that modulus of rupture (28.1, 39.8 MPa), modulus of elasticity (4530, 5030.2 MPa) and thickness swelling (6.3 and 3.9%) of the produced pressed wood from rice straw and wood sawdust, respectively were in the suitable region under conditions of 180°C pressing temperature and 8% resin ratio with acceptable sample thickness of 12 mm. Under these conditions, final quality of the produced particleboards was found to be very close with the particleboard standard quality guidelines.

Key words: Pressing temperature, agricultural residues, resin, modulus of rupture.

INTRODUCTION

Agricultural policy depends on the successful technology through mechanizing agricultural processes. Agricultural wastes are considered one of the most critical problems, which face the Egyptian farmers. Field crop residues in Egypt recorded about 43.6 million tons yearly. Fine wood sawdust is considered also as one of agricultural wastes, obtained from a lumber sawmills, and until now, has not been used in the other products. Recycling of these residues by manufacturing compressed wood is a promising route especially with the increase in wood price.

Use of agricultural wastes such as rice straw and wood sawdust for manufacturing pressed wood will reduce air pollution by avoiding field burning that save environment and can also help solving waste management problems and contribute conservation of natural resources.

The basic challenge for board producers is to convert the agricultural straw materials into particleboards (PB), medium density fiberboards (MDF), or high-density fiberboards (HDF) in a sound technical and economical process. Particleboard is a composite engineered wood product manufactured from wood particles, such as wood chips, sawmill shavings, or even saw dust and a synthetic resin or other suitable binder, which is then pressed. Particleboard is cheaper, denser and more uniform than conventional wood. There is increased interest in use of agricultural residues for composite panel manufacture. Particleboard has a homogenous structure and can be manufactured in different sizes, thickness, densities and grades for numerous uses, making it a desirable material with which to work.

Walker (2006) said that the technology for producing particleboards has developed significantly, in particular with the introduction of continuous pressing, providing new levels of product uniformity. Hoong *et al.* (2011) stated that the use of waste materials such as, sawdust, rice husk, coconut coir, empty fruit brunch

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(EFB), oil palm mass and oil palm stem (OPS) as alternative material for wood-based industry in producing various commercial product have been extensively explored. They explored the potential of a new resin treatment approach in order to produce high-grade OPS plywood. Resin treatment of OPS in plywood production indicated that with the new resin treatment method, improvement of ≥ 200% in strength, ≥ 259% in stiffness, dimensional stability (≥ 6% thickness swelling and ≥ 36% water absorption) as compared to the conventional method of commercial OPS plywood. Kudela and Resetka (2012) studied the influence of pressing parameters (pressing temperature, pressing time, compression degree) on density, hardness and dimensional stability of beech wood specimens. The results showed that the dimensional stability significantly improved with increasing pressing temperature and time. Under the given conditions, the optimum temperature was 200°C and the optimum heating time was 6 minutes. These pressing parameters, however, could not guarantee the appropriate dimensional stability under moisture loading. Rahman *et al.* (2013) studied the fabrication of composite matrix from sawdust (SD) and recycled polyethylene terephthalate (PET) at different ratios (*W/W*) by flat-pressed method. The wood plastic composites (WPCs) were made with a thickness of 6 mm. Physical, density, moisture content (MC), water absorption (WA) and thickness swelling (TS), and mechanical properties Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) were assessed as a function of mixing ratios according to the ASTM D-1037 standard. It was found that density decreased by 18.3% when SD content increased from 40% to 70% into the matrix. WA and TS increased when the PET content decreased in the matrix and the testing water temperature increased. MOE and MOR were reached to maximum for the fabricated composites (2008.34 and 27.08 N/mm^2, respectively) when the SD content was only 40%. Rofii *et al.* (2013) examined the use of furniture mill residues containing high density raw materials in particleboard 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 particleboard production. So, the aims of this work are to:

- Recycle agricultural wastes (rice straw and sawdust) to produce pressed wood (particleboard).
- Optimize some different operating parameters (pressing temperature, sample thickness and resins ratio) affecting the pressing process.
- Compare the produced particleboard with the particleboard standard quality guidelines using the standard engineering measurements.

MATERIALS AND METHODS

The main experiments were carried out through two years of 2014 and 2015 at a private workshop in Zagazig city, Sharkia Governorate, Egypt for recycling agricultural wastes to produce high quality pressed wood (particleboard).

Materials

The used raw materials

Two types of agricultural residues (rice straw and wood sawdust) were used as a raw material for producing pressed wood.

Specifications of the used rice straw are average mass 50 g, average length 95 cm, average diameter 4 mm and straw moisture content 8%. Rice straw was collected from the field, cleaned from dust, chopped by using hammer mill then, graded and regulated. Wood sawdust is the main by-product of sawmills. It is composed of fine particles of wood and it has different varieties of particle sizes. Wood sawdust was obtained from local carpentry workshop in Zagazig city, Sharkia Governorate.

Moisture content of the used raw materials were decreased by drying them in a technical oven at 105°C for 24 hours until 5% moisture content was reached. The used raw materials were analyzed to find fiber fractions such as hemi cellulose (%), cellulose (%) and lignin (%). Chemical characteristics of the used raw materials are shown in Table 1.

Table 1. Chemical characteristics of the used raw materials

Agricultural residue	Measured values			
	Hemi cellulose (%)	Cellulose (%)	Lignin (%)	Ash (%)
Rice straw	9.67	36.57	4.44	12.3
Wood sawdust	10.92	43.20	9.91	5.8

Urea formaldehyde (UF)

Urea formaldehydes were obtained from Mansoura for resins and chemicals industries to be mixed with the used raw materials for producing pressed wood 1% from 33% of ammonium chloride was added to the urea formaldehydes as a hardener. The standard properties values of the urea formaldehyde adhesive are given in Table 2.

Agglutinating the used raw materials was carried out by mixing them with additives before pressing woods samples. A small local vertical mixer for the mixing operation was used. The mixer was fed manually with raw material while the additives were sprayed for five minutes. The mixer rotates at 250 rpm for a period of 15 minutes to accomplish the mixing operation (El-Nasr company for particle Board and Resins, 2009).

The hydraulic press

The hydraulic press was used to press the raw materials to produce pressed wood (Fig. 1). The hydraulic press 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

The hydraulic press was powered by an electric motor of 7.35 kW (10 hp).

The thermal moulding (The forming pattern)

During the pressing operation, the raw material were placed in the thermal moulding (The forming pattern) and pressed by the hydraulic press. The thermal moulding consists of the following main parts:

- Moulding contained one solid sheet with thickness of 10mm and dimensions of 30×30 cm as shown in Fig. 2
- Two solid plates with dimensions of 20×25 cm and thickness of 7 cm. Each plate was provided with heater of 800 watt.
- Hollow plate with a frame of 2.5 cm in all directions with dimensions of 25×30 cm with depth of 7.5 cm.
- The thermal moulding was attached with thermometer that used to measure and control temperature. The thermometer temperature range is of (0 - 400°C) with an accuracy of 5°C and one contactor with 20 Amperes.

Universal testing machine

The universal testing machine is designed for bending, compression and tension tests. Instron testing machine (Model 1122; Instron Corporation, Canton, MA) with capacity of 5000 kN and loading rate of 5 mm/min was used to perform tests. A hydraulic loading system with a piston activated by hydraulic pressure in a cylinder is used as shown in Fig. 3.

Data logger

The data logger contains two units; load cell and strain gauge (Tokyo Sokki Kenkyuio) to record the load and percentage of deflection.

Methods

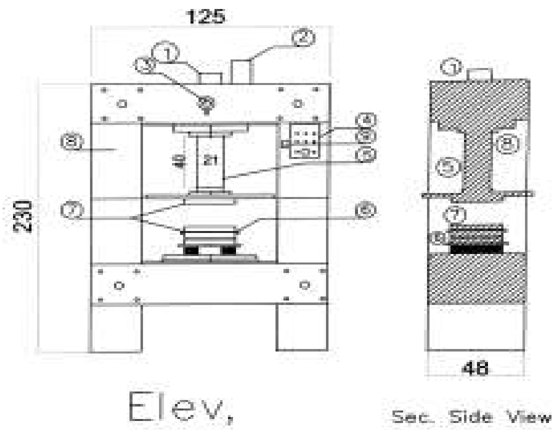
Experiments were carried out to study the suitability of using rice straw and wood sawdust as raw materials for producing pressed wood.

Preliminary experiments

Preliminary experiments were conducted under different pressures and different pressing times to select the suitable conditions for pressing particleboards. Preliminary experiments show that pressure of 25 bar (2.5 MPa) and pressing time of 20 minutes are the optimum conditions for pressing particleboards.

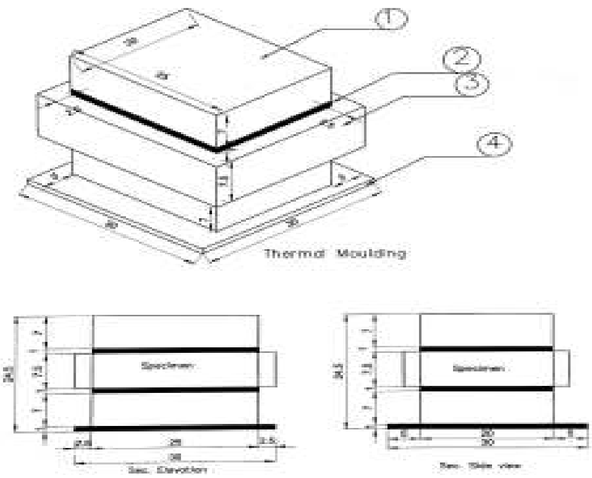
Table 2. Standard properties of urea formaldehyde

Properties of UF	Value
Density at 20°C (g/cm^3)	1.29
pH	8
Viscosity at 20°C (cps)	224
Solid content (%)	65
Free formaldehyde (%)	0.3
20% NH_4Cl content (%)	4
Storage time (day)	20



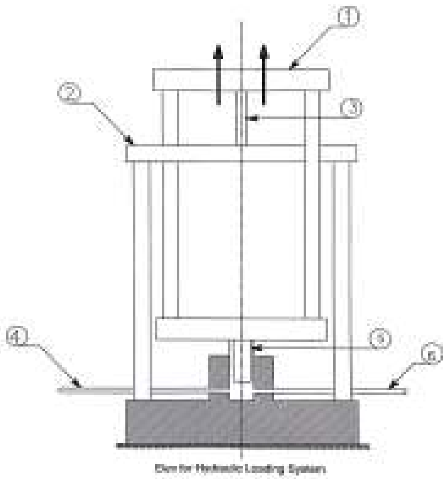
1	Oil pump	6	Fiber
2	Motor supply	7	Thermal moulding
3	Pressure gauge	8	Frame
4	Control panel	9	Thermometer
5	Piston		

Fig. 1. Elevation and section side view of the hydraulic press



1	Solid plate
2	Thermal fiber
3	Hollow plate
4	Footing

Fig. 2. Isometric, sec. elevation and sec. side view the thermal moulding



1	Driven cross head	4	To load inducator
2	Flord cross head	5	Piston
3	Specimen	6	From pump

Fig. 3. Elevation view of universal testing machine

Experimental conditions

Experiments were conducted to study the effect of the following controlled variables on the characteristics of the pressed wood:

- Two different agricultural residues (rice straw and wood sawdust).
- Four different pressing temperatures (120, 150, 180 and 210^{o}C).
- Four different thicknesses (12, 14, 16 and 18 mm).
- Four different percentages of resin (4, 6, 8 and 10% by weight from percentage of solid content).

Measurements and determinations

The manufactured particleboard samples were evaluated taking into consideration the following indicators:

Static bending strength

The static bending tests were conducted using the Universal Testing Machine. The specimen were prepared and tested according to the American Standard for Testing and Materials (ASTM D-1037 standard). The pressed wood specimen with 20 cm width, 25 cm length and different thicknesses of 12, 14, 16 and 18 mm were cut into four equal slices. Each slide has dimensions of length 25 cm, width 5 cm and different thicknesses of 12, 14, 16 and 18 mm.

The specimen was supported on a span of 20 cm and the force was applied at the mid-span using a loading head. The test was stopped when the samples started to break. Then, modulus of elasticity (MOE) and modulus of rupture (MOR) were calculated from load deflection curves.

The modulus of rupture (MOR) was calculated according to the following formula (BSI, 1993):

$$MOR = \frac{3P_bL}{2bh^2}$$

Where:

MOR, MPa

P_b: is the maximum load (N)

L: is the span, mm,

b: is the width of the specimen, mm,

h: is the thickness of the specimen, mm

The modulus of elasticity (MOE) was calculated according to the following formula (BSI, 1993):

$$MOE = \frac{P_{bp}L^3}{4bh^3Y_p}$$

Where:

MOE, MPa

P_{bp}: is the load at the proportional limit, N

Y_p: is deflection corresponding to P_{bp}, mm.

Thickness swelling (TS)

Thickness swelling is important in ascertaining dimensional changes. Samples with dimensions of 50 × 50 mm and different thicknesses were prepared for evaluation of the thickness swelling. Samples were oven-dried at 105^{o}C for 24 hours first to provide a uniform initial condition and the initial weight and thickness after oven drying. The thickness was measured with a micrometer and weight was recorded. The test samples were immersed in a water bath at room temperature for 2 hours, then taken out and weighed. The results of TS after 2 hours were determined according to the following formula (Unsal *et al.,* 2009):

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

Where:

TS_2 is the thickness swelling after immersion in water for 2 hours, mm,

TS_1- oven-dry thickness before immersion in water, mm.

RESULTS AND DISCUSSION

The discussion will cover the obtained results under the following heads:

Effect of Some Variables on the Modulus of Rupture of the Produced Particleboards

Representative values of modulus of rupture (MOR) versus pressing temperature are given for the four sample thicknesses through various resin ratios using different agricultural residues are represented in Figs. 4 and 5.

Concerning sample thickness, it can be noticed that by increasing sample thickness, modulus of rupture decreased under the all treated pressing temperatures. Results show that by increasing sample thickness from 12 to 18 mm, modulus of rupture decreased by about 71.8, 77.2, 70.6 and 58.9% for pressing temperatures of 120, 150, 180 and 210°C, respectively under 4% resin percentage for rice straw particleboards. However modulus of rupture decreased by about 75.2, 69.8, 62.4 and 56.2% for wood sawdust particleboards under the same previous conditions.

Relating to pressing temperature, results indicated that by increasing pressing temperature from 150 to 180°C, modulus of rupture increased by about 17.4%, 16.9%, 15% and 22% for sample thicknesses of 12, 14, 16 and 18 mm, respectively under 4% resin percentage for rice straw particleboards. Any further increase in pressing temperature 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 particleboards. It is noticed that high pressing temperatures changed the color of particleboard to be darker.

This results are similar to (Sundqvist, 2002 ; Ayadi *et al.,* 2003) who said that thermal treatment always results in darkening of the wood. In addition, high pressing temperatures decrease strength of particleboard mainly due to deplymerization reactions of wood polymers.

As to resin percentage, results show that increasing resin percentage from 4 to 6%, modulus of rupture increased by about 2.6, 14.7, 5.9 and 16.1% for pressing temperatures of 120, 150, 180 and 210°C, respectively under sample thicknesses of 12 mm rice straw particleboards. However modulus of rupture increased by about 1.2, 11.1, 6.7 and 4% for wood sawdust particleboards under the same previous conditions. Increasing resin percentage, increased modulus of rupture due to the high increase in cohesion between internal molecules in residues. This results are similar to (Wu, 2000) who stated that by increasing resin content from 5 to 8%, higher strength and less swelling were achieved.

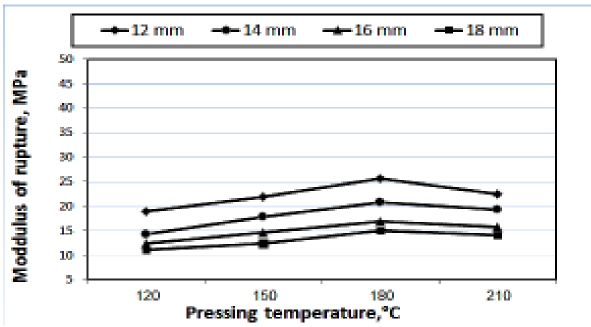
The results indicated that the lower modulus of rupture values were 21.9, 18.8, 17.6 and 15.3MPa for rice straw particleboards; and 31.9, 27, 25.4 and 22 MPa for sawdust particleboards under 8% resin and 120°C pressing temperature for 12, 14, 16 and 18 mm thicknesses. While the higher modulus of rupture values were 28.13, 25.3, 22.8 and 19.5MPa for rice straw particleboards; and 39.8, 37.1, 32.5 and 28.6 MPa for sawdust particleboard under 8% resin and 180°C pressing temperature under the same mentioned thicknesses.

Effect of Some Variables on the Modulus of Elasticity of the Produced Particleboards

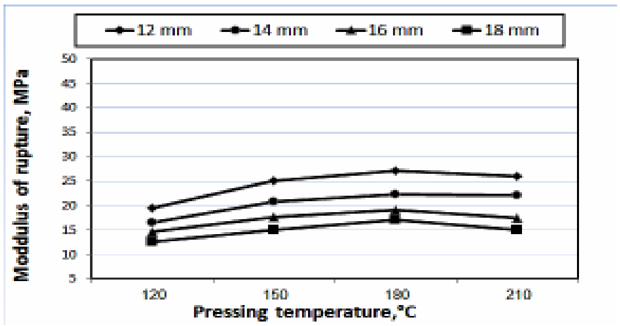
The effects of pressing temperature, sample thickness and percentage of resin on the modulus of elasticity (MOE) of the produced particleboard using different agricultural wastes are represented in Figs. 6 and 7.

Considering sample thickness, it can be noticed that by increasing sample thickness, modulus of elasticity decreased under all treated pressing temperatures. Results show that by increasing sample thickness from 12 to 18 mm, modulus of elasticity decreased by about 46.1, 54.7, 56.6 and 46.6% for pressing temperatures of 120, 150, 180 and 210°C, respectively under 4% resin percentage for rice straw particleboards. However, modulus of elasticity decreased by about 57.6, 56.7, 53.0 and 61.4% for sawdust particleboards under the same previous conditions.

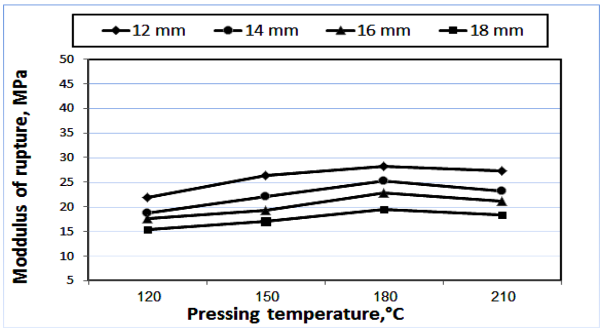
Regarding pressing temperature, results indicated that by increasing pressing temperature from 150 to 180°C, modulus of elasticity increased by about 5.9, 13, 10.5 and 11.7% for sample thicknesses of 12, 14, 16 and 18 mm, respectively under 4% resin percentage for rice straw particleboards. Any further increase in pressing temperature more than 180 up to 210°C, modulus of elasticity decreased by about 3.6, 7.0, 4.3 and 8.0% under the same mentioned sample thicknesses. The same behavior was noticed with sawdust particleboards. It is noticed that high pressing temperatures changed the color of particleboard to be darker. This results are similar to (Sundqvist, 2002; Ayadi *et al.,* 2003) who said that high pressing temperatures decrease strength of particleboard mainly due to deplymerization reactions of wood polymers.



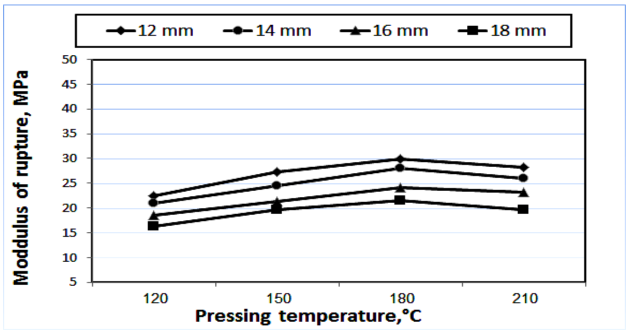
4% resin



6% resin

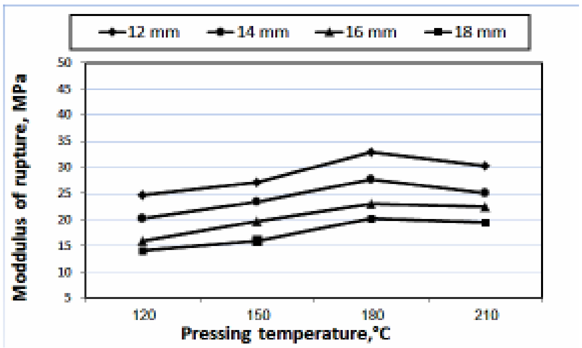


8% resin

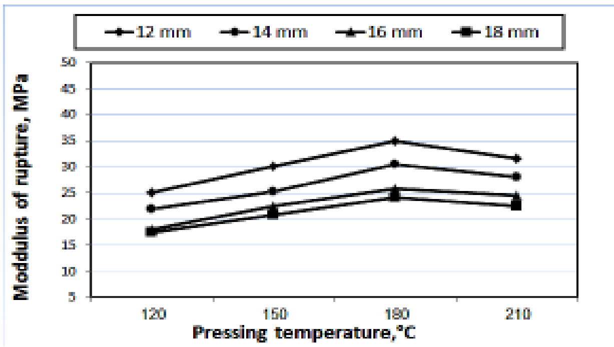


10% resin

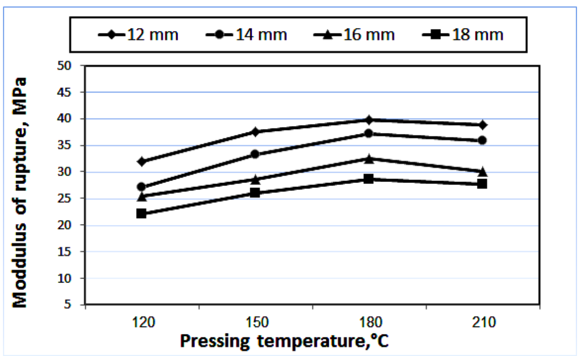
Fig. 4. Effect of percentage of resin and sample thickness on modulus of rupture under different pressing temperatures for rice straw



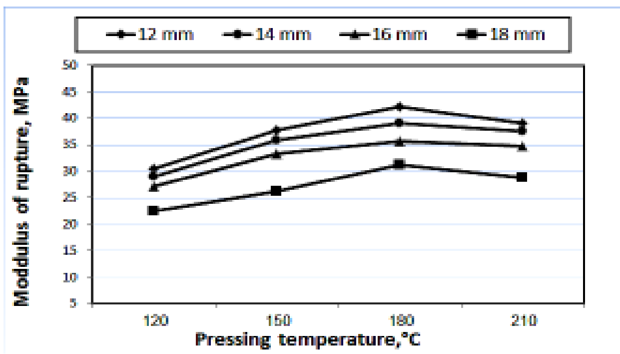
4% resin



6% resin

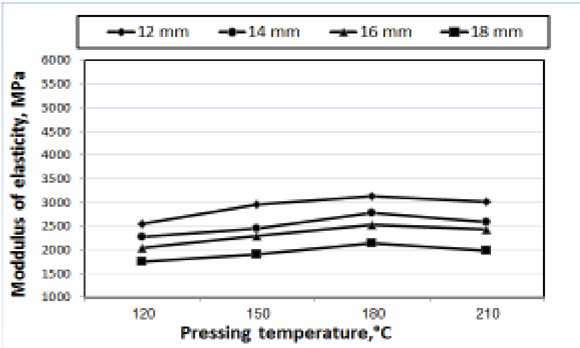


8% resin

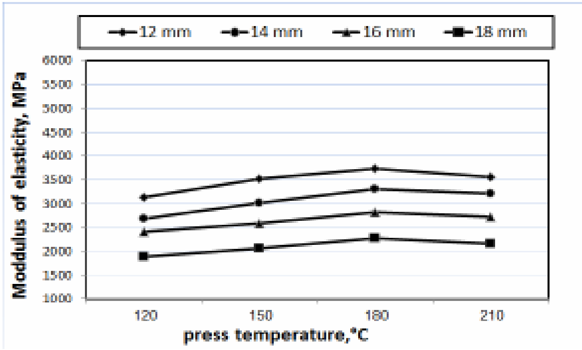


10% resin

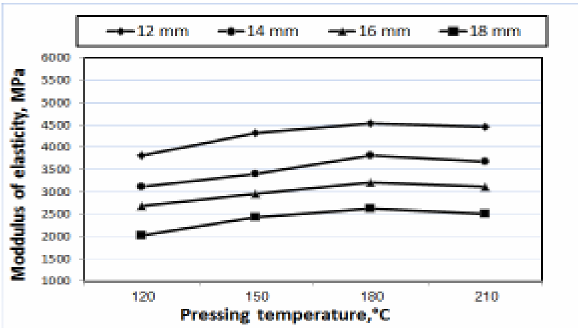
Fig. 5. Effect of percentage of resin and sample thickness on modulus of rupture under different pressing temperatures for wood sawdust



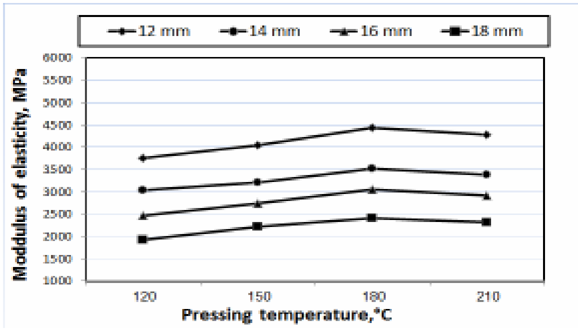
4% resin



6% resin

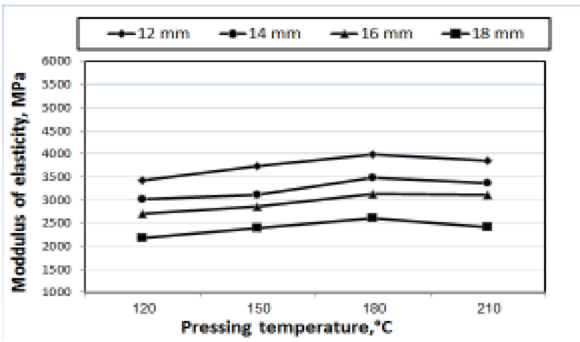


8% resin

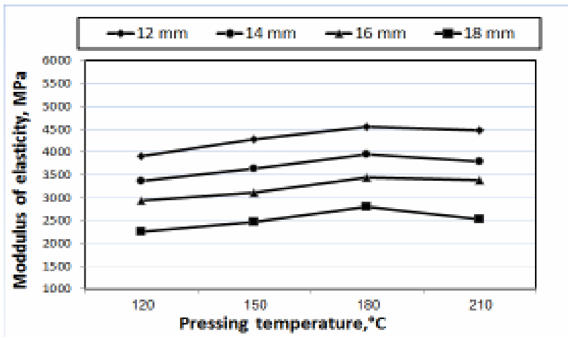


10 % resin

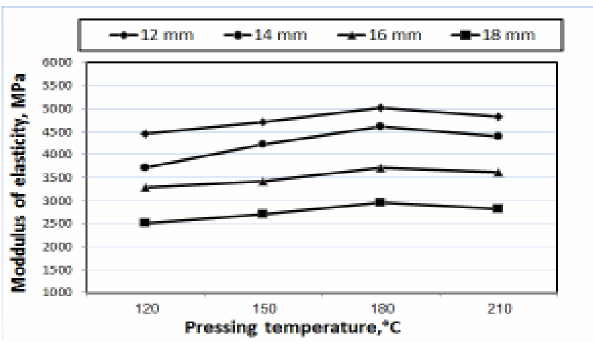
Fig. 6. Effect of percentage of resin and sample thickness on modulus of elasticity under different pressing temperatures for rice straw



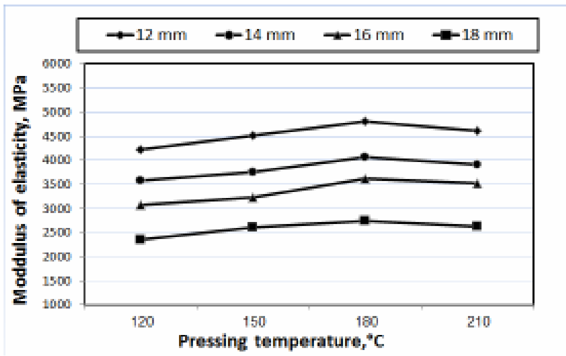
4% resin



6% resin



8% resin



10% resin

Fig. 7. Effect of percentage of resin and sample thickness on modulus of elasticity under different pressing temperatures for wood sawdust

As to resin percentage, results show that increasing resin percentage from 4 to 6%, modulus of elasticity increased by about 23.1, 19, 20.7 and 17.9% for pressing temperatures of 120, 150, 180 and 210°C, respectively under sample thickness of 12 mm for rice straw particleboards. However modulus of elasticity increased by about 13.2, 14.9, 14.6 and 16.2% for sawdust particleboards under the same previous conditions. Increasing resin percentage, increased modulus of elasticity due to the high increase in cohesion between internal molecules in residues.

The results indicated that the lower values of modulus of elasticity were 3806.2, 3120.9, 2690.2 and 2027.9MPa for rice straw particleboards; and 4457.3, 3715.6, 3283.9 and 2504.2 MPa for sawdust stalks particleboards under 8% resin and 120°C pressing temperature for 12, 14, 16 and 18 mm thicknesses. While the higher values of modulus of elasticity were 4530, 3821.2, 3200 and 2630.5 MPa for rice straw particleboards; and 5030.2, 4620.5, 3707.9 and 2950.7 MPa for sawdust particleboards under 8% resin and 180°C pressing temperature under the same mentioned thicknesses.

Effect of Some Variables on the Thickness Swelling of the Produced Particleboard

The effects of pressing temperature, sample thickness and percentage of resin on thickness swelling of the produced particleboard using different agricultural wastes are represented in Figs. 8 and 9.

Considering sample thickness, results show that by increasing sample thickness from 12 to 18 mm, thickness swelling increased by about 23.4, 36.4, 35.8 and 39% for pressing temperatures of 120, 150, 180 and 210°C, respectively under 4% resin percentage for rice straw particleboards. However thickness swelling increased by about 33, 53.9, 52.6 and 49.3% for sawdust particleboards under the same previous conditions.

Regarding pressing temperature, results indicated that by increasing pressing temperature from 150 to 210°C, thickness swelling decreased by about 21, 15.7, 16.2 and 18.7% for sample thicknesses of 12, 14, 16 and 18 mm, respectively under 4% resin percentage for rice straw particleboards.

As to resin percentage, results showed that increasing resin percentage from 4 to 6%, thickness swelling decreased by about 10.2, 17.5, 12.4 and 11.1% for pressing temperatures of 120, 150, 180 and 210°C, respectively under sample thickness of 12 mm for rice straw particleboards. However thickness swelling decreased by about 19.1, 13.1, 23.2 and 24.6% for sawdust particleboards under the same previous conditions. Although increasing the adhesive use ratio improved the physical and mechanical properties, it caused an increase in formaldehyde emissions.

The results indicated that the lower thickness swelling values were 6.1%, 7%, 8.5% and 9.4%Mpa for rice straw particleboards; and 3.3, 4.1, 4.9 and 6.8% for sawdust particleboards under 8% resin and 210°C pressing temperature for 12, 14, 16 and 18 mm thicknesses. While the higher thickness swelling values were 8.6, 10, 11.6 and 13.6% for rice straw particleboards; and 6.3, 7.6, 9 and 10.1% for sawdust particleboards under 8% resin and 120°C pressing temperature under the same mentioned thicknesses

Final Particleboards Quality

Table 3 illustrates the comparison between the produced particleboards from rice straw and sawdust with the particleboard standard quality guidelines. Results in Table 3 show that all produced particleboards under conditions of 180°C pressing temperature and 8% resin ratio with acceptable sample thickness of 12 mm, met the minimum requirement of the particleboard standard TS-EN 312 (2012).

Conclusion

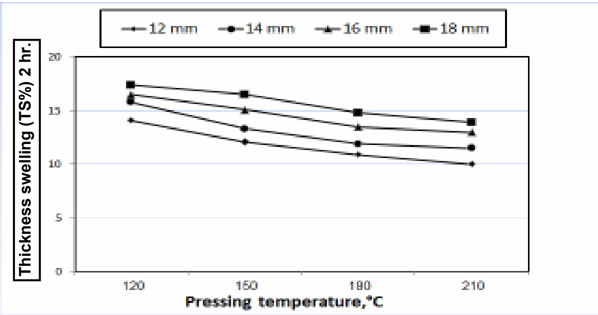
The experimental results reveal that modulus of rupture (28.1, 39.8 MPa), modulus of elasticity (4530, 5030.2 MPa) and thickness swelling (6.3, 3.9%) of the produced pressed wood from rice straw and wood sawdust, respectively were in the suitable region under the following conditions :-

-180°C pressing temperature.

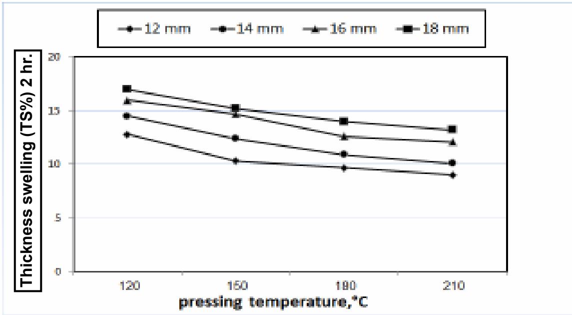
- 8% resin ratio.

- Sample thickness of 12 mm.

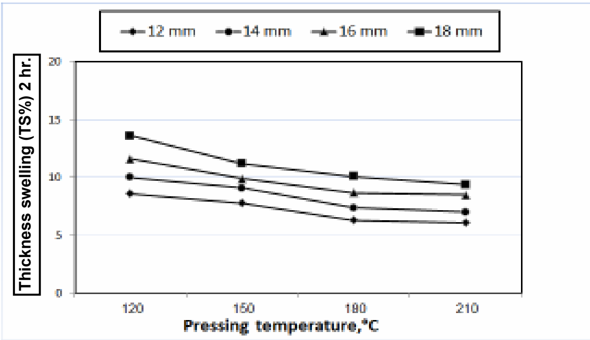
- Final quality of the produced particleboards was found to be close with the particleboard standard quality guidelines.



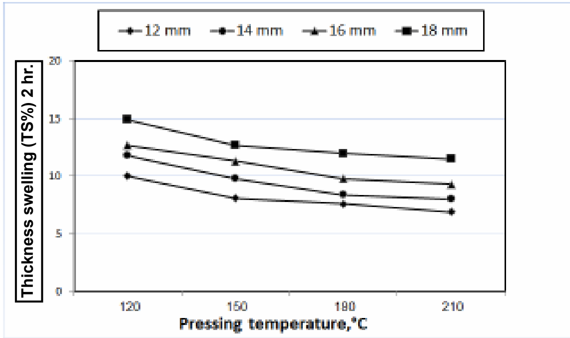
4% resin



6% resin

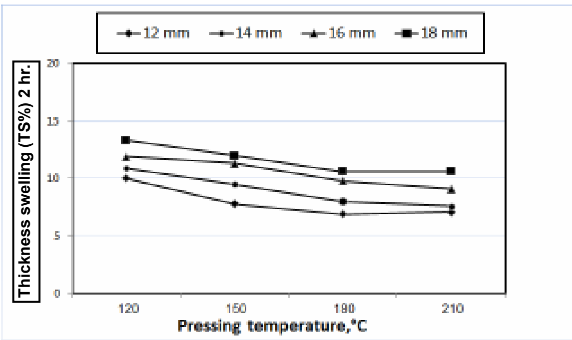


8% resin

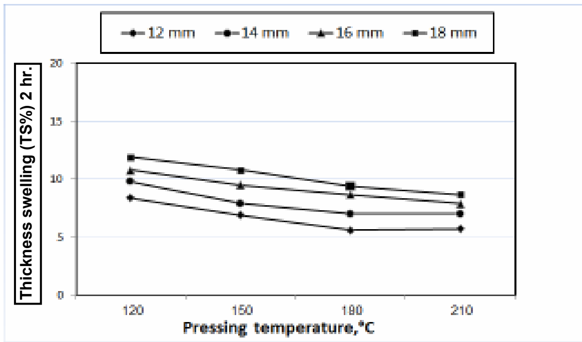


10% resin

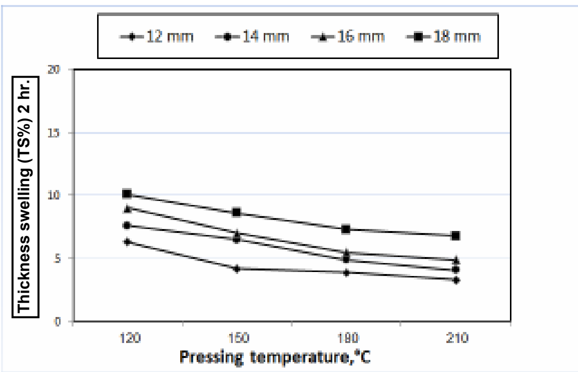
Fig. 8. Effect of percentage of resin and sample thickness on thickness swelling under different pressing temperatures for rice straw



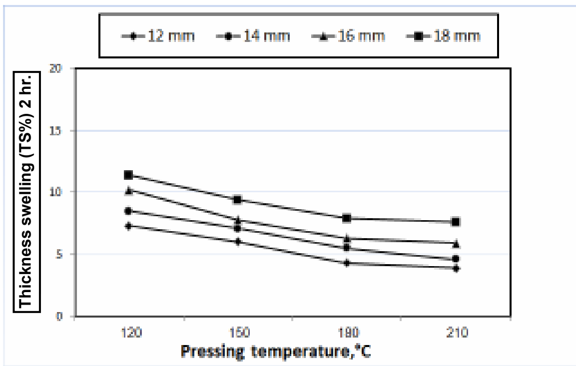
4% resin



6% resin



8% resin



10% resin

Fig. 9. Effect of percentage of resin and sample thickness on thickness swelling under different pressing temperatures for wood sawdust

Table 3. Comparison between the produced particleboards and the particleboard standard quality guidelines

Specification	Particleboard		
	Rice straw	Wood sawdust	Standard quality guidelines
MOR (Mpa)	28.1	39.8	19
MOE (Mpa)	4530	5030.2	3000
TS (%)	6.3	3.9	6-7
Density (kg/m^3)	620	650	660-700

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إعـــــادة تـــدويـــر المخلفـــــــات الــزراعيـــة لإنتـــاج أخشـــاب مضغــوطــة عاليــة الجــودة

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نظرا لزيادة المخلفات الزراعية فى الآونة الأخيرة حيث بلغت حوالى ٤٣,٦ مليون طن سنوياً مما يؤدى إلى تلوث بيئى بجانب مشكلة أخرى ألا وهى نقص الأخشاب وارتفاع أسعارها وزيادة الطلب على الاستيراد، لذا كان من الضرورى التفكير فى حل هذه المشاكل بإعادة تدوير تلك المخلفات لإنتاج أخشاب مضغوطة كبديل عن الأخشاب الطبيعية، لهذا فقد كان الهدف من هذه الدراسة هو إعادة تدوير المخلفات الزراعية لإنتاج أخشاب مضغوطة عالية الجودة ولذلك تم استخدام مكبس حرارى وتصنيع قالب تشكيل (اسطمبة) بأبعاد ٢٠ سم× ٢٥ سم مزودة بنظام حرارى كما تم تجهيز المخلفات وتجفيفها وفرمها لإجراء عمليات الكبس، تمت الدراسة على نوعين من المخلفات (قش الأرز، نشارة الخشب) حيث تم ضغط هذه المخلفات على أربعه درجات حرارة مختلفة (١٢٠، ١٥٠،١٨٠ و٢١٠°م) مع استخدام أربعه نسب من الغراء اليوريا فورمالدهيد (٤، ٦، ٨ و١٠%) لإنتاج أربعه عينات مختلفة السمك (١٢، ١٤ ، ١٦و ١٨مم) تحت ضغط ٢٥ بار لفترة زمنيه مقدارها ٢٠ دقيقة، تم تقييم الخشب الناتج من خلال قياس بعض الخصائص الميكانيكيه (معامل الكسر- معامل المرونه) وقياس بعض الخواص الفيزيائية (سمك الانتفاخ) كما تم مقارنة الخشب الناتج بالمواصفات القياسية للخشب المضغوط، وقد أظهرت النتائج التجريبية أن القيم المثلى لكل من معامل الكسر (٢٨,١٣ ، ٣٩,٨ ميجا باسكال) ومعامل المرونة (٤٥٣٠ ، ٥٠٣٠,٢ ميجا بسكال) وانتفاخ السمك (٦,٣ ، ٣,٩%) لكل من قش الارز ونشارة الخشب على الترتيب تم الحصول عليها عند ظروف التشغيل الآتية: ١٢ مم لسمك عينة الخشب المنتجة، ٨% نسبة الغراء، ١٨٠م لدرجة حرارة الكبس، تم مقارنة مواصفات الأخشاب المنتجة من كل من قش الأرز ونشارة الخشب بالمواصفات القياسية للأخشاب المضغوطة فوجد أنها متقاربة منها وبذلك فهى تعد صالحة للاستخدامات المختلفة.

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