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Articles

Fiber quality of second-rotation wood from *Eucalyptus urophylla* S.T. Blake for pulp and paper production

Qualidade das fibras da madeira de segunda rotação de *Eucalyptus urophylla* S.T. Blake para produção de celulose e papel

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ABSTRACT

The genus Eucalyptus is of great economic importance for the Brazilian forestry sector and has been planted in various regions of Brazil, where the pulp and paper industry are the largest consumer of timber. The genus Eucalyptus is also recognized for its regrowth capacity, which is one of the factors contributing to its large-scale planting. Despite numerous studies on the regrowth quality of this genus, little is known about the quality and technological properties of regrowth wood, such as that of second-rotation trees, particularly for industrial use. Thus, the goal of this study is to evaluate the wood quality of second-rotation trees of two clonal hybrids of *Eucalyptus urophylla* S.T. Blake, aiming at their use in the production of pulp and paper. Two clonal hybrids of *Eucalyptus urophylla* S.T. Blake, approximately five years old, were used. To characterize wood quality, basic density, fiber dimensions, and wood quality indices for pulp and paper production were determined, including the Runkel ratio, wall proportion, Luce's shape factor, stiffness coefficient, and flexibility coefficient. The wood from the first and second rotations showed similar patterns, especially in Clone 1. The results indicate that the second-rotation wood has the quality required for pulp and paper production.

Keywords: Cellulose; Wood anatomy; Regrouwth wood; Clone

RESUMO

O gênero Eucalyptus é de grande importância econômica para o setor florestal brasileiro, sendo plantado em diversas regiões do País, sendo que a indústria de celulose e papel é a maior consumidora de madeira em tora. O gênero Eucalyptus é também conhecido por sua capacidade de rebrota, que é um dos fatores que pode contribuir para seu plantio em larga escala. Embora se tenha inúmeros estudos voltados à qualidade da rebrota do gênero, pouco se é estudado sobre a qualidade e as propriedades tecnológicas da madeira de rebrota, como a de segunda rotação, visando seu uso industrial. Sendo assim, o objetivo do presente estudo é avaliar a qualidade da madeira de segunda rotação de dois híbridos clonais de *Eucalyptus urophylla* S. T. Blake, visando seu uso na produção de celulose e papel. Para isto, foram utilizados dois híbridos clonais de *Eucalyptus urophylla*, com cerca de cinco anos de idade. Para a caracterização da qualidade da madeira, foi determinada a densidade básica, as dimensões das fibras e os índices de qualidade da madeira para a produção de celulose e papel: índice de Runkel, fração parede, fator de forma de Luce, coeficientes de rigidez e de flexibilidade. As madeiras de primeira e segunda rotação apresentam muitas propriedades similares entre si, principalmente no clone 1 e as propriedades estudadas mostram-se desejáveis para a produção de celulose e papel. Com base nos resultados obtidos, conclui-se que madeiras de segunda rotação têm qualidade para produção de papel e celulose.

Palavras-chave: Celulose; Anatomia da madeira; Rebrota da madeira; Clone

1 INTRODUCTION

Trees of the genus Eucalyptus are the most planted in Brazil for commercial purposes (Souza et al., 2024), primarily for pulp and paper production. According to IBGE (2023), in 2022 Brazil had 7.3 million hectares of *Eucalyptus* plantations, representing 76% of all planted areas in the country. In the same period, cellulose ranked 11th in Brazil's export list, with 19.8 million tons exported, generating a value of 8.4 billion USD and achieving an average growth rate of 24.8%. According to IBA (2023), Brazil is the second-largest producer of pulp globally, with a total production of 25 million tons, 22 million tons of short fiber, 2.5 million tons of long fiber, and 0.5 million tons of high-yield pulp.

This genus possesses many characteristics that are beneficial to the forestry sector, one of which is its ability to regrow after the first harvest. This feature supports large-scale planting (Klein et al., 1997). The sprouting management regime, also known as coppice, is suitable for forest species with the potential for vegetative regeneration, such as species of this genus (Guimarães et al., 2020). This system eliminates the need for replanting, thereby reducing negative environmental impacts and operational costs.

Timber production through the coppice system can be advantageous for small and medium scale rural producers and, depending on the circumstances, for large companies, as it ensures good-quality wood with a profitable return (Ferrari et al., 2004). Although there have been several studies in Brazil on the *Eucalyptus* coppice system, there are few records on its effects on the technological properties of the wood (Cirilo et al., 2023).

Specifically, the quality of wood from second-rotation trees remains underexplored for its suitability in pulp and paper production. Existing studies generally focus on sprout quality and wood volume, with limited investigations into sapwood production (Valle et al., 2013; Cirilo et al., 2023) and wood basic density (Gonçalves et al., 2009).

Wood density tends to increase in second-rotation trees (Gonçalves et al., 2008), which may influence differences in wood fiber dimensions between rotations. Wall thickness varies significantly between species and is a critical parameter for the production and technological properties of paper (Foelkel, 2007).

Considering the advancements in Brazilian silviculture applied to the management of Eucalyptus regrowth (Stape et al., 1993; Klein, 1997; Stape, 1997; Ferreira; Silva, 2008; Guimarães et al., 2008) and the intrinsic capacity for regrowth in this genus, it is essential to deepen the understanding of this characteristic concerning the quality of regrowth wood. This study aims to evaluate the wood quality of second-rotation trees of two clonal hybrids of *Eucalyptus urophylla* S.T. Blake by determining wood fiber dimensions and basic density, with a focus on their suitability for pulp and paper production.

2 MATERIAL AND METHODS

The study was conducted using two clonal hybrids of *Eucalyptus urophylla* S.T. Blake, of unknown origin. The samples were obtained from both the first and second rotations, with the trees being of the same age (approximately five years old) and planted at a spacing of 3.0 x 2.8 meters. The material originated from commercial plantations of ArcelorMittal Jequitinhonha, located in Itamarandiba, Minas Gerais, Brazil (Table 1). According to the Köppen classification, the climate of the study area is classified as Cwb—humid temperate with dry winters and moderately hot summers. The region has an average annual precipitation of 1,156.75 mm and a relative air humidity of 68.43%.

Table 1 – Planting site information

Clonal hybrids	Genetic material	Rotation	Altitude (m)	Latitude (UTM)	Longitude (UTM)
Eucalyptus urophylla (unknown parthenal origin)	Clone 1	First	1001	8041803	741306
		Second	929	8033001	720372
	Clone 2	First	926	8037277	740590
		Second	937	8033019	720908

Source: Authors (2026)

Four trees from each clone and rotation were used, totaling 16 trees. The trees were selected randomly following the principles of simple random sampling. After felling, the trees were cut into three-meter logs, and the first three logs from the basal part of each tree were used, resulting in a total of 48 logs. From each log, a wood disc was removed 30 cm above the base to evaluate basic density, fiber dimensions, and estimate fiber quality indices for paper production. All laboratory analyses were conducted at the Wood Properties Laboratory of the Forestry Engineering Department at the Federal University of Viçosa, Viçosa, Minas Gerais.

To determine the basic density of the wood, two opposing wooden wedges were extracted from each disc. The volume was measured according to Vital (1984), and the basic density was determined following the NBR 7190 standard (ABNT, 1997). To evaluate fiber dimensions, small fragments from the sapwood region of each disc were collected. These fragments were macerated to prepare samples for fiber dimension analysis. The maceration process involved immersing the fragments in a 1:1 solution of hydrogen peroxide and glacial acetic acid inside test tubes, which were then placed in a forced-air oven at 60°C for approximately 48 hours.

Following maceration, 30 fibers from each sample were individually measured to determine their length, width, and lumen diameter. Measurements were conducted using Axio-Vision software. The wall thickness of the fibers was calculated as half the difference between the fiber width and the lumen diameter.

Based on the fiber analysis data, the following quality indices for paper production were estimated, in accord with equations 1 to 5.

Flexibility Coefficient (MILANEZ e FOELKEL, 1981):

$$FC = \frac{d}{D} \text{ x } 100 \tag{1}$$

Wall Fraction (FOELKEL e BARRICHELO, 1975):

$$WF = \frac{(2 \text{ x } CW)}{D} \text{ x } 100 \tag{2}$$

Runkel Ratio (RUNKEL, 1952):

$$RR = \frac{2CW}{d} \tag{3}$$

Luce’s Shape Factor (LUCE, 1970):

$$L = \frac{(D^2 - d^2)}{(D^2 + d^2)} \tag{4}$$

Stiffness coefficient:

$$SC = \frac{c}{D} \tag{5}$$

where: D = Fiber diameter; d = Fiber lume diameter; C = Fiber length; CW = Fiber wall thickness.

2.1 Data Analysis

Data analysis was conducted using descriptive statistics, with the estimation of mean and standard deviation. The differences between clones and rotations were evaluated using the Student's t-test for independent samples, with a significance level of 5%. All analyses were performed using Statistic software and Microsoft Excel.

3 RESULTS AND DISCUSSIONS

When analyzing the differences between the first and second rotations for each clonal hybrid of *Eucalyptus urophylla* (Table 2), significant statistical differences were observed between the rotations. For fiber dimensions in Clone 1, significant differences were found in fiber width and wall thickness. In Clone 2, significant differences were observed in the lumen diameter. Basic wood density showed a significant difference between rotations only for Clone 2. Regarding the parameters related to paper quality, significant differences were also observed in Clone 2 for the Runkel Ratio, Flexibility Coefficient, Wall Fraction, and Luce's Shape Factor. These statistically significant differences in quality indices for Clone 2 are influenced by variations in lumen diameter, which explain these observations.

Table 2 – Average values of basic density and fiber properties of wood from a clonal hybrid of *Eucalyptus urophylla*

Properties	Clone 1		Clone 2	
	1ª Rotation	2ª Rotation	1ª Rotation	2ª Rotation
Basic density ($g.cm^{-3}$)	0,472 ± 0,017 a[1]	0,498 ± 0,040 a	0,494 ± 0,014 a	0,468 ± 0,017 b
Fiber length (mm)	1,053 ± 0,046 a	1,068 ± 0,086 a	1,102 ± 0,098 a	1,103 ± 0,083 a
Fiber width (μm)	19,86 ± 0,74 b	21,08 ± 1,67 a	20,24 ± 1,92 a	21,10 ± 1,52 a
Fiber lumen diameter (μm)	9,47 ± 0,99 a	9,39 ± 1,01 a	8,68 ± 1,40 b	10,45 ± 1,89 a
Wall thickness (μm)	5,19 ± 0,47 b	5,83 ± 0,90 a	5,78 ± 0,72 a	5,32 ± 0,55 a
Runkel Ratio	1,26 ± 0,28 a	1,49 ± 0,38 a	1,57 ± 0,29 a	1,22 ± 0,36 b
Flexibility coeficiente (%)	47,28 ± 4,50 a	44,19 ± 5,37 a	42,58 ± 5,02 b	48,78 ± 6,31 a
Wall fraction (%)	52,72 ± 4,50 a	55,76 ± 5,39 a	57,42 ± 5,02 a	51,22 ± 6,31 b
Stiffness coefficient	54,96 ± 3,70 a	52,64 ± 4,49 a	56,55 ± 5,85 a	54,29 ± 6,33 a
Luce's Shape Factor	0,63 ± 0,05 a	0,67 ± 0,06 a	0,69 ± 0,06 a	0,61 ± 0,08 b

Source: Authors (2026)

In where: Averages followed by the same letter, within the same row and for the same clonal hybrid, do not differ statistically according to the Student's t-test for independent samples ($p < 0.05$).

Comparing the differences in wood properties among the clonal hybrids evaluated (Table 3), it is noted that for the first rotation, clonal hybrids 1 and 2 exhibit statistically significant differences in basic density, fiber wall thickness, Runkel ratio, flexibility coefficient, wall fraction, and Luce's shape factor. For the second rotation, statistically significant differences are observed only for basic density between the woods of the two clonal hybrids. Based on the wood properties studied, this indicates greater variation in wood properties when comparing different genetic materials for the first rotation of *Eucalyptus urophylla*, which was not observed when the same materials were compared for the second rotation.

Table 3 – Differences in basic density and fiber properties of wood between clonal hybrids of *Eucalyptus urophylla* for the same rotation

Properties	1ª Rotation		2ª Rotation	
	Clone 1	Clone 2	Clone 1	Clone 2
Basic density ($g.cm^{-3}$)	0,472 ± 0,017 b[1]	0,494 ± 0,014 a	0,498 ± 0,040 a	0,468 ± 0,017 b
Fiber length (mm)	1,053 ± 0,046 a	1,102 ± 0,098 a	1,068 ± 0,086 a	1,103 ± 0,083 a
Fiber width (µm)	19,86 ± 0,74 a	20,24 ± 1,92 a	21,08 ± 1,67 a	21,10 ± 1,52 a
Fiber lumen diameter (µm)	9,47 ± 0,99 a	8,68 ± 1,40 a	9,39 ± 1,01 a	10,45 ± 1,89 a
Wall thickness (µm)	5,19 ± 0,47 b	5,78 ± 0,72 a	5,83 ± 0,90 a	5,32 ± 0,55 a
Runkel Ratio	1,26 ± 0,28 b	1,57 ± 0,29 a	1,49 ± 0,38 a	1,22 ± 0,36 a
Flexibility coeficiente (%)	47,28 ± 4,50 a	42,58 ± 5,02 b	44,19 ± 5,37 a	48,78 ± 6,31 a
Wall fraction (%)	52,72 ± 4,50 b	57,42 ± 5,02 a	55,76 ± 5,39 a	51,22 ± 6,31 a
Stiffness coefficient	54,96 ± 3,70 a	56,55 ± 5,85 a	52,64 ± 4,49 a	54,29 ± 6,33 a
Luce's Shape Factor	0,63 ± 0,05 b	0,69 ± 0,06 a	0,67 ± 0,06 a	0,61 ± 0,08 a

Source: Authors (2026)

In where: Averages followed by the same letter, within the same row and for the same clonal hybrid, do not differ statistically according to the Student's *t*-test for independent samples ($p < 0.05$).

Analyzing the clones and rotations (Tables 1 and 2), the basic wood density ranged from 0,472 to 0,494 $g.cm^{-3}$. Similar values were reported by Lima et al. (2014) and Cruz et al. (2021). For short-fiber cellulose production from hardwood, the recommended basic density is between 0.400 $g.cm^{-3}$ and 0.550 $g.cm^{-3}$ (Magalhães et al., 2020). However, woods with lower densities tend to yield less cellulosic pulp (Dias; Cláudio-Da-Silva Jr., 1985; Mokfienski et al., 2008), making them more suitable for producing printing and writing papers (Mokfienski et al., 2008). Additionally, such pulps may result in better tensile strength (Fonseca et al., 1996; Carneiro; Amaral, 1997).

The selection of Eucalyptus species based on basic density is a crucial quality criterion (Sereghetti et al., 2015; Carvalho et al., 2023; Ramos et al., 2024). In the first rotation, clone 2 showed higher density than clone 1, whereas in the second rotation, the trend was reversed.

A proper evaluation of basic density for paper and cellulose production enables accurate guidance on chip impregnation and process yields. It is also associated with quality characteristics and the physical-mechanical resistance of the pulp (Queiroz et al., 2004). Based on basic wood density, both clones and rotations are suitable for producing paper and cellulose. However, the second rotation of clone 2 is more suitable for printing and writing papers due to its lower wood basic density.

Anatomical structure significantly influences paper quality, as well as optical properties and pulp resistance (Carpim et al., 1987), where the dimensional variation of the fibers is most relevant in terms of raw material (Pedrazzi et al., 2013). Fiber dimensions play a critical role in evaluating wood quality for paper and cellulose production, correlating with the product's physical-mechanical and surface properties (Mokfienski et al., 2008).

For fiber length, the average values for clone 1 were 1.053 mm in the first rotation and 1.068 mm in the second rotation. For clone 2, the values were 1.102 mm and 1.103 mm for the first and second rotations, respectively. Clone 1 values aligned with literature values for *E. urophylla*, while clone 2 exhibited higher values (Alves et al., 2011), however, when compared with other *Eucalyptus* species of the same age, the values were higher for all characteristics (Baldin et al., 2017). In general, fibers with greater length are more resistant to tearing, whereas shorter fibers provide better formation of the paper sheet (Alves et al., 2011). Furthermore, the properties associated with the degree of union of the fibers tend to increase with the length of the fibers (Almeida et al., 2022), such as the resistance of the paper sheet.

For fiber width, clone 1 showed average values of 19.86 μm in the first rotation and 21.08 μm in the second rotation, consistent with literature values for the first rotation and higher for the second rotation (Alves et al., 2011; Lemos et al., 2012; Baldin et al., 2017). Clone 2 exhibited values of 20.24 μm and 21.10 μm for the first and second rotations, respectively. For lumen diameter, both clones showed values below literature reports (Alves et al., 2011; Lemos et al., 2017). Clone 1 had values of 9.47 μm and 9.39 μm for the first and second rotations, respectively, while clone 2 had values of 8.68 μm and 10.45 μm for the first and second rotation, respectively and is closer to that reported in the literature. Larger lumen diameters tend to produce paper with higher tensile, tear, and burst resistance (Campos, 1997).

Wall thickness showed the highest average value in the second rotation of clone 2 (5.83 μm) and the lowest in the first rotation of clone 1 (5.19 μm). Thicker-walled, rigid fibers produce paper with a higher specific volume and greater opacity (Carpim et al., 1987; Dias; Cláudio-Da-Silva, 1991; Mokfienski et al., 2008), crucial for printing papers, for example.

The Runkel ratio is a fiber quality index that indicates the relationship between wall thickness and lumen diameter, serving as a measure of fiber flexibility. This index provides insight into the ability of fibers to bond and is a key parameter for evaluating fiber quality and performance (Nigoski et al., 2012). According to classification standards, Runkel ratio values below 0.25 are considered excellent for paper production; values between 0.25 and 0.50 are rated as very good; values from 0.50 to 1.00 are considered good; values between 1.00 and 2.00 are classified as regular; and values above 2.00 indicate that the wood is unsuitable for paper production (Miranda; Castelo, 2012). The results recorded for clonal hybrids ranged between 1.22 and 1.57. The lowest value was observed in clone 2 during the second rotation, while the highest value was recorded in the same clone during the first rotation. Both results fall within the regular classification range. The Runkel ratio, along with wall proportion, is associated with fiber hardness, as higher values indicate increased rigidity, which can affect the strength properties of the paper (Gonçalves et al., 2014).

The flexibility coefficient reflects the ease of fiber bonding (Baldin et al., 2017). Values above 50% are recommended for paper production (Foelkel, 1978). All the woods analyzed showed values close to 50%, suggesting their potential suitability for paper production, except for the first rotation of clone 1, which presented a value of 42.58%.

Wall proportion influences pulp quality (Floreshim et al., 2009). Values above 60% are less favorable for producing high-quality pulp due to rigid fibers and limited flexibility (Foelkel; Barrichelo, 1975; Foelkel et al., 1978). This is particularly critical for papers requiring tensile strength and bursting resistance (Floreshim et al., 2009). All samples in this study had values below this threshold, indicating favorable properties for producing resistant papers.

Luce's Shape Factor correlates with paper density (Baldin et al., 2017) and indicates the force required for lumen collapse (Almeida et al., 20s2). This quality parameter can be used to select wood matrices for pulp and paper production (Pirralho et al., 2014). Values ranged from 0.61 to 0.69, higher than those reported in the literature for *Eucalyptus* spp., suggesting good potential for pulp and paper production.

Table 4 presents the correlations between the studied parameters. Significant correlations were observed for fiber dimensions, quality indices, and basic density in the wood of both clonal hybrids across rotations.

Significant positive correlations above +0.80 were observed in clone 1, during the first rotation, between the thickness of the fiber walls and the Runkel ratio, wall proportion, and Luce's shape factor. Positive correlations above +0.80 were also found between the lumen diameter of the fibers and the flexibility coefficient, as well as between the Runkel ratio and Luce's shape factor. Negative correlations below -0.80 were recorded between the lumen diameter of the fibers and paper quality indices, except for the stiffness coefficient.

Table 4 – Pearson's correlation coefficient between the studied properties by clone and rotation for clonal hybrids of *Eucalyptus urophylla*

Clone 1 – First rotation										
Prop.	**FL[1]**	**FW**	**FLD**	**WT**	**RR**	**FC**	**WF**	**SC**	**LSF**	**BD**
FL	-									
FW	ns[2]	-								
FLD	ns	ns	-							
WT	ns	ns	-0,71	-						
RR	ns	ns	-0,93	0,90	-					
FC	ns	ns	0,93	-0,91	-1,00	-				
WF	ns	ns	-0,93	0,91	1,00	-1,00	-			
SC	0,66	-0,60	ns	ns	ns	ns	ns	-		
LSF	ns	ns	-0,93	0,91	0,99	-1,00	1,00	ns	-	
BD	ns	ns	-0,61	ns	0,59	-0,62	0,62	ns	0,63	-
Clone 1 – Second rotation										
Prop.	**FL**	**FW**	**FLD**	**WT**	**RR**	**FC**	**WF**	**SC**	**LSF**	**BD**
FL	-									
FW	ns	-								
FLD	0,58	ns	-							
WT	ns	0,84	ns	-						
RR	ns	0,63	-0,71	0,94	-					
FC	ns	ns	0,79	-0,90	-0,97	-				
WF	ns	ns	-0,79	0,90	0,97	-1,00	-			
SC	0,62	ns	ns	-0,70	-0,74	0,70	-0,72	-		
LSF	ns	ns	-0,81	0,89	0,96	-1,00	1,00	-0,69	-	
BD	ns	0,87	ns	0,85	0,73	-0,67	0,66	-0,62	0,65	-
Clone 2 – First rotation										
Prop.	**FL**	**FW**	**FLD**	**WT**	**RR**	**FC**	**WF**	**SC**	**LSF**	**BD**
FL	-									
FW	ns	-								
FLD	ns	0,67	-							
WT	0,63	0,69	ns	-						
RR	ns	ns	-0,76	0,67	-					
FC	ns	ns	0,84	-0,61	-0,97	-				
WF	ns	ns	-0,84	0,61	0,97	-1,00	-			
SC	ns	-0,59	-0,68	ns	ns	ns	ns	-		
LSF	ns	ns	-0,85	0,60	0,96	-1,00	1,00	ns	-	
BD	ns	ns	ns	ns	ns	ns	ns	ns	ns	-
Clone 2 – Second rotation										
Prop.	**FL**	**FW**	**FLD**	**WT**	**RR**	**FC**	**WF**	**SC**	**LSF**	**BD**
FL	-									
FW	ns	-								
FLD	ns	0,81	-							
WT	ns	ns	-0,60	-						
RR	ns	-0,62	-0,93	0,74	-					
FC	ns	0,59	0,94	-0,81	-0,97	-				
WF	ns	-0,59	-0,94	0,81	0,97	-1,00	-			
SC	0,75	0,75	ns	ns	ns	ns	ns	-		
LSF	ns	-0,58	-0,94	0,82	0,96	-1,00	1,00	ns	-	
BD	-0,63	ns	ns	ns	ns	ns	ns	ns	ns	-

Source: Authors (2026)

In where: [1/] FL = fiber length; FW = fiber width; FLD = fiber lumen diameter; WT = wall thickness; RR = Runkel ratio; FC = Flexibility coeficiente; WF = wall fraction; SC = Stiffness coefficient; LSF = Luce's Shape Factor; BD = basic density; [2/] ns = not significante.

For the second rotation of clone 1, significant positive correlations above +0.80 were observed between fiber width and wall thickness, and between fiber wall thickness and the Runkel ratio, wall proportion, Luce's shape factor, and wood basic density. Similarly, positive correlations were found between the Runkel ratio, wall proportion, and Luce's shape factor. Negative correlations below -0.80 were registered between the lumen diameter of the fibers and Luce's shape factor, and between the flexibility coefficient and the wall thickness, Runkel ratio, wall proportion, and Luce's shape factor. These observations highlight a consistency in the correlations across both rotations in clone 1, demonstrating similar relationships between wood properties and quality indices for pulp and paper production.

In clone 2, the first rotation, significant positive correlations above +0.80 were observed between the lumen diameter of the fibers and the flexibility coefficient, between the Runkel ratio and wall proportion and Luce's shape factor, and between the wall proportion and Luce's shape factor. Significant negative correlations below -0.80 were recorded between the lumen diameter of the fibers and the wall proportion and Luce's shape factor, as well as between the Runkel ratio and the flexibility coefficient, and between the flexibility coefficient and the wall proportion and Luce's shape factor.

For the second rotation of clone 2, significant positive correlations above +0.80 were found between fiber width and lumen diameter, between the lumen diameter and the flexibility coefficient, and between the fiber wall thickness and the wall proportion and Luce's shape factor. Negative correlations below -0.80 were recorded between the lumen diameter of the fibers and the Runkel ratio, wall proportion, and Luce's shape factor, as well as between the flexibility coefficient and fiber wall thickness and the Runkel ratio. In clone 2, no significant correlation was observed between basic density and anatomical properties during the first rotation. However, in the second rotation, a significant negative correlation was recorded between basic density and fiber length.

4 CONCLUSIONS

Based on the results of this study, the following conclusions can be concluded:

- There is little difference between the wood from the first and second rotations, indicating that second-rotation wood can be used for paper and cellulose production, when the first-rotation wood is intended for that purpose;
- The clonal hybrids studied are suitable to produce paper and cellulose;
- For clonal hybrid 1, the wood from the first and second rotations showed greater similarity compared to clonal hybrid 2.

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