Physical and Hydrologic Properties of Processed Pine Bark and Wood

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Significance to Industry: It is well known that substrate particle size distribution and physical properties affect irrigation frequency, nutrient availability, air space and container capacity. This research shows two common horticultural substrate components, pine bark and pine wood have varying physical properties and water release patterns at similar particle sizes. Physical properties of these materials can be manipulated by adjusting variables in processing. Attention to processing is important for attaining consistent properties. Bark particles hold more water than wood, most likely due to their internal structure. Particle size distribution of pine bark or pine wood does not guarantee that physical properties of those substrate materials will be similar, even with identical processing. An understanding of bark and wood processing and particle size is needed to produce substrates with desired physical and hydrologic properties.

Nature of Work: Pine bark has been researched for decades, but little work has been conducted on the processing of pine bark and the effects it may have on particle size and physical properties when it is used as a substrate component. The size and shape of milled pine bark has been shown to vary considerably (1). Measuring substrate particle size distribution helps determine the physical nature and anticipated physical properties of a substrate component (3,8). Altering particle size distribution of pine bark has been shown to significantly affect water-holding characteristics (12).

Generally, in soils, plant available water is held on or between particles. However, with organic materials, such as pine bark, it has been shown that individual particles can hold water within internal pore spaces. Water within these internal pore spaces has been shown to be available for plant use provided adequate root development has occurred (9,11).

Processing fresh pine wood for use in plant production substrates has become more common in recent years. However there is little research on the processing of pine wood materials and how they relate to substrate physical properties and crop production. Since pine wood particle size is created during the milling process, producers have the ability to develop particle sizes specific to their needs (7). Manipulating particle sizes and the resultant pore sizes within a substrate could allow the engineering of a substrate with desired plant growing conditions (4). However, due to the lack of research in this area useful particle size distributions of wood-based materials are currently unknown. The purpose of this study was to explore how manipulating particle size affects substrate air and water relations in milled pine wood compared to milled pine bark.

Unprocessed pine bark nuggets and coarse loblolly pine wood chips (*Pinus taeda)* were acquired. Both materials were processed in a hammer mill (Meadows Mills, North Wilkesboro, NC) at the Substrate Processing and Research Center located at the Horticultural Field Laboratory on the campus of North Carolina State University located in Raleigh, NC. The materials were processed through the mill with no screen inserted to assure a wide variation of particle sizes (known to occur as experienced in personal observations). To prevent moisture loss after milling, processed materials were sealed in plastic 55-gallon drums for further testing.

For particle size distribution, three 100g samples of each material were dried at 105°C for 48 hours and placed in a Ro-tap Shaker (Model B, W.S. Tyler, Mentor, OH) for 5 minutes with six sieve sizes of 6.3, 2, 0.71, 0.5, 0.25, and 0.106 mm and a pan at the bottom to collect all materials that passed through the smallest sieve. Due to the hydrophobicity of dried pine bark (2), and the need to keep the materials moist for physical property testing, particle size distribution of representative moist samples for both materials was obtained using the same method, on non-dried samples. Both pine wood and pine bark were then sieved and grouped into four individual size fractions: extra-large, > 6.3mm, large, < 6.3mm > 2mm, medium, < 2 > 0.5mm and fine, ≤ 0.5mm. Physical properties of all sieve fractions of both the processed pine wood and pine bark were determined using the North Carolina State University Porometer Method (5).

After sieving, the particle size fractions observed in the milled pine wood were re-engineered in pine bark. This same process was then conducted on pine wood, blending the fractioned material to have the same particle size distribution observed in pine bark. All samples were hydrated to 60% moisture (w/w) except for the largest two pine wood fractions, which were wetted to 50% (w/w) to represent appropriate wetness for use in horticulture production and allowed to equilibrate for 24 hours. The above physical properties were determined on the reengineered particle size materials.

Drying characteristics for the large (< 6.3mm > 2mm) and medium (< 2 > 0.5mm) sized fractions of both materials were determined. Nine samples were taken from the large and medium fractions of both pine wood and pine bark, for a total of 36 samples. Samples were oven dried at 30°C. Three samples of each material were weighed at 2, 4 and 26 hours to determine moisture content. Data were analyzed using general linear model procedures and regression analysis (SAS Institute version 9.3, Cary, NC). Means were separated by least significant differences at $P \leq 0.05$.

Results and Discussion: Particle size distribution of oven-dried material compared to their moist counterparts was found to have no difference in the pine wood. Similarly, no difference was found in the pine bark distributions except for the fine bark fractions of

≤ 0.5mm in which a 5% loss was observed (Table 1). This can be accounted for by the moisture present in the materials allowing a small percentage of the fines to stick to the larger particles. Wood had inherently more large particles and less than half as many fines than the bark.

Fewer fines resulted in almost twice the air space for wood (42%) compared to pine bark (25%) with only slightly different bulk densities between the two (Table 2). When pine bark was re-engineered with the same particle size distribution as pine wood, reducing the number of fines by 13%, there was no observable difference in the water holding characteristics. The physical properties of the pine wood changed considerably when modified into the bark distribution, here increasing the amount of fines increased the container capacity, which is expected (6).

Fines held more water than any other particles. Extra-large particles also behaved as expected and were similar for both materials. Large and medium sized particles collectively seem to hold approximately 20% more water in bark than in the wood materials. A large amount of the water holding capacity seems to be held in these middle two fractions. This may be accounted for by the internal cellular connections and the amount of variation in size and structure that have been observed in milled bark particles (1).

To address this difference in internal structure, the large and medium bark and wood fractions were dried. The large bark particles hold more water than wood and dry at approximately the same rate (Figure 1). However, the medium size bark and wood materials have the same moisture content but dry differently (Figure 2). The bark held more water at 2 and 4 hours of drying. This slower drying pattern is indicative of water being held within the particles and having to dry from within. The large size material did not exhibit this same pattern. Although the bark and wood used in this study were taken from the same species it is evident that there are fundamental differences in their ability to hold and release water. Wood may have less internal structure for holding water. Further research needs to be conducted on the manufacture of wood materials for use in horticultural substrates.

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Table 1. Particle size distribution of pine bark and pine wood.

Substrate	Extra–large (>6.3mm)	Large (6.3 to 2.0mm)	Medium (2.0 to 0.5mm)	Fines (≤0.5mm)
Bark dry	4.3 a[z]	30.5 b	29.2 c	40.5 a
Bark moist	5.0 a	27.3 b	32.3 bc	35.4 b
Wood dry	4.1 a	46.4 a	35.9 a	13.6 c
Wood moist	5.6 a	47.2 a	35.0 ab	12.2 c

[z]Means separation between all materials by LSD, $P<0.05$. Means followed by the same letter the same column are not significantly different.

Table 2. Physical properties of milled pine bark, wood and the materials when recreated with each other's particle size distribution (PSD).

Substrate	Total porosity (% vol)	Container capacity (% vol)	Air space (% vol)	Bulk density g/cc
Bark	81.3 b[z]	56.0 b	25.3 b	0.18 a
Engineered[1] bark	79.5 b	54.2 b	25.3 b	0.18 a
Wood	87.9 a	45.6 c	42.3 a	0.16 b
Engineered[2] wood	87.2 a	68.7 a	18.5 c	0.15 b

Means separation between all materials by LSD, $P<0.05$. Means followed by the same letter the same column are not significantly different.

[1] Bark engineered to have particle size distribution originally found in wood of 5.6% extra-large, 47.2% large, 35% medium and 12.2% fine particles.

[2] Wood engineered to have the particle size distribution originally found in bark of 5% extra-large, 27.3% large, 32.3% medium and 35.4% fine particles.

Table 3. Physical properties of four individual size fractions for milled pine bark and wood.

Substrate	Total porosity (% vol)	Container capacity (% vol)	Air space (% vol)	Bulk density g/cc
Bark x-large[y]	83.6 abc[z]	29.1 f	54.5 a	0.13 dc
Wood x-large	82.7 bc	26.1 f	56.6 a	0.18 a
Bark large[x]	82.7 bc	44.3 d	38.4 c	0.16 abc
Wood large	80.0 c	34.3 e	45.7 b	0.15 bcd
Bark medium[w]	84.8 abc	65.4 b	19.4 e	0.17 ab
Wood medium	87.9 a	55.8 c	32.0 d	0.13 dc
Bark fines[u]	83.2 abc	74.2 a	9.0 f	0.19 a
Wood fines	87.2 ab	76.3 a	10.8 f	0.12 d

[z]Means separation between all materials by LSD, $P<0.05$. Means followed by the same letter the same column are not significantly different.

[y]X-large particles > 6.3mm in diameter.

[x]Large particles < 6.3mm > 2mm in diameter.

[w]Medium particles < 2 > 0.5mm in diameter.

[u]Fine particles ≤ 0.5mm in diameter.

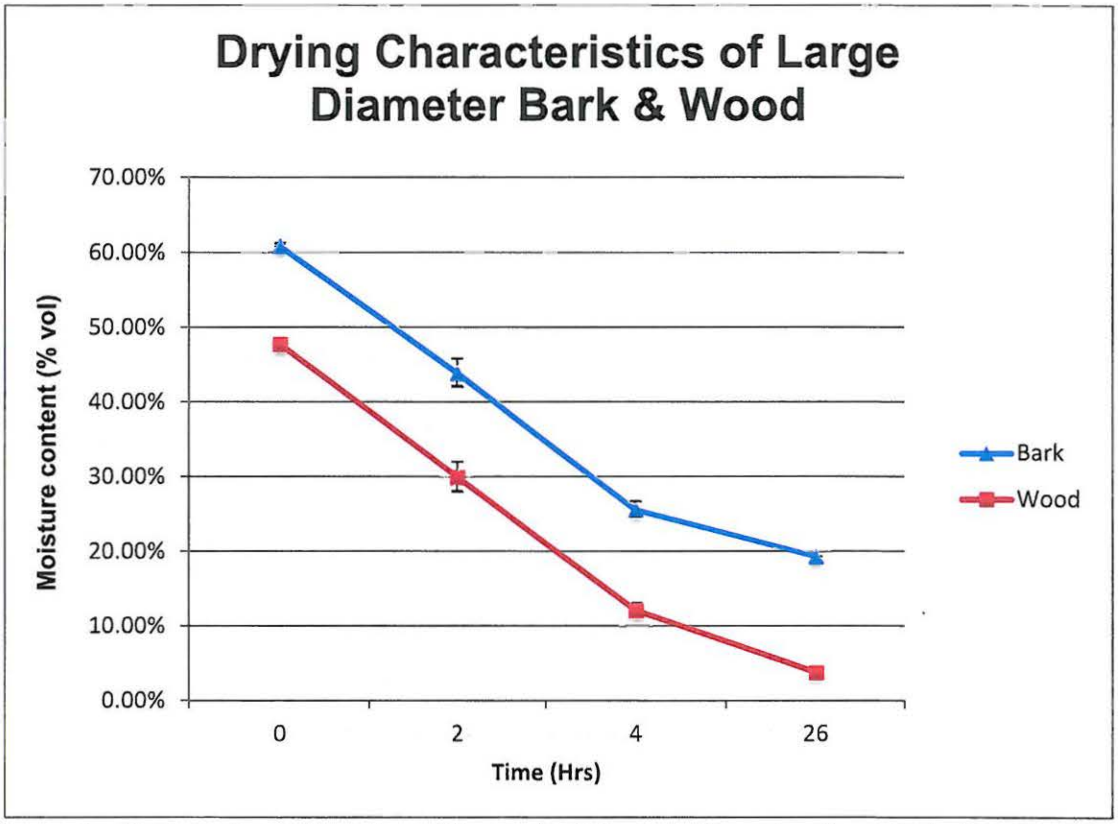

Figure 1: Drying characteristics of large (< 6.3mm > 2mm in diameter) pine bark and pine wood particles during oven drying. Vertical bars represent standard errors.

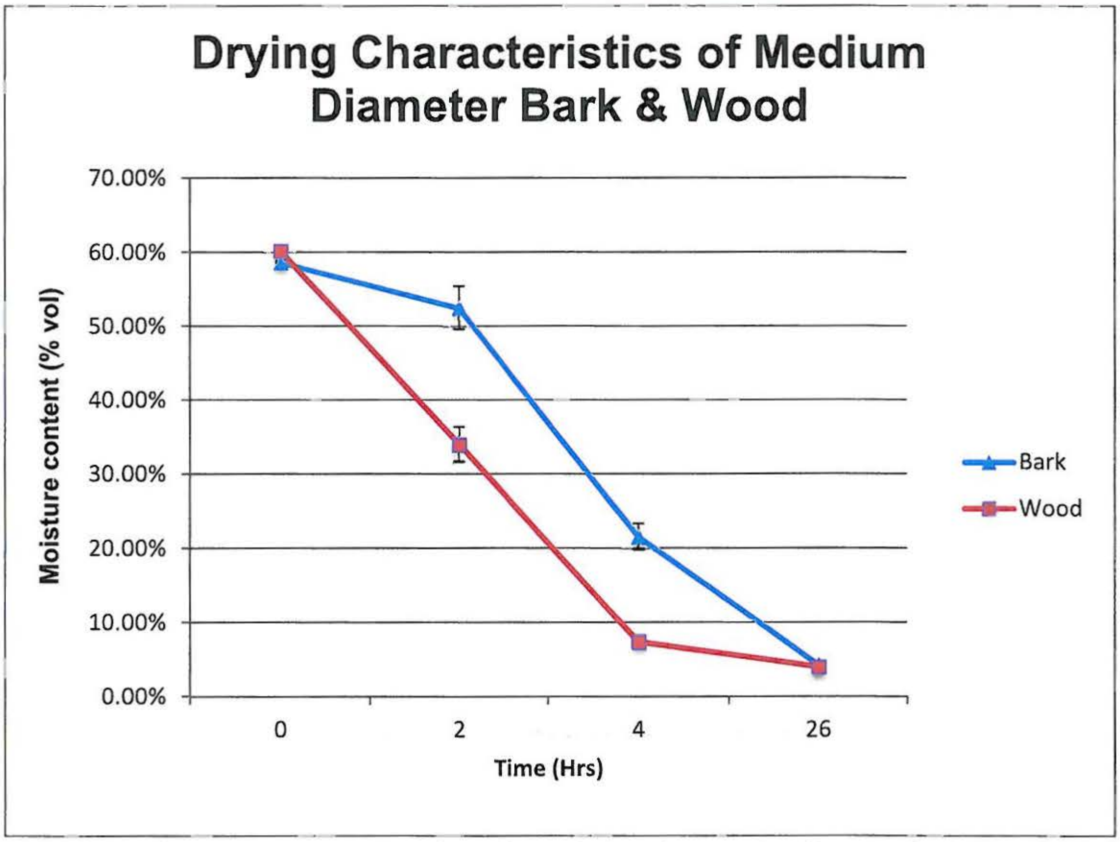

Figure 2: Drying characteristics of medium (< 2 > 0.5mm in diameter) pine bark and pine wood particles during oven drying. Vertical bars represent standard errors.