Soy Flour Substitution in Polymeric Diphenylmethane Diisocyanate Resin Reduces Press Platen Sticking*

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Abstract

Partial (10% to 30%) substitution of soy flour in polymeric diphenylmethane diisocyanate (pMDI) resin substantially reduces platen sticking during hot-pressing of particle mats. Adding the soy flour to a fixed dose of pMDI (instead of substituting it) reduces platen sticking to an even greater extent. The soy decreases the tack of cured pMDI, thereby reducing the propensity of resinated particles to transfer to the platen. The tack reduction effect of soy on cured pMDI contrasts with its effect on uncured pMDI, where the cold tack is increased.

Partial substitution of soy flour in polymeric diphenylmethane diisocyanate (pMDI) resin provides cost and operational benefits (Cheng et al. 2019). The cost of soy flour is presently less than half that of pMDI, so that soy substitution reduces the overall resin cost. Operationally, soy flour increases the cold tack of pMDI resin (Asafu-Adjaye et al. 2020a) as well as the internal bond strength of strand board and medium-density fiberboard. Wet properties improve in both laboratory and pilot settings, which further increases the cost effectiveness of soy (Asafu-Adjaye et al. 2020b). The upper limit of soy flour substitution is about 20 to 30 percent depending on the furnish, beyond which wet properties begin to degrade. Improved wet properties with our method is particularly attractive given soybean protein is not waterproof for most methods (Zheng et al. 2021).

pMDI resin (along with wood particles bonded to it) tends to stick to press platens, which increases maintenance downtime (Kawasaki et al. 1999, Gagnon et al. 2004, Sonnenschein and Wendt 2005, Gupta et al. 2010, Costa and Grunert 2019). Various release agents are applied to both the mat and the platen to partially control the problem (Halvarsson et al. 2010, Block et al. 2011), but they add to cost. Platen sticking is caused by the reaction of pMDI with the metal surface of the platens (Shimizu et al. 2010, Phanopoulos et al. 2018). Spectral analysis revealed the formation of carbamate-type bonds between the isocyanates and the oxidized metal surface. Similar carbamate bonds are formed between isocyanates and groups present in wood (Weaver and Owen 1995). In this paper we demonstrate that soy flour–modified pMDI decreases platen sticking of hot-pressed boards and propose a mechanism.

Materials and Methods

Defatted soy flour (7B) was provided by Archer Daniels Midland (Chicago, Illinois); its dry-basis moisture content was 6.2 percent. The pMDI resin was MONDUR 541 from

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* This article is part of a series of selected articles addressing a theme of bringing academia, industry, and government entities together to work on innovation and applied technologies. The research reported in these articles was presented at the PTF BPI Conference, held on November 1–3, 2021, in St. Simons Island, Georgia. All articles are published in this issue of the Forest Products Journal.

Forest Prod. J. 72(S1):5–7.
doi:10.13073/FPJ-D-21-00056

Covestro. Sawdust particles (0.5 to 1.5 mm) were provided by a local West Fraser sawmill and conditioned to an ambient 6 to 7 percent moisture content. The adhesive loading was 4 percent based on wood dry weight; it was higher for the runs where soy was added to pMDI. The soy–pMDI mixture was prepared by stirring soy flour into pMDI at 40°C and was used within a few minutes of preparation. The viscosity of the mixture rises over time, and the resin mixture was used within an hour of mixing. Particles were coated with pMDI in one case, and with soy flour–substituted pMDI in another, using a rotary blender, and placed on 0.8-mm aluminum shim stock precleaned with 320-grit sandpaper. The mats were pressed at 200°C and 2 MPa for 4 min. Control and test coupons (26 or 232 cm^2) were pressed simultaneously, and the results are only to be compared within each run.

For measurements of particle retention on the platens, the pMDI was (1) substituted and (b) supplemented with 10 to 30 percent soy flour by weight. Samples of resinated wood particles weighing 1 or 5 g were pressed simultaneously on 26 or 232 cm^2 platens respectively at 180°C for 1 min at 0.6 MPa. Similar results were obtained from the two sets of platens. The wood particles stuck on the platens were scraped off with a razor blade and weighed. All measurements were duplicated.

Results and Discussion

pMDI resinated particle mats containing various levels of soy flour were pressed between aluminum plates. The weights of particles scraped off the plates after removal of the pressed boards are listed in Table 1. Corresponding images are provided in Figure 1. Clearly, increasing soy flour substitution decreases the attachment of resinated particles. A reviewer pointed out that the reduction in particle count could merely be a consequence of the smaller amount of pMDI present in the soy-substituted resin. Because the total resin dose was unchanged at 4 percent, soy flour substitution reduced the actual amount of pMDI present. This possibility was discounted by *adding* soy flour to the pMDI, rather than *substituting* it. The results, presented in Figure 2 and Table 2, reveal that soy addition actually lowers particle deposition to a much greater extent. A comparison of the effect of soy substitution versus soy addition on the percentage of decrease in weight of the particles attached to 232-cm^2 platens is provided in Figure 3.

Table 1.—Weight of particles stuck to platens after pressing with soy-substituted polymeric diphenylmethane diisocyanate (pMDI).

Soy-substituted (% weight of pMDI)	Particle weight (mg) 232-cm^2 platen
0	570 ± 10
10	470 ± 10
20	390 ± 6
30	270 ± 10

A complementary experiment was conducted where the plates were coated with pMDI substituted with 0 to 20 percent soy flour and then used to press particle mats containing no resin. In other words, while the work described above used resin mixed with particle before pressing, here, the resin was coated on the platens and the particles were pressed untreated. Images of the plates after removal of the mats are illustrated in Figure 4. Fewer particles adhere to the soy flour–treated plates confirming that the soy-modified pMDI resin coating forms a weaker bond with the wood furnish during densification. In Figures 1 and 2, the resin, particles and metal were all present at the interface; in Figure 4, the resin coated the plate so only the resin–wood interface was involved. Hence, the soy flour weakens the pMDI bond with both metal (Figs. 1 and 2) and wood (Fig. 4). For wood, the weakness is apparently offset by an increase in the relative bonded area.

Figure 3 demonstrates that adding, rather than substituting soy flour in pMDI is much more effective for reducing platen sticking. Substituting soy flour into pMDI leads to new interactions between the (pMDI–soy) adduct and metal and wood. The metal is not present at the interface in the Figure 4 measurement, so the tack reduction caused by soy must be only due to a weaker interaction between wood and the resin. These observations relate to resin tack and not to board strength. Previous work (Asafu-Adjaye et al. 2020b) has shown that 10 to 15 percent soy flour substitution in pMDI increases board strength to a small extent. Tack and strength are not necessarily correlated, being based on surface and bulk properties respectively. There is an important practical aspect to these findings. Soy substitution would reduce resin cost and provide some benefit in platen sticking. However, if the goal is only to reduce sticking, e.g., to increase production speed, then adding soy to a constant pMDI dose would be preferred over substitution.

In conclusion, soy flour has opposing effects on the hot and cold tack of pMDI; it decreases the former and increases the latter. As reasoned above, the reduction in hot tack is likely a consequence of weaker resin-particle surface interactions. For cold tack, the better resin spread induced by the soy flour is believed to be responsible for the higher tack.

Acknowledgments

This project was funded by the United Soybean Board and the Alabama Farmers Federation.

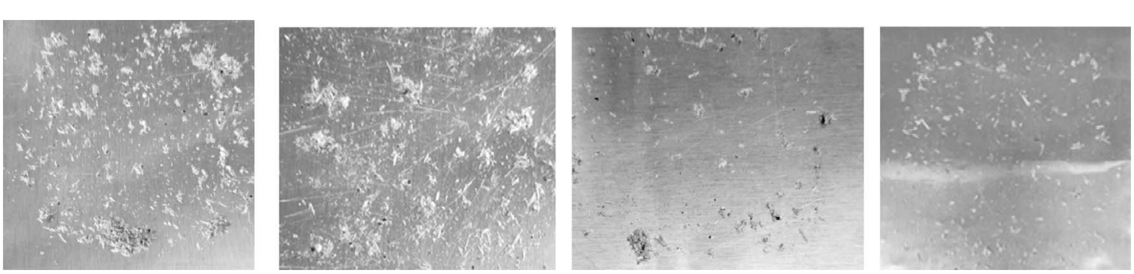

Figure 1.—Images of platens after pressing particle with polymeric diphenylmethane diisocyanate (pMDI) with 0 to 30 percent soy flour substitution (left to right).

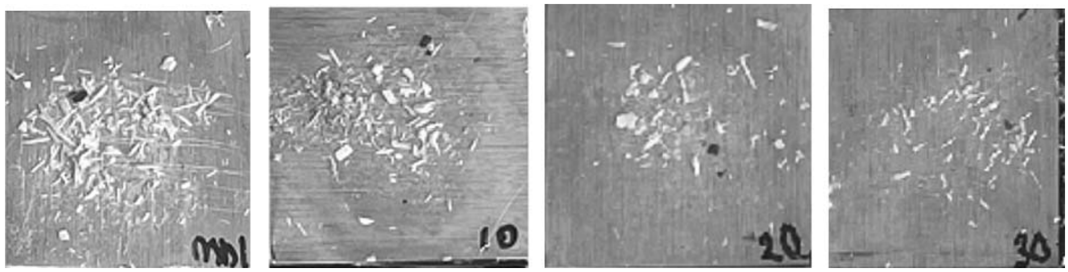

Figure 2.—Images of 26-cm^2 platen after pressing particle with polymeric diphenylmethane diisocyanate (pMDI) with 0 to 30 percent added soy flour (left to right).

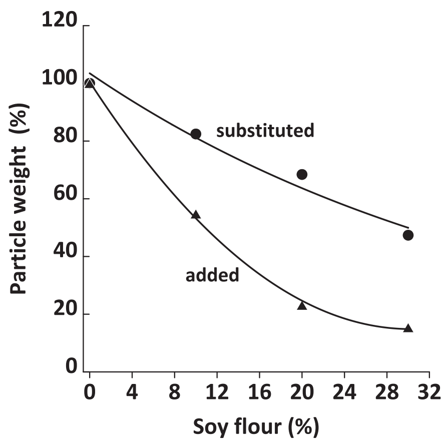

Figure 3.—Comparison of particle sticking for soy flour substitution versus addition to polymeric diphenylmethane diisocyanate (pMDI) resin.

Table 2.—Weight of particles stuck to platens after pressing with soy-supplemented polymeric diphenylmethane diisocyanate (pMDI).

Soy added (% weight of pMDI)	Particle weight (mg)	
	26-cm^2 platen	232-cm^2 platen
0	47 ± 2	670 ± 10
10	29 ± 2	367 ± 6
20	20 ± 1	155 ± 7
30	17 ± 1	103 ± 2

Figure 4.—Images of platens coated (left to right) with polymeric diphenylmethane diisocyanate (pMDI) containing 0, 10, and 20 percent soy flour (left to right).

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