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Palm Kernel based Wood Adhesive

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Abstract: Palm kernel cake is a by-product of palm kernel oil industry. The production of palm kernel cake is more than 5000 million tons annually in the past few years. This quantity is expected to rise further in the future due to production of bio-diesel. Currently palm kernel cake is used for animal feed supplement such as cattle and goat. Due to indigestible compounds in palm kernel cake, it is less suitable for animals such as poultry, fish and swine. However palm kernel cake contains about 20% protein, with this protein composition palm kernel cake can be used as ingredient of protein based resin. Unlike soya bean which contain higher protein composition and can be used directly as ingredient of protein based resin, palm kernel cake require protein enhancement before it can be used for this purposes. In this study, wood adhesive was produced using palm kernel cake with protein content enhancement as a base ingredient. Soya protein extract was selected as a protein enhancement of palm kernel cake. Here the enhanced protein content palm kernel cake was reacted with *polyetheleneimine* and *maleic anhydride* at alkali environment. The experimental study was conducted at various compositions and various strength of alkali. The wood adhesive produced was tested on type II plywood. Japanese Agriculture Standard of strength and durability test was employed for the characterization of the adhesive produced. Results show that, palm kernel cake can be used as ingredient of protein based wood adhesive. In certain condition the mixture of palm kernel and soya protein show that the wood adhesive produced better strength and reliability compared to unmixed soya protein extract.

Key words: Protein based resin, polyetheleneimine, maleic anhydride, protein enhancement

INTRODUCTION

The various forms of wood utilization represent an extremely large and diverse market for adhesives (Lambuth, 1994). The wood industry has diversified into the production of downstream products, such as composite furniture products and engineering woods products, including plywood, medium density fiberboards and particleboards. Wood adhesives and resins have greatly contributed to the construction and housing industries for about a century and will continue to play an important role in this field. In early of this decade the worldwide wood adhesive consumption was 13.3 million tons and total sale value reached more than $6 billion (Seller, 2001). At present, formaldehyde-based adhesives such as Phenol-Formaldehyde (PF) and Urea-Formaldehyde (UF) and Melamine-Urea-Formaldehyde (MUF) resins are used predominantly as adhesive for production of wood composites (Bono *et al*., 2006, 2007, 2008).

However, the emission of formaldehyde, especially from the breakdown of UF resins in wood composites, poses a great hazard to human health because formaldehyde is human carcinogen. On daily life, formaldehyde is emitted into the air from composite wood products at manufacturing plants, fabrication facilities, home construction sites, remodeling construction, goods transport, lumberyards and through windows, doors and ventilation systems in homes and other buildings when unreacted formaldehyde is released from urea-formaldehyde resins (International Agency for Research on Cancer, 2004).

In addition, formaldehyde-based adhesives are derived from non-renewable petrochemicals and natural gas and hence still have toxic chemical problems associated with their manufacture. Unfortunately, there is no method to degrade them at rate comparable to our current rate of consumption. The problem of non-biodegradability is highlighted by overflowing landfills, polluted marine waters and unsightly litter (Huang, 1995).

These problems and harmful effects of formaldehyde emission have lead to increased efforts in research towards developing formaldehyde-free, environment-friendly, safer, biodegradable green alternatives, particularly the sustainable ones based on yearly renewable plants (Peijs, 2002).

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Green chemistry is the environmentally benign chemical synthesis with attractive economics and performance. The synthesis schemes are designed in such a way that there is least pollution to the environmental and the waste products are minimum (Ahluwalia and Kidwai, 2004). There has been renewed interest in the development of protein based wood adhesives in recent years for improving the strength and water resistance of wood composite panels bonded with protein-based adhesives. Researchers prepared adhesives with alkali (NaOH)- and trypsin-modified soy proteins. They found that the bond strength and water resistance of the modified soy protein adhesives were enhanced compared with those of unmodified soy protein adhesives. Sun and Bian also found that urea-modified soy protein adhesives were more water-resistant than those modified by alkali (Sun and Bian, 1999).

Huang and Sun (2000a,b) investigated adhesive properties of soy proteins modified with different concentrations of urea and Guanidine Hydrochloride (GH). The results indicated that both urea and GH concentrations had significant effects on the extent of protein unfolding and consequently, on adhesive properties. Compared to the unmodified protein, the modified proteins also exhibited higher shear strengths after incubating with two cycles of alternating relative humidity, zero delamination and higher remaining shear strengths after three cycles water soaking and drying. These results indicate that soy proteins modified with urea and GH enhance water resistance as well as adhesive strength. Partly unfolded protein molecules with a certain amount of secondary structure may be desirable for protein adhesion (Huang and Sun, 2000a). Polyamidoamine-epi-chlorohydrin (PAE) resin has been found to be excellent curing agent for soybean protein. A patented technology based on soybean flour and the PAE resin has been successfully used in the commercial production of plywood and particleboard (Li *et al*., 2004). Although, various research groups have tried to synthesize these proteins in genetically modified bacteria, their commercial use is limited owing to high production costs (Acosta, 2007).

A novel adhesive based on Soy Flour (SF), Maleic Anhydride (MA) and polyethyleneimine (PEI) has been developed (Li and Huang, 2008). However, the usage of soy flour as a resin ingredient will compete with the production of food and animal feed. Alternatively we should look at the possibility of utilization of palm kernel cake as an ingredient of plant protein based resins. Palm kernel cake is by-product of palm kernel oil industry. The production of palm kernel cake well over 5000 million tons annually, this quantity is expected to rise further due to the current development of biodiesel demand (Sumathi *et al*., 2008). Unlike soya bean, palm kernel cake contains 20% protein which lowers than the protein contains of soya bean. Therefore, protein content enhancement of palm kernel is required in order of utilizing palm kernel as ingredient of protein based resins. The protein content enhancement of palm kernel can be done by adding protein extract of palm kernel itself, soya protein extract or protein extract from micro-algae. Here in this paper, palm protein content was enhanced by adding soya extract at various ratios to produce resin to be used as wood adhesive.

MATERIALS AND METHODS

The experimental study was conducted according to the production of soya protein based resin (Li and Huang, 2008). The study involved was the reaction of selected chemicals such as polyetheleneimine (PEI) and Maleic Anhydride (MA) with soya protein in alkali conditions. In this research soya protein is replaced with palm kernel or the mixture of palm kernel and soya protein. Therefore the experimental study involves the selection of materials (i.e., palm kernel cake, PEI and MA), preparation of palm kernel, production of wood adhesive, production of type II plywood and the test of wood adhesive on type II plywood.

Selection of materials: The chemicals used for production of wood adhesive was 50 wt.% aqueous PEI solution (M_w = 750,000), Maleic Anhydride and NaOH. These chemicals were purchased from Sigma-Aldrich. Materials for production of type II plywood was Red-Meranti veneer, it was provided by Shin Yang Chemical Sdn. Bhd. For the enhancement of palm kernel protein content, soya protein extract with 84 wt.% protein was selected. This soya protein extract was purchased from local market in the form of high protein soy drink. Palm kernel cake by-product of palm kernel oil production was purchased from local Palm Oil Mill.

Preparation of palm kernel: The palm kernel cake obtained from Palm Oil Mill was contained of trace oil. The trace oil was removed to avoid interference during the production of wood adhesives. The trace oil removal was conducted using soxhlet solid-liquid extraction technique. Prior the oil removal the palm kernel cake was grinded to form fine particle for higher extraction efficiency. Iso-propanol was selected as an extraction solvent. The extraction was conducted at solvent boiling temperature and was left running for 10 h. The palm kernel cake was then dried in oven for removal of trace solvent.

Table 1: Summary of shear strength and delaminating test of type II plywood produced using various formulation of palm kernel based wood adhesive

Weight ratio (based on dry wt of PEI 3.16 g)							
Oil free PKM	SP	PEI	MA	80 g [NaOH] solution (N)	Average shear strength of 9 specimens plywood (Mpa)	Delaminating test No. of failure/total specimens	Overall plywood test: Pass (P) or Fail (F)
0.0	5.0	1.0	0.32	0.5	0.7113±0.1390	0/6	P
				1.0	0.3724±0.0651	0/6	F
				1.5	0.1130±0.1712	1/6	F
2.5	2.5	1.0	0.32	0.5	0.5492±0.0433	0/6	F
				1.0	0.8212±0.0543	0/6	P
				1.5	0.5574±0.0881	0/6	F
3.5	1.5	1.0	0.32	0.5	0.5297±0.0607	0/6	F
				1.0	0.6831±0.1039	0/6	F
				1.5	0.8275±0.1411	0/6	P
4.5	0.5	1.0	0.32	0.5	0.0412±0.0171	5/6	F
				1.0	0.3928±0.0597	3/6	F
				1.5	0.5084±0.1393	0/6	F
5.0	0	1.0	0.32	0.5	-	-	F
				1.0	-	-	F
				1.5	-	6/6	F

Production of wood adhesives: The production of wood adhesive was involving the reaction of protein with polyetheleneimine and maleic anhydride at alkali condition. Sodium hydroxide was used for providing alkali conditions. Prior the reaction oil free palm kernel cake powder was mixed with soya protein extract at various ratios. The mixture then was added into alkaline solution of polyetheleneimine and maleic anhydride. The reaction was left for 5 min before it was used as adhesive for making type II plywood. The ratios of materials and chemicals used for the production of wood adhesive was recorded and presented in Table 1.

Production of type II plywood: The production of type II plywood was conducted using Red-Meranti 300×300×3.3 mm veneer. In order to get consistence result veneer was maintain at 10% moisture content and the equal amount of wood adhesive were used at every plywood produced. The adhesive was applied onto two sides of a core veneer using a glue spreader. The spread rate of the adhesive was 23 mg cm^{-2}. The adhesive-coated core veneer was stacked between two uncoated face veneers. The grain directions of the two adjacent veneers are perpendicular to each other. The unfinished plywood was left at room temperature for 5 min, before it was cold pressed 9 kg cm^{-2} for 20 min. Once reaches 20 min the unfinished plywood was removed from the cold press device and left free 5 min before it was transferred to hot press device. During hot pressed, pressure at 9 kg cm^{-2} and temperature of 135-140°C were applied. The process was conducted for 5 min. Once the hot press completed, the plywood product was released from the device and was stored at room environment for 24 h before it was tested for its shear strength and water resistance.

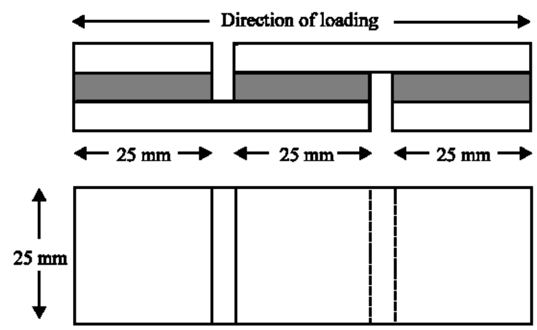

Fig. 1: Dimension of plywood test pieces for bonding test

Performance test of wood adhesive

Shear strength: The shear strength of type II plywood produced here was determined by bonding test according to the Japanese Agriculture Standard (JAS) for structural plywood. Total of nine plywood test pieces (25×80 mm) were tested for every trial plywood panel produced. The dimension of plywood test pieces is shown in Fig. 1. Prior the test, the test pieces were soaked in a hot water bath at 60°C for 3 h and followed by soaking it at cold water bath at room temperature. Once the test pieces reached cold state, then it were tested for shear strength. The test was conducted using Jiing Koou HT-8311C bonding testing machine while the plywood test pieces were wet. According to the standard, any plywood panel having the shear strength less than 0.7 MPa is considered fail.

Water resistance: The water resistance was determined by immersion delaminating test (soaking test). This test was also adopted from the Japanese Agriculture Standard (JAS) for structural plywood. Here, six of plywood test pieces with size of 75×75 mm were immersed in hot water bath at 70°C for 2 h and followed of drying in the oven at 60°C for 3 h. After the drying procedure, test pieces were inspected for the delamination. The plywood produced here will be considered fail if any of the test piece delaminated.

RESULTS AND DISCUSSION

The formulation details of wood adhesive developed in the experimental study is summarized in Table 1. This table is also present the shear test, delaminating test and overall test results. Out of fifteen formulations, only three were pass overall test. These formulations are unmixed soya protein extract with 0.5 N NaOH, Mixture of (50% palm kernel and 50% soya protein extract) with 1.0 N NaOH and mixture of (70% palm kernel and 30% soya protein extract) with 1.5 N NaOH.

The result of overall test shows that palm kernel cake can be used for production of protein based resin or wood adhesive. In certain cases the mixture of palm kernel cake with soya protein extract produces better performance wood adhesive compared to unmixed soya protein extract. However the mixture palm kernel cake with soya protein extract required higher alkali concentration in order to produce better performance wood adhesive. The alkali concentration effects on the performance of wood adhesive can be observed in Fig. 2. This figure is clearly shows that the shear strength of all plywood produced out of formulations which include palm kernel cake was rise with the increases of alkali concentration. The result also show the higher ratio of palm kernel cake to soya protein extract will require higher alkali concentration to produce better performance wood adhesive. This phenomena may due to the solubility of palm kernel cake is increases with the increase of alkali concentration.

The formulation with non-added soya protein to palm kernel cake was unable to produce usable wood adhesive. This show that the protein content of palm kernel has to be enhanced before it can be used for protein based wood adhesive production. The effect of wood adhesive performance on the addition of soya protein onto palm kernel cake can be observed in Fig. 3. This Fig. 3 show that there is optimum amount of soya protein extract can be added to palm kernel cake to get the best wood adhesive performance.

Furthermore, PEI and MA are also essential components for the final adhesive networks. In the study of Li and Huang (2008), it was demonstrated that MA first react with Pei to form amide-linked maleyl groups that further reacted with amino group in soy flour (SF) and PEI during a hot-press of making plywood panels. In this study, PKM and SP were used to replace the SF as ingredient for making PKM-SP-PEI-MA adhesive. In palm kernel wood adhesive, PKM and SP might contain some

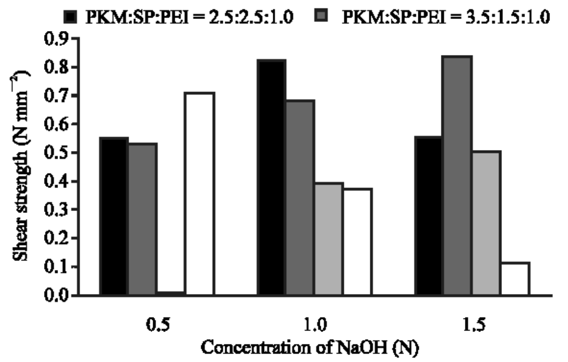

Fig. 2: Shear Strength of plywood with various alkali (NaOH) concentration

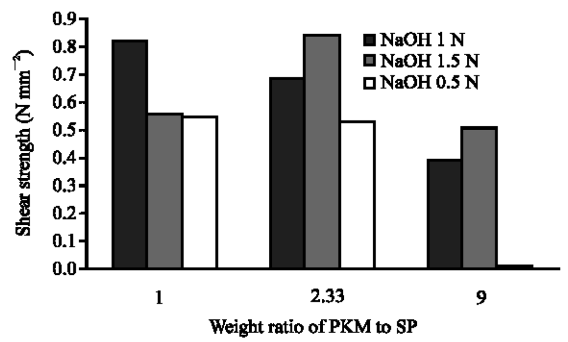

Fig. 3: Shear strength of plywood wit various ratio of PKM to soy protein extract

water-soluble carbohydrates that would reduce the water resistance of adhesive bonds. The PEI-MA adduct might coat or bundle water-soluble carbohydrates, thus minimizing their negative effects on the water resistance. Hydroxyl groups of the carbohydrates might also react with PEI-MA adduct via Micheal addition although hydroxyl groups are weaker nucleophiles than amino groups, thus further reducing the negative effects of water-soluble carbohydrates on the water resistance (Li and Huang, 2008).

CONCLUSION

The research presented in this study can be concluded that palm kernel cake can be used for protein based resin production. However due to the lower protein content of palm kernel cake, protein enhancement of palm kernel cake is required before it can be used for protein based resin or wood adhesive production. Protein content enhancement of palm kernel cake can be made by addition of palm kernel protein extract or soya protein into palm kernel cake. Using palm kernel cake as an ingredient of protein based resin will compliment the usage of soya protein.

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