Particleboard from Aspen Flakes and Sunflower Hulls

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Abstract
Laboratory particleboards of 42 lb/ft\(^3\) (pounds per cubic foot) nominal density were manufactured from sunflower hulls and \(\frac{1}{2}\)" aspen flakes. Sunflower hull to aspen flake weight proportions were: 1:0 (all sunflower Hulls), 1:2, 2:1, and 0:1 (all aspen flakes). Although the addition of sunflower hulls reduced board strength and stability, Commercial Standard CS 236-66 minimum property requirements for modulus of rupture and modulus of elasticity were met by the 100% sunflower hull boards. However, the addition of approximately 50% aspen flakes would be required to meet the same minimum property requirements for internal bond strength and linear dimensional stability. Susceptibility to decay fungi increased with increasing sunflower hull content.

INTRODUCTION
The oil-bearing sunflower industry in the United States is expected to expand greatly in the next decade and hull disposal concerns the processors. Using agricultural wastes for particleboard and fiberboard is not new, but to the best of the authors' knowledge sunflower hulls for particleboard have not been previously evaluated. In preliminary studies we found that a particleboard made of 100% sunflower hulls was inferior to a board made from 100% aspen flakes or particles. The purpose of this study was to determine if the particleboards from sunflower hulls could be upgraded sufficiently to meet the minimum requirements of the applicable commercial standards by adding aspen flakes.

Internationally the sunflower industry is large and expanding rapidly. The Soviet Union is the world's leading producer with an estimated 20 million acres under cultivation. The Baltic countries also are large producers, and acreages in Latin America and Western Europe are increasing rapidly. Sunflowers also are grown commercially in Canada.

The two types of sunflowers grown commercially in the United States are the birdseed and confectionery varieties and the oil-bearing varieties. The oil-bearing sunflowers originated in Russia and have become popular in North America because of their superior quality oil and greater production of oil per acre when compared to soybeans. United States commercial sunflower production is presently limited to the cool climate of the Red River Valley in northwestern Minnesota and adjacent counties in Minnesota and North Dakota (Robinson, Johnson, and Soine, 1967). However, when hybrids and pest resistant varieties become available, it is anticipated that sunflowers will be grown commercially from Texas to northern Minnesota.

In 1971 there were approximately 400,000 acres of sunflowers grown in the United States; about 150,000 of which were the birdseed and confectionery types. It is expected that acreages of birdseed and confectionery sunflowers will show only limited growth whereas the oil-bearing sunflower industry is undergoing rapid growth. The industry anticipates one million

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**Figure 1.** Static bending and internal bond strengths of aspen-sunflower hull particleboards as a function of sunflower hull content.

**Figure 2.** Linear and thickness swell of aspen-sunflower hull particleboards as a function of sunflower hull content.
acres of the oil-bearing varieties by 1980. If all processors de-hull, approximately 100,000 tons of hulls would be generated annually and would be concentrated at only a few sites within the sunflower growing region.

The sunflower "seed" is a one-seeded fruit or achene comprised of a hull and a kernel. The achene from the oil-bearing sunflowers average 25 percent hull and 75 percent kernel by weight of which 45 percent of the total achene weight is oil. The birdseed and confectionery types average 45 percent, 55 percent, and 30 percent respectively (Earle, Vanetten, Clark, and Wolff, 1968). Processors that dehull use disk dehullers or impact machines, and approximately one-fifth of the hulls remain with the kernels. The oil is removed from the kernels by mechanical pressing followed by extraction with hexane. At the present time the hulls are pelletized for cattle roughage, but this is not the long range answer to utilization. A Canadian company has pressed hulls into 7½ pound logs for fuel (Robinson et al. 1967), and other uses such as fur-fural production, landfill, soil amending, and fuel for the processing plants have been considered.

**Experimental Procedure**

Aspen flakes 0.014 inches thick by ¾ inch in length by random width were cut from green debarked aspen on a laboratory flaker and dried at room conditions to 8 percent moisture content. The sunflower hulls which averaged 0.012 inches in thickness and 0.4 inches in length were received air-dry from a processing center and equilibrated to 10 percent moisture content under the same room conditions. To reduce flake width and hull coarseness, both flakes and hulls were hammermilled through a one inch screen. The bulk density of loose hulls was 6 lb/ft³, but a slight packing pressure raised this value to 9 lb/ft³.

Four 18 inch x 18 inch x ½ inch thick particleboards of 45 lb/ft³ nominal density were manufactured from each of four furnishes (mixtures) consisting of sunflower hull to aspen flake weight proportions of 100 percent sunflower hulls, 1:2, 2:1 and 100 percent aspen flakes. The furnishes for the four types of boards were sprayed with phenol formaldehyde adhesive in a rotary laboratory blender. Eight percent resin solids based on the weight of moisture-free hulls and flakes were used. Mats were hot pressed to ½ inch stops at 340°F for 12 minutes. Time to stops was 1 minute. After pressing, the boards were conditioned at 50 percent relative humidity (RH) and 72°F. Three 2½ inch x 14 inch static bending samples and two 1½ inch x 14 inch linear swell samples were cut from each board. One 2 inch x 2 inch internal bond sample and one 2½ inch x 4 inch vacuum-pressure-soak (VPS) sample were cut from the static bending samples after they had been tested.

Static bending and internal bond tests were performed in accordance with ASTM D 1037-64 except that the samples were equilibrated and tested at 50 percent RH and 72°F, rather than 65 percent RH and 68°F, and the widths of the static bending samples were 2½ inches rather than 3 inches. Linear swell determinations conformed to the same ASTM
Standard and were the total swell from equilibrium at 50 percent RH to equilibrium at 90 percent RH.

Thickness swell was determined on both the linear swell and the VPS samples. For the linear swell samples, total thickness swell was that from equilibrium at 50 percent RH to equilibrium at 90 percent RH. The VPS samples were treated by one VPS cycle as outlined by Heebink, and total thickness swell was that from equilibrium at 50 percent RH to the water-soaked condition.

Relative decay resistance of 1 inch square samples was evaluated by using the standard 3 month soil-block test and the 3 month agar-block test. Two decay fungi, *Lenzites trabea* Pers. ex Fr. (U.S. Forest Products Laboratory Mad. 617) and *Polyporus versicolor* L. ex Fr. (U.S. Forest Products Laboratory Mad. 667), were used.

The pH of the aspen-sunflower hull mixtures was determined on fine milled material according to TAPPI Standard T509, the cold extraction method for determining the pH of paper.

**Results and Discussion**

The difference in pH between sunflower hulls and aspen wood (table 1) dictated the use of the phenol formaldehyde adhesive because its cure is relatively independent of furnish pH. Thus the problem of different pH levels was eliminated by not using the more pH-dependent urea formaldehyde.

With respect to modulus of rupture (MOR) and modulus of elasticity (MOE), (figure 1) boards of all four proportions met Commercial Standard CS 236-66 minimum property requirements of 2500 psi for MOR and 450,000 psi for MOE for all types and classes of medium density boards. However, for internal bond (IB), a minimum of 50 percent aspen flakes would be required to meet the 70 psi minimum. Although MOR and MOE decreased linearly with an increase in sunflower hull content, the addition of hulls in any amount had a very deleterious effect on IB. Microscopic examination of failed IB surfaces showed very minimal wood or hull failure which indicated relatively poor adhesion to the hull surface. Thus the sunflower hulls, being distributed throughout the thickness of the board, form the weak link with respect to tensile strength perpendicular to the surface (figure 1).

From figure 2 it can be predicted that a board of approximately 50 percent aspen flake content would have a percent of linear swell of 0.30 which would meet the CS 236-66 maximum allowable for all medium density boards except type 2, class 2. The fact that sunflower hulls equilibrate to a higher moisture content than wood may account in part for the increased linear swell.

For thickness swell from equilibrium at 50 percent RH to equilibrium at 90 percent RH, a subtraction of the springback or irreversible swelling from the total shows that both springback and reversible swell increase with an increase in hull content (figure 2). This particular trend for reversible swell is probably related to the higher EMC of the sunflower hulls whereas that for springback to the apparent poorer bonding of the hull surfaces. These factors would also account for the.

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<td>620 55</td>
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<td>2.5</td>
<td>460 53</td>
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(a) equilibrium at 90% RH, and (b) the water soaked condition from the VPS treatment.

* at 50% RH to second equilibrium at 50% RH. *(a) 50% RH to 90% RH to oven dry to 50% RH *(b) 50% RH to water soak

** at 90% RH,
A northwestern Minnesota sunflower field and a west central Minnesota aspen stand. Sunflower hulls are an agricultural waste but when mixed with aspen flakes or particles, offer potential as a raw material for particleboard.

Slight decrease in board density as hull content was increased (table 1). The boards containing sunflower hulls exhibited greater thickness swelling from the hot press to equilibrium at 50 percent RH. This was the primary cause for the density decrease.

For boards containing sunflower hulls, springback accounted for the majority of total swell in the VPS treatment, and it increased with increasing hull content. The reversible component of swelling showed a decrease as hull content increased. This was probably due to the increased loss of internal bonding and the consequent loss of structural integrity which reduced the amount of shrinkage back from the water soaked condition.

The results of the soil-block and agar-block decay tests show (figure 3) that boards containing sunflower hulls are considerably more susceptible to decay fungi than boards made of 100 percent aspen wood. Since the phenol formaldehyde affords some decay protection, percent weight losses would have been considerably greater if an urea formaldehyde had been used.

For comparison, the weight losses for an urea bonded commercial board containing predominantly aspen were 26.8 percent for the agar-block test with L. trabea and 42.3 percent and 34.6 percent for the soil-block tests using P. versicolor and L. trabea respectively.

Summary and Conclusions

Adding sunflower hulls to an aspen particleboard has a deleterious effect on the strength properties, dimensional stability, and decay resistance of particleboard. With respect to strength and dimensional stability, the apparent poor adhesion at the sunflower hull surfaces is probably the most limiting factor. However, comparing the properties of the boards produced in this study to Commercial Standard CS 236, we found that, except for screwholding which was not measured, the laboratory boards containing up to 50 percent sunflower hulls meet or exceed the Commercial Standard requirements for medium density interior boards. The apparent future availability of low cost hulls coupled with the growing scarcity of planer shavings makes sunflower hulls a possible future raw material for particleboard.

This study evaluated only a homogeneous board of uniform resin content and particle geometry, and thus it is obvious that other types of board remain to be explored. For example, if internal bond can be upgraded, the hulls may well be suitable as a core for three-layer boards. The effect of resin content and hull and flake geometry should be evaluated, and hull pretreatments investigated as a possible way to improve bonding.

The projections for the future indicate that by 1980, 100,000 tons of sunflower hulls could be generated annually in perhaps two or three Minnesota and North Dakota locations where sunflowers are now grown. These sites will be well within range to obtain aspen from the west central Minnesota timber resource. One sunflower processing operation can produce nearly 40,000 tons of hulls per year. Therefore, if a particleboard plant operated in conjunction with a sunflower processing operation and manufactured board containing 50 percent hulls and 50 percent aspen wood, its yearly consumption would be 40,000 tons of hulls plus 40,000 cords of aspen (one ton of dry wood fiber per cord) or the equivalency of a plant using 80,000 cords per year. The economic feasibility of such an operation has yet to be considered.

Literature Cited

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