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Variation of the marrow-bark friction coefficient of the species *Quercus cubana* A. Rich in Pinar del Río

Variación del coeficiente de rozamiento médula-corteza de la especie *Quercus cubana* A. Rich en Pinar del Río

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ABSTRACT

The species *Quercus cubana* A. Rich is the only true oak of the flora of Cuba, already recognized as Cuban endemic, exclusive of the west of the country, limited only to Pinar del Río and with a widespread use in rural life, because its fruits, commonly called acorns, are used as animal food for pigs because they have a high fat content, and its wood is useful in obtaining charcoal to make food. The research was carried out in three moments, starting from the selection of the individuals, using the *Quercus cubana* A. Rich species, which for its complexities has made difficult the introduction of this one in the industry of secondary transformation of the wood. The objective has been to determine the behaviour of the friction coefficient of this species on surface of wood and metal, obtaining as a result the existing variation between the different sections of the pith towards the bark.

Keywords: friction coefficient; *Quercus cubana A. Rich*; wood

RESUMEN

La especie *Quercus cubana* A. Rich es el único verdadero roble de la flora de Cuba, ya reconocida como endémica cubana, exclusiva del occidente del país, limitada solo a Pinar del Río y con un uso muy difundido en la vida rural, pues sus frutos, comúnmente llamados bellotas, son utilizados como alimento animal para el porcino por poseer un alto contenido en grasas y su madera es útil en la obtención de carbón para elaborar los alimentos. La investigación se realizó en tres momentos, partiendo de la selección de los individuos, utilizando la especie

Quercus cubana, la que por sus complejidades ha dificultado la introducción de esta en la industria de transformación secundaria de la madera. El objetivo ha sido determinar el comportamiento del coeficiente de rozamiento de esta especie sobre superficie de madera y de metal, obteniendo como resultado la variación existente entre las diferentes secciones de la médula hacia la corteza.

Palabras clave: coeficiente de rozamiento; *Quercus cubana A. Rich*; madera.

INTRODUCTION

The determination of the characteristics and properties of the woods that vegetate in Cuba has been carried out in national institutions for a good number of years, covering the fields of anatomy, physical properties, mechanics, treatability, natural durability, chemical composition and workability, mainly. The emphasis of these studies of technological character has been given towards those wood species that, by their abundance, form of shaft and geographical distribution present commercial potential. Magaña *et al,* (1998).

The species *Quercus cubana (Fagaceae*) is the only true oak of Cuba's flora, already recognized as endemic to Cuba by León and Alain, (1951), exclusive to the west of the country, limited only to Pinar del Río Samek, (1973), which represents one of the few references of penetration of the Holartic floristic kingdom in the Neotropic Borhidi, (1992) and with a widespread use in rural life, because its fruits, commonly called acorns, are used as animal feed for pigs to have a high fat content and its wood has been used in obtaining charcoal to make food.

It is an evergreen tree that reaches a maximum height of 30 m and a trunk diameter of about 2.5 m; the bark is cracked, pale grey or whitish. Blade leaves coriaceous, oblong or oval, varying from obovate to oblanceolate; 3 to 12 cm long, obtuse or sharp, whole (except in shoots), more or less resolute, lampiñas and often shiny on the upper face, lampiñas or sparsely pubescents underneath, never rough; petioles 0.5 to 1 cm lardo. Elongated male attachments hanging, piled up. Calyx campanulate, 4-7 lobed, subtended by deciduous bracts; stamens 6 to 12; filiform filaments. Female flowers solitary or several together; calyx urn-shaped. Ovary 3-locular. Egg 2 in each cavity, but rarely more than 1 in each pistil that matures. Fruits solitary or spiked at the ends of the peduncle by common long. The fruit consists of an acorn or coriaceous nut, subtended monosperm or almost enveloped by the acrescent involucre (cupola). The dome is hemispherical, often slightly constricted at the base, from 15 to 20 mm. wide, its scales tight, the bottom thickened at the base; nut ovoid or oblong ovoid, 2 to 2.5 cm long, double length than the dome and semi-cylindrical cotyledons. De la Paz Pérez Olvera *et al.,* (2006).

One of the few tree formations of the *Q. cubana* species and almost the only redoubt in the plain (the westernmost) is Manuel Lazo's holm oak grove in Pinar del Río. At present, this holm oak grove is being highly threatened by anthropogenic action, often illegal and excessive, such as overgrazing of state and private pig ranching, as well as the collection of seeds for such purposes, the use of the area as a micro dump for solid waste, and the extraction of sand as construction material. In addition, the region is in a favorable geographic situation to the passage of climatic events, has suffered the damages of six hurricanes in the last five years. All this situation has provoked the penetration of exotic and invasive species, displacing the characteristic vegetation of this ecosystem, mainly *Q. cubana*, compromising the current occupation area of the population, which has suffered a drastic decrease in the last 30 years. Ibáñez and others, (2002).

Friction is defined as a resisting force acting on a body, which prevents or retards the sliding of that body in relation to another or on the surface in contact. This force is always tangential to the surface at the points of contact with the body and has such a sense that it opposes the possible or existing movement of the body with respect to those points. On the other hand, these frictional forces are limited in magnitude and will not impede movement if sufficiently large forces Vignote and others, (2016) are applied.

The friction force between two bodies does not depend on the size of the contact surface between the two bodies, but it does depend on the nature of that contact surface, that is, on what materials form it and whether it is more or less rough.

MATERIALS AND METHODS

The selection of the individuals was made starting from the selection criteria proposed by Egas, (1998), where 13 individuals belonging to Pino-Encino forests with heterogeneity in age, morphology and geographic location within the area of the Estación Experimental Forestal Viñales were selected.

The variables determined for the investigation were: coefficient of friction on wood surface and metal surface, dry weight, volumetric contraction, density of freshly cut wood and anhydrous density, diameter 1.3 m, age, crown radius, crown height, total height of the individuals, dry volume and height of the 1st branch.

The ages of the individuals are: 8, 10, 12, 13, 14, 20, 35, 45, 50. For the confection of the test pieces a pattern of a log of 1 meter height was followed from 1.3 meters of the height of the clean shaft, being confectioned test pieces of 3x3x10 cm following the norm NC-43-37-87 for a total of 100 test pieces. Specimens 1, 3, 5, 7 and 9 are located at the lower end of the log, starting from the marrow towards the cortex; specimens 2, 4, 6, 8 and 10 are located at the upper end of the log following the pattern described above. Subsequently, the mechanical properties were determined in the laboratory of the Empresa Nacional de Investigaciones Aplicadas (ENIA).

Experience shows that the magnitude of the friction force between two bodies in contact is proportional to the normal force between the two bodies, that is:

Fr = m-N Fr: friction force.
m: coefficient of friction.
N: normal force exerted by the surface on the body.

It is determined by the fixed method, with an implement that goes up until the body slides over it; to determine the final value there is the tangent of the angle that marks the implement. Figure 1 shows the principle of operation of the implement, with which the experiment was performed in the physics laboratory belonging to the

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Universidad de Pinar del Río "Hermanos Saíz Montes de Oca" (Figure 1).

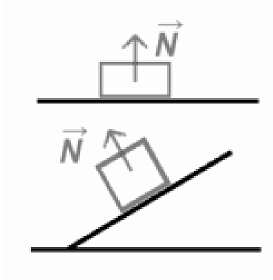

Fig. Representación gráfica de la determinación del coeficiente de rozamiento.
Fuente: Vignote *y otros.,* (2016)

The normality of the friction coefficient variable is analyzed by the Kolmogorov-Smirnov test with IBM SPSS, ver. 21 for Windows to determine the type of test to be used, parametric or non-parametric. This software allowed multiple comparisons based on the medulla cortex factor.

RESULTS AND DISCUSSION

A physical property not well studied in depth in the species is the coefficient of friction, generally determined to woods that are under constant siege of bodies that press on it. The behavior of this property does not have a defined pattern. Tables 1 and 2 show the behaviour of the coefficient of friction on metal and wood surfaces.

The coefficient of friction on a wooden surface is composed of seven groups; the behavior goes up, also related to the age of the trees and the disposition of the test tube from the marrow to the cambium. The older trees are the ones that give better answer to this property, determinant in species that are used as floors; these values correspond to those obtained by Álvarez, (2013) and Vignote *et al.,* (2016), which state that as the test tubes approach the bark the density increases. Similarly, in the aging of the tree the tendency is to lose moisture and gain in weight by the production of dry mass. The average obtained in this test is 0.7, corresponding to the values obtained by Vignote *et al.,* (2016) for bodies at rest; the nature of the force exerted by friction also depends on the roughness of the moving body or the surface on which it moves (Table 1).

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Tabla 1. Prueba de comparación de Ducan para el coeficiente de rozamiento sobre madera.

Probetas	N	1	2	3	4	5	6	7
1	10	.475212						
2	10		.532237					
3	10			.670619				
4	10			.690738				
5	10			.711460	.711460			
6	10				.752189	.752189		
7	10					.764179	.764179	
8	10					.787105	.787105	.787105
9	10						.810718	.810718
10	10							.835039
Sig.		1.000	1.000	.104	.087	.165	.064	.056

The case of the coefficient of friction on metal surface is composed in eight groups, the behavior goes in ascent as in that of wood surface, an increase towards the bark and height of the tree, with a slight difference on the wood surface, assuming that the species shows a better response on metal surface before woods of good polish. The average of the property is 0.71, being higher than those obtained by Vignote and others. (2016) who propose that the coefficient of friction for wood on metal surfaces is 0.6 for static body, presenting this species a better behavior (Table 2).

Tabla 2. Prueba de comparación de Ducan para el coeficiente de rozamiento sobre metal.

Probetas	N	1	2	3	4	5	6	7	8
1	10	.483628							
2	10		.541663						
3	10			.682496					
4	10			.702971	.702971				
5	10				.724060				
6	10					.758054			
7	10					.777333	.777333		
8	10						.800653	.800653	
9	10							.824673	.824673
10	10								.849413
Sig.		1.000	1.000	.190	.177	.216	.136	.124	.114

The behaviour of this property on the two surfaces makes it possible to decide which products are more feasible for an efficient use of the species, taking into account whether it will be subject to pushing forces or to joints when looking for firmness to avoid play between pieces. An example is at the time of making an armchair, after having all the pieces together, if the coefficient of friction is low, the pieces tend to create looseness between them quickly and brings with it uncomfortable sounds to a person to balance constantly, later the destruction or disunion of some of the pieces occurs.

It should also be noted that the coefficient of friction is given by the roughness of the bodies, this can appear in different forms and in the different sections of the pieces obtained from a tree depending on their sections, so that in the axial section tends to appear more rigorous than in other sections, by the nature of the fibers. These can be corrected with the brushing or the garlopa, but it depends to a great extent on which is the final objective that the piece is going to fulfill.

In analysis of main components to determine the influence of other variables on the behavior of the coefficient of friction on wood and metal surfaces, four components are obtained; it can be seen that there is a strong relationship between the coefficient of friction on both surfaces and the dry weight. It is shown that the extraction of the sum of squares explains the totality of the variance in 85 %, as well as the rotation (varimax) of the sum of squares, without the latter providing a better solution (Table 3).

Tabla 3. Varianza total explicada.

Componentes	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	**Total**	% of Variance	Cumulative %
1	4.194	32.262	32.262	4.194	32.262	32.262
2	3.846	29.582	61.844	3.846	29.582	61.844
3	1.834	14.111	75.954	1.834	14.111	75.954
4	1.200	9.233	85.188	1.200	9.233	85.188
5	.637	4.897	90.084			
6	.462	3.553	93.637			
7	.383	2.949	96.586			
8	.183	1.408	97.994			
9	.124	.958	98.952			
10	.077	.589	99.541			
11	.050	.382	99.922			
12	.010	.076	99.998			
13	.000	.002	100.000			

Four components are formed where the coefficients of friction determined have a strong relationship with the dry weight, taking into account the deformations that the wood suffers in the drying process, which enables greater friction with porous surfaces. (Table 4).

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Tabla 4. Matriz de componentes de la rotación de la suma de cuadrados.

	Componentes			
	1	2	3	4
CR metal	.789	-.474	.151	-.003
Peso (g) S	.757	-.536	.219	-.022
CR madera	.721	-.531	.126	.160
Contracción Volu	-.709	.346	.411	.145
Densidad Anh	.653	-.515	.462	.036
d1:30 (m)	.551	.751	.066	-.148
Edad (años)	.526	.734	.061	-.273
Radio de Copa	.499	.720	-.044	.105
h copa	.475	.711	.084	.107
H total (m)	.487	.699	.016	.401
Densidad V	-.130	.068	.846	.027
Volumen Seco	.490	-.170	-.752	-.185
h(1ra rama)	.004	-.124	-.259	.915

The significance of two models obtained for the prediction of the coefficient of friction on wood surfaces is shown. The first model assumes the variable dry weight of the samples obtained and the second model also includes the height of the first branch, this being the most complete and explaining 61% of the variable studied (Table 5).

Tabla 5. Resumen del modelo.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.762[a]	.580	.576	.0800157
2	.782[b]	.612	.604	.0773309

The first predictive model would be:

CRma=-0.426+0.012*Ps (1)

The second predictive model would be:

CRma=-0.489+0.012*Ps+0.015*h1st branch (2)

Being: CRma: coefficient of friction on wood surface
Ps: dry weight (g)
h1ra: height of first branch Table 6 shows the significance of the models, so it can be said that they are reliable and the constants differ from zero. (Table 6).

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Tabla 6. Anova.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.867	1	.867	135.454	.000[b]
	Residual	.627	98	.006		
	Total	1.495	99			
2	Regression	.915	2	.457	76.473	.000[c]
	Residual	.580	97	.006		
	Total	1.495	99			

In the case of the coefficient of friction on a metal surface only one model is obtained that is related to the dry weight of the wood. Where the variable dry weight explains 65 % the behaviour of the determined property (Table 7).

Tabla 7. Resumen del modelo.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.807[a]	.651	.647	.0703492

The predictive model obtained is: CRme=-0.432+0.012*Ps

The model is reliable from the significance obtained, shown in table 8. (See table 8).

Tabla 8. Anova.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.903	1	.903	182.510	.000[b]
	Residual	.485	98	.005		
	Total	1.388	99			

The coefficient of friction is high for both surfaces, showing an ascending behavior of the pith to the cortex.

The equation that best explains the coefficient of friction on wood surface is CRma=-0.489+0.012*Ps+0.015*h1rarama and only one equation is obtained for surface on metal, CRme=-0.432+0.012*Ps.

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