

INFLUENCE OF CORK DENSITY ON COMPRESSION

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ABSTRACT

The compression properties of cork were studied on samples grouped in three density classes: 0.11 – 0.15, 0.15 – 0.19 and 0.19 – 0.25 g cm⁻³. In all cases, cork had higher strength for the radial compression. There were significant differences between cork samples of different density classes, and cork samples with higher density showed overall larger resistance to compression in the three directions. Porosity could not be correlated with density. This shows the influence on density of anatomical features of cork namely the presence of woody inclusions of thick walled sclereids in the suberous tissue and surrounding the lenticular channels.

MATERIALS AND METHODS

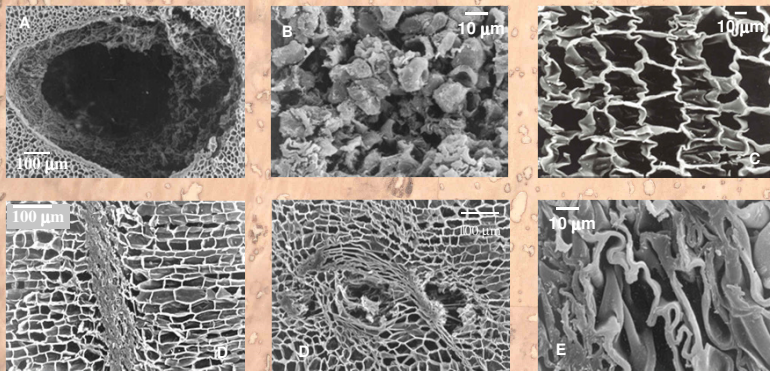
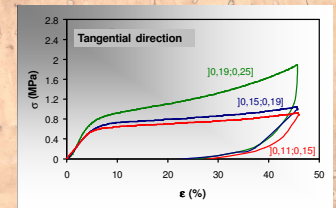
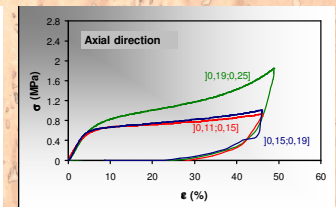
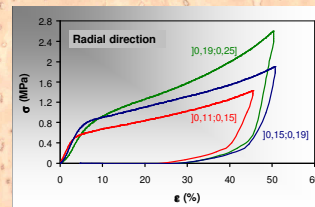
The material was sampled from raw cork planks collected at one industrial mill after water boiling and air drying as usually applied to cork in the industrial processing. The test specimens were cubes with 20 mm of edge and equilibrated in the laboratorial environment to 7% mean moisture content. The specimens were weighed and density calculated. Compression tests were made at a constant crosshead speed of 2 mm min⁻¹ (equivalent to a strain rate of 2x10⁻³ s⁻¹) up to a strain of 10000 micro. The compression axis was, in different tests, parallel to each of the three tree principal directions: axial, radial and tangential. Young's modulus was calculated from the best polynomial adjustment in the initial part of the stress-strain curve (corresponding to the stress between 10N and 100N). Previous to compression, the porosity of the specimen cubes was determined by image analysis on the faces perpendicular to the compression axis, e.g. tangential faces for a radial compression. The porosity was reported as a coefficient of porosity, in %, representing the area of pores divided by the total area, and calculated as the mean of the two faces measured in each sample.

RESULTS

Porosity of the cork specimens used in the compression tests obtained from cork planks of different density classes

Mean of eleven samples, standard deviation, minimum and maximum values

Density class	Direction of compression	Porosity of the faces perpendicular to the direction of compression	
		Mean ± std. dev.	Min.–Max.
]0.11;0.15]	Radial	3,5 ± 0,96	3,3 – 6,31
	Axial	5,1 ± 2,22	2,3 – 9,52
	Tangential	5,3 ± 2,84	0,9 – 8,09
]0.15;0.19]	Radial	7,4 ± 1,33	5,5 – 10,27
	Axial	7,4 ± 2,17	3,1 – 10,30
	Tangential	9,8 ± 6,61	3,1 – 23,12
]0.19;0.25]	Radial	8,7 ± 1,54	5,1 – 9,49
	Axial	6,5 ± 3,54	3,9 – 15,24
	Tangential	15,5 ± 4,90	5,8 – 18,64



Scanning electron microphotographs of cork:
 (A) Lenticular channel observed on a tangential section
 (B) Filling material inside a lenticular channel observed on a tangential section
 (C) Corrugated cells
 (D) Structure deformation and cell collapse
 (E) Thick walled lignified cells bordering the lenticular channels

Compression properties of cork specimens obtained from cork planks of different density class

Mean of twelve samples and standard deviation

Density class	Compression properties	Radial direction	Axial direction	Tangential direction
]0.11;0.15]	E (MPa)	28.16 ± 5.84	16.99 ± 3.20	17.57 ± 5.57
	σ ₅ (MPa)	0.72 ± 0.089	0.57 ± 0.075	0.65 ± 0.105
	σ ₃₀ (MPa)	1.07 ± 0.107	0.81 ± 0.172	0.77 ± 0.076
	σ ₆₀ (MPa)	2.22 ± 0.213	1.37 ± 0.198	1.43 ± 0.156
]0.15;0.19]	E (MPa)	29.02 ± 8.53	14.53 ± 4.95	19.71 ± 11.47
	σ ₅ (MPa)	0.74 ± 0.146	0.32 ± 0.148	0.56 ± 0.215
	σ ₃₀ (MPa)	1.29 ± 0.175	0.86 ± 0.172	0.92 ± 0.181
	σ ₆₀ (MPa)	2.34 ± 0.241	1.94 ± 0.202	2.33 ± 0.285
]0.19;0.25]	E (MPa)	29.02 ± 5.12	20.45 ± 5.64	30.30 ± 7.01
	σ ₅ (MPa)	0.74 ± 0.114	0.52 ± 0.112	0.75 ± 0.096
	σ ₃₀ (MPa)	1.54 ± 0.220	1.20 ± 0.172	1.37 ± 0.0162
	σ ₆₀ (MPa)	4.44 ± 0.307	4.33 ± 0.237	4.22 ± 0.179

CONCLUSIONS

The variation in the compressive properties of cork could be associated with differences in density. Cork samples with higher density showed overall larger resistance to compression in the three directions and in the elastic region.

Porosity was positively correlated with density and associated with structural features involving the lenticular channels.

The compressive behaviour of cork samples with dimensions in the range of those of stoppers is not influenced to a significant extent by the porosity values at the strain levels used in practice, i.e. stoppers in the wine bottle are compressed to about 30% of the initial diameter.

