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Soybean waste in particleboard production

Aproveitamento de resíduos da soja para a produção de painéis aglomerados

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ABSTRACT

Brazil is the second largest soybean producer in the world, with a yield of around 96.2 million tons per crop. This high yield leads to a great amount of waste resulting from soybean cultivation, which can reach approximately 41 million tons of waste per year. This material has lignocellulosic properties, which may enable its use as a raw material for particleboard production. Therefore, the objective of this study was to evaluate the use of soybean pods in particleboard production. For particleboard manufacture, wood of the hybrid *Eucalyptus urophylla* and *Eucalyptus grandis* was used, added with soybean pods, at proportions of 0%, 25%, 50%, 75% and 100%. For particleboard evaluation, a completely randomized design was used, with five treatments and three replicates, using linear regression and the Scott-Knott test at 5% significance for comparison among the different treatments. The properties apparent density, compaction ratio, water absorption after 2 and 24 hours, thickness swelling after 2 and 24 hours in water immersion, internal bonding, modulus of rupture and modulus of elasticity in bending properties were evaluated. The ratio soybean pod waste and eucalyptus particles in the panels led to an increase in water absorption values and thickness swelling, in addition to a decrease in mechanical properties. The production of panels with approximately 23% soybean pods is feasible.

Index terms: *Eucalyptus*; soybean pod; agricultural waste; physical and mechanical properties.

RESUMO

O Brasil é o segundo maior produtor de soja do mundo, com produções em torno de 96,2 milhões de toneladas por safra. Essa alta produtividade acarreta em um número expressivo de resíduos gerados pelo cultivo da soja, o que pode chegar a aproximadamente 41 milhões de toneladas de resíduos por ano. Este material possui propriedades lignocelulósicas, o que pode possibilitar sua utilização como matéria-prima para a produção de painéis aglomerados. Sendo assim, objetivou-se com o presente trabalho avaliar a utilização da vagem da soja na produção de painéis aglomerados. Para a manufatura dos painéis aglomerados foi utilizado madeira do híbrido *Eucalyptus urophylla* e *Eucalyptus grandis* em composição com a vagem de soja, nas proporções de 0%, 25%, 50%, 75% e 100%. Para a avaliação dos painéis utilizou-se de delineamento inteiramente casualizado, com cinco tratamentos e três repetições, utilizou-se a regressão linear e o teste de médias de Scott-Knott a 5% de significância para comparação entre os diferentes tratamentos. Foram avaliadas as propriedades densidade aparente, razão de compactação, absorção de água após 2 h e 24 h, inchamento em espessura após 2 h e 24 h em imersão em água, ligação interna, módulo de ruptura e módulo de elasticidade na flexão estática. O efeito da proporção de resíduo de vagem da soja com partículas de eucalipto nos painéis promoveu aumento nos valores de absorção de água e inchamento em espessura e diminuição das propriedades mecânicas. Os painéis produzidos com aproximadamente 23% de vagem da soja possuem viabilidade técnica de produção.

Termos para indexação: Eucalipto; vagem de soja; resíduos agrícolas; propriedades físicas e mecânicas.

INTRODUCTION

The production and use of particleboards in Brazil has been increasing in recent years. In 2014, the production of Panels was 7.98 million cubic meters, 95% of which was destined to the domestic market, mainly for building construction and furniture industry (Ibá, 2015).

Among the different types of panels, it is possible to highlight particleboards, which emerged in Germany in the early 1940s, whose main objective was to enable the use of wood waste, since there was a difficulty in the obtention of good quality wood for plywood manufacture, due to Germany's isolation during World War II (Iwakiri, 2005).

The main raw material currently used for the production of this type of board is wood from planted forests, such as eucalyptus and pine. However, the use of waste from various origins in particleboard manufacture has attracted the attention of many researchers, since it

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contributes to meeting the demand for panels, provides adequate waste disposal, preserves natural resources and reduces the disposal of matter which can be raw material for another industry segment (Mendes et al., 2009; Scatolino et al., 2013; Farrapo et al., 2014).

The use of waste from the Brazilian agroindustry is an alternative to meet the demand of the particleboard sector, due to several types of lignocellulosic residues with potential use, such as corn cob, rice husk, coffee hulls, peanut shell, banana pseudostem, coconut husk, cassava stem, castor bean meal, sugarcane bagasse, among others (Gatani et al., 2013; Cravo et al., 2015; Silva et al., 2015; Scatolino et al., 2017; César et al., 2017).

According to Conab (2017), Brazil is the second largest soybean producer, only behind the United States. In the 2015/2016 crop, it occupied an area of 33.2 million hectares, which totaled a production of approximately 95.4 million tons; from the total production obtained, about 39% are beans, and the remaining is waste.

This cellulosic fibrous material is normally intended for cattle feed manufacturing, but has physical and chemical properties which can serve as a raw material in other industrial segments, such as particleboard production.

In this context, this study aimed to evaluate the technological feasibility of the use of soybean waste in the production of low-density particleboards, in association with eucalyptus wood.

MATERIAL AND METHODS

Raw material

Eucalyptus wood of the hybrid *Eucalyptus urophylla* and *Eucalyptus grandis*, with a mean diameter of 25 cm, was collected from a 36-month-old experimental plantation on the campus of Universidade Federal de Goiás, in Jataí. The soybean pods used were obtained from the soybean processing waste of the 2014/2015 crop, in the city of Mineiros - GO.

To obtain the particles, soybean pods and eucalyptus wood passed through a hammer mill. They were then classified using a 6-mm sieve, and slivers were obtained. Subsequently, the particles were dried in a forced air oven up to 5% moisture (dry basis).

Characterization of materials

For the determination of the apparent density of soybean pods and eucalyptus wood, particles of both materials were saturated in water to determine the volume of water displaced (immersion method). Subsequently, the particles were taken to an oven at 105 °C, where they remained until reaching a constant mass, in order to determine the dry mass. Apparent density was obtained by the relationship between absolutely dry mass and saturated volume.

The calculation of total extractives present in soybean pods and eucalyptus wood followed the guidelines of Standard NBR 7987 T204 om-88 (ABNT, 1998).

Panel manufacturing

The urea-formaldehyde resin was used in the experiment at an amount of 12% in relation to particle dry mass. The resin used had the following characteristics: content of solids, 65.07%; pH, 8.04; viscosity, 499 cP, and gelation time, 53 seconds.

The particles were manually mixed with the resin, and the paraffin emulsion was not used. After the resin was impregnated with the particles, they were taken to a mat-forming box (48.0 cm x 48.0 cm). A manual press (0.4 MPa) was used for pre-pressing at room temperature. They were then brought to a hot press, where the pressing cycle was 8 minutes at 180 °C, at a pressure of 3.92 MPa. Three panels (apparent density of 0.50 g cm^{-3} and thickness of 1.5 cm) were prepared for each treatment, consisting of five soybean pod proportions mixed with eucalyptus particles (Table 1).

After production, the particleboards were squared in a circular saw to obtain the final dimensions. Subsequently, the panels were air-conditioned at 20±2 ºC and 65±3% RH; the specimens were removed for evaluation of physical and mechanical properties.

Physico-mechanical properties evaluated and analysis of results

The physical and mechanical properties of the panels were obtained by tests, according to the methodologies specified in Table 2.

Table 1: Particleboard composition with the proportions between soybean pods and eucalyptus wood.

Treatments	Percentage of soybean pods (%)	Percentage of *eucalyptus* (%)
T1	0	100
T2	25	75
T3	50	50
T4	75	25
T5	100	0

Table 2: Evaluated properties.

Properties	Methodology
Apparent density	NBR 14810-3 (ABNT, 2012)
Water absorption after 2- and 24-hour immersion (AA2h and AA24h)	ASTM D-1037 (ASTM, 2012)
Thickness swelling after 2- and 24-hour immersion (IE2h and IE24h)	ASTM D-1037 (ASTM, 2012)
Bending – Modulus of elasticity (MOE) and Modulus of rupture (MOR)	DIN-52362 (DIN,1982)
Internal bonding (LI)	NBR 14810-3 (ABNT, 2012)

The compaction ratio of each board was calculated by dividing the apparent density of the board by the apparent density of the raw material used (Maloney, 1993; Scaolino et al., 2017). The latter was calculated by multiplying the percentage of each material used by its respective apparent density.

The results were analyzed considering a completely randomized design, with the analysis of variance and regression, both at 5% significance, for tests of mechanical and water absorption, as well as thickness swelling. For the comparison of apparent density, extractive content, board density and compaction ratio, the analysis of variance and the Scott-Knott test were carried out, both at 5% significance.

RESULTS AND DISCUSSION

Properties of eucalyptus particles and soybean pods

The mean values of apparent density and extractive content for the raw materials used are shown in Table 3.

A significant difference can be observed between the mean apparent density values of the raw materials used for board manufacture. According to Iwakiri (2005), the apparent density of lignocellulosic materials is one of the main requirements regarding their adaptability for particleboard production, which demonstrates the potential use of these materials for particleboard production.

Regarding the mean values of extractives, a significant difference was observed between eucalyptus wood and soybean pods. The high extractive content in the raw material can influence resin curing and, consequently, the quality of the panels produced, due to the low resistance of the resin-particle bond (Frihart; Hunt, 2010; Scatolino et al., 2017).

Table 3: Apparent density and extractive content for *Eucalyptus* sp. wood and soybean pods.

Raw material	Apparent density (g cm^{-3})	Extractive content (%)
Eucalyptus sp	0.39 ± 0.02 a	3.47 ± 0.8 b
Soybean pods	0.17 ± 0.04 b	26.72 ± 1.6 a

*Means followed by the same letter in the same column do not differ by the Scott-Knoott test at 5% significance.

Apparent density *and compaction ratio*

Table 4 shows the results of apparent density and compaction ratio for particleboards produced with soybean pods and eucalyptus wood.

Table 4: Mean values of apparent density and compaction ratio of the panels.

Percentage of soybean pods (%)	Apparent density (g cm^{-3})	Compaction ratio (%)
0	0.48 ± 0.05 a	1.21 ± 0.13 a
25	0.44 ± 0.04 a	1.32 ± 0.12 a
50	0.46 ± 0.05 a	1.65 ± 0.17 b
75	0.44 ± 0.08 a	1.95 ± 0.35 b
100	0.50 ± 0.09 a	2.95 ± 0.56 c

Means followed by the same letter in the same column do not differ by the Scott-Knoott test at 5% significance.

It can be observed that there was no statistical difference between treatments regarding apparent density. The lowest values observed, based on the nominal apparent density (0.50 g cm^{-3}), can be attributed to the specificity of the laboratory conditions in relation to the industrial process, with losses during handling in the application of the resin, mat formation and pressing. According to Iwakiri (2005), these panels are classified as "apparent density" (up to 0.59 g cm^{-3}).

Regarding compaction ratio, the values ranged from 1.21 to 2.95, and a significant difference was observed as the percentage of soybean pods in the board increased. It is worth mentioning that the apparent density of wood and soybean pods for the calculation of the compaction ratio was 0.39 ± 0.02 g cm^{-3} and 0.17 ± 0.04 g cm^{-3}, respectively.

Only the board containing 25% soybean pods had a mean compaction ratio according to the range reported by Maloney (1993), who assert that the ideal value for particleboard production is between 1.3 and 1.6. The increase in compaction ratio with the increasing soybean pod ratio is due to the apparent density of the material (0.17 g cm^{-3}); thus, a larger number of particles is added to produce the board with the desired apparent density. However, the compaction ratio value of the above-mentioned authors is not indicative of their non-viability.

Maloney (1993) pointed out that a higher compaction ratio can lead to an increase in the specific surface area of the particles. Under these conditions, the application of the same resin content decreases its availability per unit surface area, which can result in panels with lower values in their mechanical properties.

Water absorption and thickness swelling

Figures 1 and 2 show the values obtained for the treatments evaluated in absorption tests after two (AA2h) and twenty four (AA24h) hours of immersion in water.

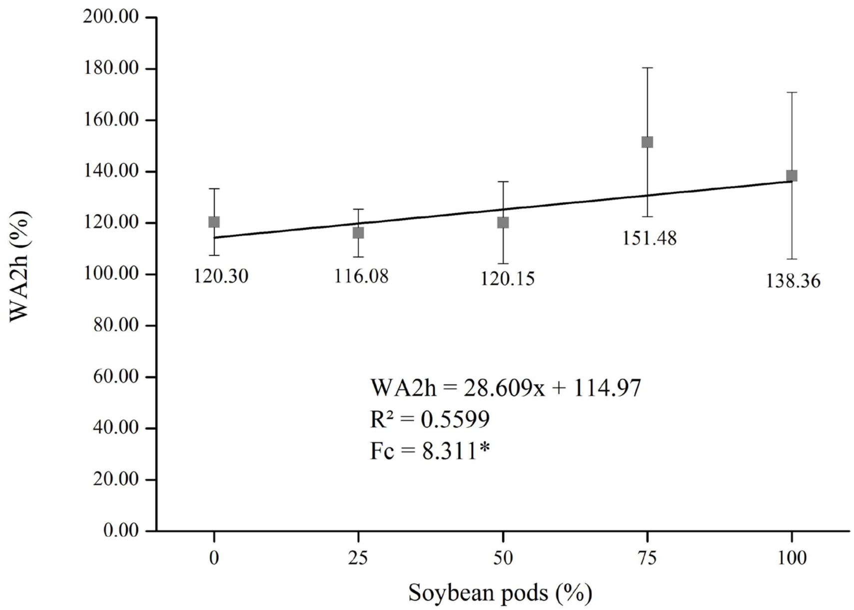

Figure 1: Water absorption after 2 hours of particleboard immersion. *Significant regression analysis at 5% significance.

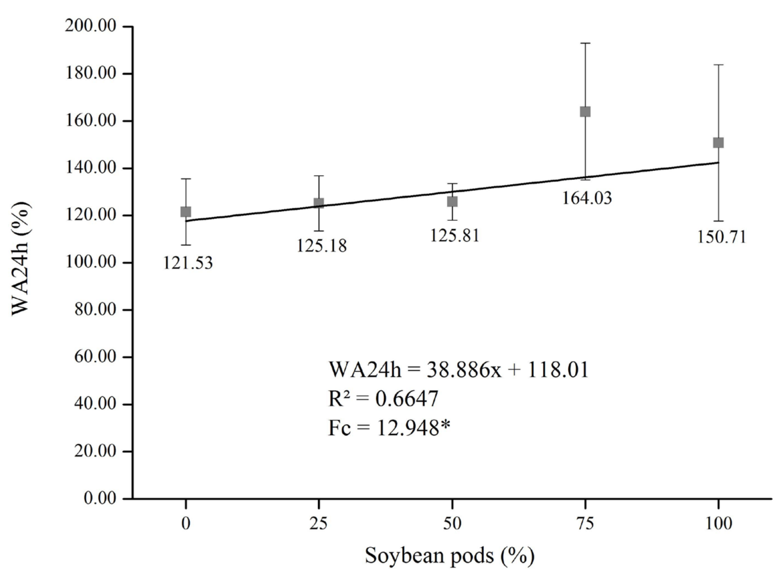

Figure 2: Water absorption after 24 hours of particleboard immersion. *Significant regression analysis at 5% significance.

A significant effect of the percentage of soybean pod particles on water absorption properties was observed after 2 and 24 hours of immersion. There was an increase in the mean values of AA2h and AA24h as the percentage of soybean pods increased. The higher water absorption by the panels with a higher percentage of soybean pods can be explained by the apparent density of the material: in order to obtain the same apparent density of the board, a larger volume of particles is required, resulting in a larger exposed surface, which generates more water sorption sites.

Mesquita et al. (2016) studied panels with different percentages of *Eucalyptus urophylla* wood (0, 10 and 20%) and sisal fibers (0, 10 and 20%), and observed a behavior similar to that of this study where, as the proportion of sisal fibers in the mixture increased, there was an increase in water absorption after 2 and 24 hours of immersion in water.

Guimarães Júnior et al. (2016) studied eucalyptus particleboards produced with different amounts of sorghum residues (0, 15, 30 and 45%), and observed an increase of 1.4 and 1.6% in the properties of AA2h and AA24h to every 1% of sorghum residue added in the panels. These values are higher than those found in this study for soybean pod waste.

The mean thickness swelling values of the particleboards after two (IE2h) and twenty four hours of immersion in water (IE24h), for each treatment, are shown in Figures 3 and 4, respectively.

Significant correlations were observed between the percentage of soybean pods in particleboards and thickness swelling after 2 and 24 hours of immersion. As for AA2h and AA24h, an increase in IE2h and IE24h values was verified as the percentage of wood replacement was increased by soybean pod particles. For IE2h and IE24h, the mean values ranged from 10.38 to 42.78% and from 15.04 to 53.18%, respectively. According to Silva et al. (2015), this result can be explained by the gradual increase in compaction ratio (Table 4), leading to the decrease in the amount of resin per unit area. Another factor that may have negatively affected the physical properties of the panels is related to the higher amount of extractives present in soybean pods, compared to *Eucalyptus grandis* wood, which can interfere with resin curing and, consequently, the dimensional stability of the panels.

Fiorelli et al. (2015) evaluated the use of different fiber percentages of green coconut shell in medium-density particleboards produced with *Pinus* spp., and observed that, the larger the amount of waste in the panels, the greater the thickness swelling values after 2 hours of immersion in water. The same behavior was observed by César et al. (2017), who studied panels produced with rice husks and *Cunninghamia lanceolata*.

For the property thickness swelling after 24 hours of immersion in water, Silva et al. (2015) concluded that, the greater the percentage of corn straw in particleboards produced with *Eucalyptus grandis* wood, the greater the thickness swelling in the board. The authors report that this increase is related to the higher compaction ratio of panels produced with corn straw.

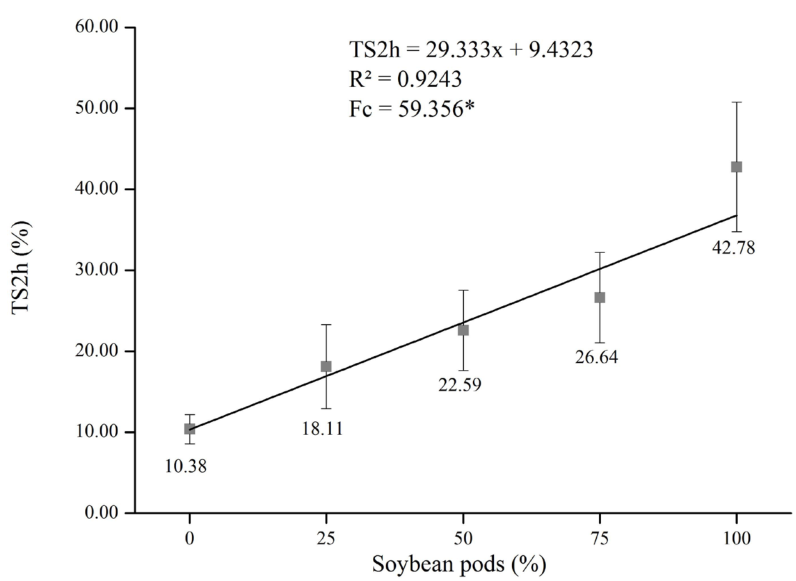

Figure 3: Thickness swelling after water immersion of particleboards for 2 hours. *Significant regression analysis at 5% significance.

The Standard CS 236-66 (Commercial Standard, 1968) requires panels with maximum thickness swelling values of 30% after 24 hours of immersion in water (low density panels produced with urea-formaldehyde) for commercialization. In this case, the maximum soybean pod proportion in the particleboard to meet the requirements of this Standard would be 43.3%.

Mechanical properties of particleboards

The regression model adjusted as a function of the increase in the percentage of soybean pods for internal bonding values, is shown in Figure 5.

A significant negative correlation is observed between the percentage of soybean pods and internal bonding, that is, the higher the percentage of soybean

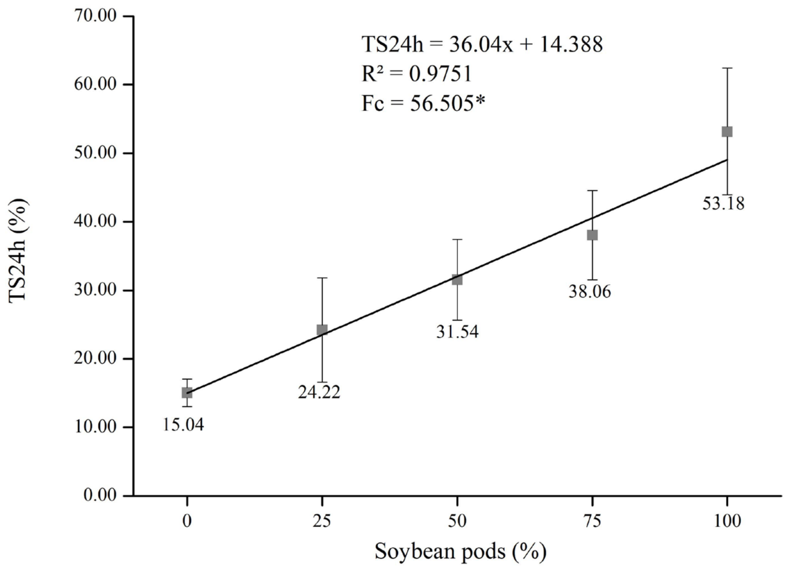

Figure 4: Thickness swelling after water immersion of particleboards for 24 hours. *Significant regression analysis at 5% significance.

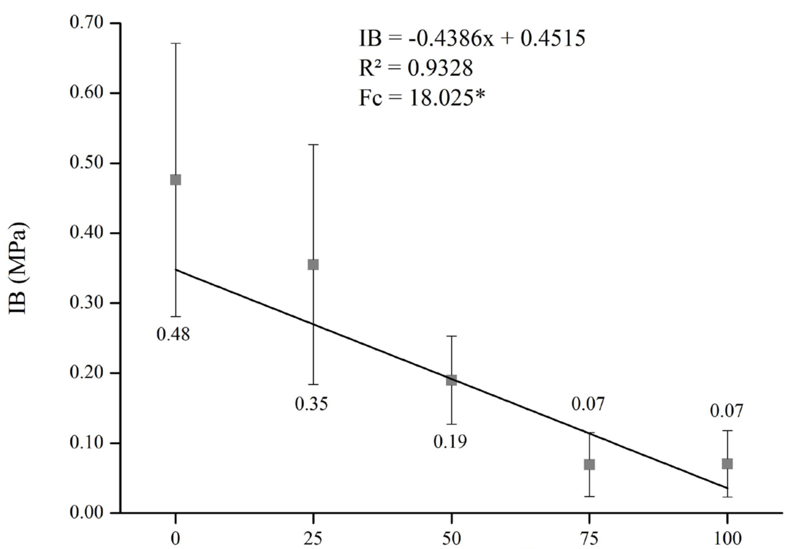

Figure 5: Relationship between the percentage of soybean pods used and internal bonding. *Significant regression analysis at 5% significance.

pods in the particleboard, the weaker its internal bonding.

Internal bonding is a property that evaluates the bonding relationship between particles. In this context, the behavior visualized in Figure 5 can be explained by the increase in extractive content of the panels, as the percentage of soybean pods increases. As noted above, high extractive concentrations impair resin curing in the board, resulting in weak bonding between particles and resin.

Mesquita et al. (2016), evaluated the physico-mechanical properties of medium-density particleboards produced with different wood proportions (*Eucalyptus urophylla*), sisal fibers and coconut fibers (coir), and observed that the increase in the percentage of sisal fibers and coir particles results in a decrease in internal bonding. According to César et al. (2014), materials that have lower density generate a larger amount of particles for a given weight and thus a higher specific surface requires higher amounts of adhesive to obtain good properties.

Commercial standard CS 236-66 (Commercial Standard, 1968) sets a minimum value of 0.14 MPa for internal bonding in low-density panels produced with urea-formaldehyde resin. In this context, equating this value with the equation observed in the linear regression, it is noticed that the maximum soybean pod proportion in the board that meets the normative requirements is 71.0% soybean waste.

The regression model adjusted as a function of the increase in the percentage of soybean pod particles for modulus of elasticity (MOE) and modulus of rupture (MOR) to bending are shown in Figures 6 and 7, respectively.

A significant negative correlation between percentage of soybean pods and modulus of elasticity (MOE) and modulus of rupture (MOR) was observed, that is, the higher the percentage of soybean pods in the particleboard, the lower the MOE and MOR. The reduction in the values of these properties is directly related to the decrease in internal binding values of the panels (Maloney, 1993).

This downward trend was also observed by Mendes et al. (2010), when evaluating MOE and MOR values as a function of increasing percentages of coffee hulls (25%, 50% and 75%) in particleboards, and this decrease ranged from 800 to 300 MPa for MOE and 6 to 2 MPa for MOR.

In a study conducted with macadamia nutshell residue to produce panels at different proportions, Ferreira, Campos and Gonçalves (2014) concluded that the decrease in MOE with increased residue insertion can be justified by the fact that these lignocellulosic residues had a lower plasticity than wood, that is, they are more elastic and less rigid, which may influence the deformability of the material.

Commercial standard CS 236-66 (Commercial Standard, 1968) sets 1052 MPa for MOE and 5.6 MPa for MOR as a minimum value for low-density panels and urea-formaldehyde resin. When the normative values are equal in the linear regression generated for these properties, it is observed that the limit point of the soybean pod proportion in the board, in compliance with the above-mentioned normative requirements, is of 23% and 27% for MOE and MOR, respectively.

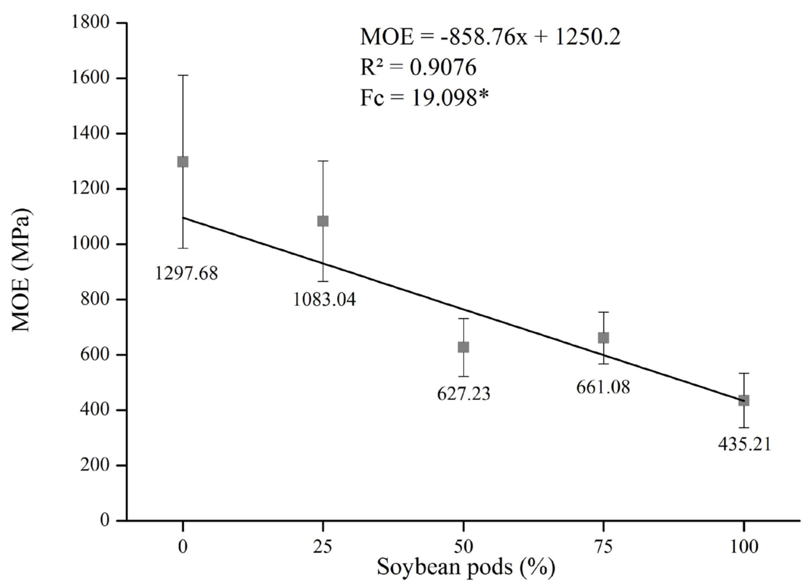

Figure 6: Modulus of elasticity in bending for particleboards. *Significant regression analysis at 5% significance.

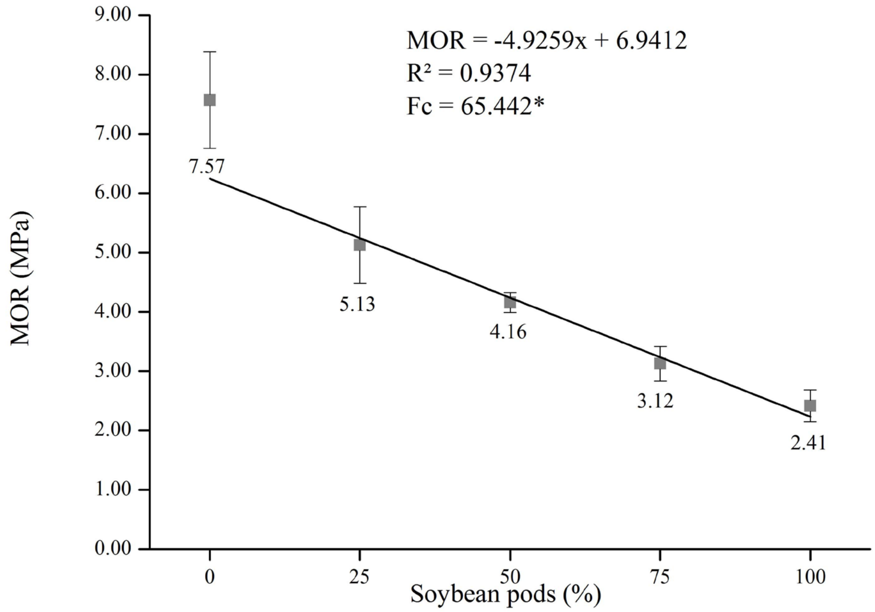

Figure 7: Modulus of rupture in bending for particleboards. *Significant regression analysis at 5% significance.

CONCLUSIONS

In general, the reduction in the physico-mechanical properties of panels produced with soybean pods is related to the apparent density of the waste used and the higher percentage of extractives. The ratio soybean pod waste and eucalyptus particles in the panels led to an increase in water absorption values and thickness swelling, in addition to a decrease in mechanical properties. The production of panels with approximately 23% soybean pods is feasible.

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REFERENCES

AMERICAN SOCIETY FOR TESTING AND MATERIALS - ASTM. **Annual book of ASTM: D-1037:** Standard methods of evaluating properties of wood-base fiber and particles materials. Philladelphia, 2012. 31p.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. **NBR 14810**: Chapas de madeira aglomerada parte 3: métodos de ensaio. Rio de Janeiro, Brasil, 2012. 51p.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. **NBR 7987 T 204 om-88**: Madeira: Determinação dos teores de extrativos. Rio de Janeiro, 1998. 6p.

CÉSAR, A. A. S. et al. Transforming rice husk into a high-added value product: Potential for particleboard production. **Ciência Florestal**, 27(1):303-313, 2017.

CÉSAR, A. A. S. et al. Analysis of the gluing quality pf particles from OSB panels in laboratorial conditions. **Cerne**, 20(4):501-508, 2014.

COMMERCIAL STANDARD - CS. **CS 236-66: Mat formed wood particleboard**. [S.l.], 1968. 3p.

COMPANHIA NACIONAL DE ABASTECIMENTO - CONAB. **Safra 2016/17 - v. 4 n. 5 - quinto levantamento, fevereiro 2017**. 2017. Available in: <www.conab.gov.br/OlalaCMS/uploads/arquivos/17_02_16_11_51_51_boletim_graos_fevereiro_2017.pdf>. Access in: February, 23 2017.

CRAVO, J. C. M. et al. Painel aglomerado de resíduos agroindustriais. **Ciência Florestal**, 25(3):721-730, 2015.

DEUTSCHES INSTITUT FUR NORMUNG - DIN. **Testing of wood chipboards, bending test, determination of bending strength:** DIN 52362. Berlin, 1982. 8p.

FARRAPO, C. L. et al. Utilization of *Pterocarpus violaceus* wood in the particleboard production. **Scientia Forestalis**, 42(103):329-335, 2014.

FERREIRA, B. S.; CAMPOS, C. I.; GONÇALVES, M. T. T. Use of macadamia nutshell in the production of *Eucalyptus Salign* particleboards. **Advanced Materials Research**, 1025(2):246-250, 2014.

FIORELLI, J. et al. Painéis de partículas monocamadas fabricados com resíduo de madeira e fibra de coco verde. **Scientia Forestalis**, 43(105):175-182, 2015.

FRIHART, C. R.; HUNT, C. G. Adhesives with wood materials - Bond formation and performance. In: FOREST PRODUCTS LABORATORY (eds.). **Wood Handbook**. USDA, Madison, WI, USA. 2010. p.10.1-10.24.

GATANI, M. P. et al. Viabilidade técnica de produção e propriedades de painéis de partículas de casca de amendoim. **Revista Matéria**, 18(2):1286-1293, 2013.

GUIMARÃES JUNIOR, J. B. et al. Inclusão de resíduo da cultura de sorgo em painéis aglomerados de eucalipto. **Pesquisa Florestal Brasileira**, 36(88):435-442, 2016.

INDÚSTRIA BRASILEIRA DE ÁRVORES - IBÁ, **Relatório IBÁ 2015**. 2015. Available in: <http://www.iba.org/images/shared/iba_2015.pdf>. Access in: July, 02 2015.

IWAKIRI, S. **Painéis de madeira**. Curitiba: FUPEF, 2005. 247p.

MALONEY, T. M. **Modern particleboard and dry-process fiberboard manufacturing**. 2. Ed. São Francisco: Miller Freeman, 1993. 689p.

MENDES, L. M. et al. *Eucalyptus urophylla* stands wood utilization at two different ages for production of particleboard panels. **Cerne**, 15(3):288-294, 2009.

MENDES, R. F. et al. Efeito da incorporação de casca de café nas propriedades físico-mecânicas de painéis aglomerados de *Eucalyptus urophylla* S. T. Blake. **Ciência e Agrotecnologia**, 34(3):610-617, 2010.

MESQUITA, R. G. A. et al. Coir and sisal fibers as fillers in the production of *Eucalyptus* medium density particleboards – MDP. **Materials Research**, 19(6):1429-1436, 2016.

SCATOLINO, M. V. et al. Eucalyptus wood and coffee parchment for particleboard production: Physical and mechanical properties. **Ciência e Agrotecnologia**, 41(2):139-146, 2017.

SCATOLINO, M. V. et al. Uso do sabugo de milho na produção de painéis aglomerados. **Ciência e Agrotecnologia**, 37(4):330-337, 2013.

SILVA, D. W. et al. MDP com partículas de eucalipto e palha de milho. **Scientia Forestalis**, 43(108):853-862, 2015.