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Bogor Agricultural University, Indonesia

PHYSICAL AND MECHANICAL PROPERTIES OF METHYL METACRYLATE IMPREGNATED BETUNG BAMBOO (*Dendrocalamus asper*)



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INDONESIAN MAP



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PHYSICAL AND MECHANICAL PROPERTIES OF METHYL METACRYLATE IMPREGNATED BETUNG BAMBOO (*Dendrocalamus asper*)

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INTRODUCTION

- Indonesia has 143 bamboo species, (1,200 world); covering 2.1 mill. ha
- Variety in
 - Size: diameter, thickness, length, node
 - Color: green, yellow, black, motive
 - Strength
- Used for building materials, bridge, music instruments, water-pipe, furniture, agricultural-equipments & handy-craft.





Species Variety
“Big”



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Species Variety
“Medium”



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**Green Fence
“Small”**



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Building Material



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Outer Curtain



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Outer Curtain



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Chicken Cage



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Furniture



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INTRODUCTION

- Betung bamboo (*Dendrocalamus asper*)
 - Length 20 m, Θ 20 cm
 - Nodes 40-60 cm, wall thick 1-1.5 cm
- Length between nodes
 - Bottom, Middle, Top: (Short, Longer, Shortens again)
- Important Properties
 - Thick wall, very strong, durable
 - Young & tender shoot: Vegetable.





Building Material



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Building Material



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BUILDING MATERIAL

- Logs Production:
 - 20-30 million m³/a (1990-1997)
 - 6-13 million m³/a (1998-2005)
- Forest Resources
 - Natural Forest
 - Plantation Forest, Fast Growing Species
- Bamboo
 - Widely Planted
 - Common used for any purpose.



MMA BAMBOO

- Stronger
- Resistant to moist
 - Tropical Area
 - Bogor, Rainy City, 4,500 mm/a
- More Durable
 - Subterranean Termite
 - Dry Wood Termite.



INTRODUCTION

- Hadjib *et al.* (1999): (Indonesia)
 - MMA rubber-wood
 - ^{60}Co gamma ray; 20 kGy dose
- The MMA Wood:
 - 19.5 % Polymer Loading,
 - Higher Density, Lower MC
 - Better: Dimensional Stability, MOE, MOR, Compression & Shear Strengths.



INTRODUCTION

- Bakraji *et al.* (2001):
 - Butylene-acrylate, ^{60}Co gamma radiation; 10, 20, and 30 kGy
 - Radiation dose affects Polymer Loading
 - Higher radiation dose \rightarrow Higher PL
 - Higher wood density \rightarrow Lower PL
- Ajji (2006):
 - Gamma rad 35 kGy is quite enough



INTRODUCTION

- Garnett & Loo-Teck (1996): Urea enhances grafting of MMA & PL
- Husain *et al.* (1999)
 - MMA; vacuum (50 mm Hg) at 70 °C for over 24 hours to remove water,
 - Methyl alcohol as swelling solvent; ^{60}Co gamma ray at 30 kGy
 - Vacuum did not enhance properties, but methyl alcohol enhanced PL, grafting & mechanical properties.



INTRODUCTION

- Yildiz *et al.* (2005)
 - Full-, half-, & quarter-loading of monomer increased mechanical strength of pine
 - Higher PL increased the strength
 - Mix styrene & MMA gave the best results comparing to styrene and MMA woods in strength and price



INTRODUCTION

- Impregnation of styrene to bamboo
 - Improved technical properties & biological resistance (Liese, 1995).
- Lawniczak & Kozlowski (1993) bamboo-polystyrene (WPG ~ 20 %)
 - Static bending strength > 60 %
Static bending in wet condition > 3 x
 - Hardness > 3 x
 - Moisture deformation < 2 x
 - Water adsorption < 3 x.



RESEARCH PURPOSE

- Physical & mechanical properties MMA betung bamboo
 - ^{60}Co gamma rad 40 kGy
 - Urea added into MMA 1 %, 3 % & 5 %
 - Without Urea (0 %), Control
 - Original or Untreated Bamboo



METHODS

- *Dendrocalamus asper* from Bogor
- Cut to testing sizes: physical and mechanical properties
- Oven at 70 °C, 24 hours
- Vacuumed: 35 mm Hg; 15 minutes
- Immersed: MMA & urea; 24 hours
- Urea concentration: 0, 1, 3 & 5 %.



METHODS

- Wrapped: Al-foil & PE plastic sheet
- Radiation ^{60}Co gamma ray; 40 kGy
- Oven at 70°C; 24 hours
- Conditioning: two weeks
- Comparison: Original or Untreated.



METHODS

- Research design
 - Factorial 2 x 4 completely randomized
- The factors:
 - Vacuum: With & Without
 - Urea dose: 0, 1, 3 & 5 %
- Six replication for each treatment
- Original bamboo was also tested.



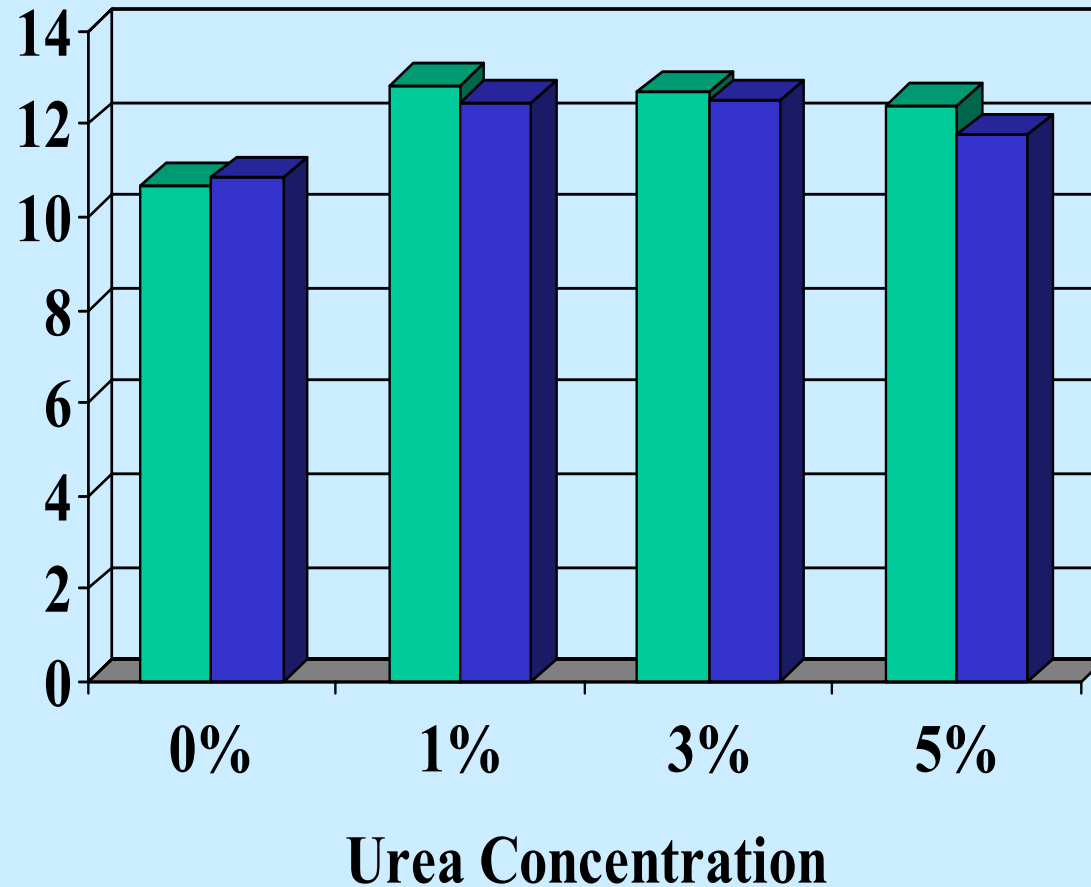
RESULTS

PHYSICAL PROPERTIES



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Polymer Loading (%)



■ No Vacuum
■ Vacuum

Vacuum: No
Urea: Yes

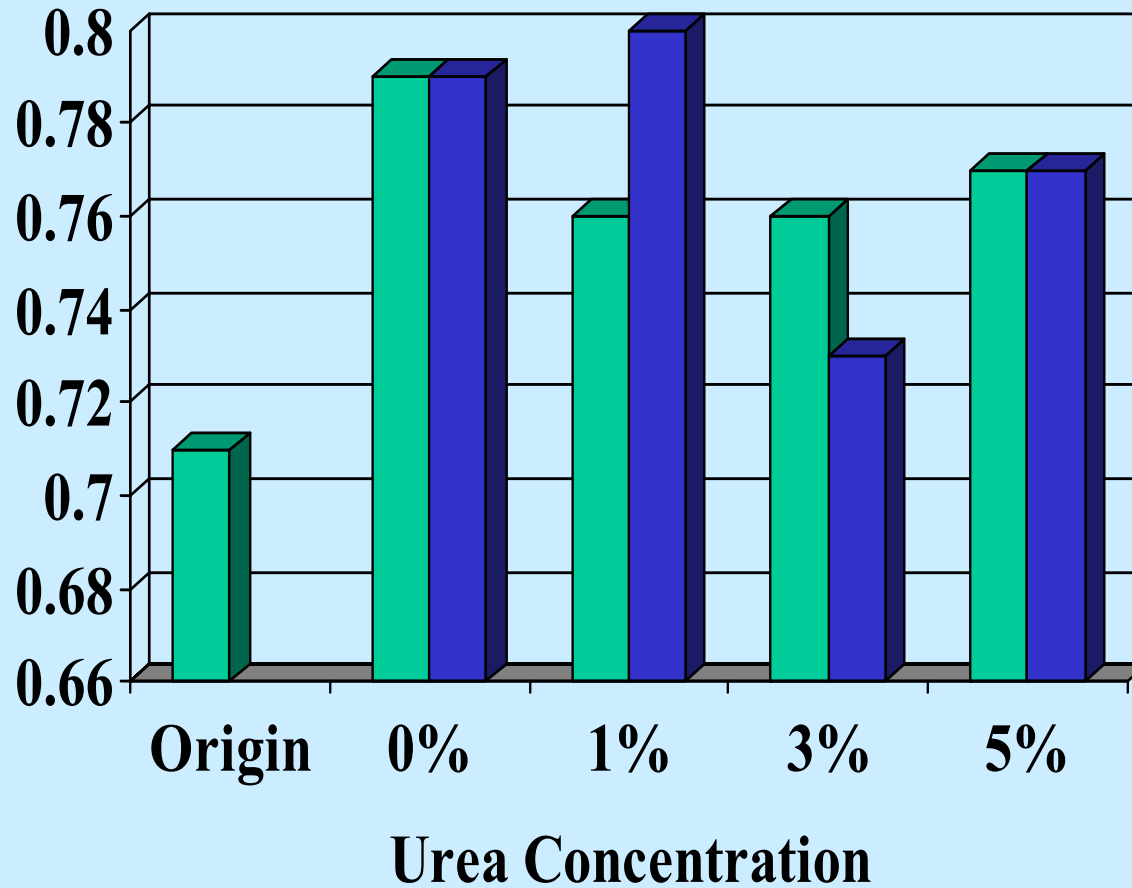


POLYMER LOADING

- PL: 10.7-12.8 % ($\bar{a} = 12.0$ %)
 - \lt *MMA Rubber wood*
 - *Density bamboo* \gt *rubber wood*
- Bakraji *et al.* (2001)
 - Higher wood density \rightarrow Lower PL
- Vacuum: Not affect \rightarrow PL
- Urea: Affect \rightarrow PL
 - Urea (12.4) \gt Without (10.8)



Density (g/cm³)



■ No Vacuum
■ Vacuum

MMA > Origin
Vacuum: No
Urea: No

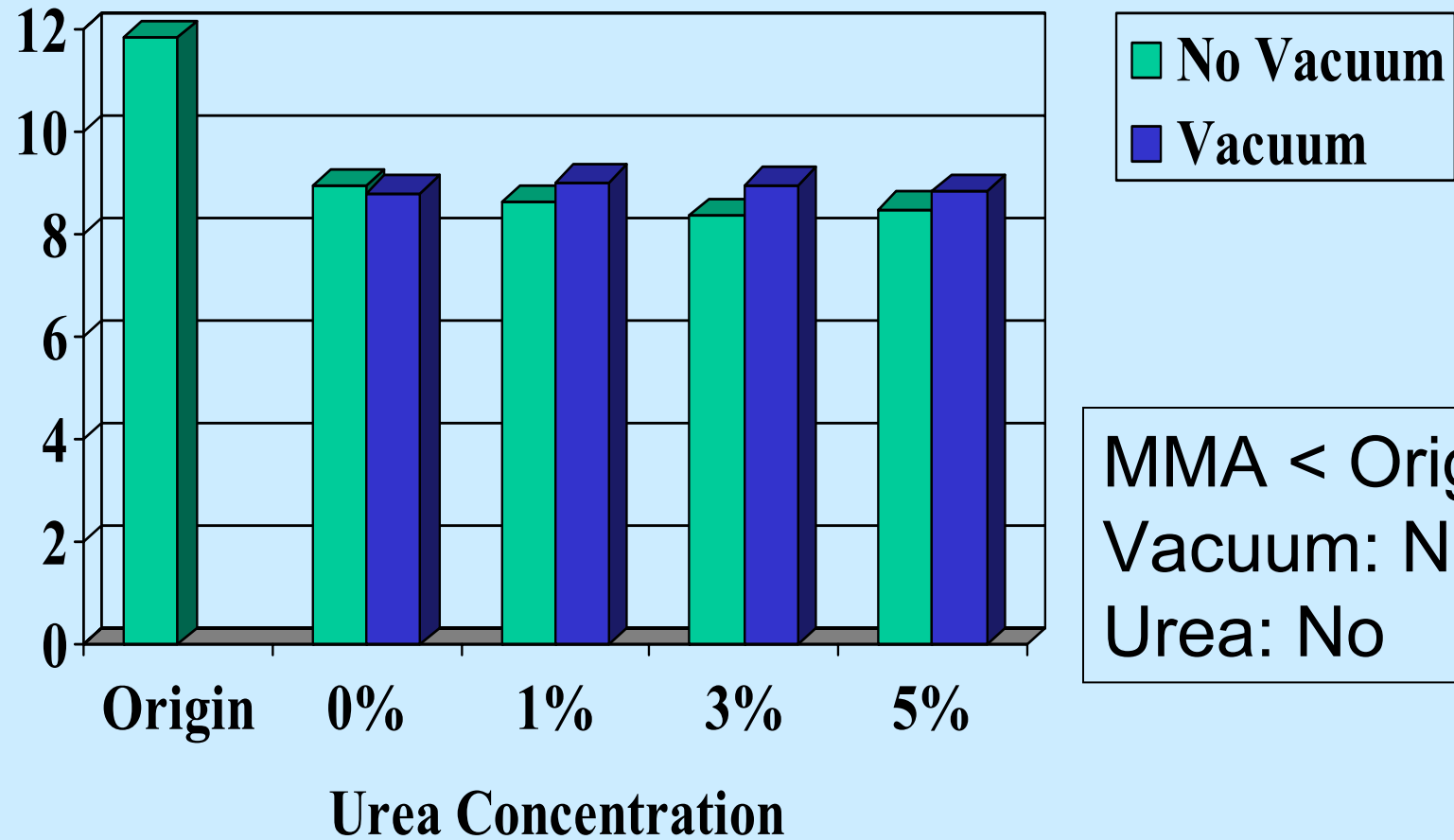


DENSITY

- MMA (0.77) > Untreated (0.71)
- Vacuum not significant
- Urea not significant



Moisture Content (%)

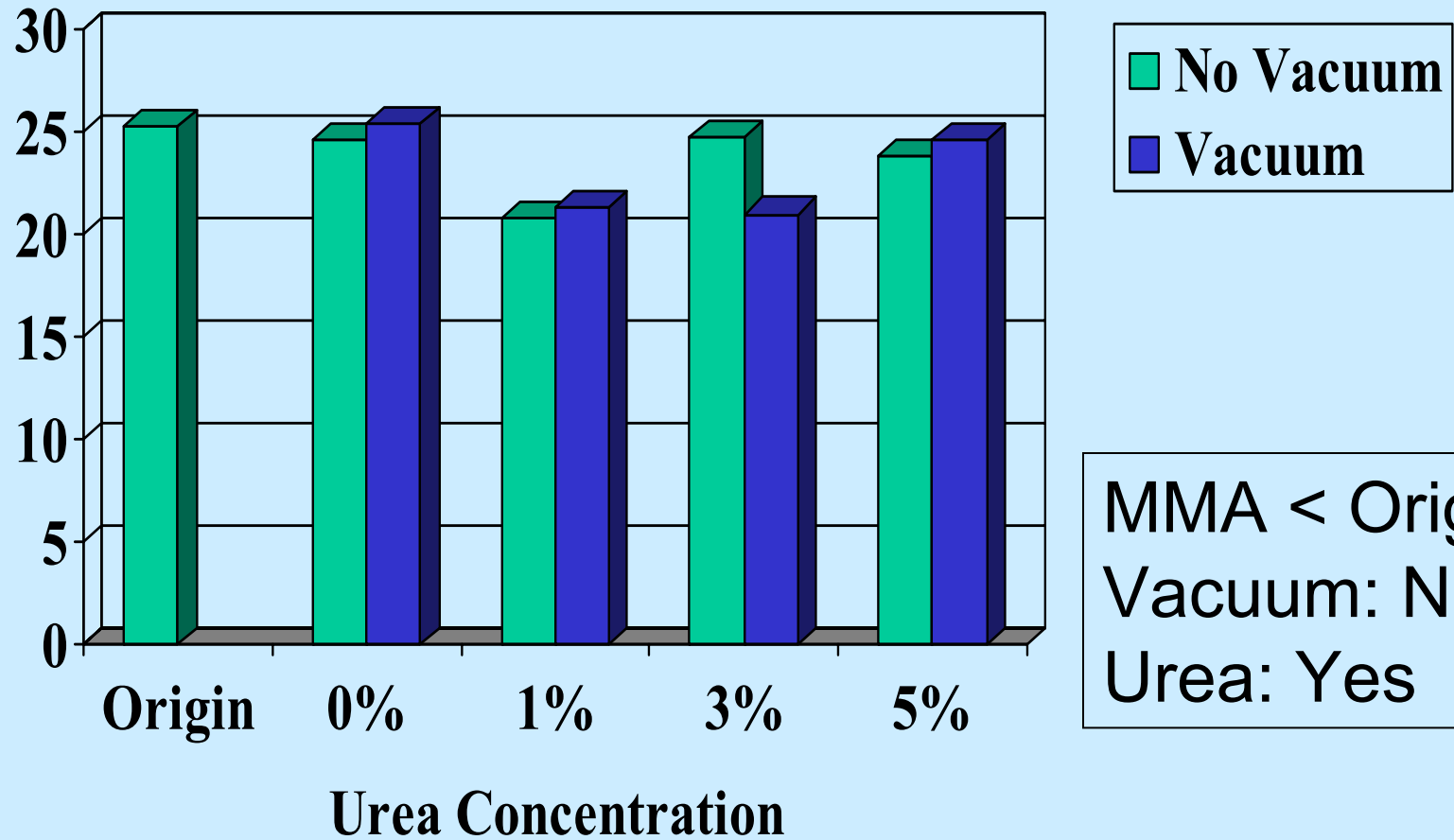


MOISTURE CONTENT

- MMA (8.8) < Untreated (11.8)
- Vacuum not significant
- Urea not significant



Water Absorption (%)

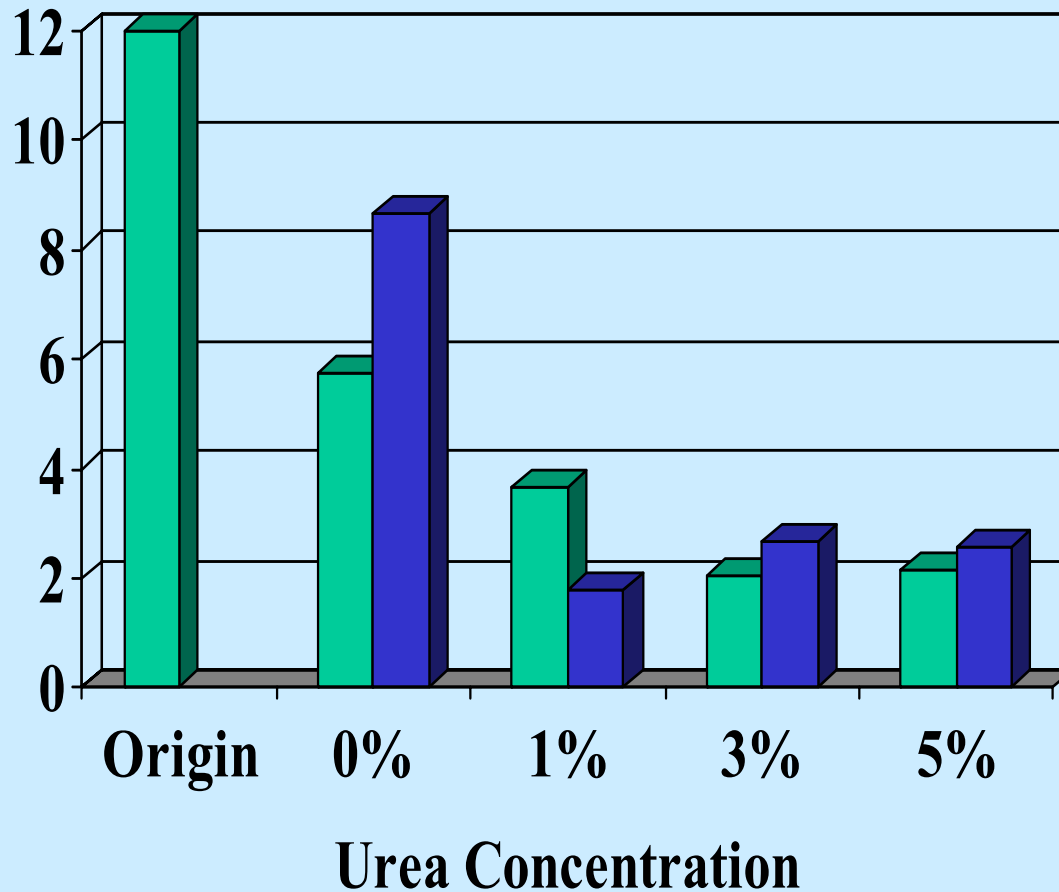


WATER ADSORPTION

- MMA (23.3) < Untreated (25.2)
- Vacuum not significant
- Urea significant
 - Urea (22.7) < Control; (25.0)



Swelling (%)



■ No Vacuum
■ Vacuum

MMA < Origin
Vacuum: No
Urea: Yes

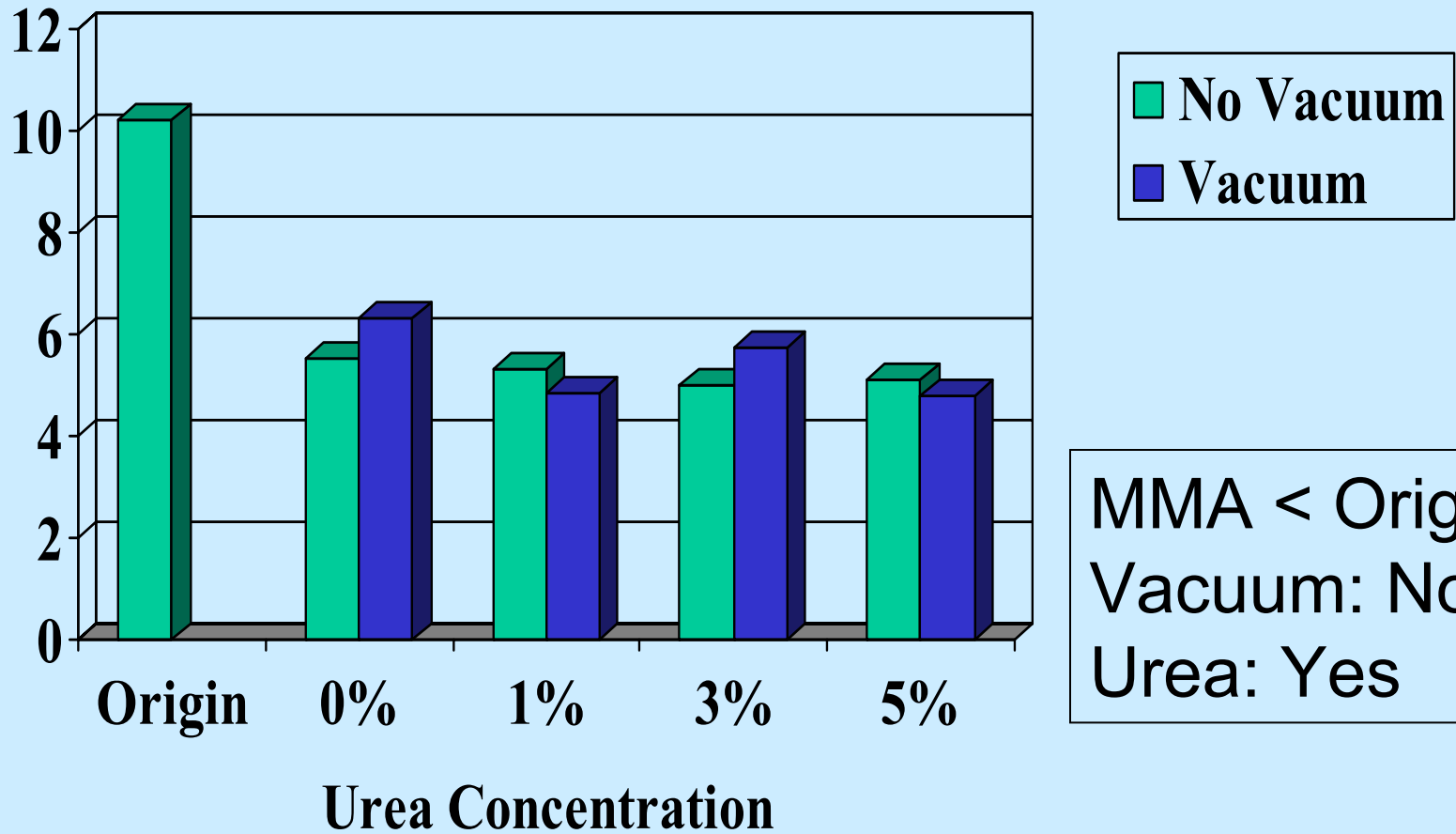


SWELLING

- MMA (12.0) < Untreated (3.4)
- Vacuum not significant
- Urea significant
 - Urea (2.5) < Control (6.2)



Shrinkage (%)



SHRINKAGE

- MMA (5.3) < Untreated (10.2)
- Vacuum not significant
- Urea significant
 - Urea (5.1) < Control (5.9)

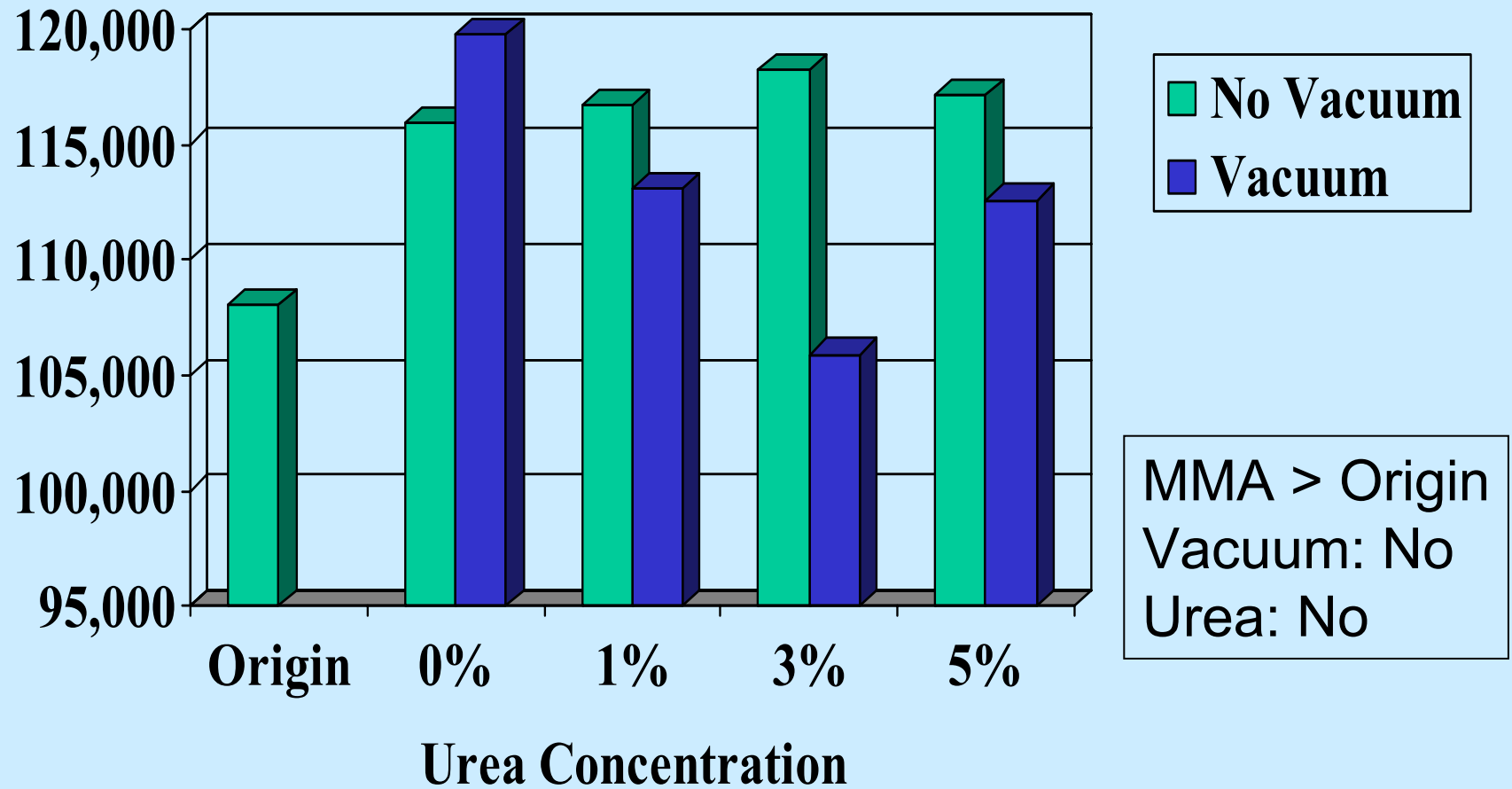


MECHANICAL PROPERTIES



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MOE (kg/cm²)



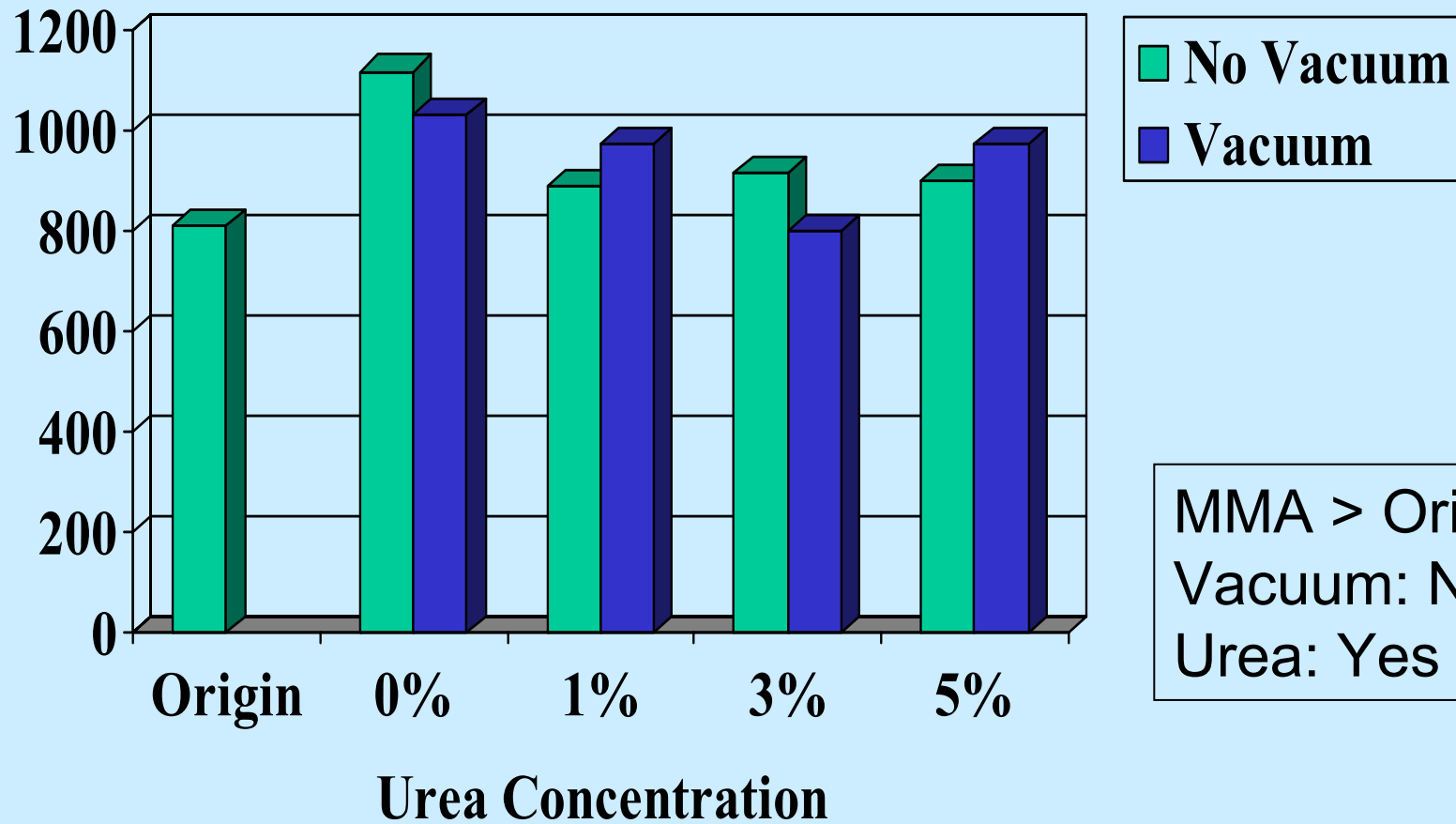
MOE

(x 1,000)

- MMA (115) > Untreated (108)
- Vacuum not significant
- Urea not significant



MOR (kg/cm²)

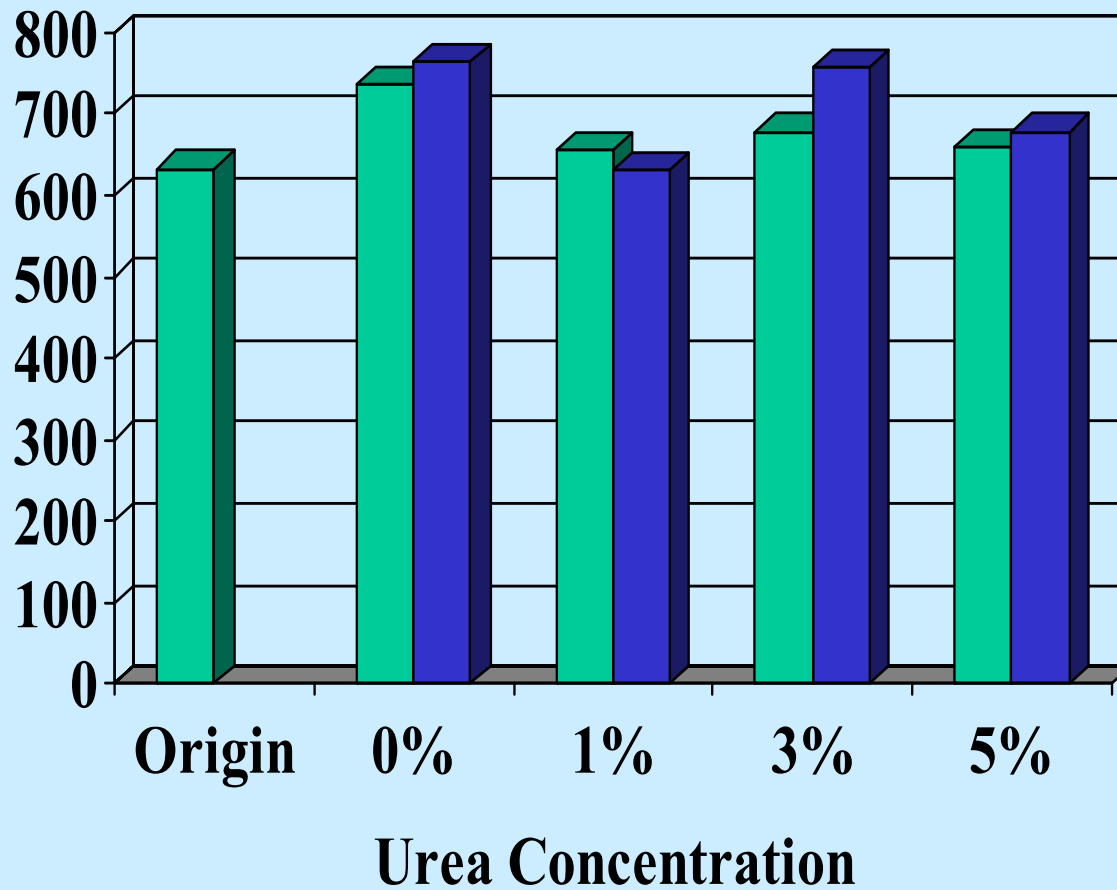


MOR

- MMA (943) > Untreated (811)
- Vacuum not significant
- Urea significant
 - Urea (907) < Control (1075)



Compression (kg/cm²)



■ No Vacuum
■ Vacuum

MMA > Origin
Vacuum: No
Urea: Yes

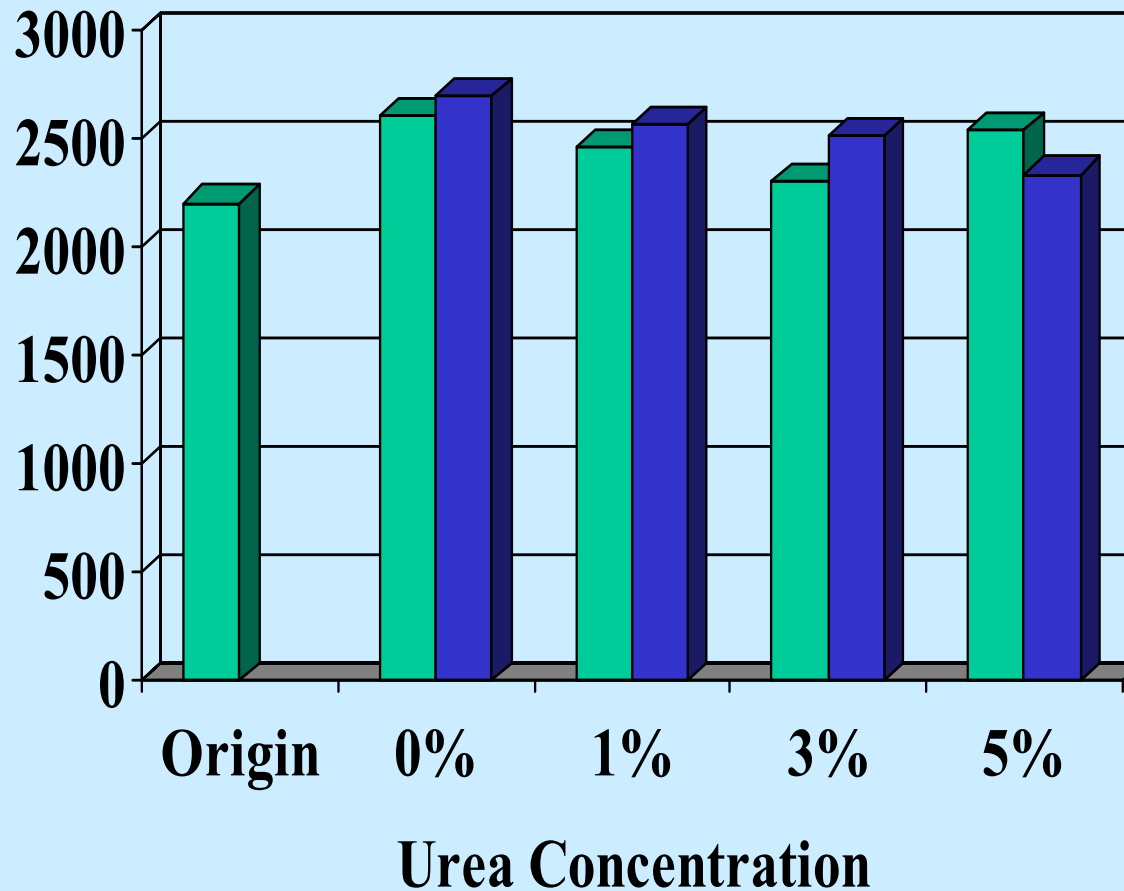


COMPRESSION

- MMA (695) $>$ Untreated (633)
- Vacuum not significant
- Urea significant
 - Urea (677) $<$ Control (749)



Tensile (kg/cm²)



■ No Vacuum
■ Vacuum

MMA > Origin
Vacuum: No
Urea: Yes

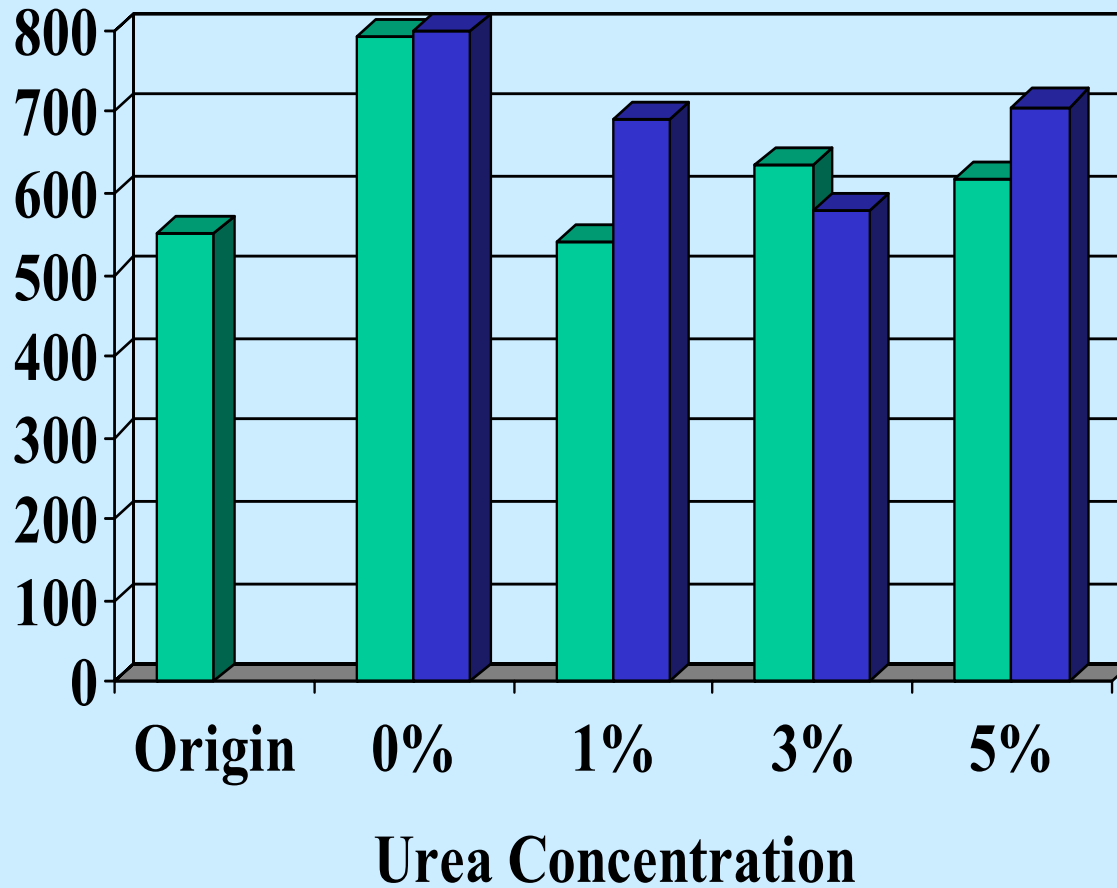


TENSILE

- MMA (1434) $>$ Untreated (1263)
- Vacuum not significant
- Urea significant
 - Urea (1405) $<$ Control (1520)



Hardness (kg/cm²)



■ No Vacuum
■ Vacuum

MMA > Origin
Vacuum: Yes
Urea: Yes



HARDNESS

- MMA (670) > Untreated; (551)
- Vacuum significant
 - Vacuum (694) > Control (646)
- Urea significant
 - Urea (628) < Control (797)



CONCLUSIONS

- Polymer loading reached 10.7-12.8 %
- Physical properties of MMA bamboo were better than the origin
- Vacuum treatment reduced mechanical properties, except hardness enhanced
- Urea enhanced polymer loading and physical properties but reduced mechanical properties, and addition at 1 % could be satisfied.



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Thank You



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