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Peeler core and slabwood fibre properties for *Pinus radiata* D.Don pulp production

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Abstract

Background: Pulp production based on *Pinus radiata* D.Don is constantly improving the value recovery of logs. One example is using the peeler cores and slabwood derived from sawing and peeling processes to produce pulp. However, these two raw materials have not been characterised for their fibre properties.

Methods: We report on four wood fibre quality attributes derived from peeler cores and slabwood, directly influencing pulp quality and pulping process: fibre length (mm), fibre width (μm), fines content (%), and coarseness (μg/m). This pilot study sampled two *P. radiata* stands grown on different sites and early silvicultural regimes in the Araucanía Region of Chile. Analysis of wood fibre consisted of three trees per stand, and six discs per tree: two at the bottom, two at breast height (1.3 m), and the last two at 5.23 m height.

Results: The trajectory of mean annual increment in diameter at breast height (MAI) and periodic annual increment in diameter at breast height (PAI) for trees in the two stands aligned with their respective site qualities and silvicultural regimes. In Stand 1, with a site index of 36, and Stand 2, with a site index of 31, the average proportions of juvenile wood (measured at 1.3 m) were 50% and 53%, respectively. Thus, despite weed control and fertiliser application in Stand 1, there was no increase observed in the proportion of juvenile wood. There were significant differences in fibre properties between peeler core and slabwood, and these differences were present across the range of tree heights and diameters ($p<0.05$). While there were no statistically significant differences among disc positions, significant distinctions emerged between stands and wood types. The interaction between these factors was also found to be statistically significant ($p<0.05$).

Conclusions: Our study suggests that adding these two materials into the mix for producing pulp would have positive implications due to pulp from peeler core is more suitable for printing and writing grades and addition of mature wood from slabwood, could improve strength properties of paper manufacture. However, it is necessary to test the optimal proportion for the final mix.

Keywords: *Pinus radiata,* fibre properties, wood quality, peeler core, slabwood

Introduction

Conifer plantations of *Pinus radiata* D.Don and *Pinus taeda* L. are becoming increasingly essential to meeting the timber, fibre, and fuel needs of society (Dillen et al. 2016; Schimleck et al. 2018). Concerning *P. radiata*, this is the most extensively planted exotic softwood worldwide (Mead 2013). Today there is over four million ha of *P. radiata*, with the most extensive plantations in Chile (1.3 M ha, Instituto Forestal 2021), New Zealand (1.6 M ha, Ministry for Primary Industries 2021), and Australia (0.77 M ha, Downham & Gavran 2019). These three Southern Hemisphere countries account for over 90 percent of the world's *P. radiata* plantations (Mead 2013). Table 1 presents the area of *P. radiata* plantation with primary uses per country.

TABLE 1: Area of *P. radiata* plantations per country and main products derived from them*.

Country	Estimated area ('000 ha)	Main uses
Australia	770	Sawlogs, pulplogs, reconstituted panels, posts and poles, energy, shelter
Chile	1299	Pulplogs, sawlogs, veneer, energy, erosion control
New Zealand	1609	Log export, sawlogs, pulplogs, posts and poles, energy, shelter, erosion control
Spain	260	Sawlogs, mixed plantations, agroforestry
Others	62	Unknown

*Adapted from Mead (2013)

In Chile, the total harvested volume in 2021 was 45 million m^3, of which 56 percent corresponded to sawlogs, 35 percent were pulp logs, and 8 percent were logs used for panel products (Instituto Forestal 2021). The *P. radiata* plantations are mainly located between Maule (Region VII) and Puerto Montt (Region X). However, Region VIII (Biobío) has the highest plantation area (44%), with the most pulp and paper industries.

The quality of natural inputs, such as logs, is based on their capacity to generate products that satisfy customer quantity and quality requirements (Zhang 1997). Pulpwood quality and value are mainly related to pulp yield, wood density, and fibre length. These traits are under genetic control and are influenced by silviculture and processing technology (Zobel & Buijtenen 1989; Mead 2013; Apiolaza & Alzamora 2013).

Globally, pulp and paper production is one of the most significant industries providing products to over 5 billion people worldwide (Bajpai 2018). In Chile, the main exported product is pulp, which represents 46 percent of the forest product shipped by value (Instituto Forestal 2021), and around 10 percent of *P. radiata* plantations are managed on non-thinned, short-rotation pulpwood regimes (Mead 2010). These stands tend to be on steep, lower-quality sites, where production thinning is less attractive. Other regimes manage stands to produce pruned and unpruned logs and generate raw material for pulp mills via commercial thinning, which occurs two to four times during an average rotation of 23 years. Pulp production based on *P. radiata* uses logs with a minimum small end diameter (SED) of 8 cm and 2.44 m long (Instituto Forestal 2021).

The demand for wood biomass has been increasing in the last 10 years for bio-based products that reduce emissions in thermal and electrical usages. These uses have generated competition for the main input to produce pulp, which has promoted more efficiency in the pulping process. An example is the use of slabwood and peeler core as inputs in pulp production coming from sawing (slabwood) and peeling logs (peeler cores) (Da Silva et al. 2004). The Chilean pulp production system, based on *P. radiata* is illustrated in Figure 1.

Peeler cores are mostly corewood (Burdon et al. 2004), regarded as "low quality" for many end-uses. Mead (2012) indicates that, compared to outerwood, the corewood is characterised by wider rings, lower wood density, lower tangential shrinkage, higher longitudinal shrinkage, lower wood stiffness, higher spiral grain, higher moisture content, shorter, thinner-walled tracheids, lower cellulose but higher lignin content. In

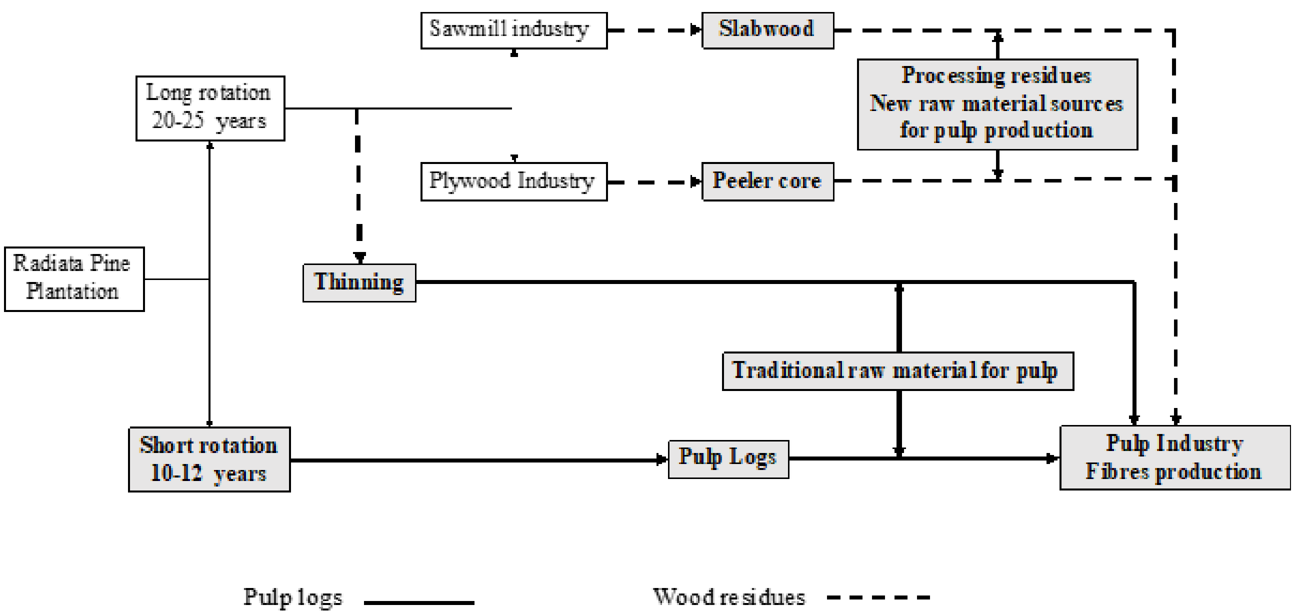

FIGURE 1: Diagram of the raw material sources (pulp logs and residues) to produce pulp from *P. radiata* in Chile.

comparison, slabwood is mostly outerwood, with high wood density, long tracheids, low microfibril angle, and low spiral grain (Cown 1992).

Fibre attributes that determine wood quality for pulp

Wood properties intimately related to pulp and paper quality in softwood are tracheid wall thickness, wood density, cellulose content, lignin content, and tracheid properties (Da Silva & Fauchon 2003; Pereira et al. 2003; Brännvall 2009). Among the latter, tracheid length, tracheid diameter, and tracheid wall thickness, fines content and coarseness are important performance metrics of fibre quality for papermaking (Kibblewhite & Hamilton 1984; Schimleck et al. 2018).

Longer fibres yield paper products with higher tearing resistance. Fibre width or thickness (µm) is closely related to the form of the wood fibre, with thinner fibres providing better wood quality for writing paper. However, width is also associated with low wood density, which is counterproductive for pulp mill productivity. Coarseness (µg/m) is defined as fibre mass per unit length. Coarseness is a pulp quality indicator, and it has a close relationship with wood density (Carrillo et al. 1997). Coarseness is a useful index for predicting pulp properties because it is positively related to the fibres' biometric properties, such as fibre density and cell wall thickness (Kibblewhite & Bawden 1992). Finally, fines content (%) corresponds to particles smaller than 0.2 mm and is considered a negative attribute for pulp production. The primary fines are constituted by ray cells, whereas the secondary fines correspond to the minor pieces from the fibre wall and broken fibres (Karlsson 2006).

Silvicultural activities like nursery systems, site preparation (which may include cultivation, drainage, and control of competing vegetation before and soon after planting), fertiliser use, control of growing space, tending and choice of harvest age, all affect wood properties (Burdon & Moore 2018; Lasserre et al. 2004; 2008).

Since wood properties in trees and logs are intimately related to end-product quality, it is necessary to identify, measure, and characterise wood, identifying when its attributes are different from the average values for a specific process. Our pilot study focused on the feasibility of assessing and reporting the fibre attributes coming from peeler cores and slabwood in a two contrasting radiata pine sites in the Araucanía Region, Chile.

Methods

Site and silviculture

We sampled two 23-year-old *P. radiata* stands grown under different site conditions in Araucanía Region, Chile (Figure 2). These stands also had different silvicultural management applied to them.

Stand 1 (38º39′28′′ S; 73º04′58′′ W) had intensive early silvicultural tending that included soil ripping, weed control, and fertiliser application. In contrast, Stand 2 (38º00′52.8′′ S; 72º21′29.9′′ W) was managed under less intensive silvicultural practices with respect to soil preparation, weed control and fertiliser application. Table 2 summarises the characteristics of Stands 1 and 2.

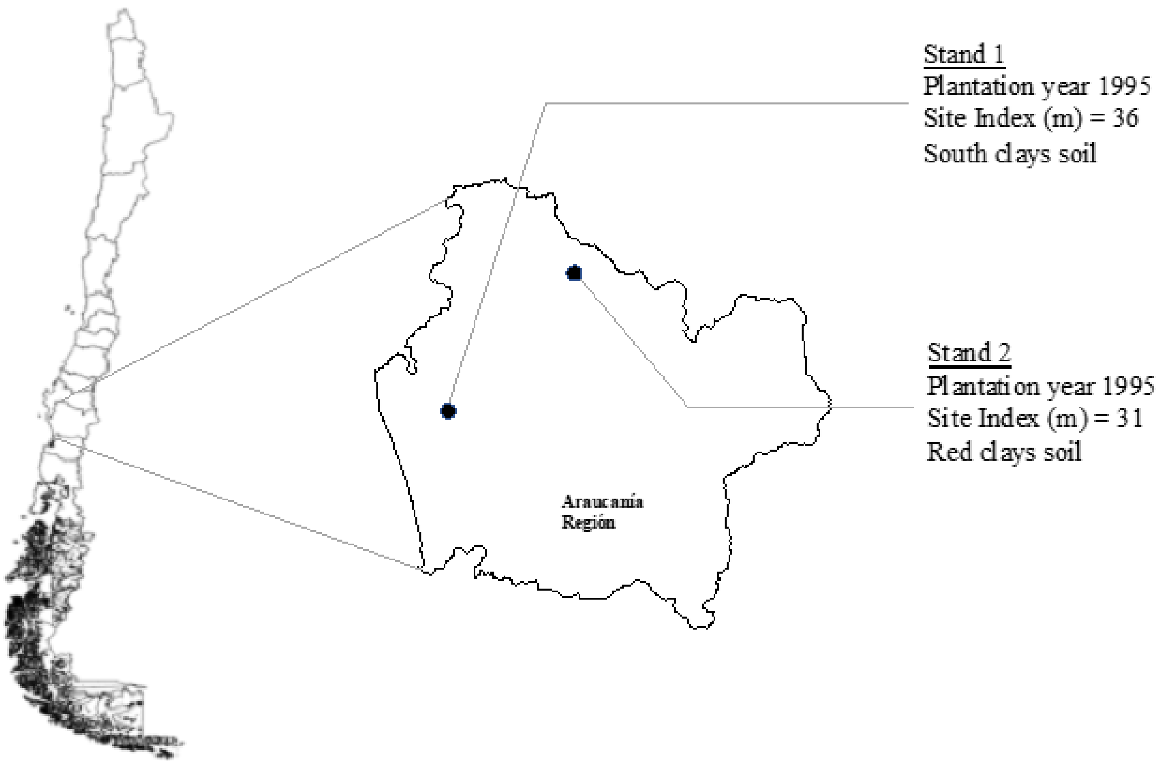

FIGURE 2: Localisation of Stand 1 and Stand 2 in Araucanía Region, Chile.

TABLE 2: Silvicultural regimes applied to *Pinus radiata* Stand 1 and Stand 2 and resulting stand attributes at the end of the 28-year rotation.

Parameter	**Stand 1**	**Stand 2**
Location	38º39´28´´ S; 73º04´58´´ W	38º00´52.8´´ S; 72º21´29.9´´ W
Soil type	South clay	Red clay
Plantation year	1995	1995
Site Index (m) at age 20	36	31
Initial stocking (plants/ha)	1250	1250
Establishment	**Year**	**Year**
Soil preparation and ripping	1	1
Weed control 1	0	0
Weed control 2	1	0
Preventive fertiliser	1	1
Productive fertiliser	1	0
Silviculture		
Final density (stems/ha) after Thinning 1 (waste thinning in Year 5)	850	850
Final density (stems/ha) after Thinning 2 (commercial thinning in Year 13)	400	400
Pruning 1 tree age (height)	4.7 (2.1 m)	4.7 (1.8 m)
Pruning 2 tree age (height)	5.5 (3.5 m)	6.1 (3.3 m)
Pruning 3 tree age (height)	6.5 (5.6 m)	8.1 (6.0 m)
Pruning 4 tree age (height)	7.3 (6.0 m)	
Rotation (28 years)		
Final Stocking rate (stems/ha)	393	403
Basal area (m^2/ha)	53.5	47.7
Mean diameter (cm)	41.0	38.5
Mean quadratic diameter (cm)	41.5	39.0
Total commercial volume (m^3/ha)	443	409

Sampling for wood analysis

Three trees were sampled per stand. From each tree, six discs were taken; two at the bottom, two at breast height (1.3 m), and the last two at 5.23 m. Two radial sections were obtained from the central part of each disc for subsequent analysis to determine fibre attributes. We extracted radial wood sections between rings 1-7, corresponding to the peeler core (juvenile wood), and rings 13 onwards, corresponding to slabwood (mature wood). Figure 3 illustrates the wood sampling procedure.

We also measured the width of growth rings at 1.3 m height to estimate the mean annual increment (MAI) and periodic yearly increment in diameter (PAI), with the aim of exploring the effect of growth rate on fibre properties. Once sections corresponding to the peeler core and slabwood were identified and sectioned, they were pre-treated to carry out the fibre quality analysis. For this purpose, the sections were chipped and macerated in Franklin's solution (1:1, 30% hydrogen peroxide: glacial acetic acid) for 8 hours at 70-80° C. Then, the fibrous material was washed with deionised water and dried overnight at 50° C. After that, fibrous material was re-suspended in deionised water using a Lorentzen & Wettre Fiber Tester Analyzer. The biometric parameters analysed included fibre length, fibre width, coarseness, and fines content.

Statistical analysis

For each of the response variables we fitted the following mixed linear model:

$$Response = \mu + stand + disc + type + stand \times disc + stand \times type + disc \times type + stand \times disc \times type + tree/disc + error$$

where μ (overall intercept), *stand* (Stand), *disc* (Disc height) and *type* (Wood type: peeler core or slabwood) are fixed effects, while *tree/disc* and *error* represent the random effects of the sampled trees, discs and error. The

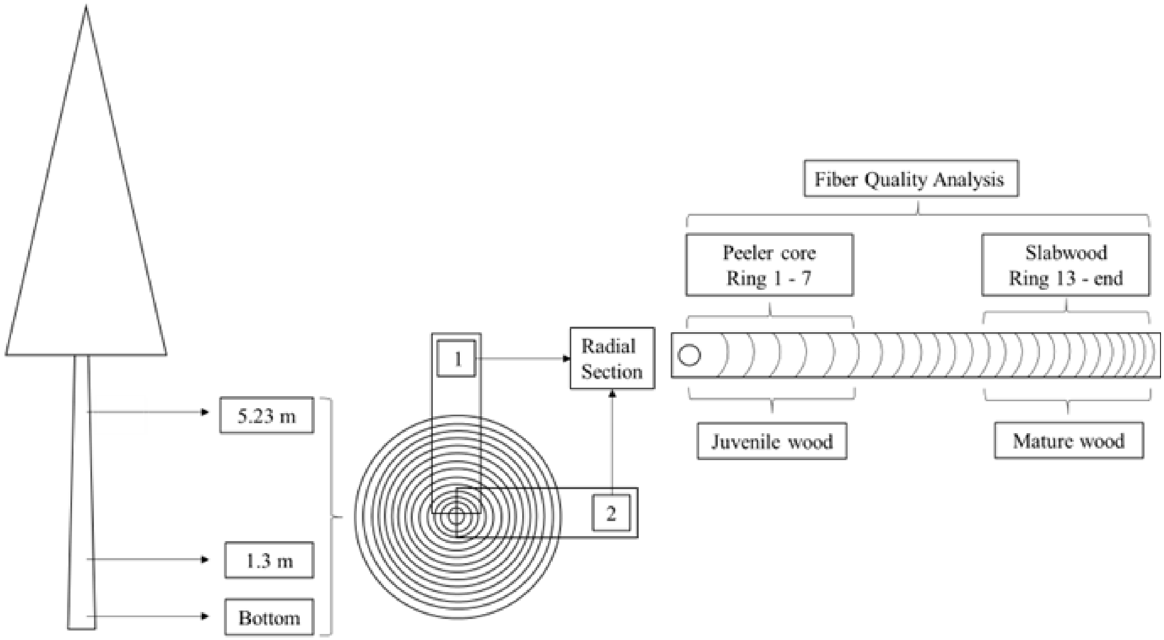

FIGURE 3: Illustration of the sampling process to obtain the wood sections per disc, for fibre quality analysis.

random effects have 0 mean and variances σ_t^2, σ_d^2 and σ_e^2, and respectively and are assumed to be independent from each other.

The linear mixed models were fitted in the R Statistical System (R Core Team 2021), using the nlme package (Pinheiro et al. 2021). Significance for the model equation terms was evaluated using the Anova Type III option from the car package (Fox & Weisberg 2019), which uses a Wald statistic that follows a chi-square distribution. Multiple comparisons of factor levels relied on the estimated marginal means package (emmeans, Lenth 2021). All statistical significance statements consider an alpha = 0.05 level. The R code for the analysis is available as an Additional File.

Results

According to the growth ring analysis, trees from Stand 1 had higher MAI and PAI (mm/year) than those from Stand 2. Trees in Stand 1 (Site Index 36), which received more intensive early silviculture, had a lower growth rate than those in Stand 2 (Site Index 31) during the first four years and a later peak of PAI, compared to the trees in Stand 2; however, starting in the 4th year, the PAI curve of Stand 1 was higher than the PAI curve of Stand 2 (Figure 4).

The mean annual increment in diameter (MAI) of Stands 1 and 2 followed the same trend, although the peak of MAI curve in Stand 2 was higher and earlier than the MAI curve of Stand 1 from the 6th year onwards.

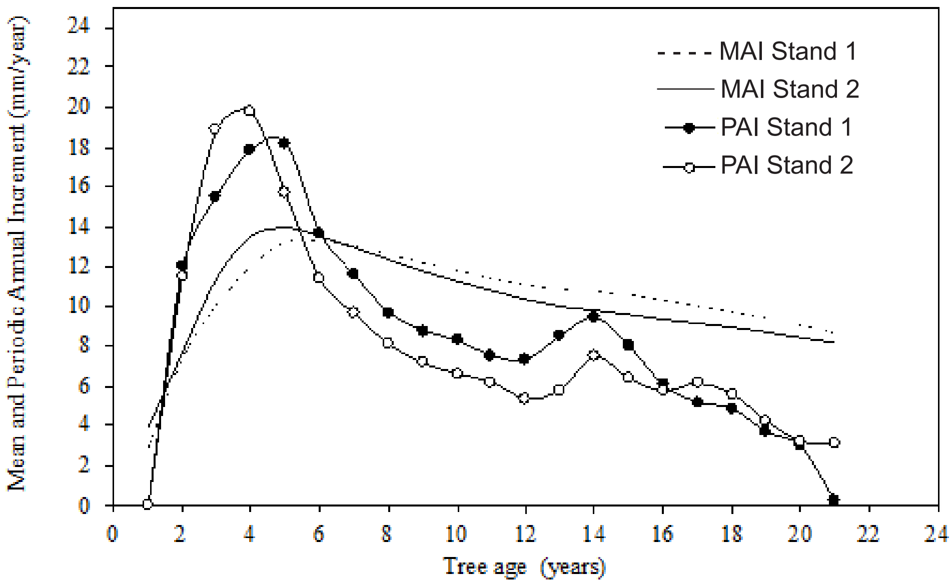

FIGURE 4: Mean annual increment in diameter at breast height (MAI) and periodic yearly increment in diameter at breast height (PAI) for trees of Stand 1 and Stand 2.

Thus, although the growth was higher at the beginning for Stand 2, after the first waste thinning (year 5), Stand 1 surpassed Stand 2. This result was expected because the site index for Stand 1 is higher than for Stand 2. In addition, Figure 4 shows a second peak at age 14 years due to the commercial thinning at age 13. Commercial thinning is a regular activity in Chile, and the main objective is obtaining logs for the pulp mills (Mead 2013).

Schimleck et al. (2018) indicate that early-age competition control in *P. radiata* plantations increases corewood diameter in conifers, implying a higher proportion of juvenile wood at the rotation age, which reduces structural wood products yields. It is also low quality for pulp production. In the study, the average proportion of juvenile wood (measured at 1.3 m) was 50.4% in Stand 1 and 52.9% in Stand 2, mainly due to the productivity differences between stands.

Although it was not possible to separate the site's effects on the growing trends in the two stands, we expected higher growth differences due to the site index differences (Stand 1: 36 m; Stand 2: 31 m) and the more intensive early silviculture applied to Stand 1.

Properties by stem height position

Table 3 summarises fibre properties derived for the sampling at different stem heights (bottom, 1.3 m, and 5.23 m) per stand. We observed an increase in fibre length, fibre width, and fibre coarseness with height for both stands.

The results presented in Table 3 indicate increasing fibre quality with tree height in Stand 1 and Stand 2, except for fines content in Stand 2, which increased with tree height. Fines content is detrimental to pulp yield because it implies having more fibres that do not meet the desired dimensions (> 0.2 mm).

Figure 5 shows the four wood fibre attributes by stand (1,2), disc position (bottom, 1.3 and 5.23 m), and wood type (peeler core and slabwood). In Stand 2, the values for fibre length, fibre width, and coarseness are separated according to wood type. Specifically, in the peeler core samples, the fibre lengths are all less than 2 mm, and fibre widths are less than 36 µm. In the slabwood samples, these values are greater than 2.8 mm and 39 µm, respectively. Wood from Stand 1 exhibited high variability and dispersion in fibre attributes such as length, width, and coarseness with values sometimes overlapping across wood types.

Supplementary Table S1 presents the Wald chi-square tests for the model terms (site, disc position, wood type and their interactions) for each of the four traits in this study. All statistical significance statements at the model term level (disc position, for example) refer to this table. Pairwise comparisons of levels of a term (bottom vs 1.3, for example) refer to Supplementary Table S2, which shows Tukey-adjusted multiple comparisons. The explanation is supported by Figure 6, with the proviso that confidence intervals for two means can overlap and yet the two means can be statistically significantly different from one another (Austin & Hux 2002; Lakens 2023). Results for fibre length, as presented in Table S1 and Figure 6, indicated there were no significant differences between stands. Differences among disc positions and between wood types are statistically significant, as is their interaction. In the case of slabwood, none of the differences among disc positions are statistically significant. In contrast, for peeler cores the differences between bottom and 5.23 m (0.45 mm, $p = 0.017$), and between 1.3 m and 5.23 mm (0.41 mm, $p = 0.023$) were statistically significant.

There were no significant differences in fibre width between stands. There were statistically significant differences for disc position and wood type, but no significant interactions. The fibre width differences between bottom and 5.23 m (0.33 µm, $p = 0.014$), and 1.3 m and 5.23 m (0.24 µm, $p = 0.045$) were statistically significant. Meanwhile, the difference between peeler core and slabwood was also significant (1.13 µm, $p < 0.001$).

In the case of fines, there were no statistically significant differences among disc positions. However, there were statistically significant differences between stands and wood types. Their interaction was also statistically significant. In both stands, there was a difference between peeler core and slabwood; however, the magnitude of the contrast is much smaller in Stand

TABLE 3: Average values from 2 discs for each of 3 trees and standard deviations (SD) of fibre properties evaluated at the bottom, 1.3 m and 5.23 m of the stem.

	Fibre properties	**Height from the bottom of the stem**					
		0 m (bottom)		**1.3 m**		**5.23 m**	
		Average	SD	Average	SD	Average	SD
Stand 1	Length (mm)	2.22	0.64	2.42	0.69	2.73	0.54
	Width (µm)	36.43	4.13	38.21	4.49	39.38	3.65
	Fines content (%)	1.43	0.88	1.62	0.90	1.39	0.81
	Coarseness (µg/m)	282.63	62.99	300.52	76.46	294.53	65.45
Stand 2	Length (mm)	2.27	0.64	2.27	0.70	2.43	0.59
	Width (µm)	37.44	3.75	36.69	3.86	38.38	2.95
	Fines content (%)	1.08	0.36	1.56	0.59	1.34	0.33
	Coarseness (µg/m)	276.17	70.50	280.58	65.68	286.41	68.89

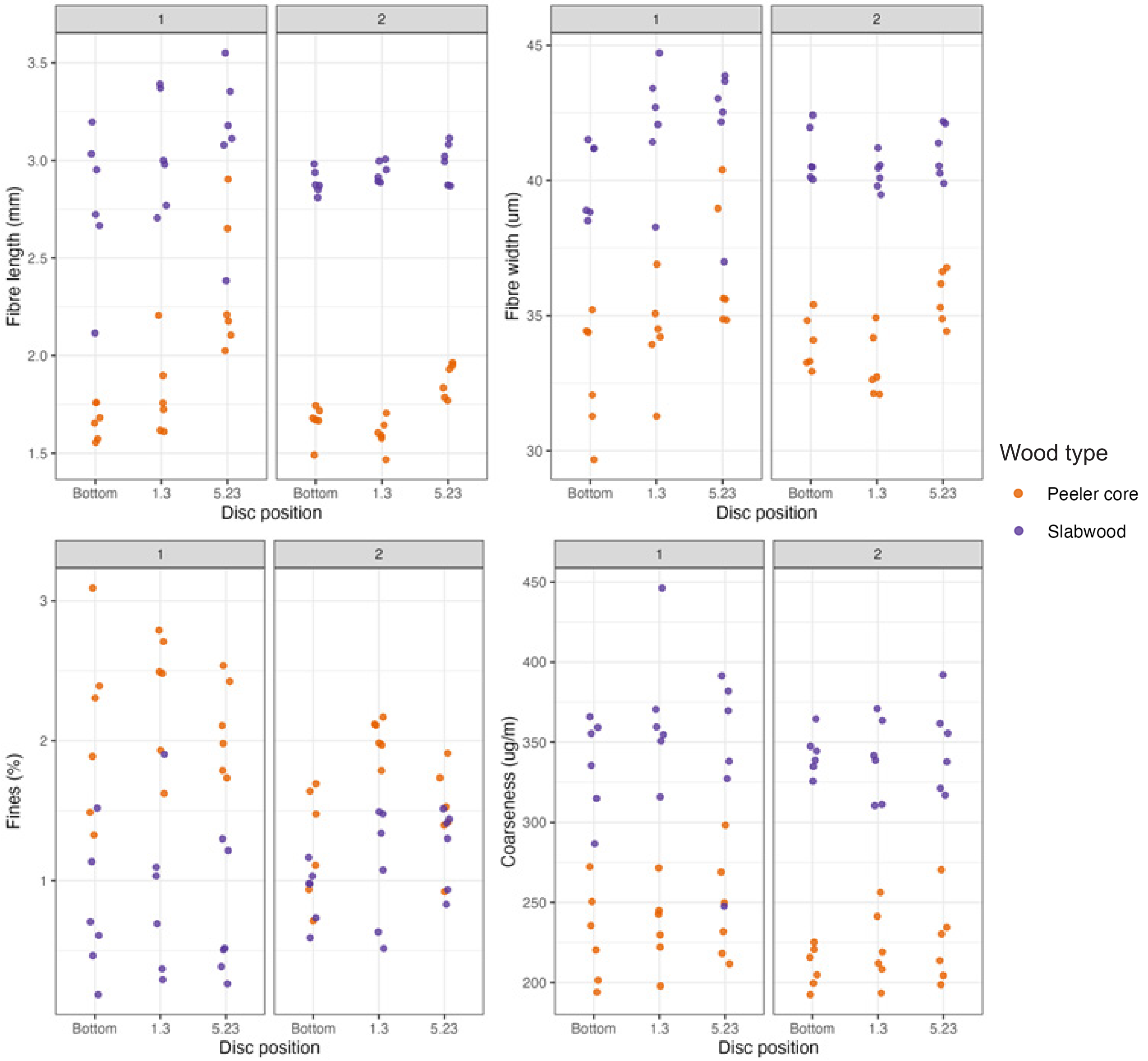

FIGURE 5: Raw data for fibre length, fibre width, coarseness and fines per stand, stem position and wood type (orange: peeler core, purple: slabwood).

2 (0.51%, p < 0.001) than in Stand 1 (1.38%, p < 0.001). There were no statistically significant differences in coarseness between stands and among disc positions. However, there were significant differences in coarseness between the peeler core and slabwood (118 um, p < 0.001).

Table 4 presents the predictions from the linear mixed models which corresponds to the estimated mean values for length (mm), width (µm), fines content (%), and coarseness (µg/m) and their 95% confidence intervals.

Discussion

Our study found that fibres in slabwood were longer and broader than fibres in the peeler core; fibres in slabwood also had greater coarseness and lower fines content than fibres in the peeler core (Table 4). Consequently, slabwood fibres would have better resistance and properties for pulp production than those in the peeler core, which is consistent with previous studies in radiata pine (Kibblewhite & Bawden 1992; Burdon et al. 1999). Kibblewhite and Hamilton (1984) and Cown (1992) investigated the impact of using peeler cores and slabwood (as well as a combination of these raw materials) on the properties of kraft pulp. They found that when using just slabwood, the fibres had a low tear index and high tensile and burst index, compared to only using peeler cores as raw material. However, when using a mixture of peeler core and slabwood, these authors reported that, on average, the handsheets showed an increase in tear index and a decrease in burst and tensile indexes when increasing the proportion of slabwood. Similarly, Uprichard (1980) investigated the effect of tree age on the kraft pulp properties of *P. radiata*, finding that slabwood pulp has three times greater tear strength than pulp based on peeler corewood; in addition, pulp made with peeler core formed sheets of higher density

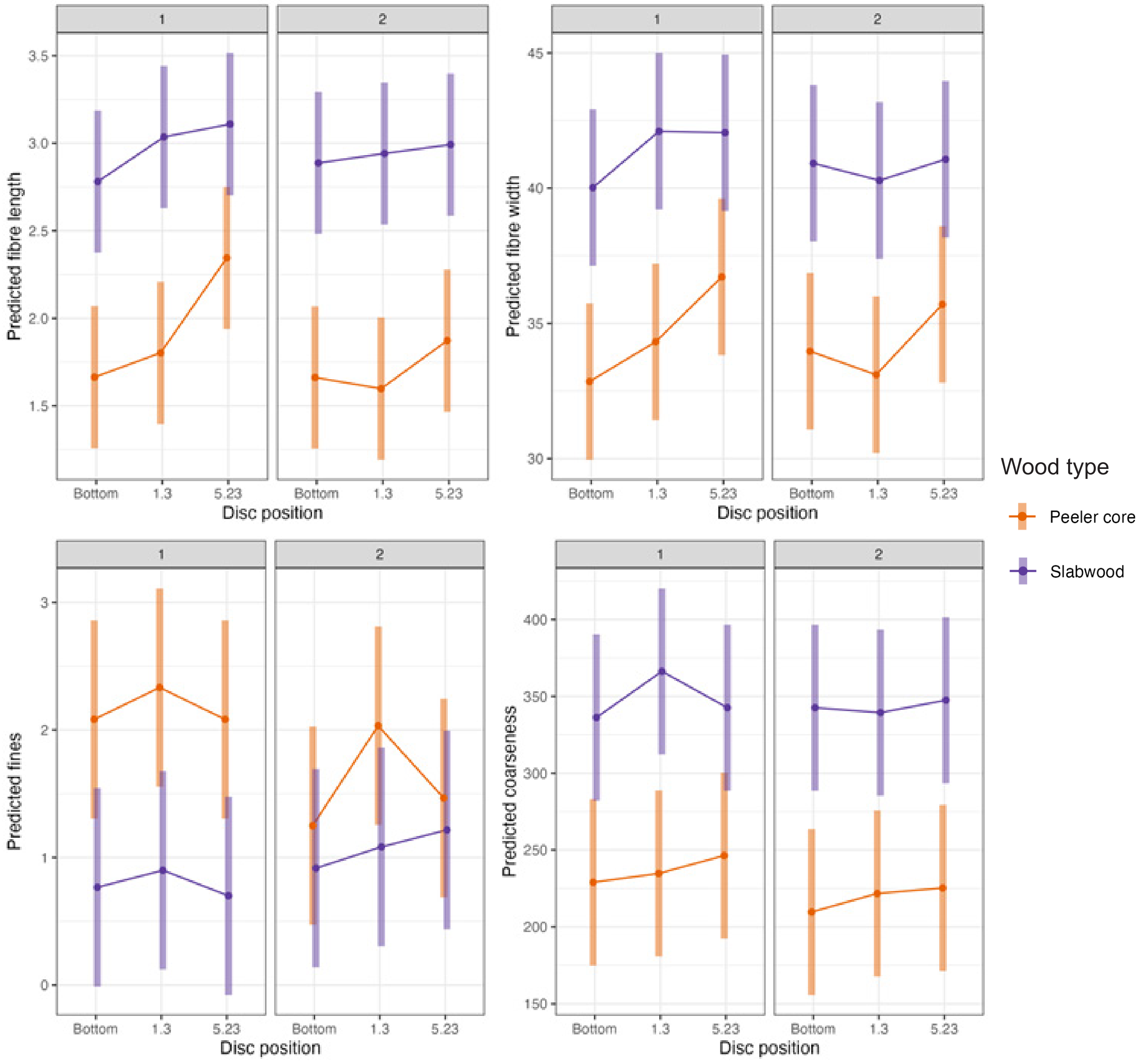

FIGURE 6: Linear prediction and 95% confidence interval for fibre length, fibre width, coarseness and fines per stand, stem position, and wood type (orange: peeler core, purple: slabwood) derived from the linear mixed model.

that quickly collapsed. Furthermore, Cown & Dowling (2015), reported that peeler core fibres had lower cellulose and lignin than those contained in slabwood, implying higher reagent consumption during pulping processes compared with the pulping process based on slabwood having lower lignin content and higher cellulose content.

Mills commonly use logs coming from commercial thinning (young trees), residues from harvesting (stem tops and rejected logs due to small end diameter or quality standards), and residues coming from sawmills such as chips and slabwood (Albert et al. 2002). High-density wood from the periphery of logs (slabwood) generally has long and coarse (thicker walled) fibres that are more suitable for products such as sack kraft papers. Wood from the top and central part of the tree is mostly corewood; characterised by low density with shorter, thinner-walled (low coarseness) fibres. Thus, pulp from this wood would be more suitable for printing and writing grades or tissues grade papers.

Few studies have reported the effect of site index on the wood fibre of *P. radiata*; however, it is possible to approximate the impact of site by looking at practices that increase plantation productivity, such as weed control and fertiliser application, because early-age competition control substantially increases volume productivity. Still, it also increases corewood diameter in conifers, reducing the average wood density (e.g., Mora et al. 2007). Watson et al (2003) reported that very wide initial tree spacing in which the trees possessed a larger live crown for a much longer time, had a negative impact on the fibre length development by delaying the onset of mature wood, i.e., wood formation, thus indirectly increasing the juvenile wood proportion.

TABLE 4. Mixed models estimated means and 95% confidence intervals for fibre attributes for the combinations of stand, disc position and wood type

Stand	Disc position	Wood type	Fibre length (mm)			Fibre width (µm)			Fines (%)			Coarseness (µg/m)		
			Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper	Estimate	Lower	Upper
1	bottom	Peeler core	1.66	1.26	2.07	32.90	30.00	35.70	2.08	1.31	2.86	229	175	283
2	bottom	Peeler core	1.66	1.26	2.07	34.00	31.10	36.90	1.25	0.47	2.03	210	156	264
1	1.3	Peeler core	1.80	1.40	2.21	34.30	31.40	37.20	2.33	1.56	3.11	235	181	289
2	1.3	Peeler core	1.60	1.19	2.00	33.10	30.20	36.00	2.03	1.26	2.81	222	168	276
1	5.23	Peeler core	2.34	1.94	2.75	36.70	33.80	39.60	2.08	1.31	2.86	246	192	300
2	5.23	Peeler core	1.87	1.47	2.28	35.70	32.80	38.60	1.47	0.69	2.24	225	171	279
1	bottom	Slabwood	2.78	2.38	3.19	40.00	37.10	42.90	0.77	-0.01	1.54	336	282	390
2	bottom	Slabwood	2.89	2.48	3.29	40.90	38.00	43.80	0.92	0.14	1.69	343	289	397
1	1.3	Slabwood	3.04	2.63	3.44	42.10	39.20	45.00	0.90	0.12	1.68	366	312	420
2	1.3	Slabwood	2.94	2.54	3.35	40.30	37.40	43.20	1.08	0.31	1.86	339	285	393
1	5.23	Slabwood	3.11	2.70	3.52	42.00	39.20	44.90	0.70	-0.08	1.48	343	289	397
2	5.23	Slabwood	2.99	2.59	3.40	41.10	38.20	44.00	1.22	0.44	1.99	348	293	402

Since Stand 1 received more intensive early silviculture and it has a higher site index, we expected advantages in the fibre attributes; however, our results showed no differences in some fibre attributes, consistent with the study of Clark et al. (2006) who reported no effects on the wood properties of loblolly pine (*P. taeda* L.) at the annual ring level, such as ring wood density, when applying weed control, compared with those that received no weed control. The authors concluded that growth gains substantially offset the slight reduction in percent latewood and wood density. In a similar way, Watt et al. (2008) reported that fibre length exhibited significant variation among sites in a study that was based on 22 *P. radiata* site quality plots in New Zealand. However, fertiliser application did not significantly affect fibre length in this study. Gräns et al. (2021) studied the effect of herbicide and fertiliser application in loblolly pine and found that fertiliser application decreased wood density compared to weed control.

Considering the results from previous studies along with those from this study, using slabwood (mature wood) and peeler cores (juvenile wood) in the pulp and paper industry would improve pulp yield and pulp quality provided the best mix be found to achieve an average fibre pulp with better properties and under a cost/effective pulping process. Finally, the reuse and recovery of residues from different wood industry processes such as peeler cores and slabwood are an opportunity for other products as a source of raw material for the pulp industry, improving final fibre quality.

The results of this study show that using slabwood (mature wood) and peeler core (juvenile wood) in the pulp and paper industry would improve pulp yield and pulp quality; however, future studies should focus on finding the optimal mix for efficient production. Finally, reusing and recovering residues, such as peeler core and slabwood, is an increasing sustainability challenge for the Chilean pulp industry, which is being addressed through applied research such as that undertaken in the present study.

Conclusions

We found that there were significant differences in the most fundamental fibre properties for pulp production (i.e., length, width, and coarseness) between peeler core and slabwood within the sampled stands. Minimum values of these properties were found in the corewood. Fibre properties in the peeler core increased with height up the stem, but this was not the case for fibre properties of slabwood. It was impossible to determine the effect of silviculture and productivity on fibre properties because the available data did not come from an appropriately designed experiment.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

JPEM was the primary author, designed the study and manuscript writing. RMA contributed to the manuscript writing and editing. LA contributed to the data analysis, writing and editing. JPL and LSF contributed providing data collection.

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Supplementary Tables

TABLE S1: Wald chi-squared tests for the terms of the full model for each of the response variables.

TABLE S2: Pairwise comparisons for statistically significant terms of the full model for each of the response variables.

Additional File

NZJFS 54_4 Additional File analisis_basico_R.txt
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Supplementary Tables

TABLE S1: Wald chi-squared tests for the terms of the full model for each of the response variables

Source	Fibre length			Fibre width			Fines			Coarseness		
	Chisq	**df**	**Pr(>Chisq)**	**Chisq**	**df**	**Pr(>Chisq)**	**Chisq**	**df**	**Pr(>Chisq)**	**Chisq**	**df**	**Pr(>Chisq)**
intercept	310.9705	1	$< 2.2e^{-16}$	2385.4112	1	$< 2.2e^{-16}$	132.8060	1	$< 2.2e^{-16}$	332.5090	1	$< 2.2e^{-16}$
stand	0.0002	1	0.9885	1.3782	1	0.2404	12.5757	1	0.0004	1.2106	1	0.2712
disc position	32.0151	2	$1.1e^{-7}$	16.8457	2	0.0002	1.2749	2	0.5286	1.0003	2	0.6064
wood type	77.1254	1	$< 2.2e^{-16}$	56.7671	1	$4.906e^{-14}$	31.3939	1	2.106^{e-8}	37.4467	1	$9.395e^{-10}$
stand × disc	6.8786	2	0.0321	3.6973	2	0.1575	2.6057	2	0.2718	0.1168	2	0.9433
stand × wood	0.3615	1	0.5477	0.0259	1	0.8720	8.7552	1	0.0031	1.0709	1	0.3007
disc × wood	7.3636	2	0.0252	3.5898	2	0.1661	0.1241	2	0.9398	2.1229	2	0.3460
stand × disc × wood	1.2424	2	0.5373	0.1125	2	0.9453	2.0976	2	0.3500	1.7033	2	0.4267

TABLE S2: Pairwise comparisons for statistically significant terms of the full model for each of the response variables

Contrast	Estimate	SE	df	t-ratio	p-value
Fibre length: differences between disc position for peeler core					
base - d13	-0.0373	0.09	4	-0.415	0.9114
base - 5.23	-0.4458	0.09	4	-4.956	0.0168
d13 - 5.23	-0.4085	0.09	4	-4.541	0.0227
Fibre length: differences between disc position for slabwood					
base - d13	-0.1544	0.09	4	-1.717	0.3058
base - 5.23	-0.2165	0.09	4	-2.407	0.1495
d13 - 5.23	-0.0621	0.09	4	-0.690	0.7816
Fibre width: differences between disc position					
base - d13	-0.0959	0.0636	4	-1.507	0.3793
base - 5.23	-0.3312	0.0636	4	-5.207	0.0142
d13 - 5.23	-0.2353	0.0636	4	-3.699	0.0445
Fibre width: differences between wood types					
peeler - slabwood	-1.13	0.0519	54	-21.833	< 0.001
Fines: difference between wood types for Stand 1					
peeler - slabwood	1.378	0.136	54	10.155	< 0.001
Fines: difference between wood types for Stand 2					
peeler - slabwood	0.511	0.136	54	3.767	0.0004
Coarseness: differences between wood types					
peeler - slabwood	-118	7.16	54	-16.487	< 0.0001