

PREDICTION OF SECONDARY CORK INDUSTRIAL QUALITY AND POROSITY BASED ON VIRGIN CORK CHARACTERISTICS

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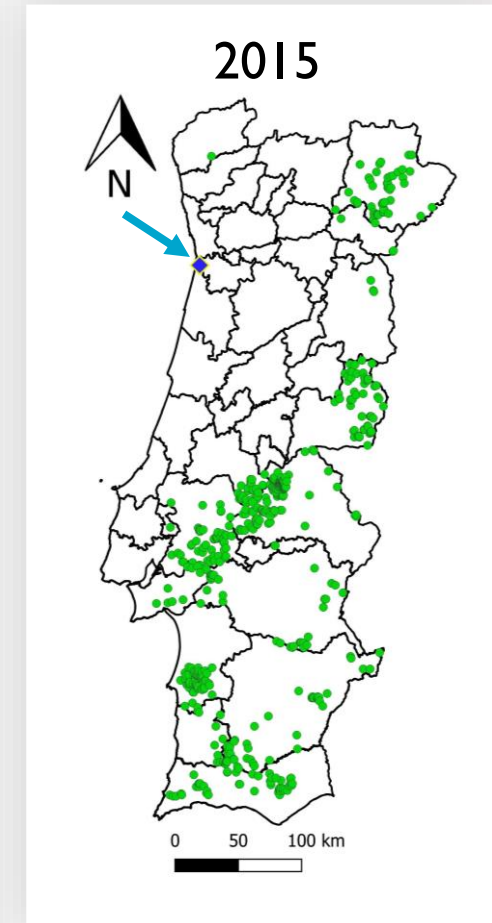
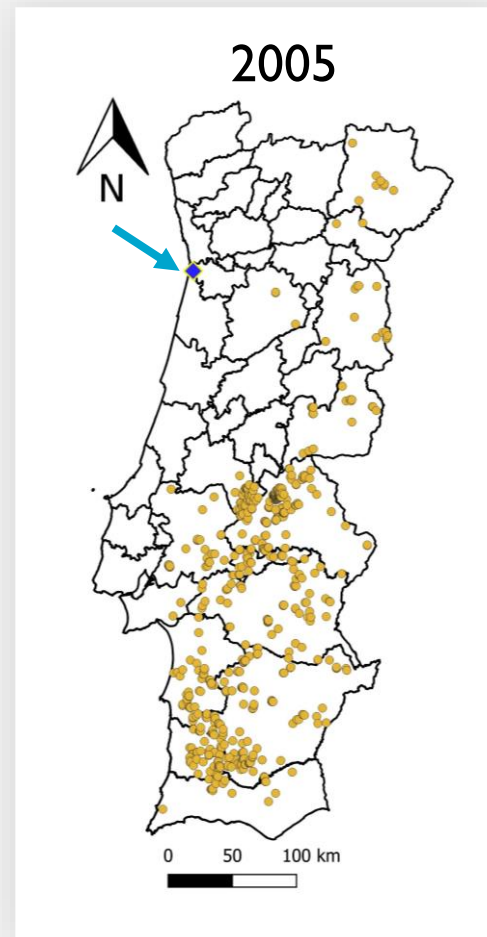


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Introduction and objectives

- The Portuguese official statistics show an increase of the cork oak plantation area during the last 30 years.
- Many have initial stand densities higher than $800 \text{ trees ha}^{-1}$.
 - Thinning previous to cork production!
 - Sanitary and systematic criteria for tree density reduction versus early cork quality indicators!



Introduction and objectives

Objectives:

- research the relationship between cork colour and cork porosity, in virgin and secondary cork, at tree level.
- Test the viability of cork colour and cork porosity, taken from virgin cork, to be used as indicators of secondary cork industrial quality classes.

Final outcome for the cork sector:

- increase the production of higher quality cork.



Materials and methods

Cork sampling and classification

- Three plantations sampled: Stand A (Barrancos), stands B and C (Coruche).
- Virgin cork samples and, nine years after, the same trees were resampled for secondary cork. The latest (secondary) was divided in two.
- Secondary cork was classified for cork industrial quality: 1st to 7th, following the traditional boiling procedure.
- *NOTE: Classification criteria excluded defects originated by external biological agents (mainly ants and *Coroebus undatus*). Other cork defects and porosity were considered.*



Materials and methods

Cork sampling and classification

- After the cork quality classification, sixty-six trees were randomly selected in order to equally cover all cork quality classes to the best possible.
- These sixty-six trees were distributed: 33 from stand A, 18 from stand B and 15 from stand C.

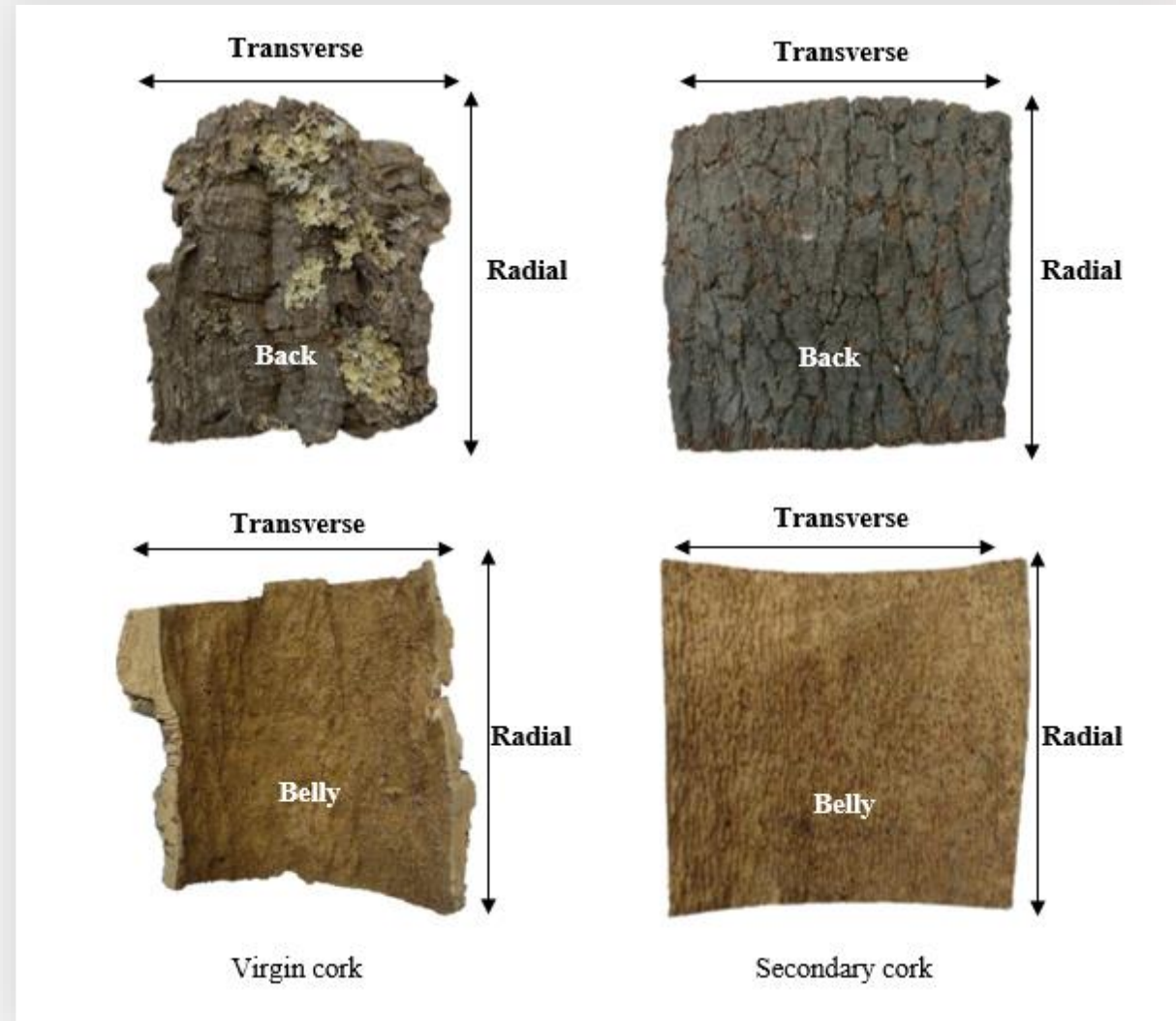
Cork quality	n	n (grouped)
1	3	18
2	3	
3	12	24
4	12	
5	12	24
6	11	
7	13	
Total		66



Materials and methods

Cork colour measurements

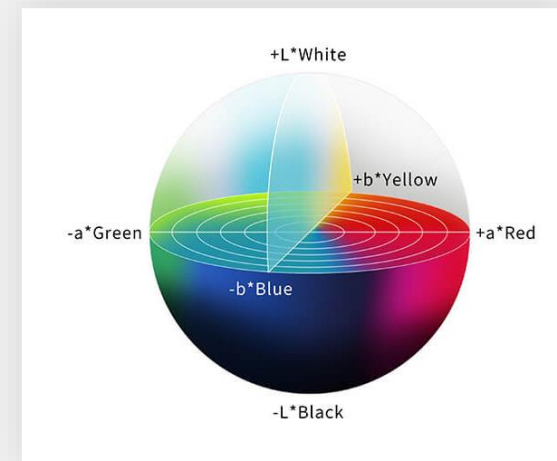
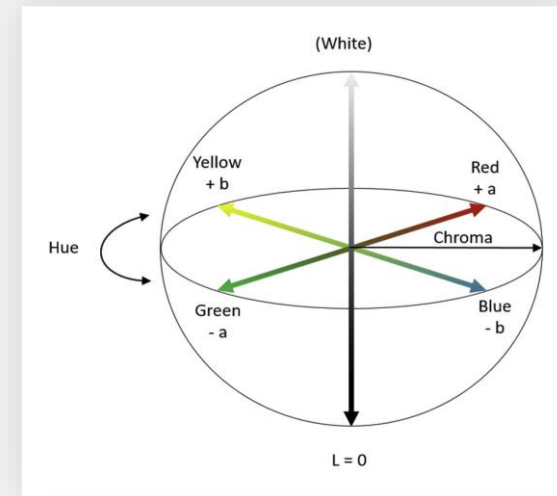
- Evaluated in two directions (radial, transverse) and on two surfaces (back and belly — external and internal layers of the sample) of each raw virgin cork sample and each raw secondary cork subsample.
- Regarding the radial and transverse directions, colour measurements were carried out after polishing and cleaning with compressed air to clear the pores of sanding residues.



Materials and methods

Cork colour measurements

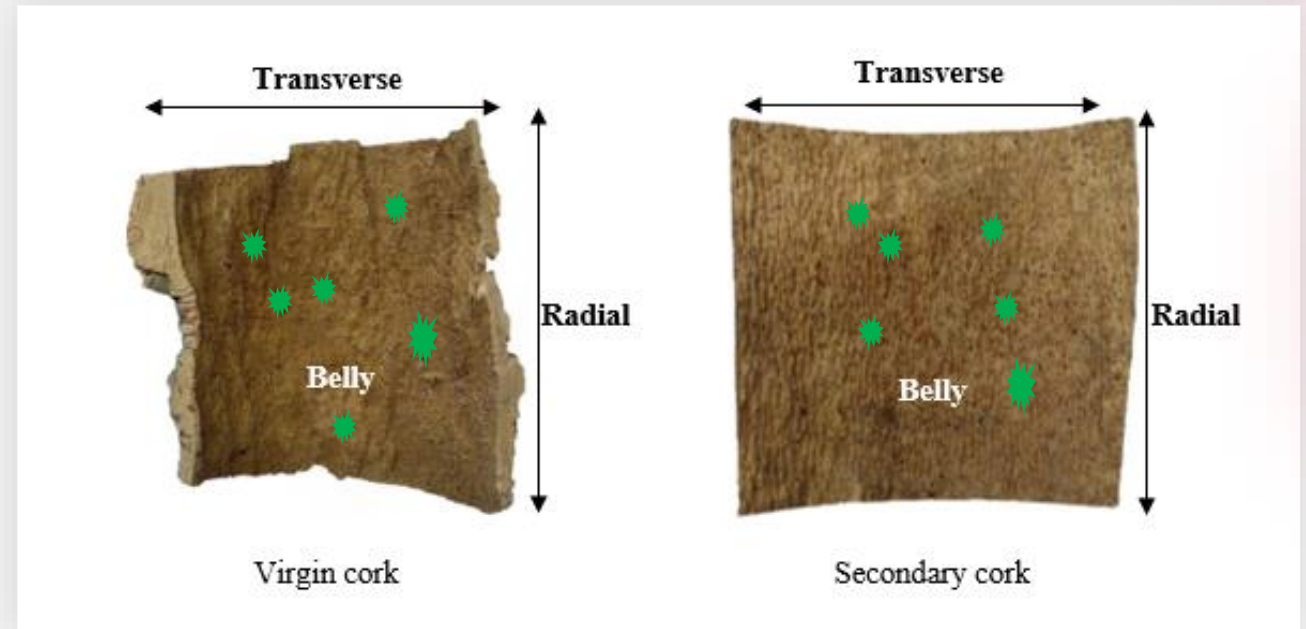
- The measurements were carried out using the L^* , a^* and b^* coordinates from the CIELAB colour system (response variables).
- The L^* value indicates the lightness (from 0 – absolute black to 100 – absolute white), while the a^* and b^* indicate the chromatic coordinates.
- The a^* indicates the coordinate value across the red-green axis (from $+a$ to $-a$). The b^* indicates the coordinate value across the yellow-blue axis (from $+b$ to $-b$).



Materials and methods

Cork colour measurements

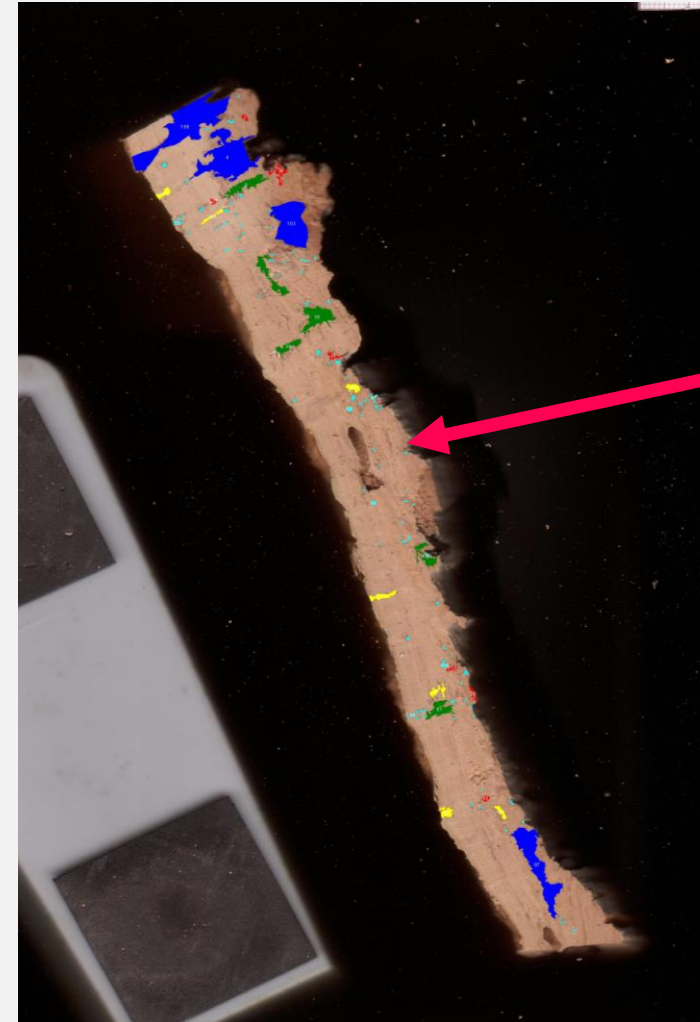
- Six distinct measurements carried out on each surface and on each direction of each sample. The location of each measurement was random, but ensured that cork defects or other specific features external to the cork material were not measured.
- The final value for each L^* , a^* and b^* colour parameter resulted from the mean of these six measurements.



Materials and methods

Cork porosity measurements

- This was determined in the sanded transverse sections of each raw virgin cork sample and each raw secondary cork subsample.
- Response variable: cork porosity coefficient (CPC) - ratio between the total pore area (mm^2) and total cork surface area (mm^2).
- *Note: the CPC was computed excluding the area occupied by insect galleries*



Materials and methods

Data analyses

- The differences in L^* , a^* and b^* average values between three cork quality groups (high, medium and low) were tested and confidence intervals constructed (Student's unpaired t-test for average values or non-parametric Mann-Whitney U test).
- Quantification of the monotonic correlation carried out by computing the Spearman correlation coefficient (ρ) between cork porosity of virgin and secondary cork (CPV and CPS).
- Modelling approach to estimate cork porosity coefficient of secondary cork using virgin cork variables.



Results

Average/median virgin cork colour differences for distinct cork quality groups in secondary cork

Table 2. Summary of the p-values obtained for the Student's unpaired t-test for comparing L*, a* or b* virgin cork means from two cork quality groups. (a) indicates the Welch's unequal variances t-test was used instead; (b) indicates the Mann-Whitney test was used instead; * Indicates the rejection of the null hypothesis for a significance value of 5%.

Cork quality groups	Back			Belly			Radial			Transverse		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
High versus Low	0.002*	0.001*(a)	<0.001*(a)	0.003*	0.554(b)	0.093	0.004*(a)	0.006*	0.006*	<0.001*	0.001*	0.027*
High versus Medium	0.001*	0.153(b)	<0.001*(b)	0.310	0.633	0.996	0.020*	0.011*	0.223	0.001*	0.031*	0.416
Medium versus Low	0.528	0.074(b)	0.560(b)	0.072	0.431(b)	0.108	0.544	0.757	0.041*	0.021*	0.175	0.111



Results

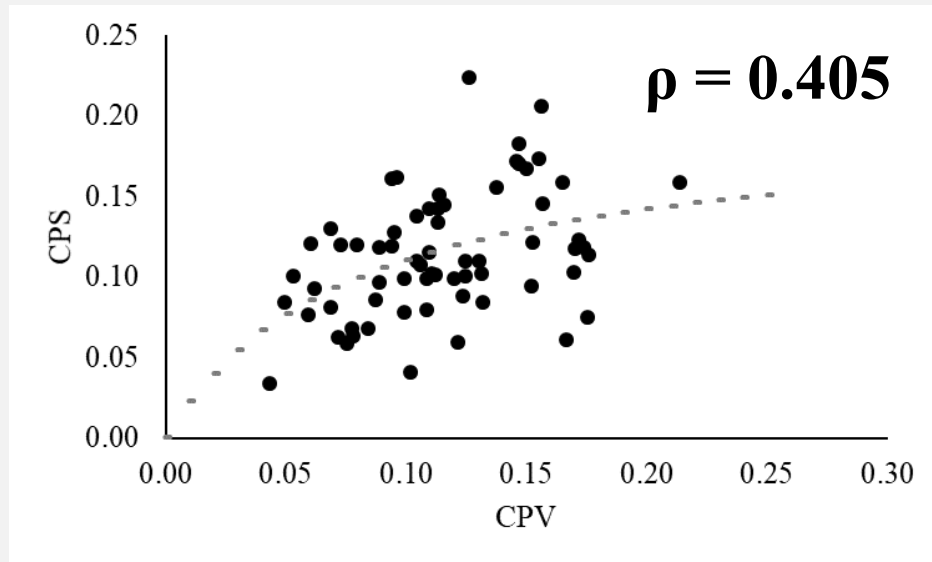
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Materials and methods

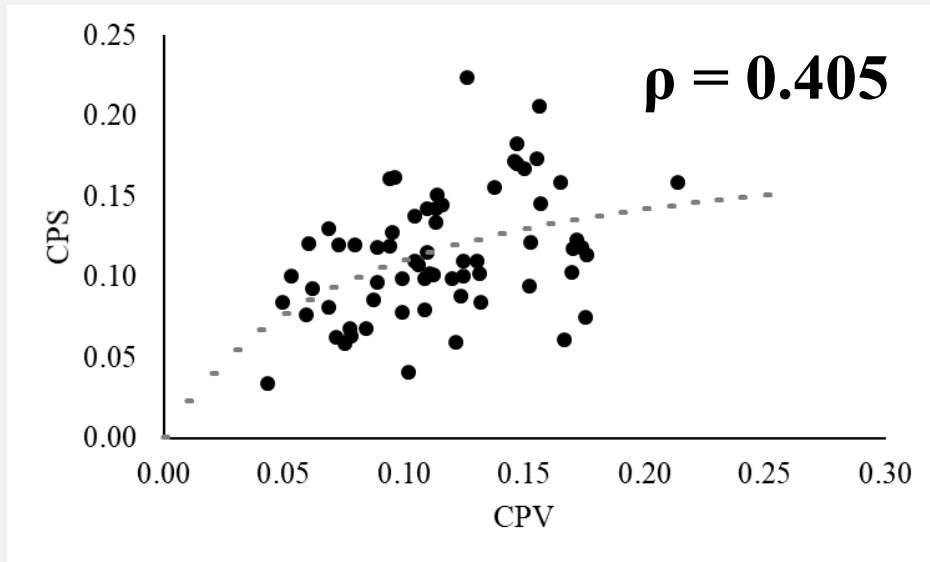
Cork porosity correlation and modelling



A value of $\rho = 0.405$ (p -value < 0.05) revealed a moderate positive monotonic correlation

Materials and methods

Cork porosity correlation and modelling



Linear: $Y = a + bX$

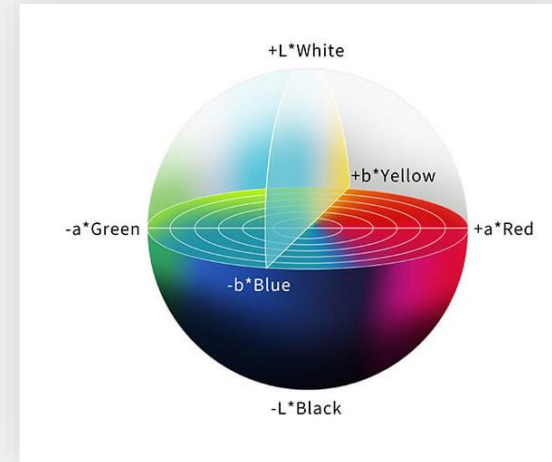
Exponential: $Y = aX^b$

Hyperbolic I: $Y = \frac{X}{aX+b}$

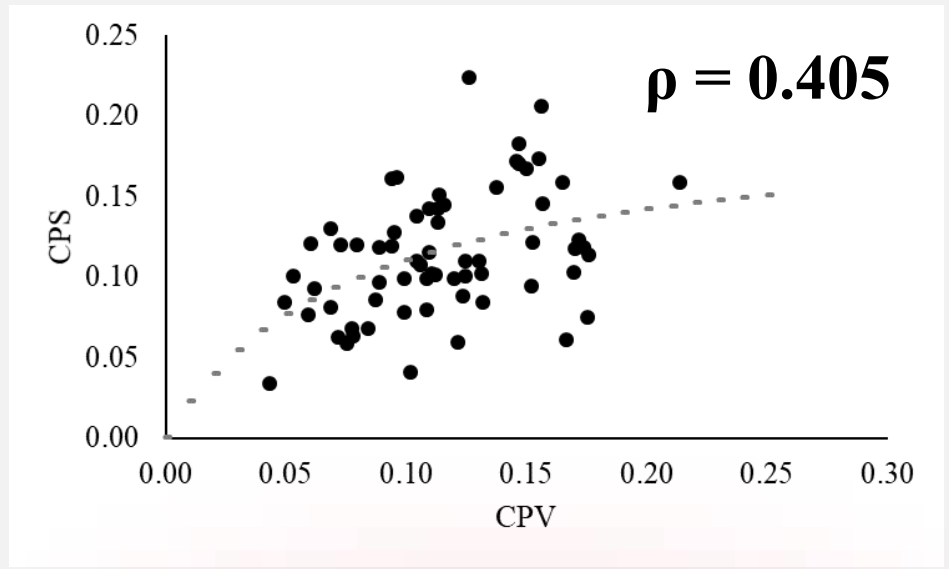
Hyperbolic II: $Y = 1 - \frac{1}{(1+aX)^b}$

Materials and methods

Cork porosity correlation and modelling



Hyperbolic I: $Y = \frac{X}{aX+b}$



L* and b* colour coordinates, measured in raw virgin cork samples at the transverse surface.

$$CPS = \frac{CPV}{(-0.3995L^* + 1.1429b^*)CPV + 0.3975}$$

R² = 0.445 and an MSE = 0.00086.

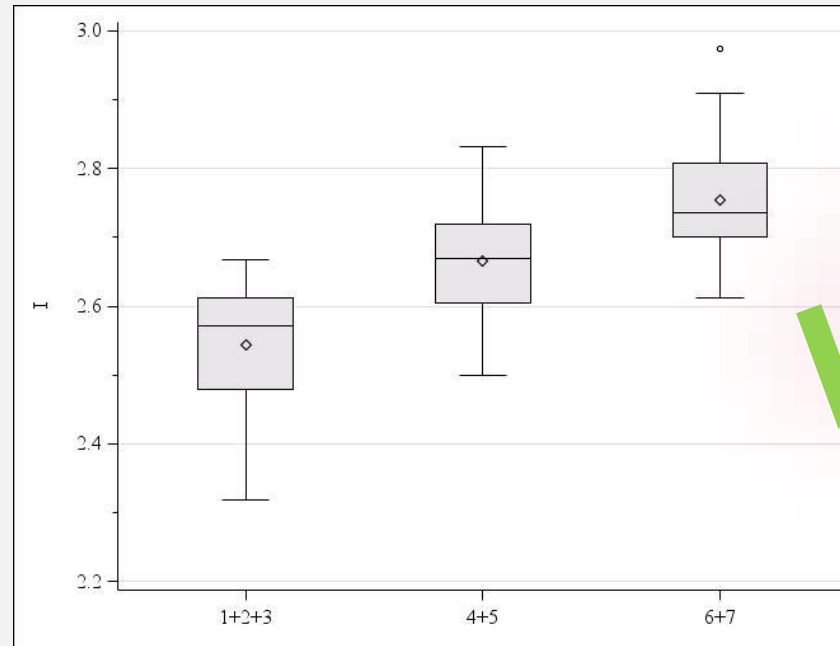
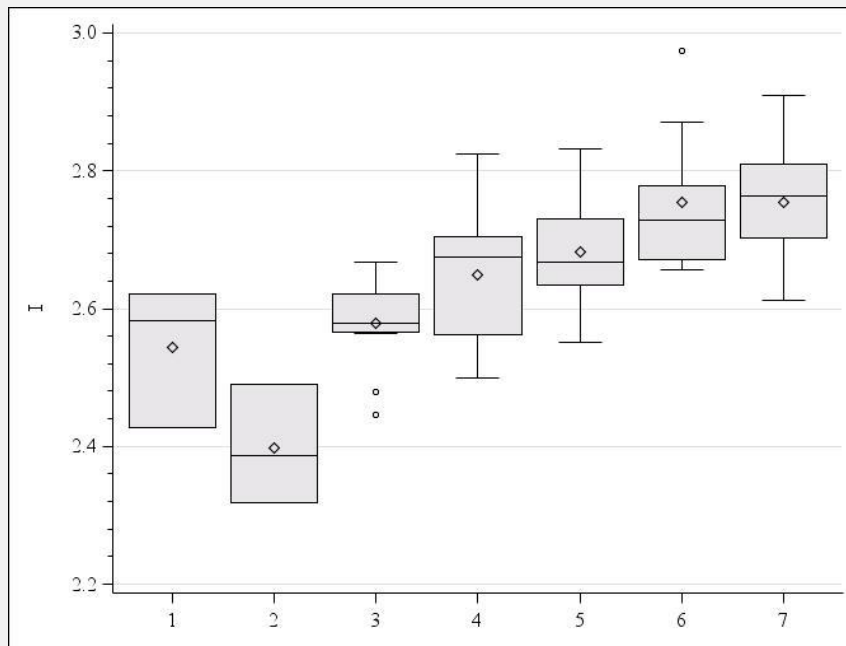
Materials and methods

Cork porosity correlation and modelling

$$I = \frac{L^*}{b^*}$$

Increase I ratio for decreasing cork porosity.

L* and b* colour coordinates, measured in raw virgin cork samples at the transverse surface.



Highlights

- Virgin cork colour average values allow to differentiate main secondary cork quality groups
- Increase L^* in virgin cork was associated to lower quality of the secondary cork
- Increase b^* in virgin cork was associated to higher quality of the secondary cork
- Virgin and secondary cork porosity present a moderate positive monotonic relationship
- Increase of virgin cork $\frac{L^*}{b^*}$ ratio is associated to a decrease of secondary cork quality and an increasing of secondary cork porosity coefficient.

Thank You

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