ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Mechanical, physical and chemical properties of wood, heat-treated with the vacuum-press-dewatering method

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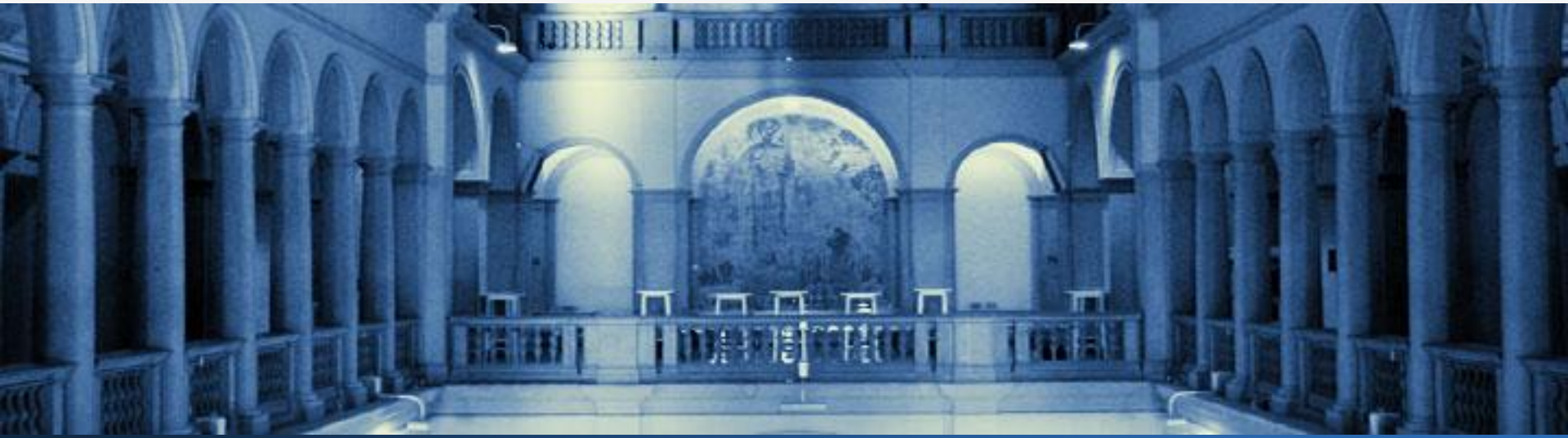

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1 Introduction

Trends:

- Intensified use of renewable primary products
- Growing ecological awareness tends to result in using fewer chemical preservatives

Advantages:

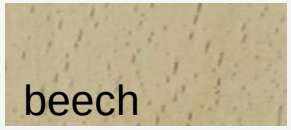
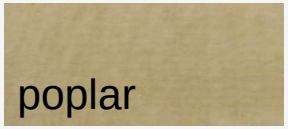
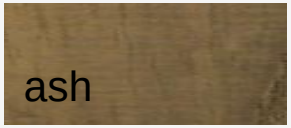
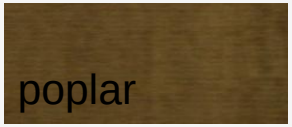
- Increasing durability
- Increasing dimensional stability

- Heat-treated wood gains in importance
- Different methods to produce heat-treated wood are developed

2 Vacuum-press-dewatering – Vacu^3

- Technology
  - Conductive heat transfer with heating platens
  - Vacuum up to 150mbar
  - Airbag-system applies a pressure up to 70tons
  - Condensation water is exhausted during the entire treatment

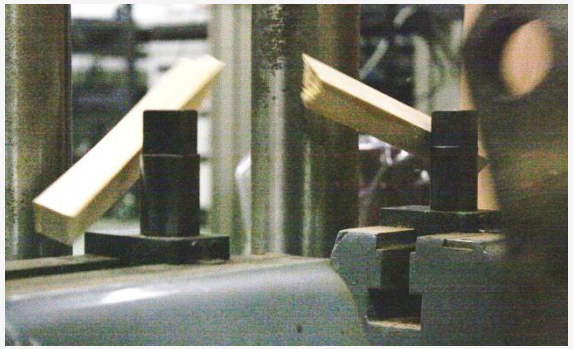
Investigated industrial treated hardwood

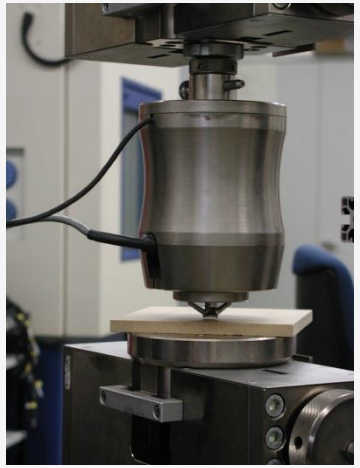
	Treatment temperature*		
Properties	**untreated (u)**	**medium (m)**	**high (h)**
mechanical and physical	  	 	  
chemical	beech ash oak	beech ash oak	beech ash oak

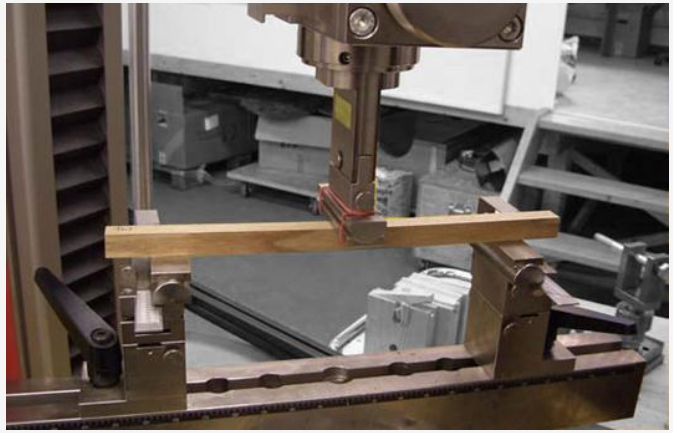
*The treatment temperatures of the samples which were investigated of mechanical/physical and chemical properties are the same, but the process management was different

4 Properties of heat-treated wood
4.1 Physical and mechanical properties

- Colour changes
- Density
- Brinell hardness
- Bending strength
- EMC and Swelling



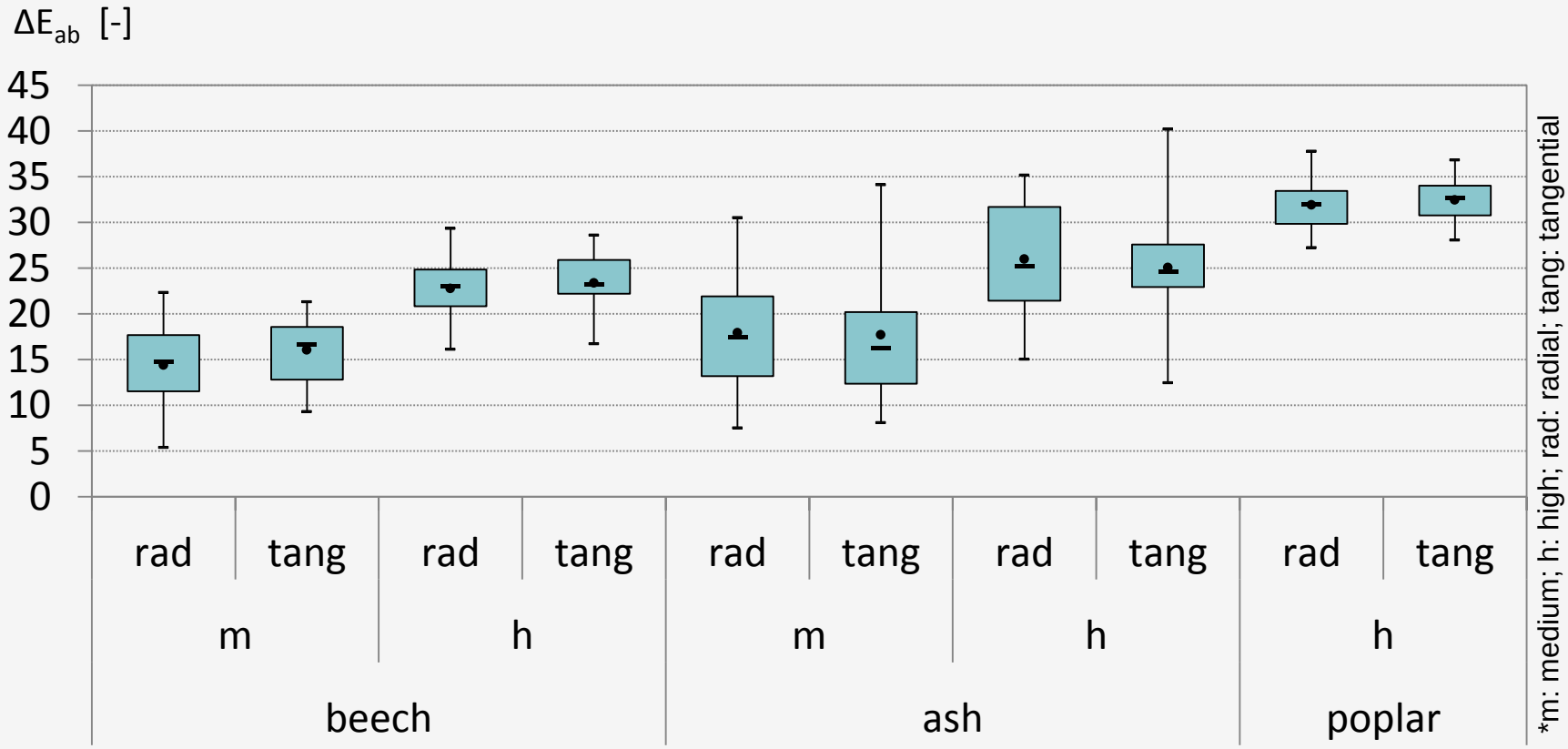




4.1 Physical and mechanical properties

4.1.1 Colour changes ΔE_{ab}

in relation to untreated wood



4.1 Physical and mechanical properties
4.1.1 Colour changes in relation to untreated wood

-Unequal colour distribution caused by red heartwood
-Treated with high temperature

4.1 Physical and mechanical properties
4.1.1 Colour changes in relation to untreated wood

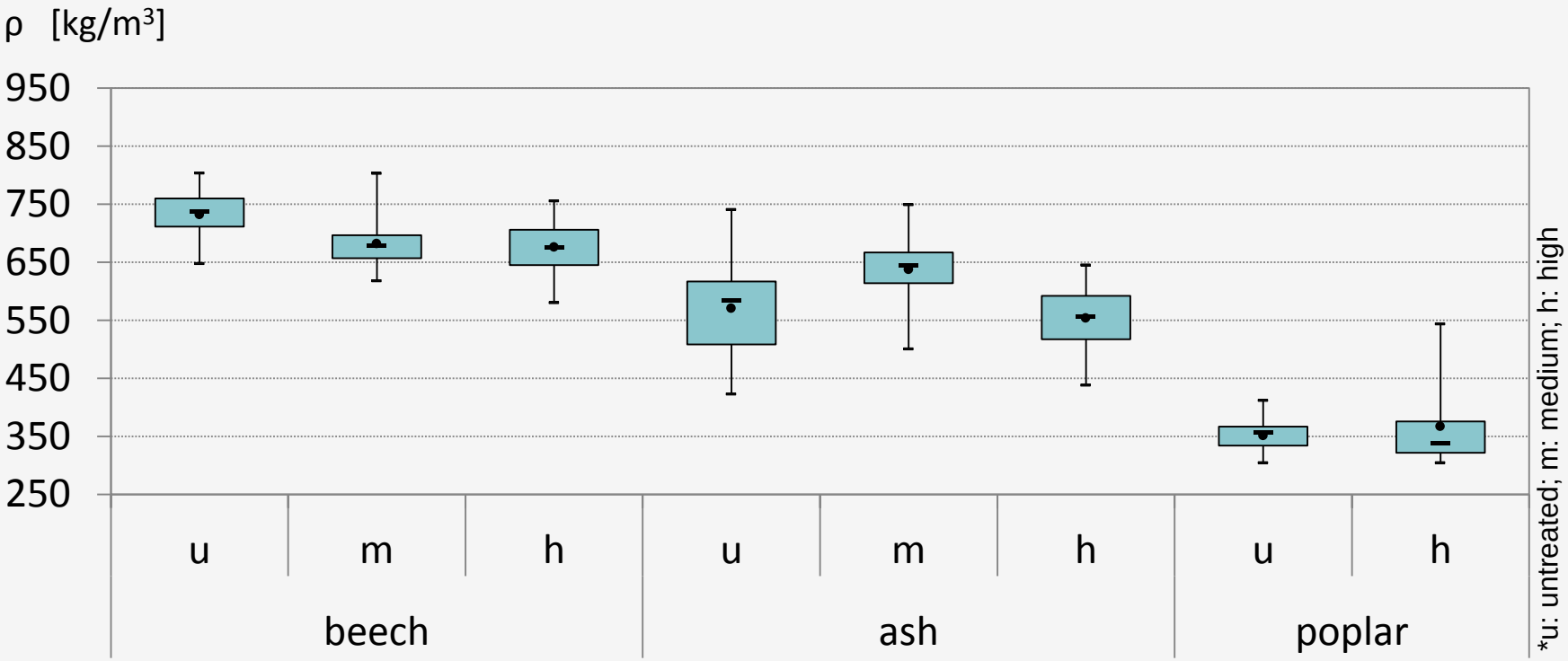

untreated


treated in autoclave (<200°C)

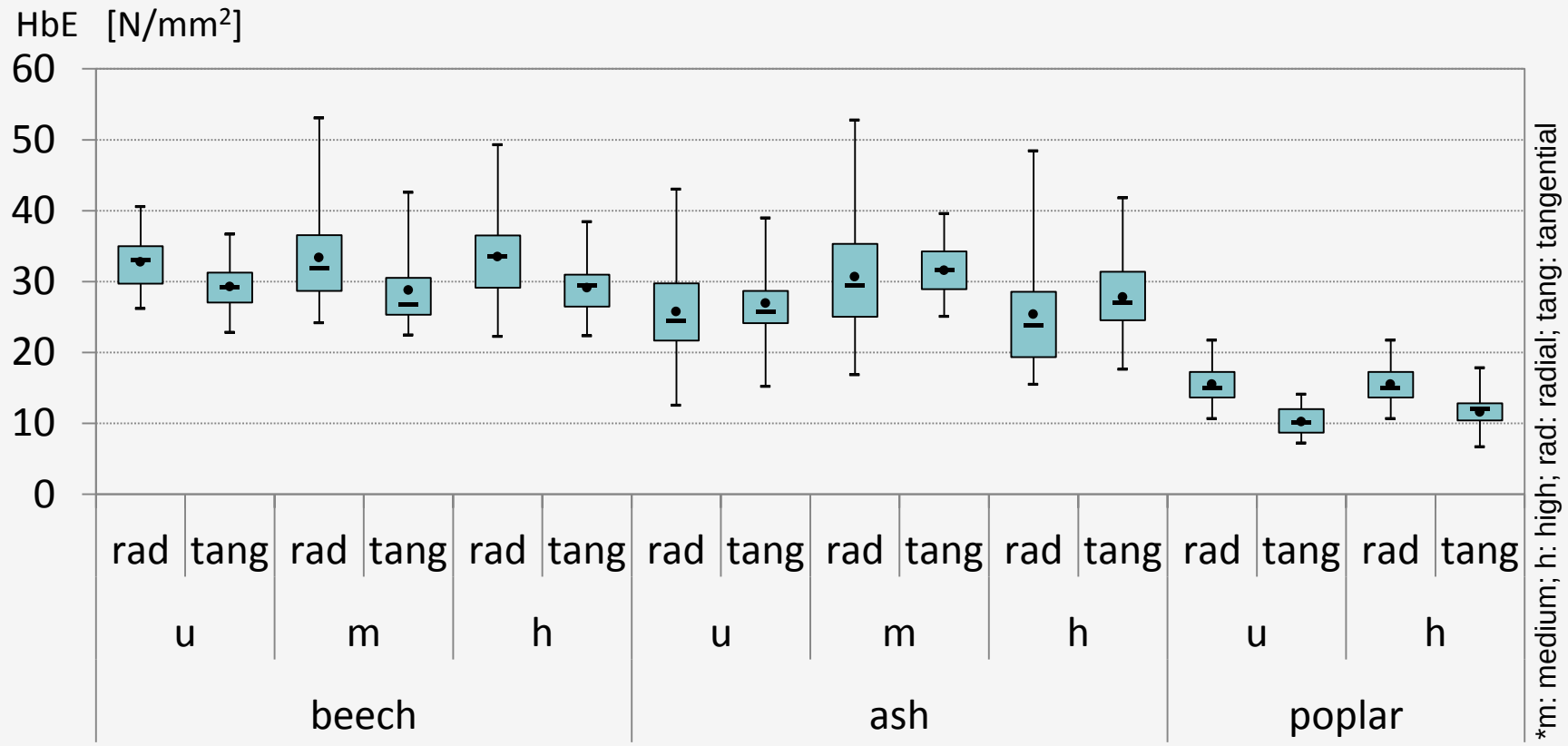

treated by Vacu^3 (>200°C)

- Colour changes effect by a treatment with Vacu^3 is low compared to a treatment in an autoclave

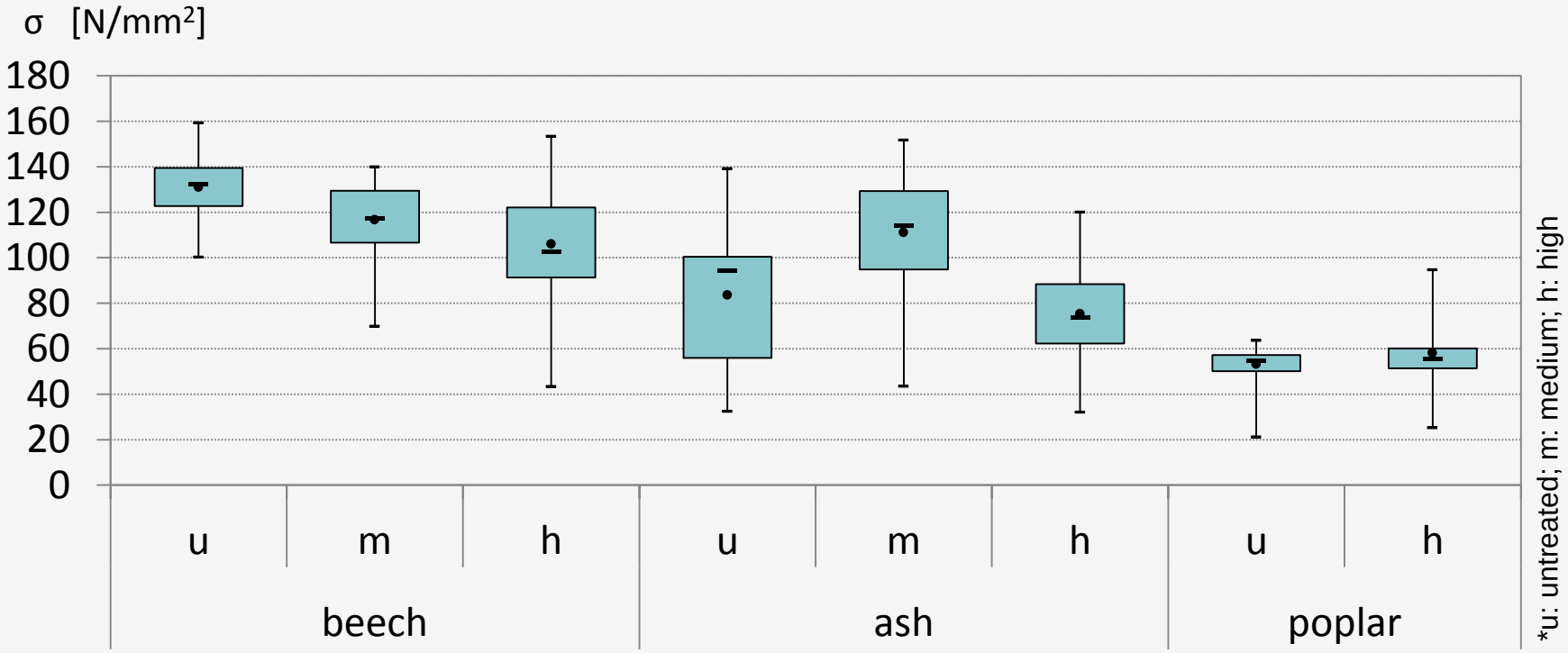
4.1 Physical and mechanical properties
4.1.2 Density



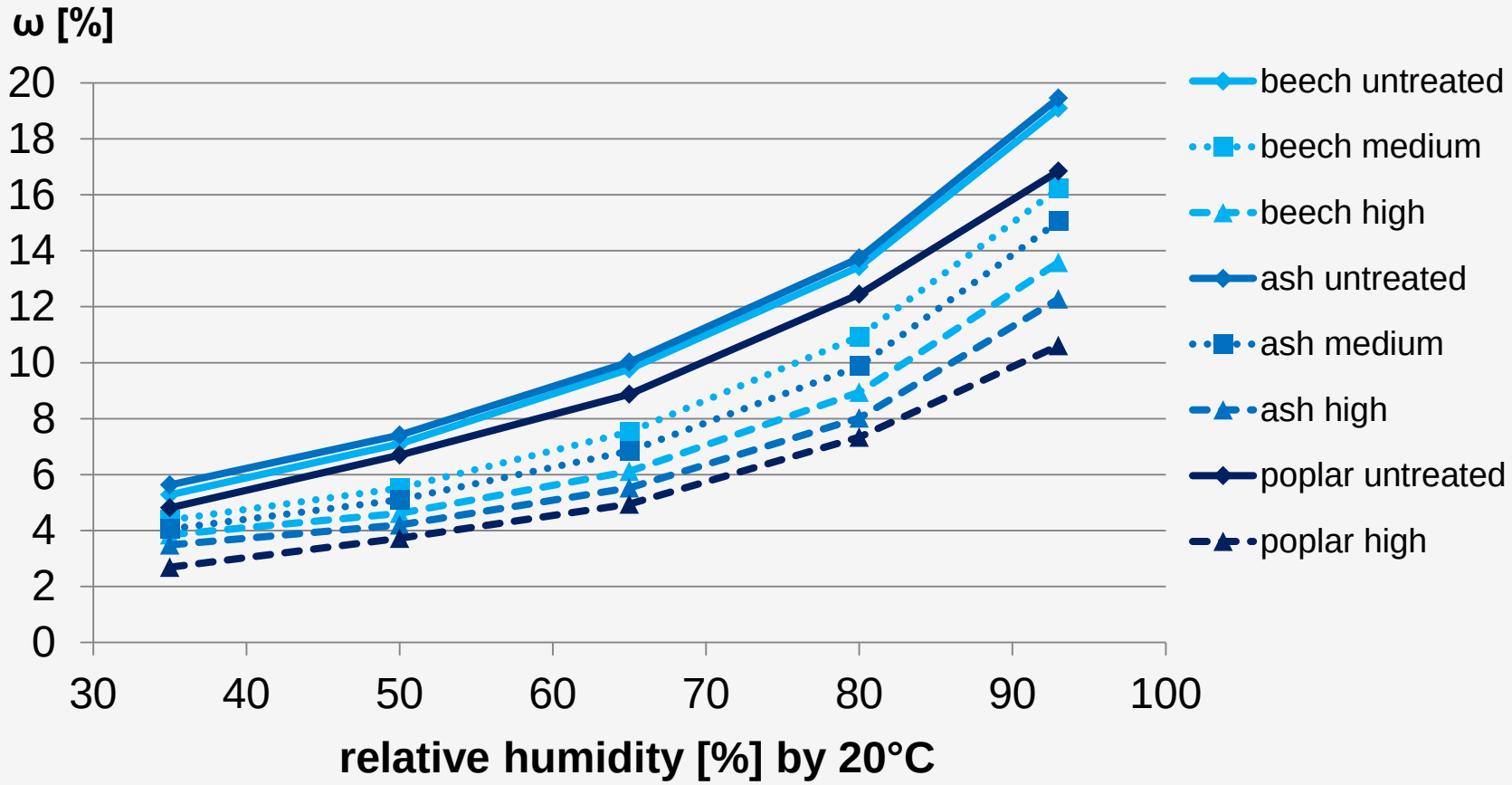
4.1 Physical and mechanical properties
4.1.3 Brinell hardness



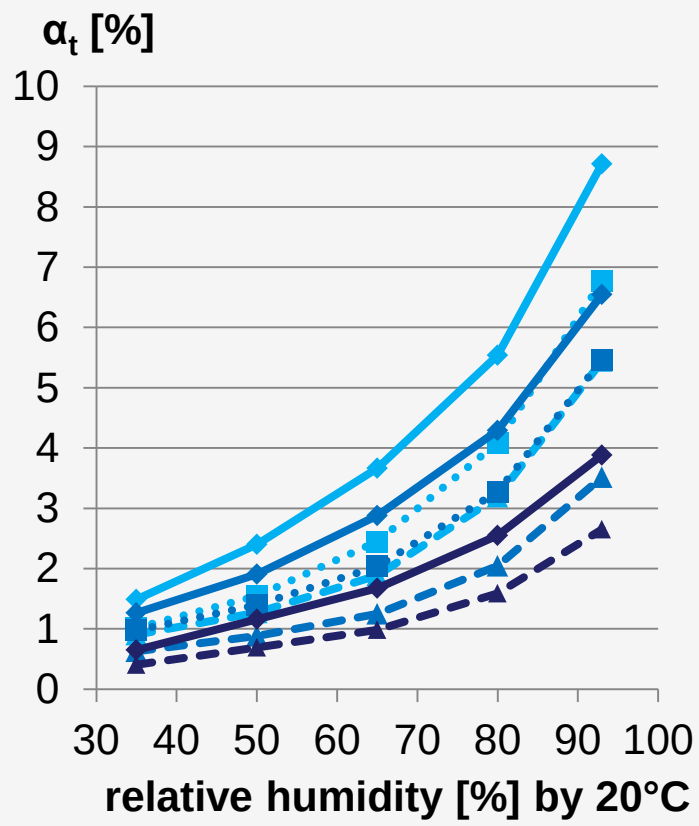
4.1 Physical and mechanical properties
4.1.4 Bending strength

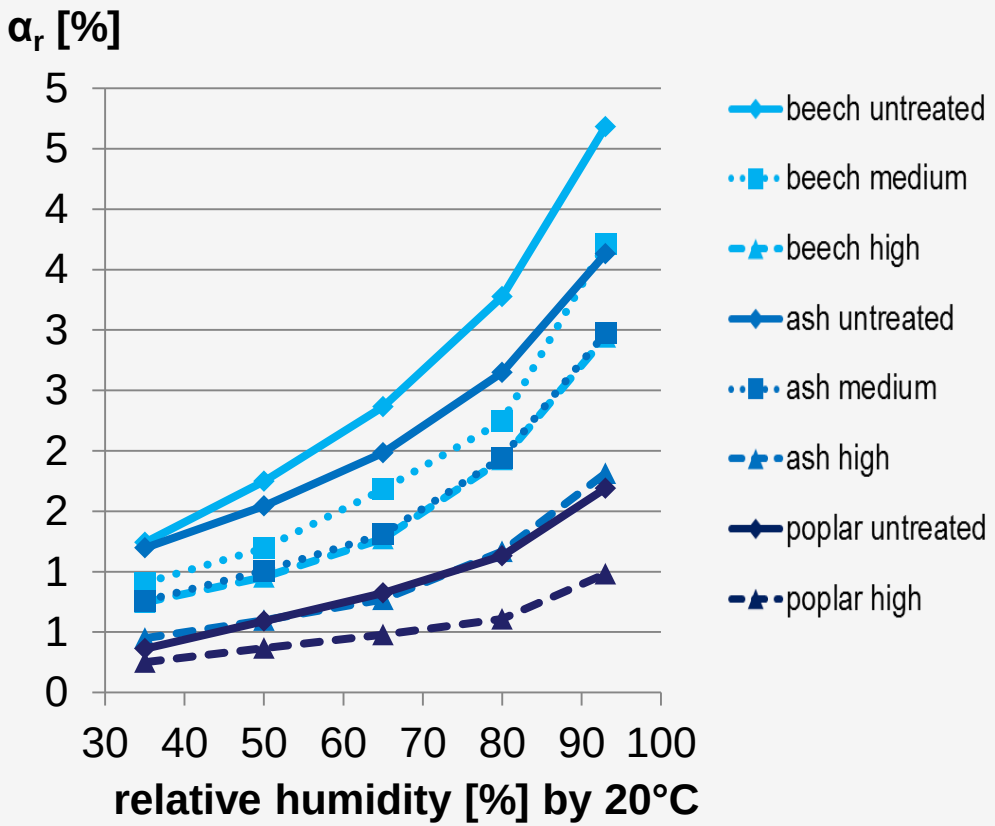


4.1 Physical and mechanical properties
4.1.6 Equilibrium moisture content (EMC)



4.1 Physical and mechanical properties
4.1.7 Swelling tangential and radial



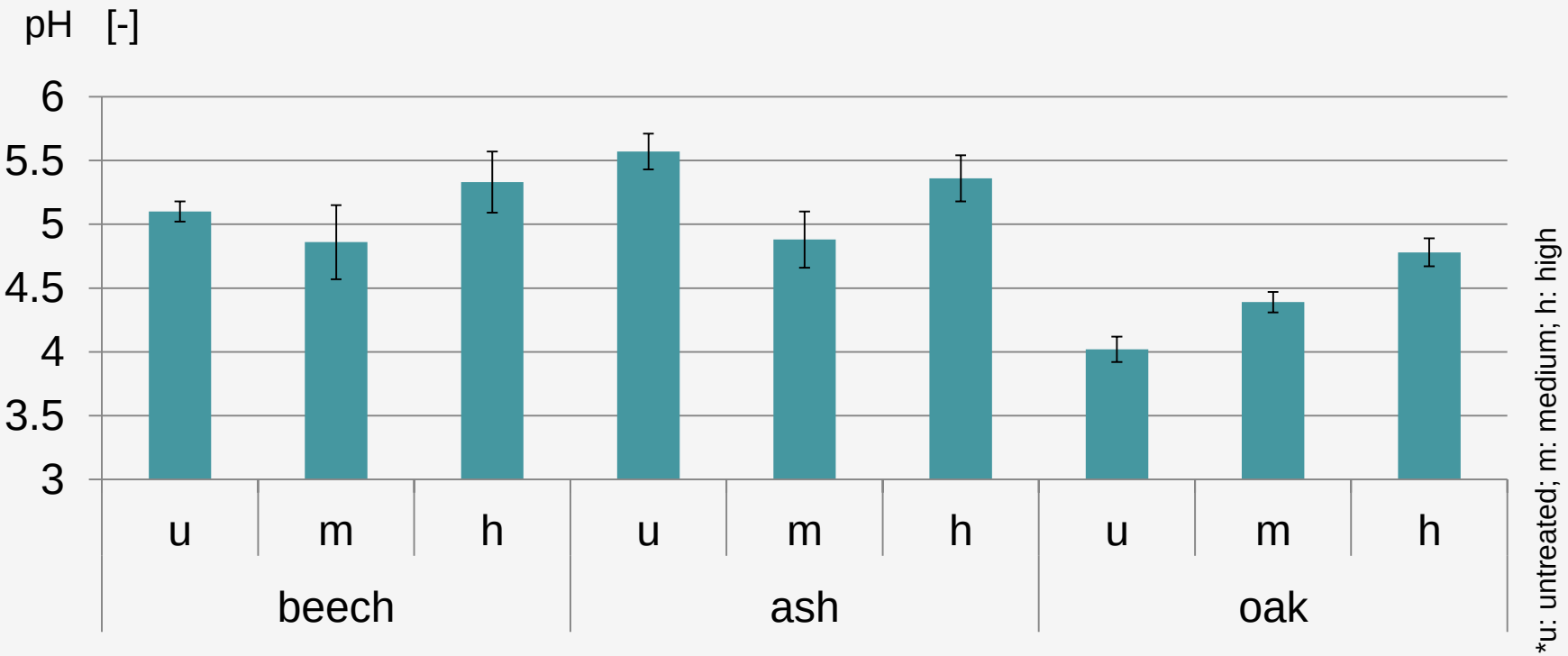


4.2 Chemical Properties

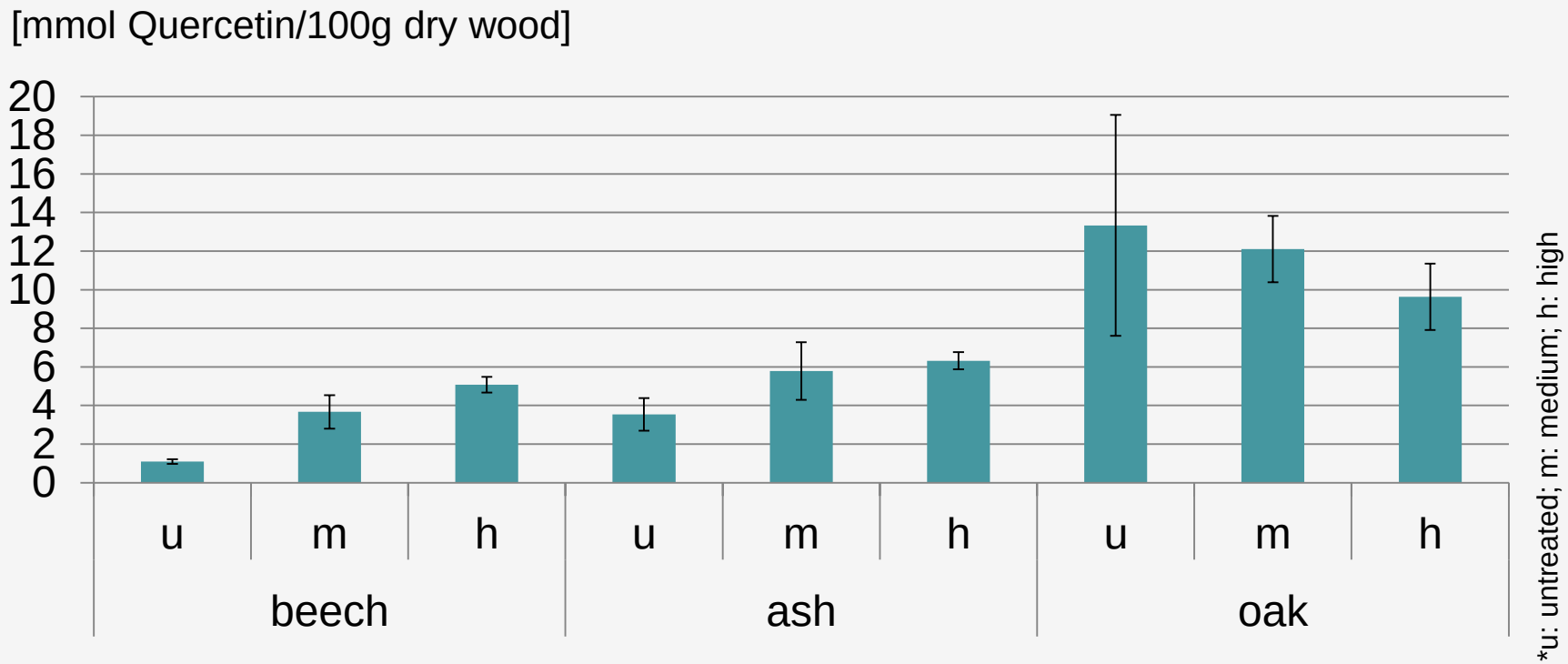
by T. Hofmann and T. Rétfalvi, Sopron, University of West Hungary

- pH-value
- Total Phenol content
- Loss of VOCs (volatile organic compounds)
  - acetic acid
  - formic acid
  - furfural
- Complex investigation of condensation water exhausted during heat-treatment

4.2 Chemical Properties
4.2.1 pH-value



4.2 Chemical Properties
4.2.2 Total phenol content



4.2 Chemical Properties
4.2.3 Volatile organic compounds (VOC)

	sample	formic acid*	acetic acid*	furfural*
beech	untreated	1.53 ± 0.84	33.26 ± 7.31	0.60 ± 0.27
	medium	2.19 ± 1.48	53.44 ± 33.12	4.84 ± 4.43
	high	3.32 ± 1.61	48.62 ± 13.44	2.86 ± 1.17
ash	untreated	1.44 ± 0.84	6.43 ± 1.23	not detectable
	medium	4.89 ± 2.61	94.25 ± 58.07	4.61 ± 2.26
	high	3.43 ± 1.59	60.21 ± 26.41	2.52 ± 1.41
oak	untreated	3.06 ± 0.34	141.89 ± 36.94	2.58 ± 0.68
	medium	2.76 ± 0.31	75.57 ± 32.34	27.36 ± 8.28
	high	2.58 ± 0.42	27.32 ± 8.34	7.35 ± 0.74

*in mg /100g dry wood; reviewed by the flask method (40°C, 24h); mean value ± 95% confidence

4.2 Chemical Properties
4.2.4 VOC time course – beech medium

time after treatment	formic acid*	acetic acid*	furfural*
10 weeks	2.19 ± 1.48	53.44 ± 33.12	4.84 ± 4.43
20 weeks	4.26 ± 0.55	36.79 ± 9.83	2.26 ± 0.77
40 weeks	3.25 ± 1.52	43.14 ± 22.75	3.45 ± 2.13
52 weeks	3.35 ± 1.95	47.90 ± 37.70	4.55 ± 3.88

*in mg /100g dry wood; mean value ± 95% confidence

Trends of mean values:

- formic acid at the highest after 20 weeks
- acetic acid and furfural decrease after 20 weeks and rise again to 52 weeks

4.2 Chemical Properties
4.2.5 Compounds in condensation waters

- Absolute concentration [g/l] of the most VOC compounds in condensation waters

Source	Furfural	Acetic acid	Formic acid	5-methyl-Furfural	Guaiacol	2,6-dimethoxy-phenol	Vanillin
ash	1.81	49.6	7.0	2.34	0.660	0.059	0.217
oak	25.53	108.1	13.6	6.46	0.115	0.166	0.416

- High concentration of VOCs (composition depends on wood species) have technological aspects and raise waste handling and environmental issues
- Application fields for the valuable compounds amongst others in chemical industry or in food industry
- Alternatively the utilization of the mixture as a whole could be considered

5 Summary

- Vacu^3 method is an effective wood modification process
- Vacu^3 effects lower colour changes as other treatment processes
  - unequal colour distribution for heat-treated beech samples with red heartwood
- Strength decrease for all samples except for ash medium
- Swelling decrease with increasing treatment temperature up to 61% compared to untreated wood
- The produced wood is characterised by low VOC emissions
- Condensation waters are highly acidic and concentrated, containing valuable compounds

Thank you for your attention