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Effect of a new mono-component polyurethane coating on untreated and heat-treated Ayous wood (*Triplochiton scleroxylon* K. Schum)

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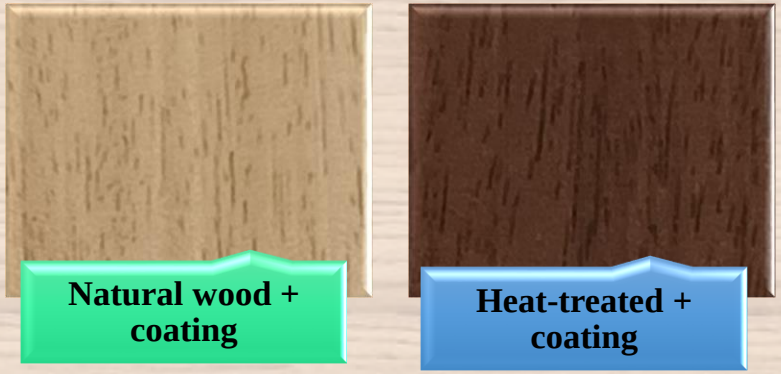
Natural wood

L*= 73.8±0.44
a*= 7.57±0.36
b*= 26.0±0.87

Heat-treated

L*= 37.1±0.57
a*= 8.08±0.39
b*= 17.8±0.45

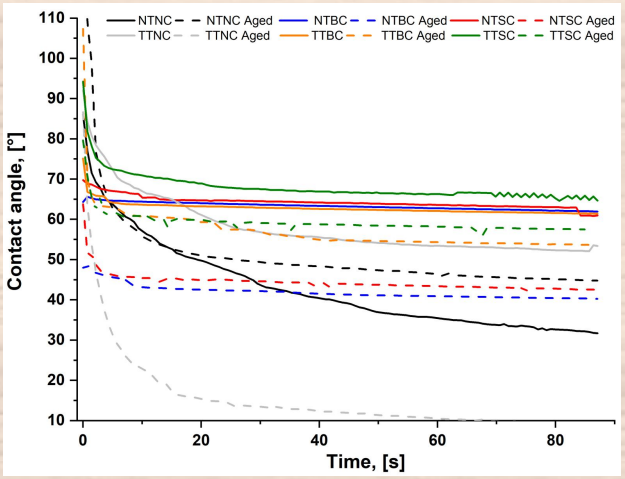


Natural wood + coating

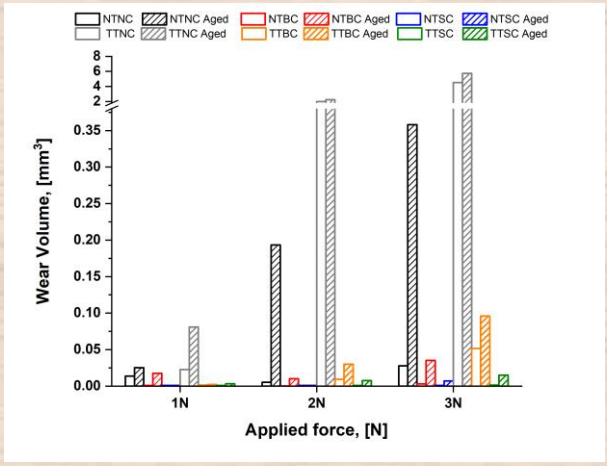
L*= 71.2±0.67
a*= 8.29±0.50
b*= 30.9±1.13

Heat-treated + coating

L*= 20.3±1.98
a*= 11.2±1.25
b*= 14.1±3.53



NTNC = Natural wood without coating
TTNC = Thermally treated wood without coating
NTBC = Natural wood with coating by brush
TTBC = Thermally treated wood with coating by brush
NTSC = Natural wood with coating by spray
TTSC = Thermally treated wood with coating by spray



ABSTRACT AND KEWYWORDS

This contribution shows the results from the study of the behaviour of Ayous (*Triplochiton scleroxylon* K. Schum) wood, untreated and industrially heat-treated at 215 °C, with the subsequent application of a mono-component polyurethane coating. The samples were artificially aged under simulated solar irradiation (168 h at 55 °C and 550 W/m^2) to verify the behaviour over time of the protective and of the unprotected wood, untreated and heat-treated. To investigate the behaviour of the specimens, micro-hardness, wettability, wearing, colour and roughness were measured and compared before and after artificial ageing in the SolarBox chamber.

The obtained data highlighted that the coating improve the surface characteristics of Ayous wood by increasing the hydrophobicity, the homogeneity of the surfaces, the micro-hardness, and the resistance to wearing.

The ageing process under simulated solar irradiation causes relevant changes in the surface properties, generally getting worse the wood surface characteristics especially in the uncoated samples: hydrophobicity decreases significantly in the heat-treated uncoated samples, whereas in the same samples but coated the hydrophobicity is maintained thanks to the presence of the polyurethane layer; micro-hardness little decreases in all samples, because of ageing; the wearing resistance is highly improved in coated samples. This result demonstrates the good performance of the polyurethane coating and its effectiveness in the protection of wood exposed to outdoor conditions.

Keywords

Ayous wood; polyurethane coating; surface properties; mechanical tests; colour; artificial ageing

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INTRODUCTION

- **Ayous wood, obtained from the species *Triplochiton scleroxylon* K. Schum, is a species widely diffused in tropical areas of central western Africa with uneven annual rainfall distribution. The major exporting countries are Cameroon, Ghana, Ivory Coast, Niger and Nigeria [1-3].**
- **Ayous wood is very appreciated and diffused in the occidental market mainly due to the low cost if compared to that of species having similar characteristics but produced in Europe.**
- **The main use of this wood is addressed to outdoor covering of the buildings that exposes ayous to the main degradation agents such as UV, moisture, and biological attacks [4-5].**
- **Durability could be improved by applying different kinds of coatings or by thermal treatment. This last causes reduction of the mechanical characteristics, such as compression strength, static bending and Brinell hardness [6-7].**
- **Previous works showed that thermally treated samples exhibited great variation in colour and chemical properties because of artificial ageing [7-14].**
- **For this reason, surface protection could be necessary also in the case of thermally treated ayous wood leading us to test the protective affect a new mono-component polyurethane coating applied to both un-treated and heat-treated samples.**

MATERIALS AND METHODS

- **Prepare the samples of ayous wood: natural and thermally treated at 215 °C. Dimension: 10x5x1 cm. Three replicas for each sample typology.**
- **Characterize the commercial mono-component polyurethane product by FTIR spectroscopy. A Nicolet Avatar 360 spectrometer was used operating in the MIR region with a resolution of 4 cm^{-1}.**
- **Apply the coating on ayous wood, both natural and heat-treated. The coating was applied both by brush and spray according to the technical data sheet.**
- **Measure colour, contact angle, roughness, micro-hardness, wearing (time 0 h). Details of the single technique are reported in the slides devoted to each single technique.**
- **Age the samples under simulated solar radiation for 168 h. Ageing was performed in a Solar Box chamber at 55 °C and 550 W/m^2.**
- **Measure colour, contact angle, roughness, micro-hardness, wearing (time 168 h). Details of the single technique are reported in the slides devoted to each single technique.**

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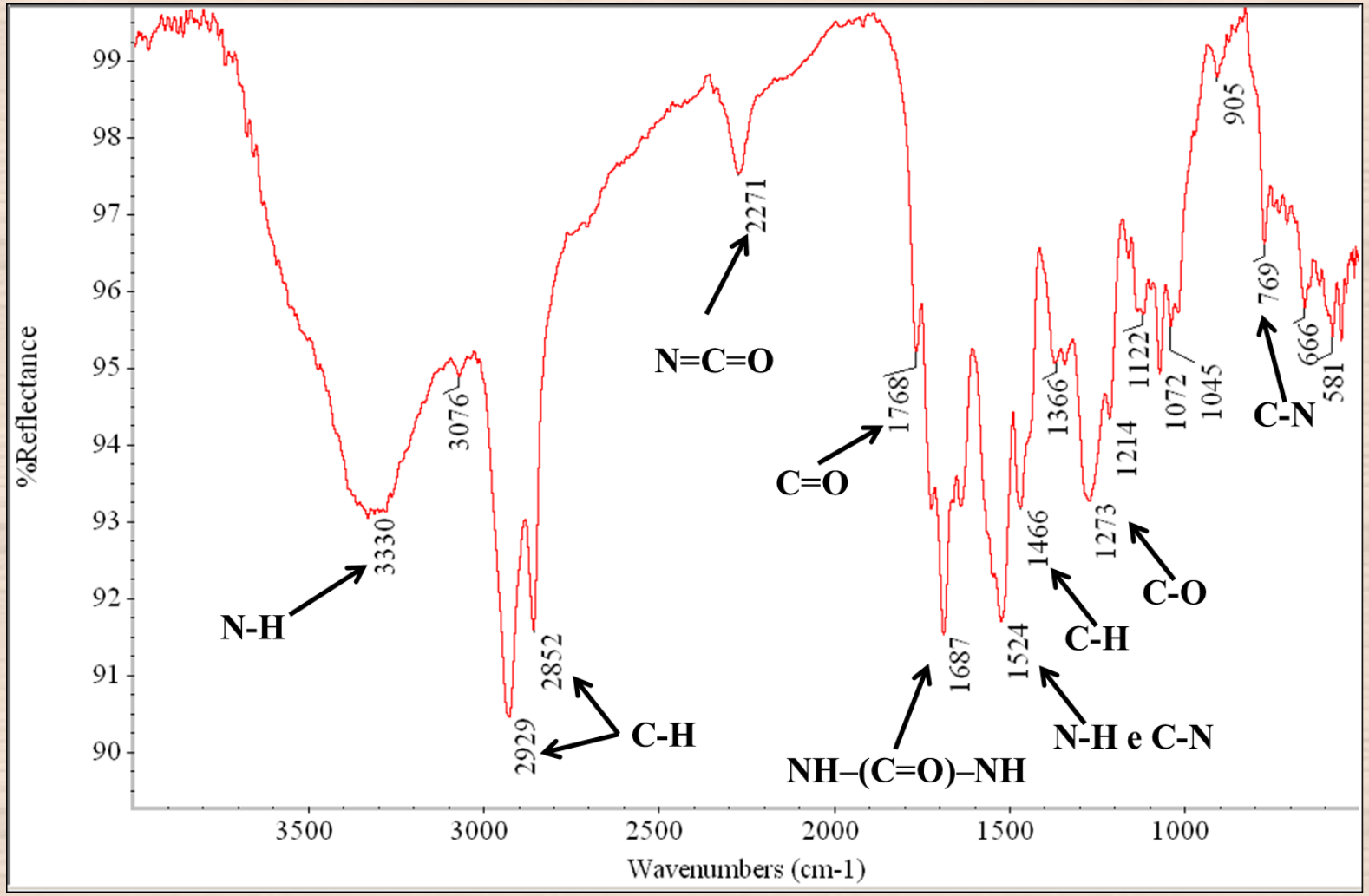
Results: FTIR spectroscopy for characterization of the commercial product (mono-component polyurethane resin)



To perform the analysis the resin, after drying, was grounded with KBr and examined with the FTIR spectrometer (Nicolet Avatar 360) in diffuse reflectance modality using KBr as background. Range 4000-400 cm^{-1}.

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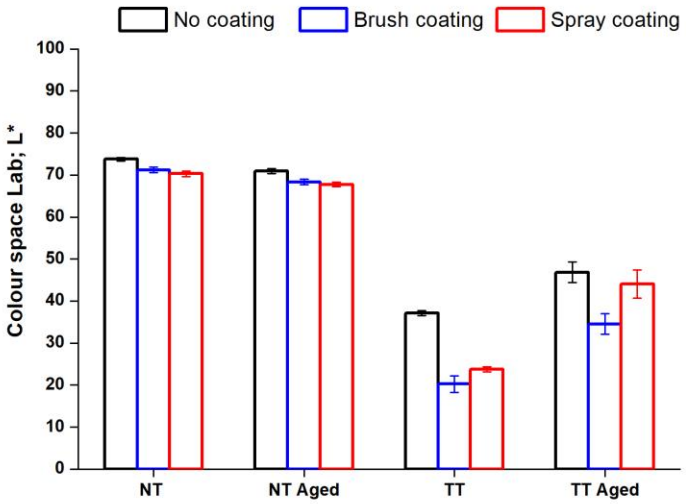
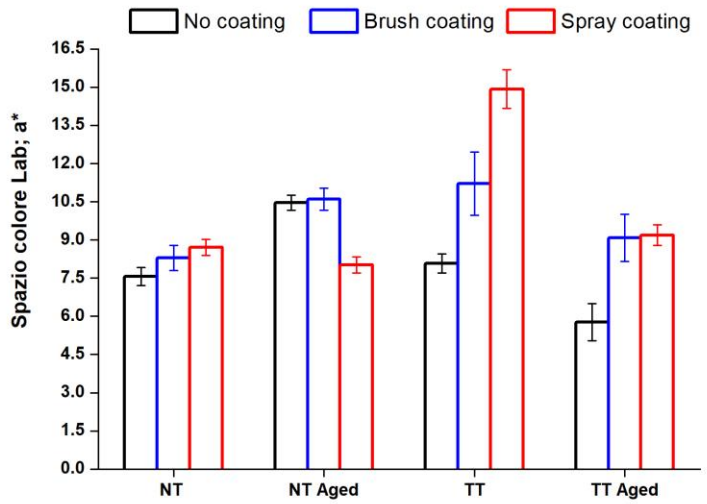
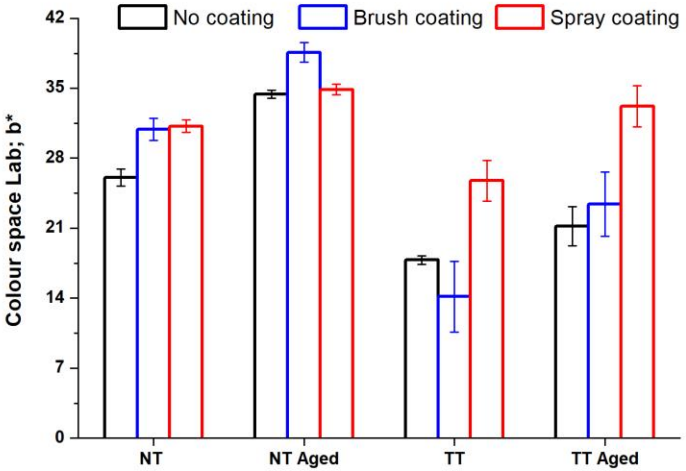
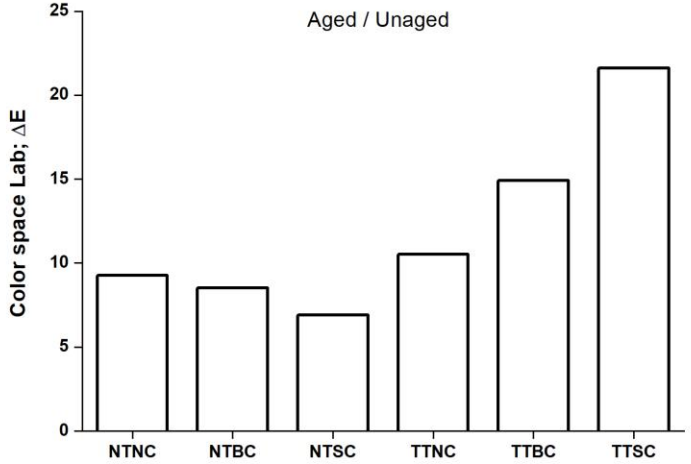
Results: colour data









NT = natural wood; TT = thermally treated wood; BC = brush coating; SC = spray coating

EOPTIS CLM 19x colorimeter
CIELAB colour system: illuminant D65, standard observer 10°, geometry of measurement 45°/0°, measurement diameter 6 mm, white reference supplied with the instrument. Thirty points of colour measurement for each specimen.

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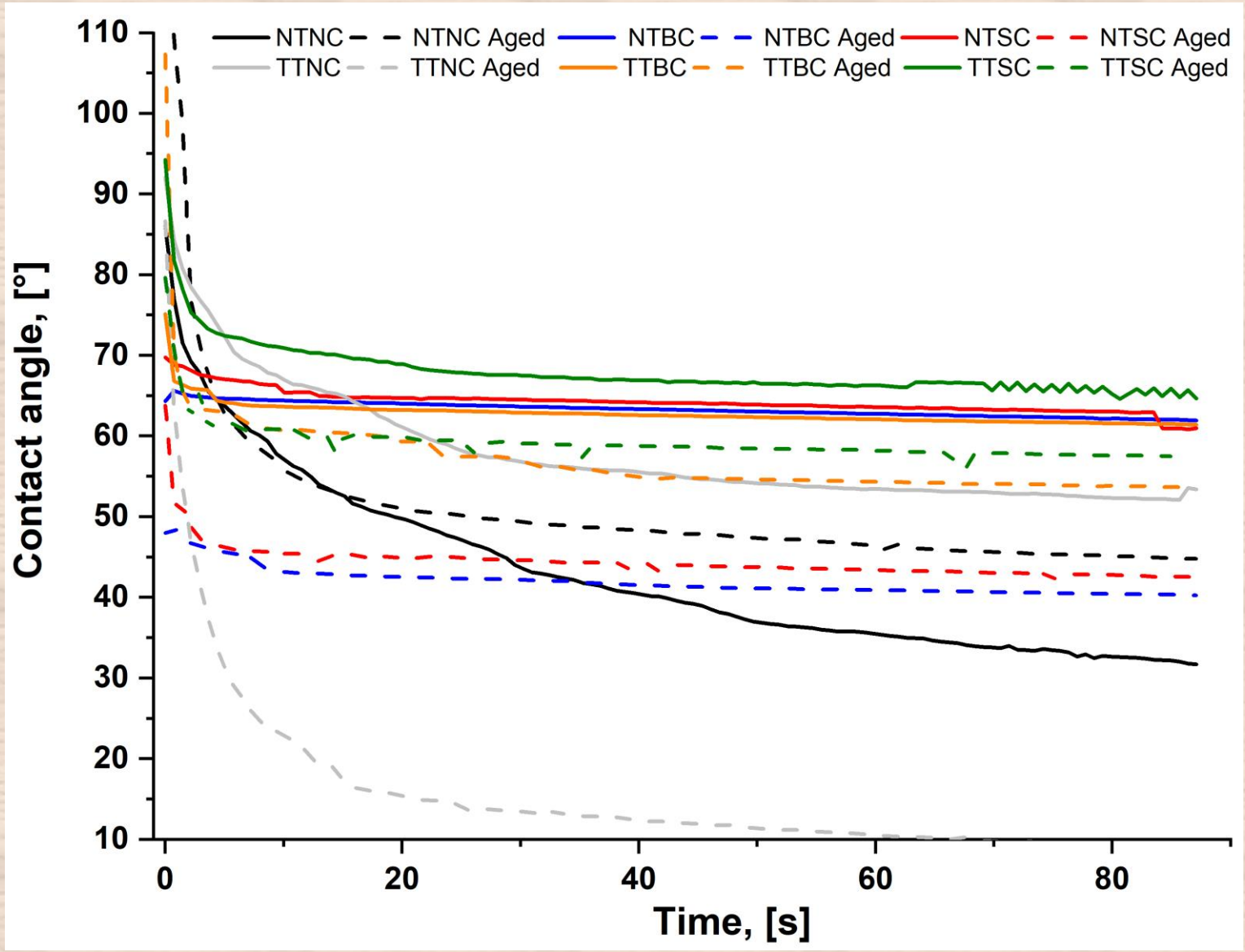
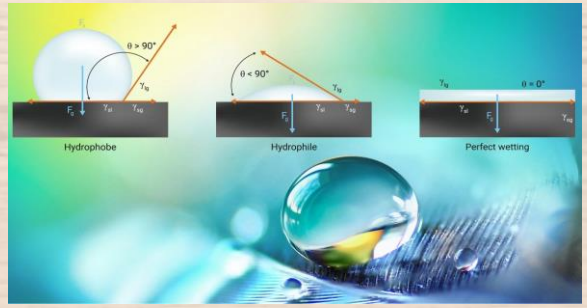
Results: wettability





Direct observation method

Measurement of the angle generated by the tangent to water drop profile and the wood solid surface.

The drop was observed through a FireWire camera with telecentric optics and 55 mm focus length. The software OneAttension elaborated directly the visual data supplying the values of contact angles every 0.72 s for a time of 90 s.

Three replica were obtained for each kind of sample (radial section).

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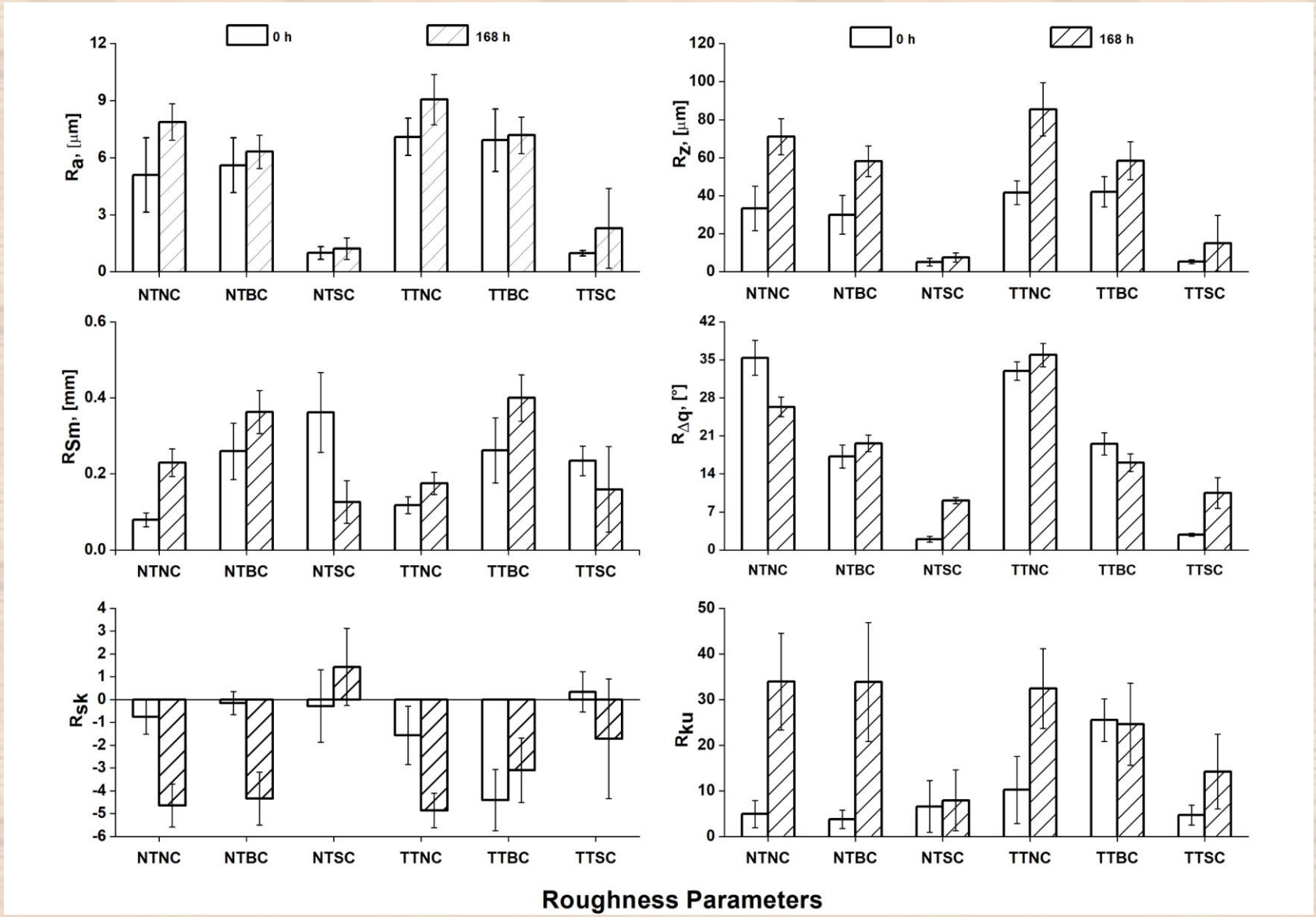
Results: roughness parameters



Roughness measurements were performed by a Taylor-Hobson TalySurf CLI 2000 apparatus, according to the standards DIN 4768:1990 and ISO 4287:1997. Roughness was measured on 4x4 mm^2 area by registering 1334 profiles.

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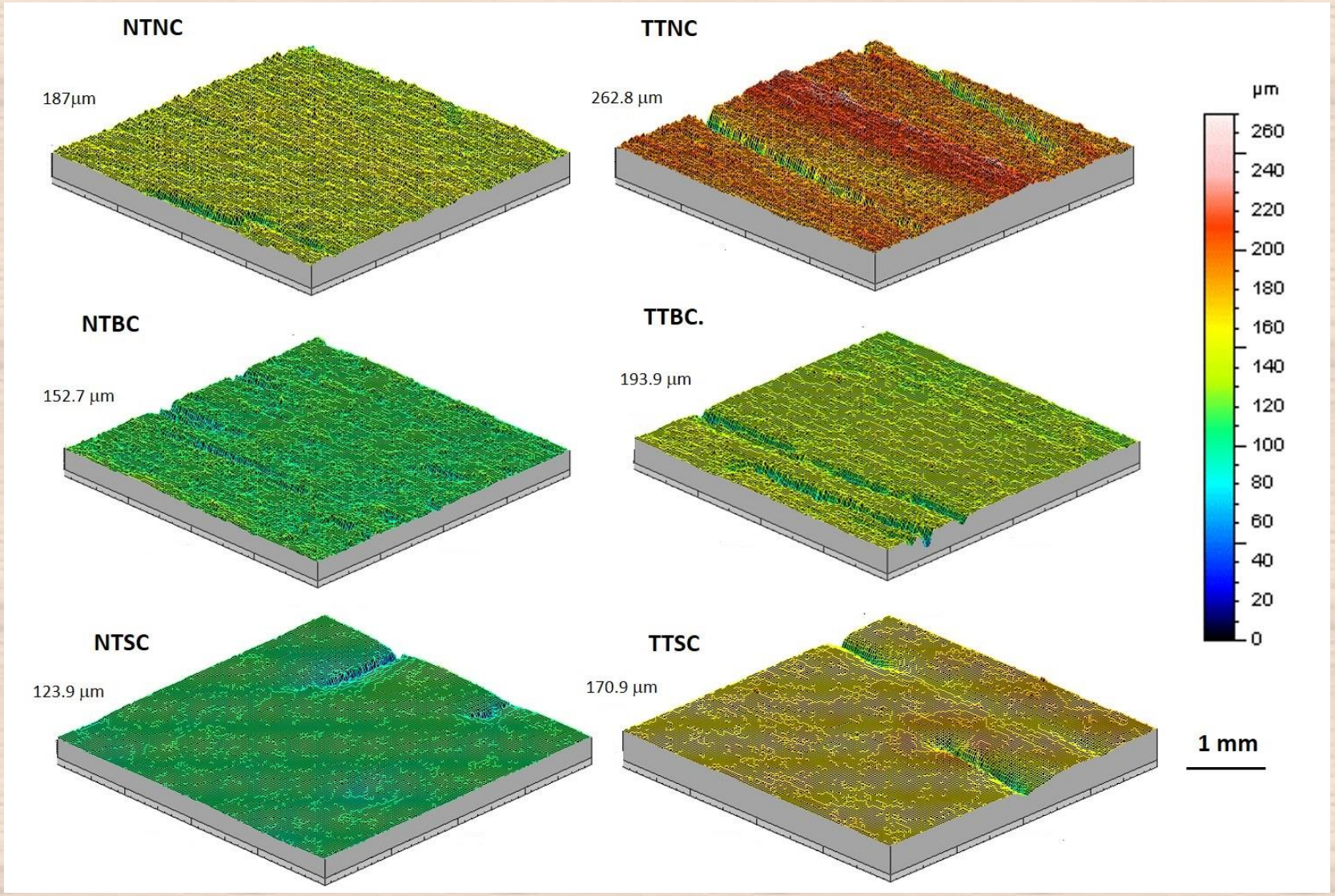
Results: roughness



Roughness measurements were performed by a Taylor-Hobson TalySurf CLI 2000 apparatus, according to the standards DIN 4768:1990 and ISO 4287:1997

The numbers on the left of the roughness map are the average distance peak-to-valley calculated on the entire measured area (4x4 mm^2)

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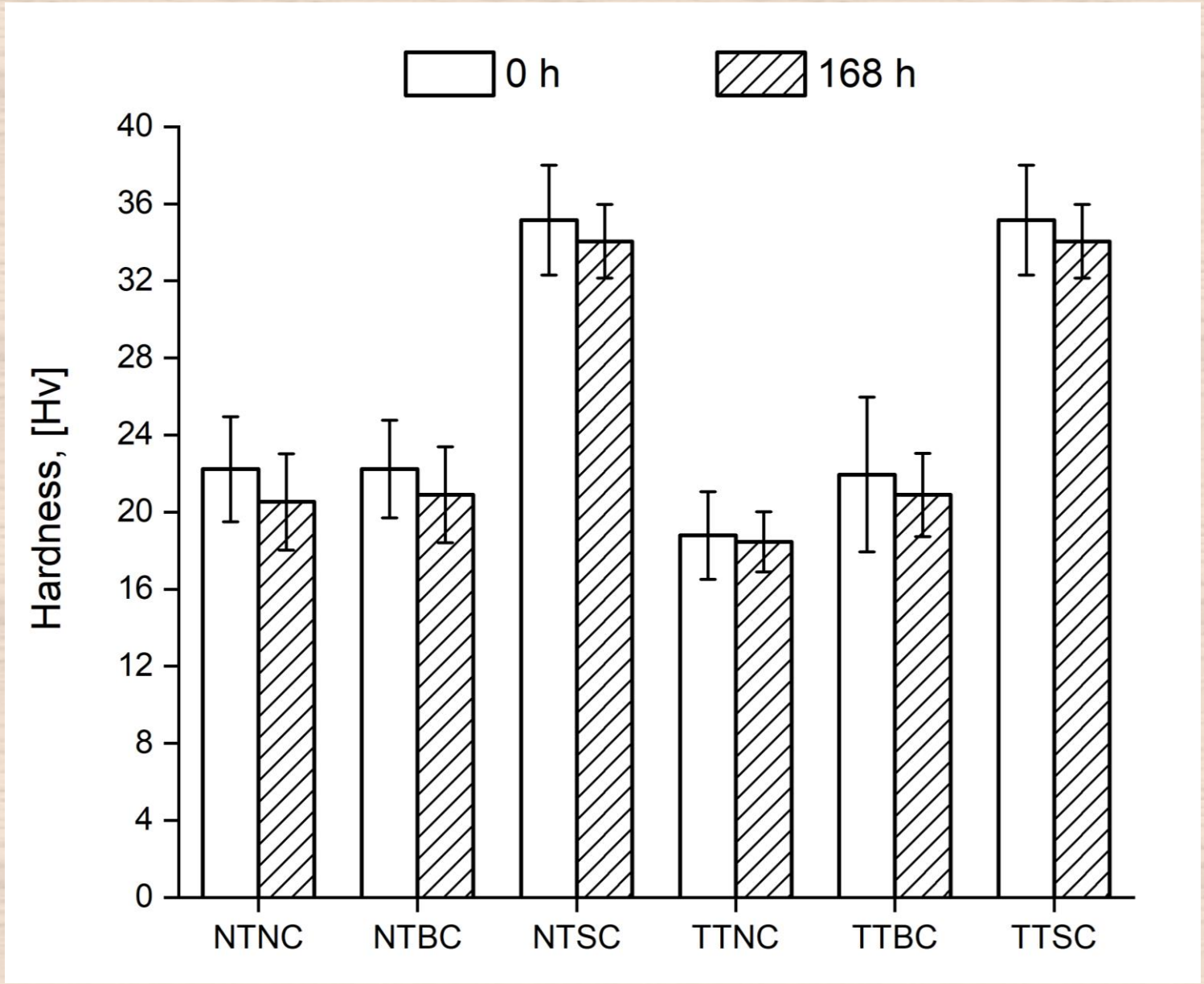
Results: micro-hardness



Depth-sensing micro-indentation (Micro-Combi, CSM Instruments, Peseaux, Switzerland), load of 10 N [15-16].

Dino-lite digital microscope to measure the diagonals of the indentations

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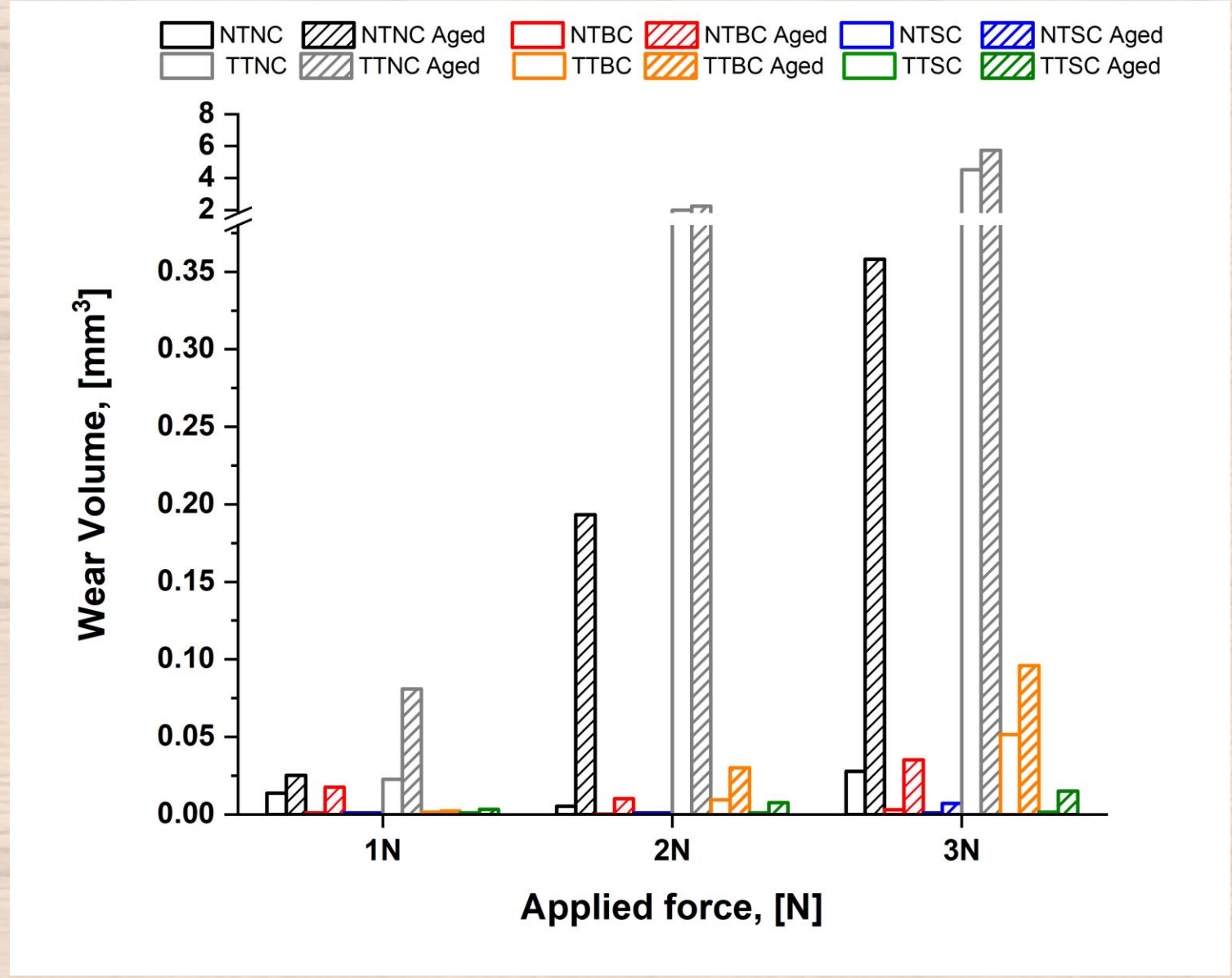
Results: wearing resistance



Tribometer, C.S.M. Instruments, Peseaux, Switzerland) operating at 25 ◦C and relative humidity 40%. The ball tip was made of 100Cr6 and the track formed had a length of 6 mm, with a speed equal to 8 cm/min. Wear length 100 m.

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DISCUSSION

- **Thermal treatment (TT) greatly affect the surface and bulk properties of wood by changing the colour (darkening), the wettability (the heat-treated wood becomes hydrophobic) [15-20], the roughness (it increases in the TT), the micro-hardness (it decreases in TT wood) and wearing resistance (this parameter highly decreases in TT wood with a significative increase of the wear volume).**

- **The application of the coating causes some changes: the colour exhibits little variations in natural wood, higher in the heat-treated wood; the wettability undergoes a significant decrease in all coated samples independently from the modality of application (brush or spray) indicating that the polyurethane coating exerts its hydrophobic effect [21]; the roughness is highly decreased by the spray application that allows for obtaining a more homogeneous distribution of the coating in respect to the brush modality; the micro-hardness exhibit the same behaviour of roughness (much high increase in the samples with the coating applied by spray); at last the wearing resistance is significantly improved by the coating.**

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DISCUSSION

- **The ageing under simulated solar irradiation causes changes in all samples with different trends depending on wood typology (natural or thermally-treated) and coating application (brush or spray).**

- **Concerning the colour, the natural wood (NT) undergoes little variation of lightness and chromatic coordinates more evident in the samples with the polyurethane coating applied by spray. In the case of thermally-treated (TT) wood the colour changes are much more relevant especially for the a* coordinate in the samples with the product applied by spray (SC). The value of ΔE*, expressing the total colour variation, in TT samples with SC is very high indicating a probable alteration of both wood and coating.**

- **The contact angle undergoes a decrease because of the ageing suggesting that this process increase the wettability of the wood surface. The TT wood without coating has a peculiar behaviour because the ageing causes a great change in the contact angle (high decrease) producing a surface completely wettable [22-27].**

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DISCUSSION

- **As expected, according to the literature on the topic, the surface roughness increases in all samples because of the ageing [28-32].**

- **Micro-hardness shows a little decrease in all samples indicating that the ageing has a little effect on this parameter**

- **Lastly, the wearing resistance is highly influenced by the presence of the coating. In fact, the samples without coating, especially those thermally-treated, exhibit high decrease of wearing resistance (high increase of wear volume). On the other hand, the samples with the surface coating have a very low wear volume values after the ageing demonstrating the effectiveness of the polyurethane product in the protection of the wood surface against wear.**

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CONCLUSIONS AND FUTURE PERSPECTIVES

- **Industrial thermal treatment changes significantly the surface and mechanical characteristics of wood to an extend that makes the materials fragile and not resistant to outdoor exposure. For the future it will be useful to test temperature for the treatment lower than 215 °C that could maintain the mechanical characteristics of the wood, as shown in a previous paper [11].**

- **The polyurethane coating demonstrated effectiveness to protect the wood surface (significant increase of wearing resistance) and to maintain the hydrophobic characteristic, also affecting little the colour, in the case of natural wood. For the future it will be useful to study the behavior of the sole polyurethane product in respect to the artificial ageing.**

- **This work supplied valid information about the short-term ageing of a commercial polyurethane mono-component coating giving a practical indication about maintenance planning on surface treated with this product.**

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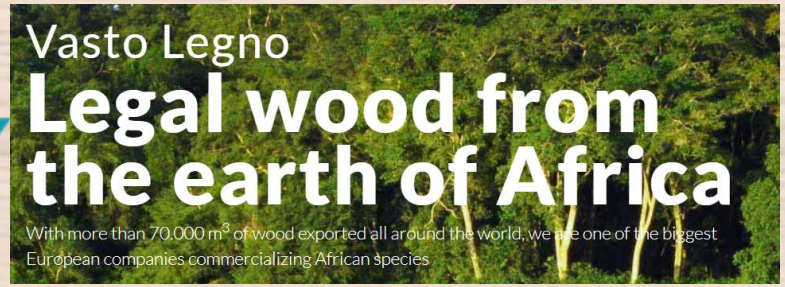

Thank you for the kind attention