

## SOME TRENDS IN WOOD ADHESIVES FOR LOW OR NO FORMALDEHYDE EMISSION

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### UFs of LOW FORMALDEHYDE EMISSION

- Not a yet a Problem in Europe, BUT
- JAPAN F\*\*\*\* standard is far more severe
- If JAPAN's F\*\*\*\* spreads to other countries are there ways to satisfy easily the standards, or better? :
- the answer is YES, with a variety of different technologies, new and/or old.

### Technologies to decrease/eliminate formaldehyde content and emission

- Phenol-formaldehyde (PF) and phenol-urea-formaldehyde (PUF) resins
- UF/isocyanate, MUF/isocyanate, PF/isocyanate
- MUF resins of low formaldehyde content
- Tannin adhesives without formaldehyde
- isocyanates
- M, U and MU resins with non-toxic, non volatile aldehyde.
- New Entries

**MOST OF THESE RESINS  
ALREADY EXIST  
AND  
ARE ALREADY USED  
INDUSTRIALLY TO-DAY**

## AND UF RESINS?

- UF resins of formaldehyde emission low enough to satisfy F\*\*\*\* can be produced. It seems one major adhesive manufacturer already produces them for the Japanese market
- But they are more expensive and higher amounts used
- And Japanese standard intends tightening further formaldehyde emission regulation: towards an effective formaldehyde emission ban? (note, not a ban of formaldehyde).

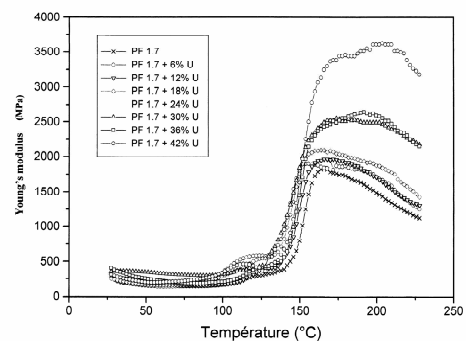
## IF JAPAN'S F\*\*\*\* TAKES HOLD

- ONLY PF RESINS, PUF, hybrid PF/MDI, UF/MDI resins, top range MUF resins and Tannin adhesives WILL SURVIVE SHORT TO MEDIUM TERM
- NEW RESINS AND TECHNOLOGIES WILL PENETRATE MORE DEEPLY THE MARKET. AMONG THEM, BUT NOT ONLY, NATURAL ADHESIVES AND SOME OF THE ABOVE
- ISOCYANATES ALONE MIGHT HAVE EVENTUALLY THE SAME POLLUTION PROBLEMS OF FORMALDEHYDE

## FAST-CURING PF RESINS

- To-day as fast pressing as UF and MUF by
- 1. use of ester accelerators
- 2. alkaline setting PUF resins
- 3. alkaline setting PF/MDI hybrid resins
- Extremely low emission as these resins are completely stable

## FAST-CURING PF RESINS

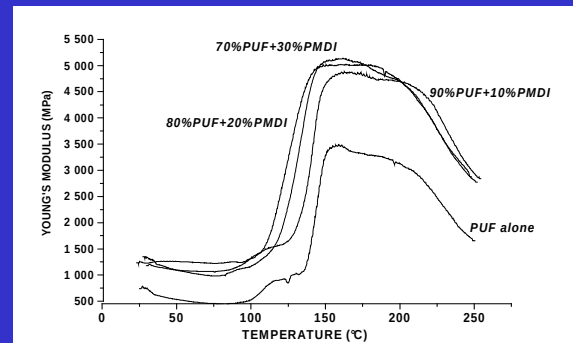


### HYBRID ISOCYANATE RESINS

by DECREASE/ELIMINATION OF  
TOXIC  
-NCO GROUPS IN ISOCYANATES

- BY CO-REACTION OF ISOCYANATES  
WITH TRADITIONAL WATER-BORN  
ADHESIVES

### PF/pMDI, PUF/pMDI, UF/pMDI



### Melamine and Urea resins without any formaldehyde

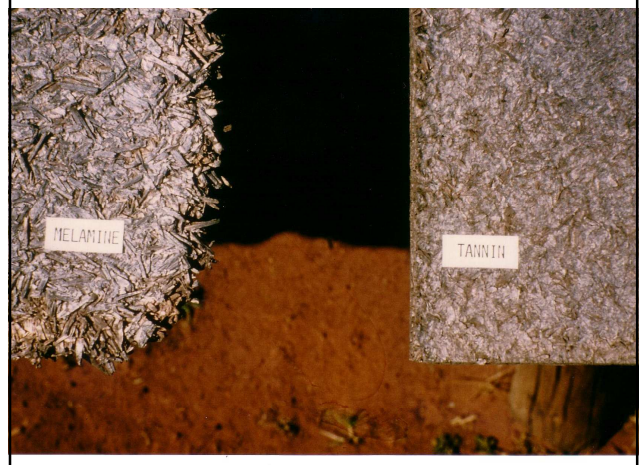
- A major chemical group has developed M and U formulations based on a non-toxic, non-volatile aldehyde.
- Press time is still slower but will be improved
- This aldehyde is still relatively expensive, but if industrial demand increases dramatic shifts in prices will result

### SHIFT TO NATURAL ADHESIVES

- Tannin Adhesives NEW TECHNOLOGIES (not the old ones)
- Protein Adhesives
- Carbohydrate Adhesives
- Unsaturated Oils Adhesives
- Hybrid glyoxylated lignin adhesives

## TANNIN ADHESIVES

1. IMPROVEMENT OF TRADITIONAL SYSTEMS
2. NEW HARDENERS
3. AUTOCONDENSATION

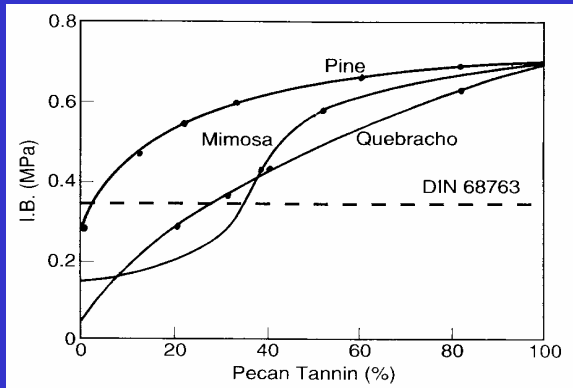
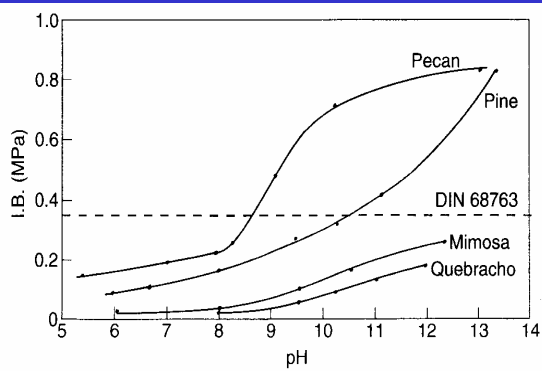


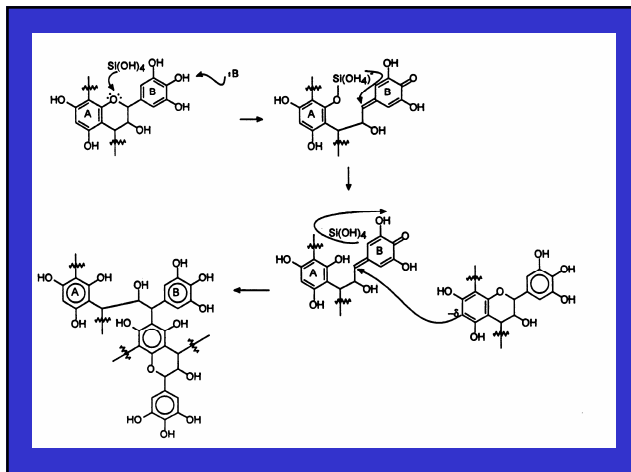
2005-2006 Japanese Use of Tannins:  
EFFECTIVE EMISSION = 0.0



## BONDING BY TANNINS AUTOCONDENSATION

ENVIRONMENT FRIENDLY GLUING  
WITHOUT ANY ALDEHYDE



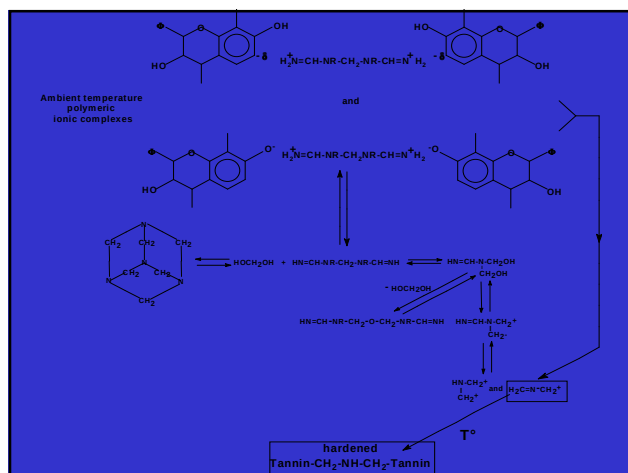


## ALTERNATIVE HARDENERS

- Methylolated Nitroparaffins, i.e. Trishydroxymethyl nitromethane
- glyoxal
- Hexamethylenetetramine (HEXAMINE)

IN PRESENCE OF FAST-REACTING COMPOUNDS HEXAMINE IS NOT A FORMALDEHYDE-YIELDING COMPOUND

- In presence of MELAMINE
- In presence of RESORCINOL
- In presence of TANNINS



## PROTEIN ADHESIVE (SOY)

Properties of soy-PF40 and commercial PF random strand laboratory panels\*

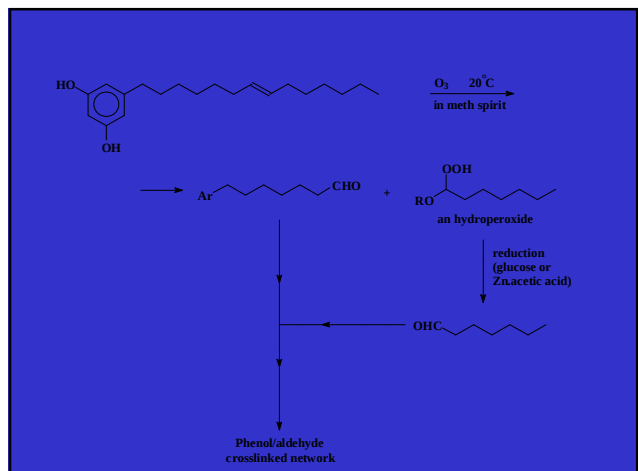
| Face resin | Density (kg/m <sup>3</sup> ) | Thickness swell (%) |       |                 |       | Internal bond (MPa) |      |
|------------|------------------------------|---------------------|-------|-----------------|-------|---------------------|------|
|            |                              | 2-h Boil            |       | 24-h Cold water |       | Dry                 | Wet  |
| PF control | 677                          | 62.8                | (4.8) | 15.2            | (1.5) | 0.60                | 0.06 |
| Soy-PF40   | 696                          | 65.1                | (3.6) | 14.5            | (1.7) | 0.62                | 0.06 |

## CARBOHYDRATE ADHESIVES

- As modifiers of existing PF and UF adhesives
- By forming degradation compounds that can be used to form resins for adhesives: i.e. FURANIC RESINS (but furanic monomers are toxic)
- Directly as wood Adhesives: i.e. Liquefied Wood (phenol present)

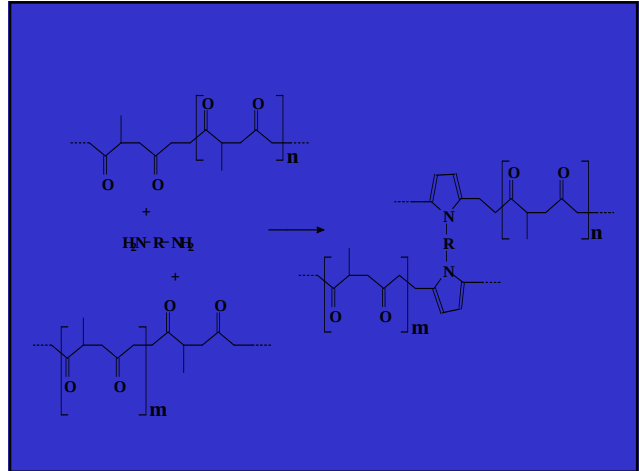
## UNSATURATED OILS

- Epoxidized unsaturated oils: acceptable results for panels but pressing times are far too long. They are relatively expensive
- Cashew nut shell liquid



## Hybrid Glyoxylated Lignin Adhesives

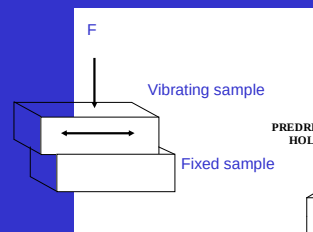
- Non-traditional technology
- Must watch out not to be drawn in traditional lignin/PF resins
- Hybrid MDI/PF/glyoxylated lignin and MDI.glyoxylated lignin adhesives, with lignin up to 65% of total
- glyoxal is classified as non toxic (LD50 > 7000 mg /kg) and non-volatile
- Pressing times industrially significant



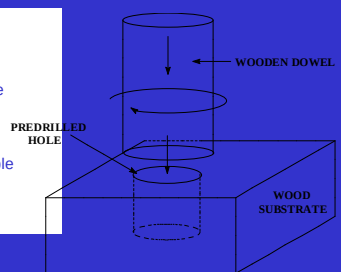
## WOOD WELDING WITHOUT ADHESIVES



### 1. Vibrational

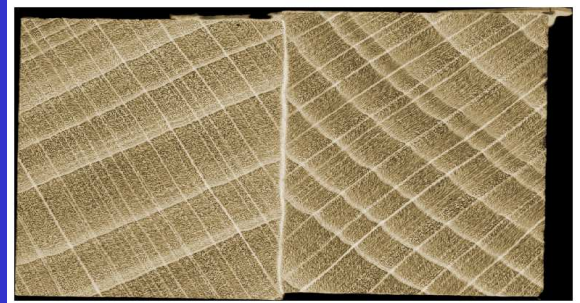


### 2. Dowel rotation



### RESULTS - PARAMETERS

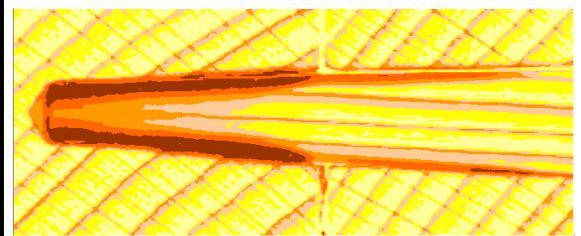
| Welding Time (s) | Welding Pressure (MPa) | Holding Time (s) | Holding Pressure (MPa) | Water spray (g/min) | Number of specimens tested | Tensile Strength (MPa) |
|------------------|------------------------|------------------|------------------------|---------------------|----------------------------|------------------------|
| 3                | 1.3                    | 2                | 1.3                    | No                  | 10                         | 3.84 ± 1.3             |
| 3                | 1.3                    | 2                | 2                      | No                  | 10                         | 2.36 ± 1.8             |
| 3                | 1.3                    | 5                | 1.3                    | No                  | 10                         | 9.40 ± 1.2             |
| 3                | 1.3                    | 5                | 2                      | No                  | 10                         | 10.45 ± 0.9            |
| 3                | 1.3                    | 5                | 2                      | yes                 | 10                         | 10.37 ± 1.0            |
| 4                | 1.3                    | 2                | 1.3                    | No                  | 10                         | 1.18 ± 0.4             |
| 4                | 1.3                    | 2                | 2                      | No                  | 10                         | 0.86 ± 0.2             |
| 4                | 1.3                    | 5                | 1.3                    | No                  | 10                         | 0.79 ± 0.8             |
| 4                | 1.3                    | 5                | 2                      | No                  | 10                         | 0.41 ± 1.2             |
| 4                | 1.3                    | 5                | 2                      | yes                 | 10                         | 0.47 ± 0.8             |
| 5                | 1.3                    | 2                | 1.3                    | No                  | 10                         | 0.82 ± 0.3             |
| 5                | 1.3                    | 2                | 2                      | No                  | 10                         | 0.31 ± 0.2             |
| 5                | 1.3                    | 5                | 1.3                    | No                  | 10                         | 7.54 ± 0.8             |
| 5                | 1.3                    | 5                | 2                      | No                  | 10                         | 4.55 ± 1.3             |
| 5                | 1.3                    | 5                | 2                      | yes                 | 10                         | 4.44 ± 1.2             |



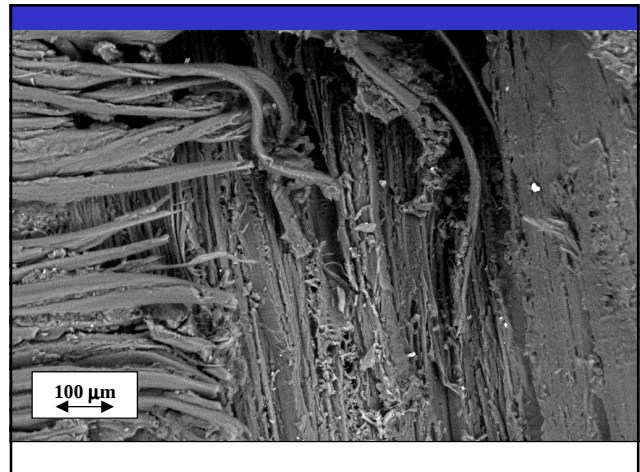
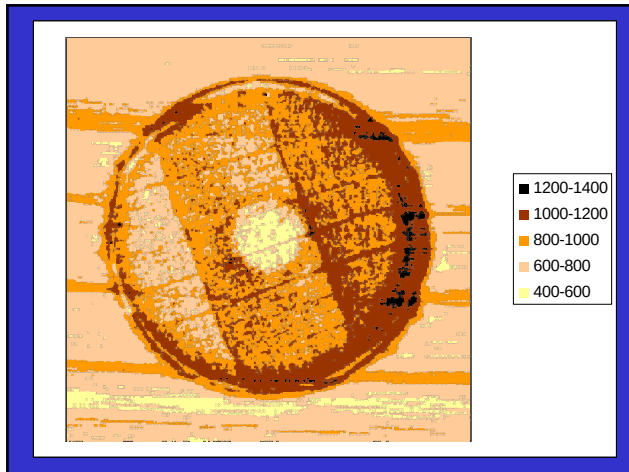
### BUT ONLY FOR JOINING

- Solid Wood to Solid Wood
- Solid Wood to Wood Panel
- Wood panel to Wood Panel
- CANNOT BE USED FOR BOARDS

### Dowel Welding



kg/m<sup>3</sup> 550-700 700-850 850-1000 1000-1150 1150-1300 1300-1450



## Dowel Welding

| Test                     | Grain direction | Wood species | Dowel type    | Hole diameter (mm) | Rotation rate (rpm) | Insertion time & holding time | Average tensile strength (N) |
|--------------------------|-----------------|--------------|---------------|--------------------|---------------------|-------------------------------|------------------------------|
| Welding Best combination | T+R             | Beech        | Fluted groove | 9                  | 1200                | 400 minutes                   | > 33247                      |
| PVAc control             | T+R             | Beech        | Fluted groove | 10                 | 0                   | 24 hours                      | > 33880                      |

\* dowel shaft breaks outside welded area in all cases. R = radial section, T = tangential section

## Conclusions

- Accelerated PFs, PUFs resins
- Mixed PF/pMDI, UF/pMDI, PUF/pMDI
- Top of the range MUFs
- M and U resins with other aldehyde
- New adhesives, as yet unknown
- Wood Welding without adhesives
- Natural adhesives
  - tannin autocondensation
  - hexamine (for synthetic adh. too), and other hardeners
  - protein adhesives
  - carbohydrate adhesives
  - Unsaturated oil adhesives

THANK YOU

FOR YOUR KIND ATTENTION