Typical H:G:S Ratio for Lignin from Biomass

It is widely accepted that the biosynthesis of lignin stems from the polymerization of three types of phenylpropane units, also referred to as monolignols. These units are coniferyl, sinapyl, and *p*-coumaryl alcohol. The three structures are depicted in Figure 1. Table 1 summzrizes the distribution of guaiacyl (G), *p*-hydroxyl phenol (H) and syringyl (S) lignin in several sources of biomass.

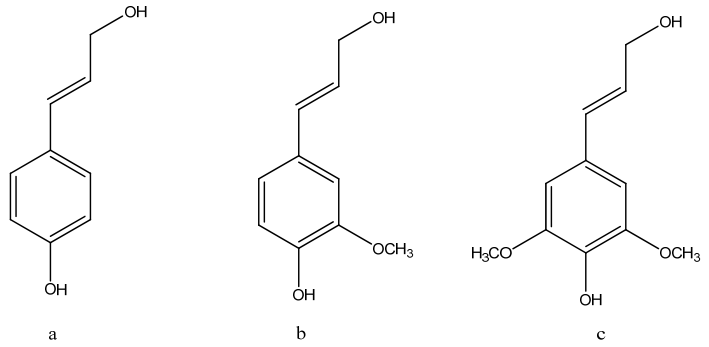

Figure 1. The basic units of lignin; (a) *p*-coumaryl/hydroxyphenyl (b) coniferyl/guaiacyl, and (c) sinapyl/syringyl alcohol.

Table 1. Lignin Composition and G:S:H Ratio for Select Biomass Resources

	%Lignin	G : S : H
Wheat Straw	16-21	45 : 46 : 9[1]
Rice Straw	6	45 : 40 : 15
Rye Straw	18	43 : 53 : 1[2]
Hemp	8-13	51 : 40 : 9[3]
Tall Fescue:		
Stems	7-10	55 : 42 : 3
Internodes	11	48 : 50 : 2[4]
Flax	21-34	67 : 29 : 4
Jute	15-26	36 : 62 : 2[5]
Sisal	7-14	22 : 76 : 2
Curaua Leaf fiber	7	29 : 41 : 30[6]
Banana Plant Leaf		43 : 50 : 7[7]
Piassava Fiber (Plam Tree)	45	40 : 9 : 51[8]
Abaca	7-9	19 : 55 : 26

Loblolly Pine	29	86	2	12[9]
	29	87	0	13[10]
Compression		60		40
Spruce (Picea Abies)	28	94	1	5[11]
MWL		98	2	0[12]
Eucalyptus globus	22	14	84	2[13]
Eucalyptus grandis	27	27	69	4
Birch pendula	22	29	69	2
Beech	26	56	40	4[14]
Acacia	28	48	49	3[15]

White Birch[16]	G	:	S
• Fiber, S2 layer	12		88
• Vessel, S2 Layer	88		12
• Ray parenchyma, S-layer	49		51
• Middle lamella (fiber/fiber)	91		9
• Middle lamella (fiber/vessel)	80		20
• Middle lamella (fiber/ray)	100		0
• Middle lamella (ray/ray)	88		12

	G	:	S	:	H
Lignin Samples[17]					
Carpinus betulus MWL	19		80		1
Eucryphia codrifolia MWL	35		59		6
Bambusa sp. MWL	23		57		20
Fagus sylvatica kraft lignin	25		72		3
Eucalyptus globulus kraft lignin	22		73		6
Lobolly Pine Juvenile[18]					
• Normal	95				5
• Wind Opposite	96				4
• Wind Compression	89				11
• Bent Opposite	96				4
• Bent Compression	88				12

The lignin polymerization process is initiated by the oxidation of the monolignol phenolic hydroxyl groups. The oxidation itself has been shown to be catalyzed via an enzymatic route. The enzymatic dehydrogenation is initiated by an electron transfer that yields reactive monolignol species with free radicals. A monolignol can react with a free

radical coupling to generate a dilignol. Subsequent nucleophilic attack by water, alcohols, or phenolic hydroxyl groups on the benzyl carbon of the quinone methide intermediate will restore the aromaticity of the aromatic ring. The generated dilignols will then undergo further polymerization.

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