Seventh Conference of Nuclear Sciences & Applications
6-10 February 2000, Cairo, Egypt

Rad.C-7 In Situ Gamma Irradiation and Thermal Treatment Effects on the Static Bending Properties of Particleboards Based on Waste Materials and Different Adhesives

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ABSTRACT

Particleboards based on different waste materials and different polymers as adhesives have been prepared by compression molding in a hot press at 120°C and constant pressure. The used waste materials were cotton stalks, flax stalks and wood saw-dust whereas urea formaldehyde(UF), polystyrene(PS) and the epoxy resins 103(E103) and 150 (E150) were used as adhesives. The thermally treated particleboard woods were subsequently exposed to gamma radiation. The static bending parameters of the different particleboards before and after gamma irradiation were evaluated. Moreover the different factors that may affect the mechanical properties such as irradiation dose, time of thermal treatment and adhesive content were also investigated. In general, it was found that the highest mechanical properties of the unirradiated woods were obtained when the preparation was carried out under hot press for 20 min and the adhesive content was 20 wt.% (based on weight of waste material). The obtained results showed that the mechanical properties were greatly increased with increasing irradiation dose from 3 to 5 Mrad. Meanwhile, particleboard based on cotton or flax stalks and the epoxy resins 103 and 150 displayed higher mechanical properties than these based on wood saw-dust and the same adhesives.

Key Words: Particleboard / Gamma Radiation / Epoxy Resins

INTRODUCTION

The chemical and physical properties of particleboards prepared by thermal curing have been extensively investigated[1-3]. The most widely investigated particleboard in the literature so far have mostly utilized an expensive woody materials as a base. However, a few authers used waste materials. In this regard, particleboard were prepared from cotton seed hulls with urea formaldehyde and phenol formaldehyde as binders[4]. Mechanical and thermal properties of particleboards made from farm residues using urea formaldehyde as a binding material was investigated[5]. It was demonstrated that maize board was superior to other boards in mechanical properties while paddy straw and coconut pith boards were suitable for insulation purposes. Also, particleboards with good surface appearance and satisfactory physical and mechanical properties made from twigs, veneer trimmings and wood shavings have been studied[6].

One of the largest problems facing the manfacturing of particleboards is the formaldehyde release from pressed wood products. A big effort is being made to minimize this release by e.g., lowering the molar ratio of formaldehyde to urea or by addition of scavengers after treatment with ammonia or urea and also by modifying the resin itself[7,8]. Thus it is the aim in this paper to present a balanced view to overcome this problem by introducing radiation curing after thermal treatment. Also, it has been assumed that the most promising view is to replace the thermal curing by radiation curing. This approach will eventually depend on how sensitive the chosen resins to fill the voids of particleboards is are to radiation initiation crosslinking. Therefore, the effect of gamma irradiation on the mechanical properties (static bending) of different particleboard based on different waste materials and different adhesives made by thermal curing is the purpose of this study. The waste materials used in this study are cotton stalks, flax stalks and wood saw-dust while the adhesives are urea formaldehyde, polystyrene and some commercial epoxy resins.

EXPERIMENTAL

Materials

The base waste materials used throughout this work for the preparation of the particleboard woods were cotton stalks, flax stalks and wood saw-dust. The cotton and flax stalks were collected from farm residue which are considered as waste materials. However, before use they made cleaned from the dust and fiber residue and curshed into small peices by a locally made shatter machine. The wood saw-dust was a by-product produced in the carpenter work shop and it is a mixture of different kinds of woods usually used in the furnatures industry ; in-door and out-door articles. The polymers used as adhesives for the particleboards were urea formaldehyde resin (UF), polystyrene(PS), kemapoxy 103(E103) and kemapoxy 150(E150). The Urea formaldehyde resin was a commercial product of El-Nasr Company for particleboard and Resins, El-Mansoura, Egypt. It is a milky solution free from foreign matters (60%). Kemapoxy 103 and 150 are commercial products based on specifically modified epoxy resins purchased from Chemicals for Modern Building Co., Cairo, Egypt. Kemapoxy 103 is a low viscosity two component product originally used for concrete cracks while kemapoxy 150 is also a two component product, solvent free and used for reparing mortor and floor toppings. The used PS was a pure grade ,purchased from Aldrich Chemical Co., it is in the form of pellets and has an average molecular weight of 280,000.

Preparation of Particleboards

The crushed cotton or flax stalks and wood saw-dust were first conditioned to remove the contained moisture by placing them in an oven at 105°C for 2 hrs. The conditioned materials were thoroughly mixed with various ratios of each polymeric adhesives under investigation dissolved in the appropriate solvent. The mixture was then the compressed under hot press at 80°C and 120°C for various lengths of time to form sheets of dimensions of 10 mm in thickness and 100 mm in width and length. The particleboard wood sheets were prepared under constant pressure of 12 tons/m^2.

Gamma Irradiation

Irradiation to the required doses was carried out with a ^{60}CO gamma source (made in India) at the National Center for Radiation Research and Technology, Cairo, Egypt. The particleboards were exposed to gamma irradiation in air at a dose rate of 0.40 Mrad/h.

Static Bending Testing

The static bending tests were carried out on conditioned specimens of the different particleboards according to ASTM Designation (D1037-87) using a universal Instron machine model 1195. The specimens for static bending tests were cut into reactangular pieces of 10cm (length) x 2.6 (width) x 1 cm (thickness) in dimention ,such that the four edges are smoothly and squarely trimmed. The static bending test assembly was designed to compose of two rounded supports for the specimen in which the distance between the two points of contact with specimen being 7 cm. The specimen was loaded at the center of span with a rounded head ap using a cross head speed of 5mm/min. The load-deflection curves to maximum load were obtained and the different bending parameters were calculated as the average of four specimens. The different bending parameters for each specimen were calculated according to the following equations:

Modulus of elasticity = $PL^3/4bd^3y$ kgf/cm^2

Stress at rupture = $3PL/2bd^2$ kgf/cm^2.

Work to maximum load = A/bdL kgf.cm/cm^3.

Where:

A = Area under load-deflection curve to maximum load, kgf.cm

b = width of specimen, cm.
D = Thickness (depth) of specimen, cm.
L = Length of span, cm.
P = Maximum lead, kgf.

RESULTS AND DISCUSSION

The driving force behined this work is the utilization of non-useful and polluent materials to produce a suitable industrial product for special in- door applications. In this regard, cotton stalks, flax stalks and saw-dust are examples of abundant waste materials if not used they will cause damage to cultivated land. Even though the particle base fiber woods, particularly flax stalks, are manufactured in industrial scale, they have low mechanical and high water absorption properties and the materials are dimensionally unstable.Moreover, most of the adhesives or resins used for the production of these materials should be sensitive to thermal curing. Therefore, in the present work , as a first attempt to replace thermal curing by high energy radiation, the mechanical parameters of different particleboards prepared by thermal treatment and subsequently exposed to various doses of gamma radiation were investigated. Moreover, the effect of type and content of different adhesives on the mechanical properties was also considered.

Particleboards Based on Cotton Stalks

A set of prelminary experiments was carried out with the objective of obtaining particleboards based on cotton stalks and different adhesives by thermal compression molding with suitable shaping and dimensional stability. While compression molding is a routine preparation method for particleboards, it is desirable to minimize the exposure to excessive heating. The conditions chosen for molding to obtain uniform particleboards of suitable shapes were a pressing temperature of 120°C and a molding pressure of of 12 ton/m^2.

Irradiation Dose and Time of Thermal Curing

Tables 1-4 show the different static bending parameters of particleboard woods based on cotton stalks and reinforced with different adhesives (polymers) pre-cured at various times at 120°C. The adhesive content in the particleboards, regardless of the type, was 8% (based on the weight of the cotton stalks).

Stress at Rupture

As shown in Table 1, the stress at rupture of the unirradiated particleboard woods subjected to thermal treatment for 10, 20 and 30 min., may be arranged according to the type of adhesive, respectively, as follows:
Epoxy 150 > urea formaldehyde > Epoxy 103 > Polystyrene.
Epoxy 103 > Urea formaldehyde > Epoxy 150 > Polystyrene.
Epoxy 150 > Epoxy 103 > Urea formaldehyde> polystyrene.

The particleboards based on urea formaldehyde and Epoxy 103 prepared by thermal treatment for 20 minutes showed the highest value of stress at rupture. In the case of using polystyrene and Epoxy 150 as adhesives, the particleboard woods prepared by thermal curing for 30 min. displayed the highest value of stress at rupture.

In general, the stress at rupture of the particleboards was found to increase with increasing irradiation dose regardless of the type of the used adhesive as shown in Table 1. Moreover, all the used adhesives are sensitive to radiation crosslinking particularly urea formaldehyde and epoxy 150 resins. On the basis of the result of stress at rupture of the gamma irradiated particleboards initially prepared by thermal curing, several points may be indicated : (1) it is clear that using urea formaldehyde as an adhesive for cotton stalks, the resulting particleboard displayed the highest value of stress at rupture of 252 kgf/cm^2 over all the investigated materials. This result was obtained when the sample was pre-cured for 20 min and exposed to a dose of 5

Mrad. For the same type of particleboard, it was observed that the increase in stress at rupture was found to be about 109% and 29% with increasing irradiation dose from 0 Mrad to 3 Mrad and from 3 to 5 Mrad, respectively. (2) the particleboards based on polystyrene as an adhesive showed the lowest values of stress at rupture compared to the both type of adhesive either before and after gamma irradiation. However, the stress at rupture of these materials was found to increase with increasing irradiation dose irrespective of the time of pre-thermal curing. (3) For particleboards based on epoxy 103 initially pre-cured by thermal treatment for 10, 20 and 30 min., the improvements in stress at rupture associated with increasing irradiation dose from 0 Mrad to 3 Mrad were found to be 127.3%, 39.6% and 29.1% (based on the initial value of unirrdiated boards), respectively. The increament in stress at rupture by increasing irradiation dose from 3 to 5 Mrad for the same type of adhesive prepared under the same conditions were found to be 41.2, 31.9 and 19.2%, respectively. The relatively lower increase in stress at rupture seen by increasing irradiation dose from 0 Mrad to 3 Mrad in the case of 10 min. is due to the lower value of the initial stress of the boards. (4) It can be observed that the stress of the woods based on Epoxy 150 was increased by 19.2%, 98.4% and 96.1% with increasing irradiation dose from 0 to 3 Mrad for the samples pre-cured for 10, 20 and 30 minutes, respectively. (5) As can be seen, for all the particleboards, a larger enhancement in stress at rupture was obtained when the initially thermally cured boards were exposed to 3 Mrad rather than increasing dose from 3 to 5 Mrad.

It was reported that the extraction of particleboards based on UF and made by thermal curing with water yielded nearly all the urea added and thus it was concluded that the urea does not become part of the resin during the curing process [9]. In the present work, the partcleboard was pre-cured at 120°C before exposure to gamma radiation. This temperature according to the standard industrial manufactureing of particleboards is not enough for complete thermal curing. For this reason it was intended to expose the pre-cured board directly to gamma radiation. Thus the enhancement in stress at rupture of cotton stalks based on different polymeric adhesives may be explained as follows: The interaction of radiation with PS has been reported to produce two types of radical intermediates[10]. The G(X) values are between 0.02 and 0.054, while G(S) has been reported to be 0.02. Therefore, it can suggested the crosslinking of PS inside the matrix of boards is possible. Also, it is possible PS or acrylate resins(E103 and E150) are grafted onto the cellulose molecules of cotton stalks which in turn becomes part of the boards.

Modulus of Elasticity

Elastic modulus measures the resistance to small deformation of a material when external forces are applied; it is the ratio of the applied force to the resulting strain. In general, there are three kinds of moduli: Young's moduli, shear moduli and bulk moduli. Isotropic materials, such as unoriented amorphous polymers and annealed glasses, have only one of each of the three kinds of moduli. The distinguishing feature about isotropic elastic materials is that their properties are the same in all directions. On the other hand, anisotropic materials, include fibers, wood, oriented amorphous polymers, fiber filled composites and crystalline polymers, have different properties in different directions. Cotton stalks particleboards are examples of biaxially oriented or planar random anisotropic system in which the cotton stalks are randomly oriented in the plane of the boards. In the present work, Young's modulus was measured by a flexural test in which a reactangular cross section specimen was supported at two points and loaded at the midpoint by a force.

Table 2 shows the effect of irradiation dose and time of pre-thermal curing on the modulus of elasticity (Young's modulus) of particleboards based on cotton stalks and different adhesives. It can be seen that the value of the modulus of elasticity is greatly dependent on the type of adhesive and different largely from one to another. Nevertheless, for any two particalcboars based on different adhesives but having nearly equal stress at rupture, the corresponding values of modulus are not equal. This may be due to the difference in elasticity of the different adhesives. While, the particleboards based on polystyrene showed the lowest modulus, the board based on urea formaldehyde and epoxy 150 displayed higher values. However, the modulus of elasticity was found to increase significantly after the woods had been exposed to gamma irradiation regardless of the type of adhesive.

Crosslinking is an important factor that affect the modulus of elasticity. In this regard, chemical crosslinks act about the same as entanglements upon stretching or deformation and hence increase the modulus of elasticity. Therefore, the increase in modulus can be explained on the basis of formation of further crosslinking upon gamma radiation in addition to crosslinking through thermal treatment. However the density of crosslinking resulted from exposure to gamma irradiation is much higher than that by thermal curing.Also, crosslinking produces two other effects. First, when the crosslink density becomes fairly high, the glass transition temperature is increased, so the drop in modulus becomes noticeable . On the basis of this fact, the glass transition temperature of polystyrene is about 100°C and the pre-thermal curing was carried out at 120°C, i.e., beyond its Tg. Thus, the low values of modulus of particle boards based on polystyrene may be explained as due to the combined effect of increasing density of crosslinking and the temperature of preparation.

Work to Maximum Load and Deflection at the Center

Particleboards are essencially composed of randomly dispersed chips of cotton or flax, adhered together with the polymeric material used as an adhesive. Even though, the cellulosic material constitute the major phase in particleboard, yet the polymeric material will determine the physical and chemical properties of the materials. Toughness of polymers is measured by the area under the stress-strain curve or load-deflection curve in the case of bending testing. This area has the units of energy per unit volume and it is the work expended in deforming the material.

Table 3 shows the work-to maximum load for particleboards based on cotton stalks and different adhesives prepared by thermal curing for various lengthes of time before and after they had been exposed to various doses of gamma radiation. It can be seen that, for board based on UF, the work decreases with increasing time of thermal curing. However, the work was found to increase with increasing irradiation dose from 3 to 5 Mrad irrespective of the time of thermal curing. Similar trends can be seen in the case of PS, E103 and E150 as adhesives.

As shown in Table 4, the bending at the center of cotton stalks based woods is pretty dependent on the type of adhesive rather than irradiation dose or time of thermal treatment. while the bending of woods based on UF before gamma irradiation was found to increase with increasing time of curing, an opposite trend was observed in the case of woods based on E150.

Effect of Irradiation Dose and adhesive Content

Adhesive content may be considered one of the most important factors that affect the physical and chemical properties of particleboard woods. This is because cotton stalks in the form of chips are relatively large in size and hence the particleboard is full of spacing even after compression.

The effect of various ratios of the different adhesives used for the preparation of the particleboard woods on the stress at rupture was investigated as shown in Table 5. It should be noted that the pressure and temperature of pressing were kept constant at 12 ton/m^2 and 120°C, respectively. However, the time of thermal pressing is adjusted according to the best results of static bending properties specific for each adhesive.

Generally, it can be seen that the stress at rupture of particle board based on cotton stalks before gamma irradiation increases greatly with increasing adhesive content from 12% up to 20% regardless of the type of adhesive. However, the value of stress was found to differ from one adhesive to the other. In this regard, the particleboard woods based on UF and E150 showed higher stress at rupture than those based on PS and E103. A substantially different behaviour was observed when the thermally treated particleboards were directly exposed to various doses of gamma radiation. Some typical examples of the enhancement in stress at break upon gamma irradiation can be seen in the case of particleboard woods based on 20% adhesive. The icnrease of stress at rupture in the case of using PS, E103, UF and E150 with respect to the values of stress of unirradiated particuleboard were found to be 12%, 21%, 60% and 114%, respectively. These trends can be attributed to the relative higher resistance of PS to gamma radiation than that of E150 which is based on acrylate groups.

Particleboards Based on Flax Stalks

Table 6 shows the effect of the subsequent gamma irradiation with various doses on the stress at rupture of particleboard woods based on flax stalks pre-treated thermally at various length of time. It is obvious that the effect of time of thermal treatment on the stress at rupture differs from one adhesive to other before gamma irradiation. While the stress at rupture is found to increase with increasing the time of thermal treatment in the case of UF and Epoxy 150, an opposite behaviour can be noticed in the case of polystyrene and Epoxy 103. However, the stress at rupture was found to increase with increasing irradiation dose in all cases. Meanwhile, the effect of gamma irradiation is pronounced in the case of Uf as an adhesive. The dependence of the stress at rupture of this type of particleboard on the type of adhesive before or after they had been exposed to gamma irradiation can be arranged as follows:
UF> Epoxy 103 > Epoxy 103> PS.

As shown in Table 7, the stress at rupture of flax boards swas found to increase with increasing either adhesive content or irradiation dose. Meanwhile, the enhancement in stress at rupture caused by changing adhesive content or dose is rather small than that occurred by the effect of the time of thermal treatment and irradiation dose as shown in Table 6. The other bending parameters such as modulus of elasticity, work-to-maximum load and deflection at the center of particleboard woods based on flax stalks were also calculated (not shown). The obtained results revealed that these parameters are strongly depend on time of thermal treatment, adhesive content and irradiation dose. In this contest, the the values of modulus of elasticity of particleboard woods based on UF (8%) was in the order of six digits before or after exposure to gamma irradiation or by increasing the time of thermal treatment from 10 to 30 minutes. On the other hand, by changing the adhesive content from 8 to 20% and at constant time of thermal treatment of 30 min, the values of modulus were greatly decreased from six digits to four and five digits. This drop in modulus causes the deflection at the center of such samples to increase from fractions of millimeters to multiple of millimeters.

On the basis of the above results, it may be indicated that the suitable conditions at which an appreciable enhancement in stress at rupture of such particleboard woods were: adhesive (20%), time of thermal (30 min) and irradiation dose (5 Mrad). At such conditions, the measured modulus of elasticity, work-to-maximum load and deflection at the center for the particleboard woods based on the different adhesives were found as follows, respectively.
For UF : 24305 kgf/cm^2, 136.6 kgf.cm/cm^3 and 3.84 mm.
For PS: 8619 kgf/cm^2, 42.2 kgf cm/cm^3 and 2.22 mm
For E103: 19112 kgf/cm^2, 81.6 kgfcm/cm^3 and 2.60 mm
For E150: 12729 kgf/cm^2, 69.5 kgfcm/cm^3 and 2.30 cm.

The static bending parameters were measured for a sample of particleboard based on flax stalks produced by El-Nasr company for particleboard and resins, El-Mansoura, Egypt. This type of particleboard wood is being produced on industrial scale. The stress at rupture, modulus of elasticity, work-to maximum load and deflection at the center for this material were found to be 95.9 kgf/cm^2, 35949 kgf/cm^2, 3.57 kgf.cm/cm^3 and 0.245 mm, respectively. It should be noted that this particleboard wood is made based on UF as an adhesive (12%) and compressed by thermal treatment only at 140°C for 20 minutes. It is evident that gamma radiation enhances greatly the mechanical properties of the particleboard woods under investigation even though other materials than UF were used as an adhesive.

Particleboards Based on Wood Saw-Dust

Wood saw-dust as a waste material resulting during the manufacturing of wood articles is usually composed of different kinds of woods. Also, unlike cotton and flax stalks, the size of wood saw-dust as a base material for particleboard is relatively very small. Thus, it expected that the mixture of wood saw-dust and the dissolved adhesives will be more homogenously distributed than in case of cotton and flax stalks compositions.

In a similar manner, the stress at rupture of particleboard woods composed of wood saw dust and the same adhesives at a constant content of 8wt% pre-treated at 120°C and directly exposed to various doses was investigated as shown in Table 8. It can be seen the factor which directly effects the stress of this type of wood is the sensitivity of the each adhesive towards the pre-thermal treatment. Before exposure to gamma irradiation, the highest stress at break of woods based on UF was achieved at 10 min,wood based on E103 and E150 at 20 min whereas woods based on PS was at 30 min. At these conditions, the woods may be evaluated in terms of stress according to the used adhesive before gamma irradiation as follows:

E103> UF> E150> PS.

After these particleboard woods had been exposed to gamma irradiation, this arrangement is changed to :

UF> E103 = E150> PS

The influence of adhesive content and irradiation dose on the stress at rupture saw-dust woods prepared at the corrsponding conditions of time of thermal pre-treatment was also studied (not shown). The data suggest that the increase of UF content has a negative effect on the stress at rupture of this wood even though the stress was found to increase with irradiation dose at any content of UF. On the other hand, the stress at break was shown to improve markedly with increasing either PS, E103 and E150 contents or irradiation dose.

The improvement in the mechanical properties of the different particleboard woods via gamma irradiation was confirmed by investigating the static bending properties of particleboard woods pre-thermal treated at lower temperature than 120°. Thus, the effect of irradiation dose on the stress at rupture of particleboard woods based on different waste materials and constant ratio of the different adhesives (20 wt%) prepared by thermal treatment at 80°C for 20 min was studied as shown in Table 9. It is clear that reducing the temperature of the pre-thermal treatment affects progressively the stress at rupture to some extent in all systems before gamma irradiation. This can be seen if the values of stress at rupture were compared with the corssponding values for the same substrates in Tables 5, 7 and 9. However, the stress at rupture was found to icnrease substationally with increasing irradiation dose in all systems. Meanwhile, the increase in stress is not as that observed when the pre-thermal treatment was carried out at 130°C. This finding may be explained as the reduction in temperature will eventually result in a greater number of polymer chains are available in the system to form grafting chains instead of crosslinking. Accordingly, it may be concluded that gamma irradiation has a contributing role in the improvement of the mechanical properties of the particleboard woods.

Conclusions

An attempt has been made to make use of waste materials to prepare particleboard woods using non-conventional polymers as adhesives. Also,this study showed that the static mechanical properties of these materials can be significantly improved by exposing pre-thermally treated particleboard woods directly to gamma radiation. Moreover, it has been demonstrated that the pre-thermal curing of the different adhesives included in the particleboard woods does not prevent the radiation-induced polymerization, crosslinking and grafting. The results also showed that the stress at rupture of the particleboard woods always depends entirely on the type of the base material rather than the type of adhesive. In this respect, at constant UF content of 8% and time of pre-thermal curing of 20 min, the stress at rupture of cotton stalks, flax stalks and saw-dust woods were found to be 93.3, 156.1 and 61.9 as shown in Tables, 1, 6 and 8, respectively. However, the stress at rupture for particleboard woods based on the same waste material, e.g., cotton stalks was found to depend completely on the type of adhesive as shown in Table 1. Increasing the time of pre-thermal curing may not always lead to an improvement in the mechanical properties of the particleboard woods. Meantime, by increasing adhesive content or irradiation dose have shown to be more effective in enhancing the mechanical properties. The increase in mechanical properties associated with these factors may be attributed to the increase in molecular weight of the polymeric adhesive that fills the voids in the particleboard woods brough about by crosslinking, polymerization or grafting. To make a statistics on the improvement in the static mechanical properties of the systems under investigation, two points may be indicated : (1) The system cotton stalks/E150 (20 wt%) irradiated to 5 Mrad displayed the highest stress at rupture over all the studied systems (426.7 kgf/cm^2). The systems flax stalks/UF and saw-dust/UF prepared under similar conditions also showed high stress at rupture of 390.5 and 308.7kg f/cm^2. (2) The lowest improvement in the Static mechanical properties among the gamma irradiated particleboard woods was observed in the system saw-dust/PS (109.8 kgf/cm^2). However, it still possesses higher stress at rupture than than for the industrial sample based on flax stalks and UF (95.6 kgf/cm^2).

The future study will include the evaluation of these systems from the point of view of water absorption, dimentional stability and thermal stability. The following up of the release of the different adhesives from the particleboard woods after gamma irradiation will be considered.

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Table 1. Effect of Irradiation Dose on the Stress at Rupture of Particleoard Woods Based on Cotton Stalks and Different Polymers (Adhesives) Initially Made By Thermal Treatment at Various Pressing Times.

Time of Thermal Curing (min.)	Irradiation Dose (Mrad)	Stress at Rupture (Kgf/ cm^2)			
		Urea Formaldehyde	Poly(styrene)	Epoxy 103	Epoxy150
10	Unirradiated	78.7	8.8	42.5	83.7
	3	150.1	22.5	96.6	99.8
	5	172.9	51.1	136.4	190.8
20	Unirradiated	93.3	19.2	96.2	88.9
	3	192.6	43.8	134.3	176.4
	5	194.9	61.2	177.1	188.2
30	Unirradiated	78.5	25.0	91.4	92.5
	3	165.4	47.9	118.0	181.4
	5	176.3	66.0	140.7	193.6

Fixed molding conditions:

Polymer content=8 wt.% (based on cotton stalks weight)

Pressure of moulding= 12 Ton/m^2

Temperature of pressing= 120 °C

Table 2. Effect of Irradiation Dose on the Modulus of Elasticity of Particleboard Woods Based on Cotton Stalks and Different Polymers(Adhesives) Intially Made By Thermal Treatment at Various Pressing Times.

Time of Thermal Curing (min.)	Irradiation Dose (Mrad)	Modulus of Elasticity (Kgf/ cm^2)			
		Urea Formaldehyde	Poly(styrene)	Epoxy 103	Epoxy150
10	Unirradiated	43909	18943	39898	64458
	3	98043	44848	95354	135847
	5	106954	59245	98253	151320
20	Unirradiated	72554	21236	81294	74824
	3	113680	32046	94635	89406
	5	155909	52022	160676	147820
30	Unirradiated	56392	22939	84776	86854
	3	108032	46505	107023	142634
	5	116472	64922	110785	155023

Fixed molding conditions:

Polymer content=8 wt.% (based on cotton stalks weight)

Pressure of moulding= 12 Ton/m^2

Temperature of pressing= 120 °C

Table 3. Effect of Irradiation Dose on the Work To Maximum Load of Particleboard Woods Based on Cotton Stalks And Different Polymers (Adhesives) Initially Made By Thermal Treatment at Various Pressing Times.

Time of Thermal Curing (min.)	Irradiation Dose (Mrad)	Work To Maximum Load (Kgf.cm/ cm^3)			
		Urea Formaldehyde	Poly(styrene)	Epoxy 103	Epoxy150
10	Unirradiated	1.190	0.102	0.605	1.186
	3	1.862	0.410	1.801	2.341
	5	3.438	1.469	3.324	4.604
20	Unirradiated	1.082	0.215	0.943	0.900
	3	2.646	0.249	1.252	1.127
	5	4.718	1.687	4.359	4.710
30	Unirradiated	0.737	0.237	1.130	1.725
	3	2.003	0.465	1.753	2.161
	5	4.306	2.257	3.695	5.131

Fixed molding conditions:

Polymer content=8 wt.% (based on cotton stalks weight)

Pressure of molding= 12 Ton/m^2

Temperature of pressing= 120 °C

Table4. Effect of Irradiation Dose on the Deflection at the Center of Particleboard Woods Based on Cotton Stalks and Different Polymers(Adhesives) Initially Made By Thermal Treatment at Various Pressing Times.

Time of Thermal Curing (min.)	Irradiation Dose (Mrad)	Deflection At The Center (mm.)			
		Urea Formaldehyde	Poly(styrene)	Epoxy 103	Epoxy150
10	Unirradiated	0.105	0.034	0.091	0.097
	3	0.125	0.066	0.087	0.103
	5	0.132	0.093	0.115	0.109
20	Unirradiated	0.127	0.049	0.083	0.091
	3	0.132	0.096	0.090	0.104
	5	0.140	0.097	0.097	0.106
30	Unirradiated	0.116	0.077	0.087	0.087
	3	0.133	0.083	0.088	0.101
	5	0.146	0.089	0.104	0.102

Fixed molding conditions:

Polymer content=8 wt.% (based on cotton stalks weight)

Pressure of molding= 12 Ton/m^2

Temperature of pressing= 120 ^oC

Table 5. Effect of Polymer Content on the Stress at Rupture of Particleboard Woods Based on Cotton Stalks and Different Polymers(Adhesives) Initially Made By Thermal Treatment and Exposed toVarious Doses of Gamma Radiation.

polymer Content (wt.%)	Irradiation Dose (Mrad)	Stress at Rupture (Kgf/cm^2)			
		Urea Formaldehyde (UF)	Poly(styrene) (PS)	Epoxy 103 (E103)	Epoxy150 (E150)
12	Unirradiated	109.6	51.0	98.9	145.8
	3	177.9	67.3	167.0	187.0
	5	183.7	68.5	187.4	203.9
16	Unirradiated	163.0	78.5	116.6	162.0
	3	192.3	97.0	183.9	206.8
	5	224.1	102.7	215.1	249.3
20	Unirradiated	175.5	128.4	305.9	199.7
	3	268.3	150.3	318.1	356.2
	5	280.8	168.0	370.0	426.7

Fixed molding Conditions:

Pressure of molding= 12 Ton/m^2

Temperature of pressing= 120 °C

Time of pressing:

For UFand E103=20 min.

For PS and E150=30 min.

Table 6. Effect of Irradiation Dose on the Stress at Rupture of Particleboard Woods Based on Flax Stalks and Different (Polymers) Adhesives Initially Made By Thermal Treatment at Various Pressing Times.

Time of Thermal Curing (min.)	Irradiation Dose (Mrad)	Stress at Rupture (Kgf/cm^2)			
		Urea Formaldehyde	Poly(styrene)	Epoxy 103	Epoxy150
10	Unirradiated	149.6	73.3	117.7	46.2
	3	220.9	111.8	136.5	66.4
	5	241.9	125.5	265.0	99.5
20	Unirradiated	156.1	61.1	73.5	54.6
	3	241.9	103.6	112.1	112.4
	5	271.4	103.9	159.2	159.6
30	Unirradiated	218.5	38.2	69.0	110.2
	3	258.2	38.9	92.6	129.2
	5	376.9	96.8	120.5	181.9

Fixed molding conditions:

Polymer content=8 wt.% (based on flax stalks weight)

Pressure of moulding= 12 Ton/m^2

Temperature of pressing= 120 °C

Table 7. Effect of Polymer Content on the Stress at Rupture of Particleboard Woods Based on Flax Stalks and Different Polymers (Adhesives) InitiallyMade By Thermal Treatment and Exposed toVarious Doses of Gamma Radiation.

Polymer Content (wt.%)	Irradiation Dose (Mrad)	Stress at Rupture (Kgf/ cm^2)			
		Urea Formaldehyde (UF)	Poly(styrene) (PS)	Epoxy 103 (E103)	Epoxy150 (E150)
12	Unirradiated	224.1	122.7	186.6	107.0
	3	357.8	125.8	215.8	111.2
	5	359.7	137.0	223.7	137.0
16	Unirradiated	252.0	99.7	134.0	133.9
	3	265.9	117.7	137.0	194.7
	5	770.2	131.2	207.8	241.6
20	Unirradiated	262.5	90.4	239.3	174.3
	3	368.4	146.6	279.0	239.3
	5	390.5	171.6	303.2	249.7

Fixed molding Conditions:

Pressure of molding= 12 Ton/m^2

Temperature of pressing= 120 °C

Time of pressing :

For UF and E150=20 min.

For PS, and E103=10 min.

Table 8. Effect of Irradiation Dose on the Stress at Rupture of Particleboard Woods Based on Wood Saw-Dust and Different Adhesives Initially Made By Thermal Treatment at Various Pressing Times.

Time of Thermal Curing (min.)	Irradiation Dose (Mrad)	Stress at Rupture (Kgf/cm^2)			
		Urea Formaldehyde	Poly(styrene)	Epoxy 103	Epoxy150
10	Unirradiated	65.4	16.5	32.7	5.7
	3	141.4	31.8	75.0	24.9
	5	170.1	41.2	82.0	50.9
20	Unirradiated	61.4	19.5	75.1	18.5
	3	120.2	29.8	95.8	82.4
	5	149.0	45.7	98.3	98.2
30	Unirradiated	55.8	20.1	70.3	16.5
	3	99.4	50.1	86.6	32.2
	5	141.4	67.3	90.8	68.9

Fixed molding conditions:

Polymer content=8 wt.% (based on wood-saw dust weight)

Pressure of moulding= 12 Ton/m^2

Temperature of pressing= 120 °C