THE SOYBEAN-BAGASSE BOARD

José López Hernández
National University of Tucumán, Argentina

ABSTRACT

The use of soybean glue as a binder in the production of bagasse boards is described. Physical characteristics of the soybean-bagasse board are also described and compared with resin bound board. It is emphasized that the soybean-bagasse board is more comparable to wood than the standard board with resin. The manufacturing process is described with particular reference to elimination of some steps, as well as some equipment, in comparison with standard methods. Reference is made to the economic aspect, pointing out how soybean and sugarcane crops are complementary.

INTRODUCTION

Soybean glue has been widely used in the plywood industry since 1923 (Skeist), reaching in the USA a figure of 27 million kg in 1940; it then gradually decreased to 13.6 million kg, mainly due to the introduction of synthetic resins from 1935 onwards. In 1950 the use of soybean binders again increased, reaching 45 million kg in 1956, since when it has slowly increased (Skeist). The production of wood chip boards bound with resins commenced in 1945, while resin and bagasse boards started in 1966.

The only literature that could be found on the use of soybean binders in the manufacture of boards made of both wood chips and bagasse was that of J. López Hernández and H. Paz (1971), and these authors refer to studies started in 1969 on the subject.

The Soybean-Bagasse Process

Whole bagasse from a sugarcane factory’s last mill feeds the 2 hammer mills (1), Fig. 1, which separate in a single stage operation the pith which returns to the boilers and the useful fiber which feeds a Büttner type drier (2) where moisture is reduced from 48% to 15%. The drier operates with flue gases at 200-300°C, from the gas heated boilers. Two-thirds of the dry fiber is baled and stored for the inter-season and one-third enters the glue-fiber mixer (3).

The glued fiber is sent to a second drier (4) of lower capacity than the first, and is also heated by flue gases. This drier removes some of the water of the glue incorporated in the fiber until the mixture has a moisture content suitable for the hot plate press (20-30%). The dried mixture is sent to the silo (5) from which the dosing and spreading machine is fed (6). The glued bagasse mat enters the pre-press (7) where it is pressed into a cake which feeds the loading device (8) of the hot plate press (9). The boards there formed are pushed into the discharging device (10) and are sent to the cooling storage room where they are left for 24 hours. After that, the boards are trimmed and sanded in the conventional way.
Fiber Preparation

The Gunkel type hammer mills are fed with whole bagasse of 48-50% moisture coming from the last mill. The pith crosses the holed basket and is returned to be burned in the boilers. The fiber drops from the bottom of the mill for drying. A single stage operation is adequate for depithing the fiber to be processed, no additional mills or screens being required to remove the remaining pith. This mill has a 100 ton/22 hr whole bagasse (dry basis) capacity and a 50-70 ton/22 hr depithed fiber (dry basis) capacity.

Drying Process

The fiber from the hammer mill is dried in a Buttner type drier where moisture is reduced from 48% to 15-20%. Flue gases at 200-300 °C from the sugar factory boilers, heated by gas, are used and no special equipment is required to screen the flue gases for dust, sparks, and ashes. One-third of the depithed fiber is processed and the rest is baled. The dry fiber bales are stacked without leaving space for air circulation, since there is no fermentation or temperature increase and the stacks can be covered with plastic sheeting.

Fiber and Glue Mixture

Conventional mixers for synthetic resins, without spraying nozzles, can be used. A suitable mixture can also be obtained in hammer mills adapted for this operation. Fiber and glue are mixed in a single stage.

Drying the Glued Fiber

The glued fiber, as it leaves the mixer, has 40-45% moisture, which in order to shorten the pressing time, is reduced to 20-30% in a Buttner type drier heated by flue gases.

Mat Formation

The glued fiber is spread with the same equipment used in resin board technology. But for the soybean-bagasse process, a single machine is used, as it is not necessary to make 3-layer boards to obtain good quality and smooth surfaces.
**Pre-Pressing**

The mat is pre-pressed to reduce its thickness and to prepare it for the hot-plate press. The glued fiber is easily compressed because the water in the glue wets the fiber. The pressure in the pre-press ranges from 0.025 to 0.50 kg/cm² over the cake.

**Hot Pressing**

Due to the high compressibility of the glued fiber and the relatively lower working pressure, a less robust press can be used than is required for resin boards. A pressure of 7 kg/cm² provides 600 kg/m³ specific gravity boards.

The plates can be heated up to 300 °C without affecting the board because the board temperature never exceeds 100 °C because of the water in the glue. A special oil may be used as a heat carrier at atmospheric pressure, or hot water can be used to heat the press.

**Storage and Finishing**

Boards 3 years old, even when exposed to unfavourable moisture and temperature conditions, have not been adversely affected. The author considers that the rough boards can be sanded and trimmed 24 hours after being pressed. Trimming, which removes at most 10 mm, is carried out by using standard equipment, as is sanding. Owing to the smooth non-abrasive surfaces of the rough boards maintenance costs of the sanding machine are low.

**Experimental Procedure**

Laboratory experiments were started 3 years ago with a 0.20 × 0.20 m plate Carver press, electrically heated and provided with a recorder, temperature regulator and maximum pressure manometer.

The following points were studied:

1) Fiber-glue relationship;  
2) Different formulae of glue;  
3) Fiber length and depithing level;  
4) Moisture of the mixture;  
5) Pressing time;  
6) Temperature in plates and boards;  
7) Age of the glued fiber;  
8) Thickness of the boards;  
9) Density of the boards;  
10) Trays;  
11) Quality of the boards.

**RESULTS**

1. **Fiber-glue relationship**

Trials were carried out using fiber-glue mixtures with ratios: 1:0.5, 1:1 and 1:1.5. With regard to appearance and physical characteristics, the best boards are obtained with the 1:1 ratio.

2. **Different formulae of glue**

The glue is prepared in a vessel provided with a mixer, by adding water, soybean oil meal and the other components. After mixing for a few minutes the glue is ready to be used.
A standard formula for soybean glue is as follows: (Skeist)

a) water at 15-20°C 175 kg
untoasted soybean oil meal 97 kg
pine oil or antifoam mix 3 minutes
b) water at 15-20°C 145 kg
mix 2 minutes
hydrated lime 12 kg
water at 15-25°C 24 kg
mix 1 minute

c) 50% sodium hydroxide 14 kg
mix 1 minute
d) sodium silicate make “N”
(Philadelphia Quartz Co) 25 kg
mix 1 minute
e) carbon bisulfide 1.25 kg
carbon tetrachloride 0.5 kg
pentachlorophenol in flakes 4.25 kg
mix 10 minutes

**FIGURE 2.** Bending strength of different density boards.
This formula which was worked out for the plywood industry, has been modified for the board industry. Sodium hydroxide is replaced by borax, which not only is cheaper but also provides the alkalinity needed to degrade the protein and acts as a fungicide, eliminating the use of preservers. Carbon bisulfide and tetrachloride, as well as antifoams, have also been eliminated.

In the standards for soybean glues, the bibliography refers to defatted untoasted soybean oil meal, (Skeist,1 Marckley2), which was used in these investigations to prepare the glue for the boards. Also used with great success was flour obtained by directly milling dehulled soybean.

From all standards used, the best results were obtained with glues made of defatted soybean oil meal or full fat soybean flour, borax, lime, and sodium silicate in suitable quantities for this industry. Glues prepared in this way have 20-25% dry matter and 15-20% meal content.

Fig. 2 shows the bending strength variations of different density boards resulting from different glue formulas. Each point of the graph represents the mean of 5 trials. Points 6 and 7 refer to the glue prepared with standard formulas recommended in the bibliography for the plywood industry (Skeist,1 Marckley4). Points 8 and 9 refer to the same glue as used in points 6 and 7, but sodium hydroxide being replaced by borax. Point 26 refers to the glue made from full fat soybean flour. The remaining points refer to different glue formulas made from defatted soybean oil meal. The lower line refers to different density boards made of chip wood and bound with urea-formaldehyde resins, as indicated in a catalogue provided by the seller (Linex4). Point T is the figure obtained for the same board purchased in a local market and used as check no. 1. Point P is the figure obtained for the best board on the local market, made of chip wood, bound with urea-formaldehyde and used as check no. 2.

**FIGURE 3.** Effect of moisture level of glued fiber on bending strength.
3. Fiber length and depithing level

The most suitable fiber length ranges between 20 and 30 mm, lengths under 10 mm affecting the resistance of the board. The amount of pith in the fiber used ranged between 10 and 15%.

4. Moisture of the glue-fiber mixture

The moisture level of the mixture affects the strength values of the board, strength improving with increasing moisture content (Fig. 3). Moisture levels between 20 and 25% provide strength values which are in accordance with standard regulations.

5. Pressing time

The pressing time varies according to the temperature of the plate, moisture of the mixture, and density and thickness of the boards. At a density of 600 kg/m³, a temperature 230°C in the plates, for 4 mm boards the pressing time is 2 minutes; for 6 mm, 4 minutes; and for 19 mm, 15 minutes. Pressing times are generally longer than those required for synthetic resin binders. This is countered economically however by taking into account the following considerations:

1) The hot plate press is cheaper, as it is less robust because of the lower working pressure used.
2) By pre-pressing the mixture, which is not a costly operation the height of the mat is reduced, increasing therefore the hot plate press capacity.
3) Soybean binders being cheaper than resins, it may be considered that binders are always part of the production cost because they fall under the variable costs. However, a large investment in presses (for example, if 2 presses in parallel are used) only affects costs during their depreciation period.

6. Temperature in plates and boards

Depending on pressing times, temperature of 140-250°C can be used. Whatever the temperature of the plates, the board temperature remains at 100°C during the pressing time.

7. Age of the glued fiber

Boards have been made using both newly-prepared glued fiber and glued fiber 50 hours old.

Experience leads to the conclusion that the age of the mixture does not affect the strength of the boards. This feature is useful because the factory can

![Bending strength vs. hours graph](image)
stop working for some time or the glued fiber can be stored for the week-end without damage, Fig. 4.

8. **Thickness of the board**

Boards of different densities, ranging from 3 to 40 mm, were made for all possible uses, e.g. a thin board for fruit boxes or to replace plywood, a thick board of low density for door-cores or for thermal and acoustic insulation.

9. **Density of boards**

Boards varying from 300 to 1 000 kg/m³ were made for all possible uses.

10. **Trays**

The moisture level of the glued fiber as it enters the hot plate press is too high to use standard trays in the resin process, and therefore to remove steam, a perforated tray is used.

In processes where trays are expendable, the perforated trays are permanently fixed to the press plate. But where trays are re-used it is not necessary to cool the perforated ones, since the moisture of the glued fiber easily absorbs the heat. On the other hand, if cooling is eliminated from the process, heat may be recovered.

Trays may be made of aluminium or brass, in a standard thickness.

11. **Quality trials of the boards**

Tests were designed to determine the quality of the soybean-bagasse board in respect of: bending strength, tensile parallel strength, tensile perpendicular strength, screw-holding on sides and faces, % swelling after 2 hours.

In all trials, boards made of wood and urea-formaldehyde resins from the local market were used as check. Check no 1 was a medium quality board and check no. 2 was the best board in the local market. Table 1 refers to trials on bending strength, according to ASTM D 1037 standards and showing maximum, mean and minimum values.

<table>
<thead>
<tr>
<th>Density kg/m³</th>
<th>500</th>
<th>550</th>
<th>600</th>
<th>650</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum</td>
<td>166</td>
<td>197</td>
<td>254</td>
<td>310</td>
</tr>
<tr>
<td>Medium</td>
<td>137</td>
<td>174</td>
<td>223</td>
<td>274</td>
</tr>
<tr>
<td>Minimum</td>
<td>123</td>
<td>161</td>
<td>200</td>
<td>238</td>
</tr>
<tr>
<td>Check 1</td>
<td>100</td>
<td>125</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>Check 2</td>
<td></td>
<td></td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>Resin Bagasse</td>
<td></td>
<td></td>
<td>220</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 refers to the physical properties of the soybean-bagasse board taking into account mean values. For comparative purposes published data for resin bagasse board are included.

<table>
<thead>
<tr>
<th>Raw Material</th>
<th>Soybean</th>
<th>resin*</th>
<th>Check 1</th>
<th>Check 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bagasse</td>
<td>Bagasse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of layers</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Density kg/m³</td>
<td>600</td>
<td>610</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Thickness mm</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>Bending strength kg/cm²</td>
<td>223</td>
<td>220</td>
<td>160</td>
<td>195</td>
</tr>
<tr>
<td>Tensile strength parallel kg/cm²</td>
<td>119</td>
<td>—</td>
<td>75</td>
<td>—</td>
</tr>
<tr>
<td>Tensile strength perpendicular kg/cm²</td>
<td>4,4</td>
<td>6,5</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Swelling after 2 h % (Size of test piece: 25 x 25 mm)</td>
<td>13,7</td>
<td>6,1</td>
<td>24,6</td>
<td>24,0</td>
</tr>
<tr>
<td>Screw holding kg (q of screw, 4 mm; depth of screw, 20 mm) face and side</td>
<td>122</td>
<td>80</td>
<td>100</td>
<td>—</td>
</tr>
</tbody>
</table>

Factory Experiments

Experiments were carried out using a hot plate press from a plywood factory. Plates were 1,60 x 1,60 m and the boards formed were 0,80 x 1,50 m in size.

Conclusions from laboratory experiments were applied to the board production and results were confirmed.

The boards were trimmed and sanded 20 h after leaving the press. They were used 3 years ago to make furniture (desks with drawers) and no problems have arisen even though they were exposed to unfavourable conditions such as moisture and temperature variations. Wallboard models were also made, and different trials were conducted to study the behaviour of the boards in regard to tools and carpentry machinery, the performance being good in both cases.

Pilot Plant Experiments

At present, a pilot plant is being built by agreement between the National University of Tucumán and CONASA, a corporation which owns 5 sugarcane factories. The pilot plant is being built at Bella Vista, Tucumán, Argentina, with the equipment shown in the diagram. The hot plate press runs with three 0,90 x 1,30 m plates.

DISCUSSION AND CONCLUSIONS

Soybean-Bagasse Boards

Due to its mechanical-physical properties and texture, the soybean-bagasse board is more like wood than a board bound with synthetic resins which more closely resembles rigid plastic. With tools and carpentry machinery the soybean-bagasse board behaves like wood because, although it is hard, the tools do not wear badly and in most of the cases where wood is used the board can be used.

The rough boards have a very smooth surface and can be sanded with little wear of the band.

The borax added to the glue has fire-proofing qualities and acts as a preservative against the attacks of insects and fungi. These features are very valuable in relation to furniture making or house building.
The soybean-bagasse boards have better screw and nail holding properties than the resin bound boards. Nails can be hammered in less than 5 mm from the edge without causing splits.

Chemical does not have to be added to the glue to increase water resistance. In the swelling test the soybean-bagasse board behaves better than the resin board. The fundamental difference in this respect is that a soybean-bagasse board which has been submerged in water, when dried assumes the same mechanical strength and properties which it had prior to wetting and also returns to its original size, as wood does. The boards bound with resins do not have this property. The water resistance of the board can be increased using full fat soybean flour, owing to its oil content.

**Process and Equipment**

The manufacturing process for soybean-bagasse is simpler than that for resin-bagasse. The fiber can be prepared in a single stage operation in the hammer mill, without the need for additional refining mills or screens. Sugar normally present in the raw bagasse does not interfere with the process. Furthermore, more pith can be added with the fiber than is possible in the resin process, which leads to a reduction in equipment.

In order to produce smooth surfaces and good physical properties it is unnecessary to make 3-layer boards. Because the cost of the glue is low, larger amounts can be added to obtain a single layer board with the same properties as the 3-layer board with resin. This also means less equipment is required in the factory.

As the working pressure of the hot plate press is 60-70% lower than in the resin process, the equipment is naturally cheaper for the soybean-bagasse process.

Soybean glues do not interfere in the process and it is only necessary to remove the moisture of the glued fiber during hot pressing. Staff can be trained in a week to handle this process.

The reduction in equipment and the lower cost of the presses suggest that production could be doubled in established factories with little additional investment.

**Further uses**

The low cost of the soybean-bagasse boards, as well as their mechanical properties means they have more uses than are possible with resin-boards. Preliminary tests show that the soybean-bagasse boards can be used in plank lining for concrete, and for fruit boxes.

The object of the pilot plant, which is being built, is to produce boards as soon as possible to confirm their performance in these new uses and the plant for 75 ton/day which CONASA Co is erecting will begin production by 1976 - 77.

**Production Costs**

With regard to binder cost in the board production, the prices of soybean and urea-formaldehyde resin must be compared in each country. The 20% value of the board weight in soybean against the 8% of the board weight in resins (dry basis) must also be taken into account. In Argentina, for example,
The soybean-bagasse boards have better screw and nail holding properties than the resin bound boards. Nails can be hammered in less than 5 mm from the edge without causing splits.

Chemical does not have to be added to the glue to increase water resistance. In the swelling test the soybean-bagasse board behaves better than the resin board. The fundamental difference in this respect is that a soybean-bagasse board which has been submerged in water, when dried assumes the same mechanical strength and properties which it had prior to wetting and also returns to its original size, as wood does. The boards bound with resins do not have this property. The water resistance of the board can be increased using full fat soybean flour, owing to its oil content.

**Process and Equipment**

The manufacturing process for soybean-bagasse is simpler than that for resin-bagasse. The fiber can be prepared in a single stage operation in the hammer mill, without the need for additional refining mills or screens. Sugar normally present in the raw bagasse does not interfere with the process. Furthermore, more pith can be added with the fiber than is possible in the resin process, which leads to a reduction in equipment.

In order to produce smooth surfaces and good physical properties it is unnecessary to make 3-layer boards. Because the cost of the glue is low, larger amounts can be added to obtain a single layer board with the same properties as the 3-layer board with resin. This also means less equipment is required in the factory.

As the working pressure of the hot plate press is 60-70% lower than in the resin process, the equipment is naturally cheaper for the soybean-bagasse process.

Soybean glues do not interfere in the process and it is only necessary to remove the moisture of the glued fiber during hot pressing. Staff can be trained in a week to handle this process.

The reduction in equipment and the lower cost of the presses suggest that production could be doubled in established factories with little additional investment.

**Further uses**

The low cost of the soybean-bagasse boards, as well as their mechanical properties means they have more uses than are possible with resin-boards. Preliminary tests show that the soybean-bagasse boards can be used in plank lining for concrete, and for fruit boxes.

The object of the pilot plant, which is being built, is to produce boards as soon as possible to confirm their performance in these new uses and the plant for 75 ton/day which CONASA Co is erecting will begin production by 1976-77.

**Production Costs**

With regard to binder cost in the board production, the prices of soybean and urea-formaldehyde resin must be compared in each country. The 20% value of the board weight in soybean against the 8% of the board weight in resins (dry basis) must also be taken into account. In Argentina, for example,
TABLE 3. Comparison of two methods to produce 1856100 m²/year of boards of 19 mm thickness and 180 kg/cm² bending strength.

<table>
<thead>
<tr>
<th></th>
<th>Resin-Bagasse</th>
<th>Soybean-Bagasse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment in equipment, (the same amount assumed for both processes) US $</td>
<td>2,000,000</td>
<td>2,000,000</td>
</tr>
<tr>
<td>Production m²/day</td>
<td>6,187</td>
<td>6,187</td>
</tr>
<tr>
<td>Production ton/day</td>
<td>75.0</td>
<td>62.5</td>
</tr>
<tr>
<td>Density kg/m³</td>
<td>630</td>
<td>520</td>
</tr>
<tr>
<td>Bending strength kg/cm²</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Production cost (Argentina)</td>
<td>1,262 US $/m³</td>
<td>0,577 US $/m³</td>
</tr>
<tr>
<td>Selling price (Argentina)</td>
<td>2,520 US $/m³</td>
<td>2,520 US $/m³</td>
</tr>
<tr>
<td>Minimum production to cover costs</td>
<td>34.0%</td>
<td>15.5%</td>
</tr>
<tr>
<td>Rate of return on capital invested</td>
<td>57.8%</td>
<td>101.0%</td>
</tr>
</tbody>
</table>

the soybean price is about US $0.12 per kg and the resin price is US $0.51 per kg. Therefore, the soybean cost per kg of board is US $0.024 and the resin cost per kg of board is US $0.041. This excludes the cost of minor chemicals of the soybean glue formula and of the emulsifier and hardener of the resin-binders.

Most sugar-producing countries do not have chemical industries sufficiently developed to produce their own synthetic resins, and therefore they must import them, with the corresponding loss in foreign exchange. But it is scarcely likely that any country will lack an area ecologically suited to soybean culture.

In the case of a soybean-producing country, the additional value of the soybean must be considered. It must be calculated that 20% of the board weight comes from the use of soybean, and the price per kg of soybean must be compared against the price per kg of board.

The lower investment in equipment and its influence on the cost of the board must be taken into account in a new factory, as well as on production increases in factories already established.

In any country it is important to consider the economic and social aspect of a new crop. For a factory processing 75 ton/day of boards, a soybean acreage of 4000 ha is needed, as well as 150 men working for 120 days on a 30 hr/men per ha basis. If we consider the 50% gain in the selling price of the soybean it is easy to appreciate the economic importance of this new crop for soybean producers.

REFERENCES

RESUMEN
La pega de soya usada como aglutinante en la producción de planchas de bagazo, está descrita en esta página. Las características físicas de las planchas de bagazo están también descritas, así como comparadas con las de resina. Se enfatiza que la pega de bagazo de soya se parece más a la madera que la plancha standard con resina. El proceso de manufactura está descrito con énfasis en la eliminación de algunos pasos, así como equipo, en comparación con los métodos standards. Se hace referencia al aspecto económico en la manufactura de la pega de soya para planchas de bagazo, puntualizando el complemento conveniente de la siembra de soya y caña de azúcar.