Drying modeling of canelo regrowth

Rubén A. ANANIAS, Patricio PEREZ
Department of Wood Engineering, University of Bío-Bío
Concepción, CHILE
Carlos SALINAS
Department of Mechanical Engineering, University of Bío-Bío
Concepción, CHILE.

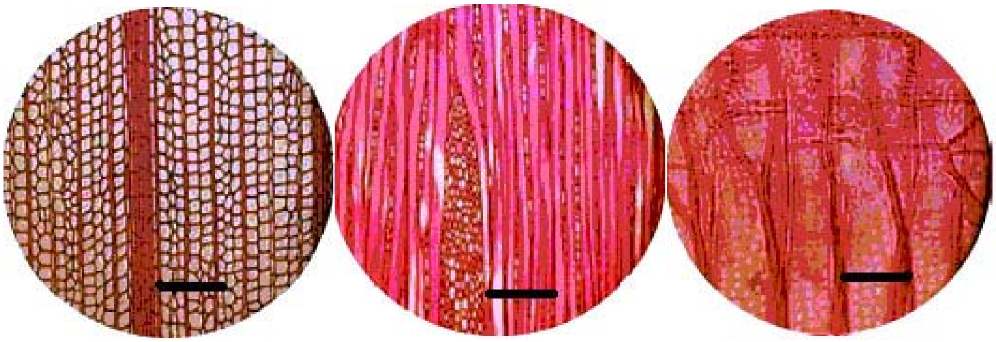
Abstract

A phenomenological model has been used to describe the conventional drying curves of canelo *Drimys winteri* regrowth. This model is based on an overall mass transfer coefficient K. To determine K, six drying runs at laboratory and industrial-scale were performed. The model did suitably describe the transient moisture-transfer behaviour for laboratory-drying curves with the mass transfer coefficient ranging from $1.1\text{x}10^{-5}$ to $6.6\text{x}10^{-5}$ kg/m^2.s. Under similar conditions industrial kiln showed that the drying curves could be represented by a mass transfer coefficient from $0.3\text{x}10^{-5}$ to $4.7\text{x}10^{-5}$ kg/m^2.s.

Keywords: drying modeling, mass transfer coefficient, canelo, *Drimys winteri*, Chile.

Introduction

Canelo regrowth (*Drimys winteri*) is difficult to dry (Díaz-Vaz *et al*. 1986, Infor-Corfo 1990, Hall y Witte 1998, Ananías 2005, Pérez *et al.* 2005, 2007), being an hardwood species without vessels and wide wood-rays (Figure 1).



a) Transversal (200 um) b) Tangencial (200 um) c) Radial (40 um)

Figure 1: Canelo regrowth microstructure (Pérez *et al*. 2005)

His behaviour during drying is conditioned by their particular anatomical structure lack of vessels and with a significant proportion of wood-rays, in addition a low density basic and important transversal shrinkage anisotropy (Infor-Corfo 1990, Escriba 1991, Infor-Conaf 1998). However canelo regrowth is increasingly appreciated as a commercial interest because of their decorative qualities.

A phenomenological wood-drying model may be characterized by an overall mass-transfer coefficient, K (Karabagli *et al*. 1997). Such a coefficient includes both the internal moisture movement through the wood and well as the mass transfer from the wood surface to the drying air flow (Chrusciel *et al*. 1999). In this work, the drying curves of Chilean canelo regrowth are represented by a phenomenological model.

Mathematical model

The model states that the drying rate is a linear function of the drying potential, which is the moisture-content difference (MC – EMC), and a constant coefficient of proportionality, which is the overall mass-transfer coefficient K. This hypothesis has been verified in another study (Ananías *et al*. 2008).

The model equations, introduced by Karabagli *et al.* (1997) are four equations, only equation resulting from the mass balance of water in wood is examined here, it is

$$-M_0 * \frac{dMC}{dt} = K * S * (MC - EMC) \qquad (1)$$

The four equations have been solved as an initial-value problem in another study (Ananias *et al.* 2001). If this is solved by means of a finite-difference method, then we can calculate the theoretical wood moisture content at any time (MC^{j+1}). When rearranging the above equation to find moisture content at any time (MC^{j+1}), we get:

$$MC^{j+1} = \frac{(2-K).MC^{j}}{2+K} + \frac{K.(EMC^{j} + EMC^{j+1})}{2+K} \qquad (2)$$

Note that MC^j and EMC^j are experimental values and K could be calculated by the correlation proposed by Ananias *et al*. 2008

$$\frac{1}{K} = a_0 \cdot \exp\left(\frac{c_0}{T_K}\right) \cdot e + b_0 \cdot \exp\left(\frac{c_0}{T_K}\right) \cdot v^{-0.8} \cdot \exp\left[\frac{(1-RH)}{(MC_{FSP} - EMC)}\right] \qquad (3)$$

Since the model assumes that the coefficient *K* remains constant during drying, it is necessary to work the kiln under constant operating conditions.

Materials and method

A laboratory-kiln was used to dry 0.3m^3 of boards (Figure 2). The temperatures of the air and wood were measured at different levels in the stack by thermocouple, and the data recorded by computer. The moisture content of the wood was determined by gravimetric analysis, using a balance of 0.01g precision.

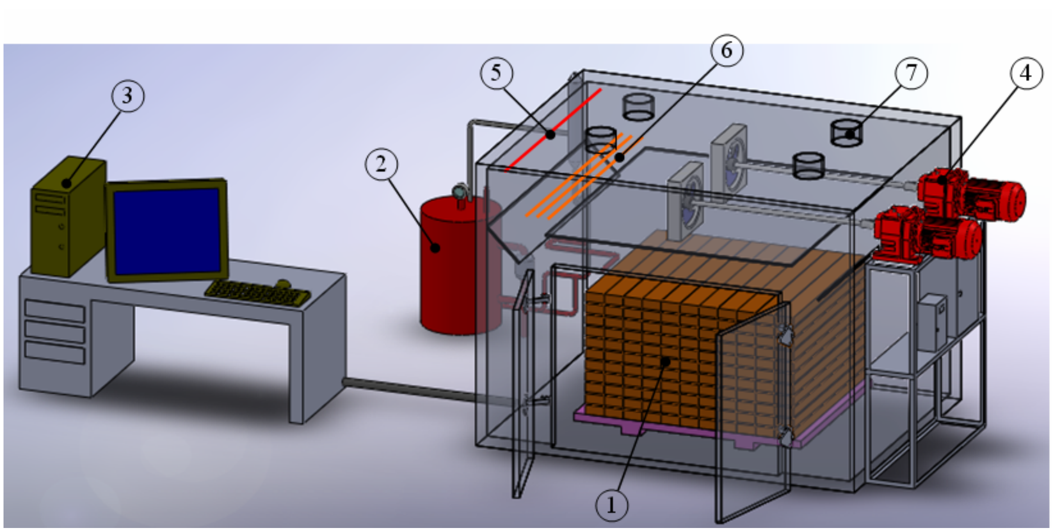


Figure 2: Laboratory kiln dryer: 1.- Wood to be dried. 2.- Boiler. 3.- PC data system. 4.- Motor with fan. 5.- Steam spray line. 6.- Heating coils. 7.- Vents.

Canelo regrowth (*Drimys winteri*) used in this laboratory-experiment was taken from a forest of the Southern Region of Chile (Lanco). Timber boards, 920mm long and 110mm wide, were cut for the study. These boards were stored wrapped in polythene film until further processing for the drying tests. The boards were either 25 or 50 mm thick. The wood was placed in a 10-15 level stack and separated by 25mm stickers (Figure 3). Four laboratory-drying runs were carried out at variable temperatures and fixed air velocity (3 m/s).

a) Before drying

b) After drying

Figure 3: Drying stack of 50 mm canelo regrowth

A industrial-kiln was used to dry $40m^3$ of boards. Canelo regrowth used in this industrial-experiment was taken from a forest of the Southern Region of Chile (Chiloé). Timber boards, 3600mm long and 110mm wide were prepared for the study. The boards were either 25 or 50 mm thick. These boards were air-stored until further processing for the industrial-drying runs. The temperatures of the air were measured at different levels in the stack by an automatic drying control, and the data recorded by computer. The air velocity was fixed at 3 m/s. Before and after drying the wood moisture were determined by oven-dry method and the gravimetric method was used to obtain the wood moisture content, measurements being carried out at different time intervals.

The dry-bulb temperature and the wet-bulb temperature schedules (Table 1) were established according with the experience and literature suggests (Pérez *et a*l. 2007).

Table 1: Drying schedules for canelo regrowth

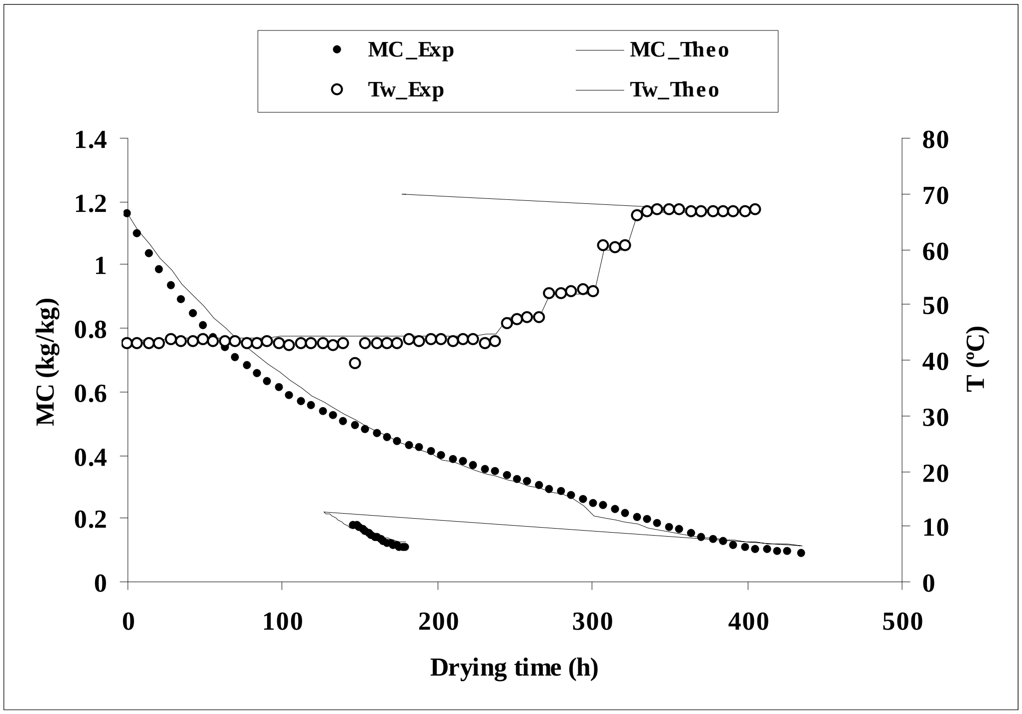
Run	**MC** (%)	**T** (ºC)	T_W (ºC)	**EMC** (%)
1	Verde	50	50	-
	Verde-40	44	40	14
	40-30	48	42	12
	30-25	52	44	10
	25-18	60	50	9
	18	60	60	-
	20-15	66	54	8
	15-8	70	54	6
	8	70	70	-
2	Verde	44	44	-
	Verde-30	44	40	14
	30-25	48	42	12
	25-18	52	44	10
	18	52	52	-
	20-15	60	50	9
	15-8	66	54	8
	8	66	66	-

Results and discussion

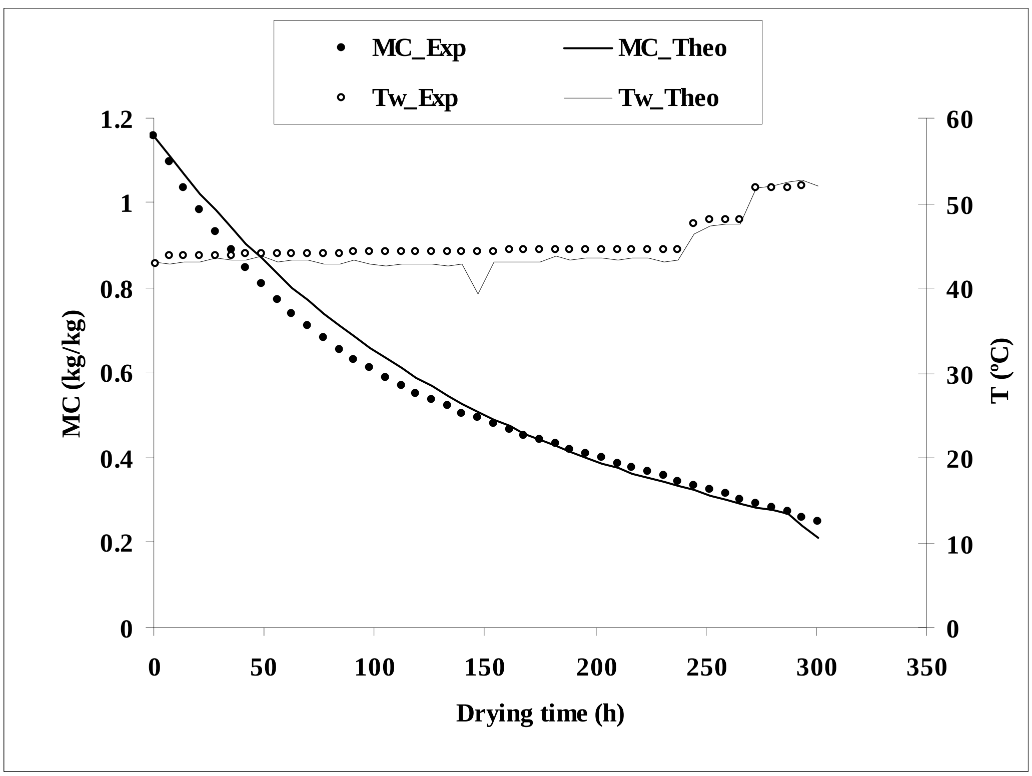
The laboratory-drying curves of canelo regrowth are showed in Figures 4 and 5 There are slight differences between the experimental and calculated moisture content of the wood (Figure 4 and 5). The magnitude of the overall mass-transfer coefficients Kx is in the range of $1.1x10^{-5}$ to $6.6x10^{-5}$ kg/m^2s (Table 2), and is higher than to previously obtained values for Chilean coigüe (Ananías *et al*. 2001, Broche *et al*. 2002, Alvear *et al*. 2003), it is consistent with the least slow drying of canelo. These values are higher than the industrially found ones $0.3x10^{-5}$ to $4.7x10^{-5}$ kg/m^2s (Table 2), which may indicate some scale changes are present: temperature and humidity variations, uneven airflow distribution (Figure 6).

Table 2. Overall mass and heat transfer coefficient during kiln-drying of canelo regrowth

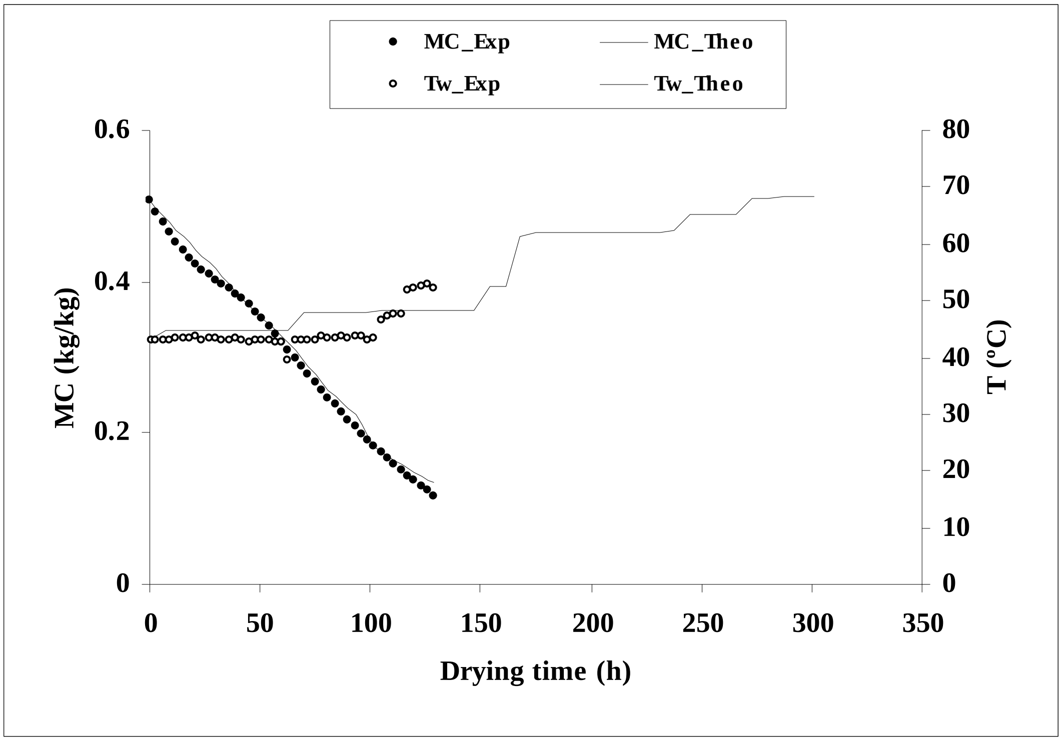
Drying steps		**I**	**II**	**III**	**IV**	**V**	**VI**
Cycle 1							
K*10⁵	**(kg/m²s)**	**2,2**	**4,1**	**4,8**	**5,9**	**6,6**	**3,1**
h	**(w/m²K)**	**17,9**	**17,8**	**17,7**	**17,5**	**17,4**	**17,3**
Cycle 2							
K*10⁵	**(kg/m²s)**	**1,8**	**3,5**	**4,0**	**4,8**	**4,9**	**4,1**
h	**(w/m²K)**	**17,9**	**17,8**	**17,7**	**17,5**	**17,4**	**17,2**
Cycle 3							
K*10⁵	**(kg/m²s)**	**1,3**	**1,3**	**1,5**	**2,0**	**3,2**	**no**
h	**(w/m²K)**	**17,9**	**17,8**	**17,7**	**17,5**	**17,3**	**no**
Cycle 4							
K*10⁵	**(kg/m²s)**	**1,1**	**1,7**	**2,5**	**3,0**	**3,3**	**no**
h	**(w/m²K)**	**17,9**	**17,8**	**17,7**	**17,5**	**17,3**	**no**
Cycle 5							
K*10⁵	**(kg/m²s)**	**1.1**	**1.5**	**2.4**	**2.6**	**3.8**	**4.7**
h	**(w/m²K)**	**17.9**	**17.8**	**17.7**	**17.5**	**17.4**	**17.3**
Cycle 6							
K*10⁵	**(kg/m²s)**	**0.3**	**0.7**	**1.6**	**2.7**	**2.7**	**no**
h	**(w/m²K)**	**17.9**	**17.9**	**17.7**	**17.4**	**17.4**	**no**



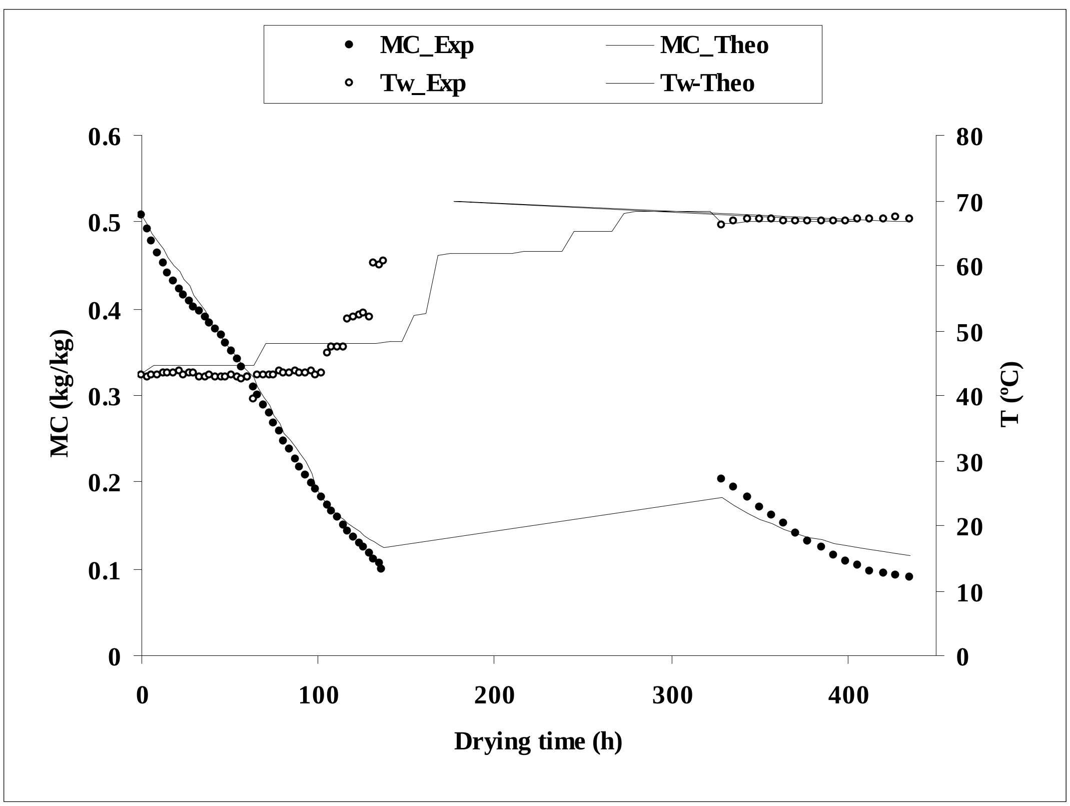
a) Cycle 1



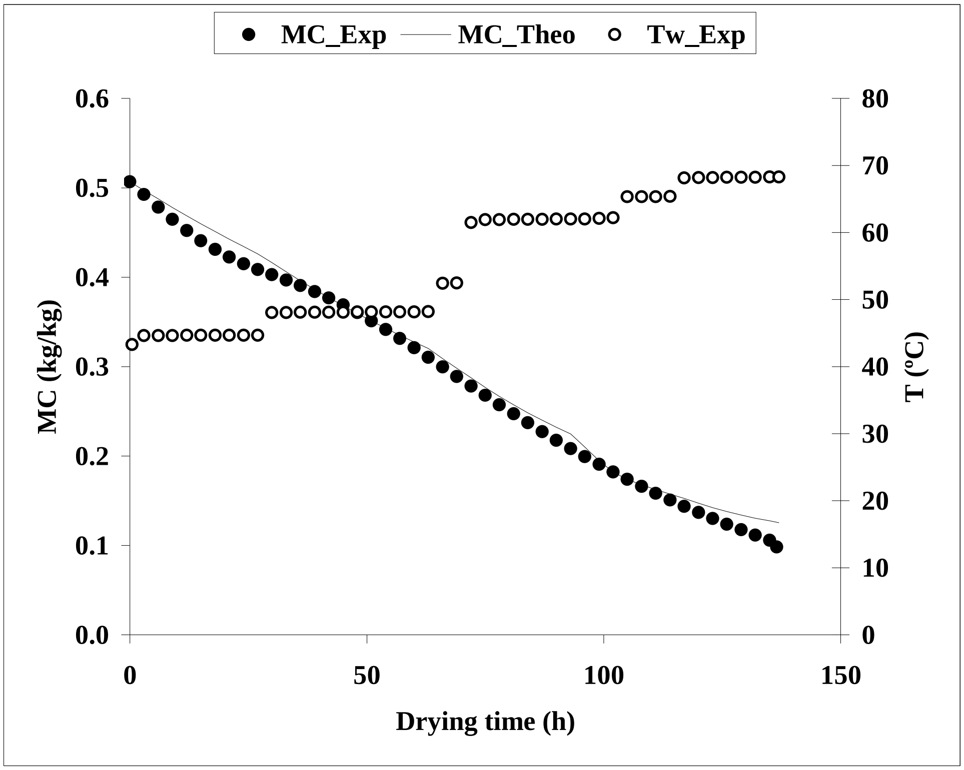
b) Cycle 2
Figure 4: Laboratory drying curves of 25 mm canelo regrowth



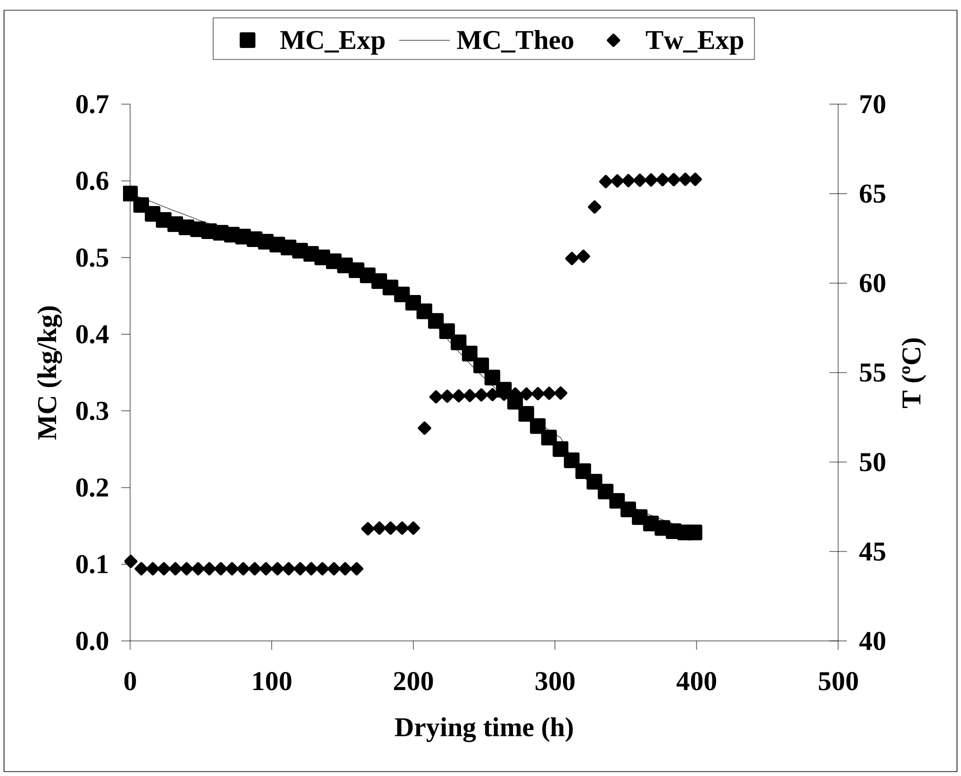
a) Cycle 3



b) Cycle 4
Figure 5: Laboratory drying curves of 50 mm canelo regrowth



a) Cycle 5: 25 mm



b) Cycle 6: 50 mm
Figure 6: Industrial drying curves of canelo regrowth

Conclusions

For much of the low-temperature conventional drying curves of Chilean canelo regrowth may be modeling by a constant overall mass-transfer coefficient. It can be successfully used for drying schedule optimization at industrial scale.

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