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INFLUENCE OF EXTRACTIVES ON WATER VAPOUR SORPTION BY THE EXAMPLE OF WOOD SPECIES FROM CHILE

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ABSTRACT

At 28 wood species from Chile the equilibrium moisture content was determined at 20°C and 35, 50, 65, 80 and 93 % relative humidity. Using the experimentally determined average values the selected parameter of the Hailwood Horrobin model such as fiber saturation point, mono- and polymolecular sorptions as well as inaccessibility of the sorbent to sorbate and the specific surface of the sorbent were computed. The influence of extractives on the equilibrium moisture content was investigated.

KEY WORDS: wood extractives, water vapour sorption properties

INTRODUCTION

For the evaluation of the sorption behaviour of domestic wood species the sorption isotherm of fir wood is usually used. Due to differences in the wood extractives it can come to clear differences in the sorption behaviour (Willeitner and Schwab 1981, Popper et al. 2005). Also the equilibrium moisture content of domestic wood species varied within a relatively broad range. A comprehensive representation to the sorption behaviour of over 100 wood species gives Keylwerth (1969). Investigations of Popper et al. (2005) showed that between the equilibrium moisture content and the amount of extractives a close correlation exists.

In the present work the equilibrium moisture content at 20°C and variable relative humidity of selected wood species from Chile were determined. Afterwards the constants according to the model by Hailwood and Horrobin (1946) were computed. The influence of extractives on the equilibrium moisture content was investigated.

MATERIALS AND METHODS

Wood species used in this study are summarized in Tab. 1. Wood species with a very different extractive portion (Tab. 4) were examined (sorption analysis), in order to be able to recognize tendencies better. For each wood species 3 samples were used. The values in the tables are average values.

Tab. 1: The test material

Trade name:	Latin name	Plant family
Pino araucaria	*Araucaria araucana* (Mol.) K. Koch	Aracariaceae
Alerce	*Fitzroya cupressoides* (Molina) I.M. Johnston	Cupressaceae
Cipres de las Guatecas	Pilgerodendron uviferum (D. Don) Florin	Cupressaceae
Mañio	*Podocarpus* sp., *Saxegothaea conspicua* Lindl.	Podocarpaceae
Olivillo	*Aextoxicon punctatum* Ruiz et Pavon	Aextoxicaceae
Maiten	*Maytenus boaria* Mol.	Celastraceae
Trevo	*Dasyphyllum diacanthoides* (Less.) Cabrera	Asteraceae
Tineo	*Weinmannia trichosperma* Cav.	Cunionaceae
Ulmo	*Eucryphia cordifolia* Cav.	Eucryphiaceae
Ruil	*Nothofagus alessandrii* Esp.	Fagaceae
Rauli	*Nothofagus alpina* (P. et E.) Oerst.	Fagaceae
Coique de Magallanes	*Nothofagus betuloides* (Mirb.) Oerst.	Fagaceae
Roble de Maule	*Nothofagus glauca* (Phil.) Krasser	Fagaceae
Coyan, Roble	*Nothofagus obliqua* (Mirb.) Oerst.	Fagaceae
Lenga	*Nothofagus pumilo* (P. et E.) Krasser	Fagaceae
Chin-Chin	*Azara microphylla* Hook. f.	Flacourtiaceae
Belloto del Norte	*Beilschmiedia miersii* (Gay) Kosterm.	Lauraceae
Peumo	*Cryptocarya alba* (Mol.) Looser	Lauraceae
Lingue	*Persea lingue* (R. et P.) Nees ex Koop	Lauraceae
Tepa	*Laurelia philippiana* Looser	Monimiaceae
Laurel	*Laurelia sempervirens* (R. et P.) Tul.	Monimiaceae
Luma	*Amomyrtus luma* (Mol.) Legr. et Kaus.	Myrtaceae
Arrayan	*Luma apiculata* (DC.) Burret	Myrtaceae
Temu	*Blepharocalyx cruckshanksii* (H. et A.) Nied.	Myrtaceae
Notro Cirelluilo	*Embothrium coccineum* J. R. et G. Forster	Proteaceae
Avellano	*Gevuina avellana* Mol.	Proteaceae
Radal	*Lomatia hirsuta* (Lam.) Diels ex Macbr.	Proteaceae
Quillay	*Quillaja saponaria* Mol.	Rosaceae

Sorption analysis

The attempt samples were conditioned in a climatic chamber (KPK 200, Feutron)at constant temperature of 20±0.2°C and with relative humidities RH from 35%, 50%, 65%, 80% to 93% (ΔRH±3%) and the equilibrium moisture content MC according to DIN 52 183 (1977) determined. The sorption analysis was submitted with the Hailwood and Horrobin (1946) sorption model (further called HH-model). The HH-model was derived on the assumption that the sorbed water exists as a simple solution and as hydrate of the wood. It is continued to accept that the sorbed layer, which consists of no hydrated, hydrated wood and of free liquid water forms an ideal solid solution. This sorption model makes possible to separate the monomolecular *Um* from the polymolecular sorption *Up* and the estimation of the fiber saturation point U_{FS}. The adsorption equation for the HH-model is as follows:

$$Utot = Um + Up \tag{1}$$

$$Utot = \frac{1800}{Mp} \cdot \left(\frac{\alpha \cdot \beta \cdot h}{1 + \alpha \cdot \beta \cdot h} \right) + \frac{1800}{Mp} \left(\frac{\alpha \cdot h}{1 - \alpha \cdot h} \right), \tag{2}$$

Where *Utot* total water sorbed (%),
Um monomolecular water sorbed (%),
Up polymolecular water sorbed (%),
h relative humidity (%),
Mp hypothetical molecular weight of the dry wood polymer,
α equilibrium constant of the hydrated wood,
β equilibrium constant of the no hydrated wood.

Further allows the HH-model to calculate following values:

- The specific surface of the sorbent Σ
- and the inaccessibility of the sorbent to the sorbate *Z*.

Ethanol-toluol-extraction

Wood extractives, also known as accessory components of the wood are chemical compounds, which do not take part in the anatomical structure and can be extracted from the wood with neutral solvents. The chemistry and biochemistry of the extractives are in detail described in the literature (Hillis 1962, Geissman 1962, Sandermann 1966). One finds work about the influence of the wood extractives on the setting of adhesives at some authors (Narayanamurti 1957, Herrick and Conca 1960, Narayanamurti et al. 1962, Chen 1970, Roffael and Rauch 1974, Chen and Paulitsch 1974, Popper 1975, Plomley et al. 1976, Albritton and Short 1979, Eaton and Hale 1979). Some extractives, particularly from the bark, are used in the woodworking industry as adhesives (Hall et al. 1960, Stanley 1964, Sedliačik and Eisner 1972, Saayman and Oatley 1976). The extractives have an influence on the sorption behaviour (Wangaard and Granados 1967, Ladomerský 1978, Themelin 1998) and on the swelling and shrinking (Burmester 1989, Militz and Homan 1993) of wood.

The ethanol-toluol-extract (further called EtOH-toluol-extract) was determinated according to TAPPI (1997a and 1997b). The extract portion was based on the oven dry weight of the wood.

RESULTS AND DISCUSSION

The adsorption isotherms

The submicroscopic characteristics of the wood / water system can be derived from the accomplished water vapour sorption measurements. The average values of the measured equilibrium moisture contents (obtained from three samples) are presented in Tab. 2. The figures 1 till 4 show exemplary the computed and measured sorption isotherms of two wood species with high and two with low fiber saturation point. Tab. 3 shows the values *Um*, *Up*, U_{FS}, Z and Σ computed according to the HH-model at fiber saturation.

The used sorption model shows a relative good fitting of the measured (*Umes*) and the computed (*Utot*) values for all examined wood species.

The influence of extractives on equilibrium moisture content

The results of the amount of extractives as well as bulk specific gravities of the selected wood species are summarized in Tab. 4. Fig. 5 shows the influence of extractives on the equilibrium moisture contents U_{FS}, *Up* and *Um*. A linear regression model was used to describe the relationship between U_{FS}, *Up*, *Um* and EtOH-Toluol-Extract. Since the P-value of the ANOVA is less than 0.01 (for U_{FS} and *Up* at the 99% confidence level) and less then 0.05 (for *Um* at the 95% confidence level), there is a statistically significant relationship between U_{FS}, *Um*, *Up* and EtOH-Toluol-Extract at fiber saturation point. From the slopes of the linear model it is evident, that in contrary to the *Um* the U_{FS} and *Up* are strong influenced by the extractives.

CONCLUSIONS

The fitted curves computed according to the Hailwood-Horrobin model agree very well with the experimentally measured values. With increase of extractives the equilibrium moisture content at fiber saturation point U_{FS} decreases linearly. The extractive portion does not show any influence on the monomolecular bound water *Um*. In contrary to the *Um* the U_{FS} and *Up* are strong influenced by the extractives. The inaccessibility (Z) of the sorbent to sorbate and the specific surface (Σ) show as expected no dependence on EtOH-toluol extract because they are both a function of monomolecular sorption *Um*.

Tab. 2: Equilibrium moisture content of selected woods from Chile

Wood species	Equilibrium moisture content MC% at relative humidity					
	20%	35%	50%	65%	80%	93%
Pino arancaria	3.3	5.3	8.3	11.2	13.9	19.8
Alerce	3.3	4.9	6.6	8.5	10.4	15.3
Cipres de las Guatecas	3.2	5.1	7.6	10.4	12.6	18.0
Mañio	3.4	5.5	8.3	11.3	13.7	19.1
Olivillo	3.3	5.5	8.4	11.4	14.0	20.1
Maiten	3.2	5.1	7.9	10.8	13.3	18.9
Trevo	3.6	5.2	8.0	10.9	13.9	20.3
Tineo	3.1	5.0	7.7	10.7	13.2	19.0
Ulmo	3.1	5.2	8.0	10.9	13.6	19.3
Ruil	3.8	5.2	5.9	8.1	10.7	16.4
Rauli	2.9	4.9	7.5	10.2	12.5	18.2
Coique de Magallanes	2.9	5.1	7.7	10.7	13.3	19.1
Roble de Maule	3.0	5.3	8.1	11.1	13.8	19.8
Coyan	2.8	3.8	6.2	8.9	11.2	16.0
Lenga	2.8	4.7	7.4	10.1	12.1	17.7
Chin-Chin	3.2	5.5	8.2	11.3	14.0	20.0
Belloto del Norte	3.2	5.5	8.3	11.5	14.2	20.4
Peumo	3.3	5.6	8.4	11.5	14.3	20.4
Lingue	4.0	5.1	6.3	9.2	11.3	16.5
Tepa	3.4	5.3	8.0	11.0	13.5	19.4
Laurel	2.9	4.8	7.7	10.5	13.0	19.1
Luma	2.7	4.6	7.2	9.9	12.4	17.7
Arrayan	3.5	6.4	7.6	10.6	13.2	19.2
Temu	3.1	5.2	7.9	10.9	13.6	20.0
Notro Cirelluilo	3.2	5.0	8.0	11.0	13.8	20.4
Avellano	3.2	5.1	7.4	10.1	12.3	18.1
Radal	3.2	4.0	5.1	7.6	9.7	14.9
Quillay	3.9	5.6	8.5	11.8	14.7	21.3

Tab. 3: Computed values of the sorption analysis according to the HH-model of selected woods from Chile at fiber saturation point

Wood species	*Um*%	*Up*%	U_{FS}%	*Z*%	Σm²/g
Pino arancaria	4.3	25.9	30.3	58	153
Alerce	4.6	17.6	22.1	56	162
Cipres de las Guatecas	4.0	23.9	27.9	61	143
Mañio	4.4	24.8	29.2	57	156
Olivillo	4.3	27.8	32.2	58	154
Maiten	4.1	26.6	30.7	60	144
Trevo	4.0	31.5	35.5	61	142
Tineo	4.0	27.8	31.8	61	140
Ulmo	4.1	27.8	31.9	60	145
Ruil	3.7	21.5	25.2	65	132
Rauli	3.9	23.9	27.8	62	138
Coique de Magallanes	3.9	28.4	32.3	61	139
Roble de Maule	4.1	28.8	32.9	59	147
Coyan	4.1	19.3	23.4	60	147
Lenga	3.7	25.3	29.0	64	132
Chin-Chin	4.3	28.2	32.4	58	151
Belloto del Norte	4.3	29.8	34.0	58	151
Peumo	4.4	28.6	33.0	57	155
Lingue	3.9	18.4	22.3	64	137
Tepa	4.2	26.7	30.9	59	148
Laurel	3.8	29.8	33.6	63	134
Luma	3.6	26.8	30.5	65	129
Arrayan	4.5	21.6	26.1	56	159
Temu	4.1	29.3	33.4	60	144
Notro Cirelluilo	4.0	31.8	35.8	61	142
Avellano	3.3	27.8	31.1	68	117
Radal	3.0	19.1	22.1	72	107
Quillay	4.4	30.7	35.1	57	156

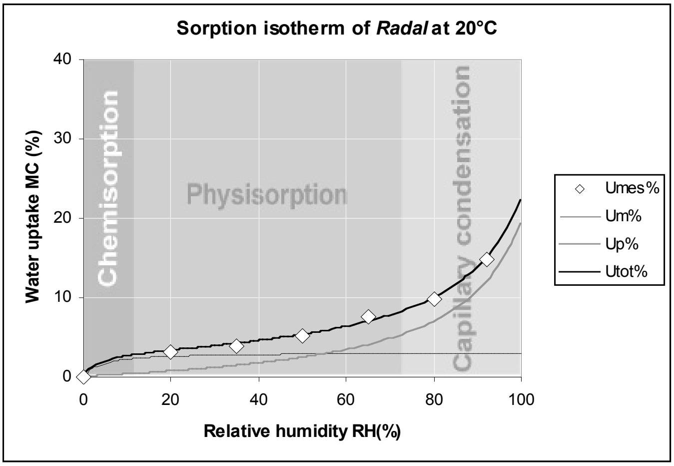

Fig. 1: Measured and according to the HH-model computed sorption isotherm of Radal

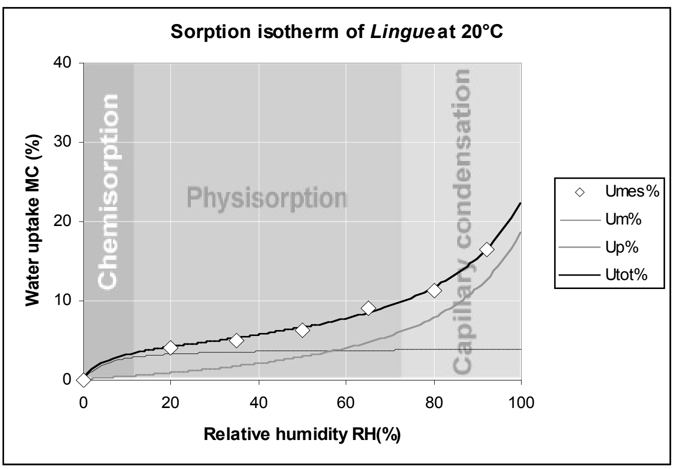

Fig. 2: Measured and according to the HH-model computed sorption isotherm of Lingue

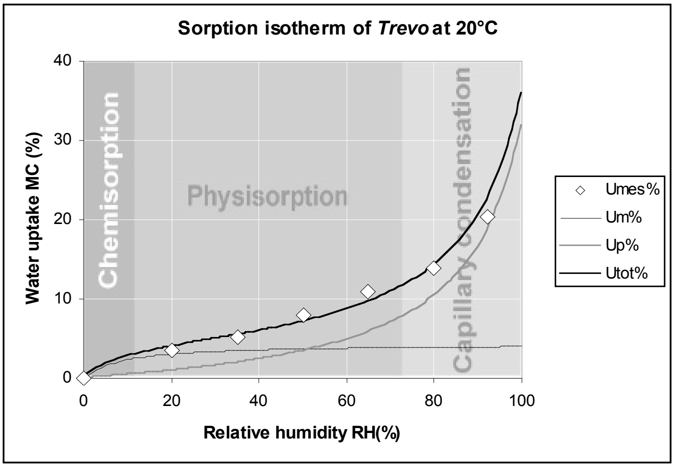

Fig. 3: Measured and according to the HH-model computed sorption isotherm of Trevo

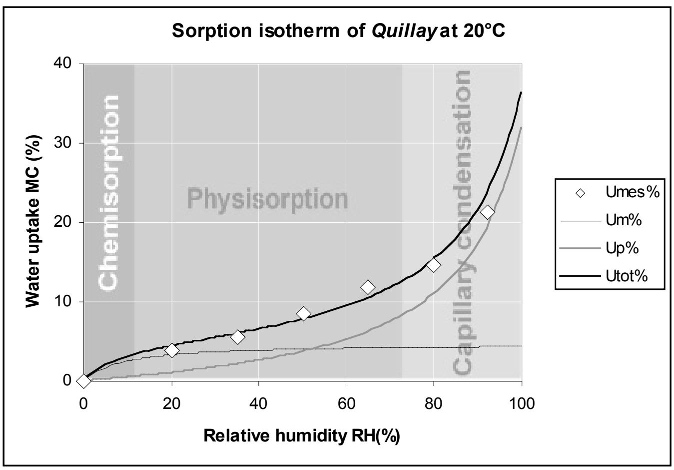

Fig. 4: Measured and according to the HH-model computed sorption isotherm of Quillay

Tab. 4: Ethanol-Toluol extractives and bulk specific gravity of selected woods

Wood species	Bulk specific gravity kg/m^3	Ethanol-Toluol-Extract *) %
Pino arancaria	469	1.5
Alerce	330	6.9
Cipres de las Guatecas	398	2.3
Mañio	470	1.2
Olivillo	397	1.3
Maiten	530	1.1
Trevo	540	1.4
Tineo	532	1.2
Ulmo	603	1.6
Ruil	484	9.2
Rauli	437	2.5
Coique de Magallanes	486	3.1
Roble de Maule	655	0.7
Coyan	598	8.1
Lenga	462	3.7
Chin-Chin	560	1.0
Belloto del Norte	580	0.7
Peumo	497	1.3
Lingue	502	10.0
Tepa	415	1.3
Laurel	383	4.4
Luma	762	3.6
Arrayan	444	2.2
Temu	609	3.1
Notro Cirelluilo	361	0.9
Avellano	418	1.0
Radal	502	11.3
Quillay	550	4.2

*) The EtOH-Toluol-Extract was determined at the Universidad Austral de Chile, Valdivia/Chile

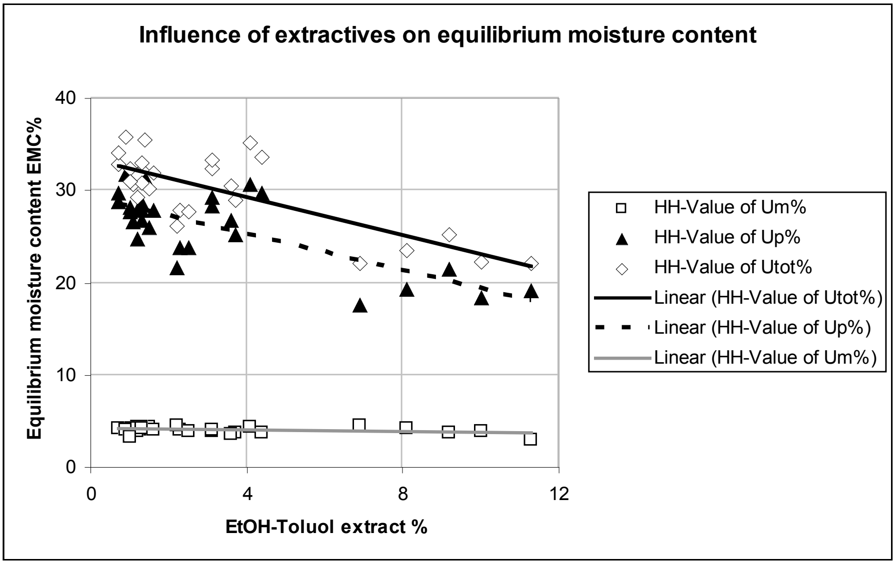

Fig. 5: The influence of extractives on the equilibrium moisture content

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