Epicuticular Waxes from Leaves and Stems of *Jojoba* (*Simmondsia chinensis* [Link] Schneider)

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Epicuticular waxes were extracted with chloroform from air dried *Jojoba* leaves and stems. These cuticular waxes consisted of homologues of *n*-alkanes, branched alkanes, alkenes, wax esters, aldehydes, acetates, esters, free long chain fatty acids and alcohols. Both leaves and stems showed the same qualitative and quantitative composition with similar distribution patterns. Very long chain and in most cases saturated compounds are dominating. The composition of epicuticular waxes from *Jojoba* leaves and stems is quite different from that of *Jojoba* pericarp and seed coats and demonstrates an organ specific wax composition of different aerial parts of this plant.

Introduction

Jojoba is a plant of growing interest for agricultural, economic and scientific studies [1–3]. The ripe *Jojoba* seeds consist of more than 50% of wax esters, which result from a combination of monounsaturated long chain fatty acids and alcohols [4–7]. These liquid wax esters are able to substitute for walrat in industrial applications. On the other hand these wax esters are the storage lipids of germinating *Jojoba* seeds in contrast to triacylglycerols in other plant seeds [8–10].

Wax esters are well known as components of cuticular waxes from all aerial parts of land plants. Therefore epicuticular waxes from *Jojoba* pericarp and seed coats were analysed recently [11]. In the following study the epicuticular waxes from *Jojoba* leaves and stems were isolated and analysed.

Materials and Methods

Jojoba leaves and stems were collected in Baja California (Mexico) in Januar 1982. From the air dried materials epicuticular waxes were extracted with chloroform. Fractionation and analysis of the waxes were carried out as described earlier [11].

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Results and Discussion

Epicuticular waxes could be extracted from *Jojoba* leaves and stems in amounts of 0.34% and 0.10% of the dry weight, respectively. The epicuticular waxes contained homologues of alkanes, alkenes, wax esters, aldehydes, acetates, esters, free fatty acids and alcohols in similar proportions in weight both in leaves and stems (Table I). No significant qualitative and quantitative differences could be observed between the waxes of these two plant parts.

Hydrocarbons

The hydrocarbon fractions show a complex mixture of homologous series of *n*-alkanes, branched alkanes and alkenes which could be separated in

Table I. Composition and yield of epicuticular waxes from *Jojoba* leaves and stems.

	Leaves		Stems	
	[mg]	[% wax]	[mg]	[% wax]
hydrocarbons	18	3.9	3	2.8
wax esters	58	12.6	12	11.1
aldehydes	10	2.2	9	8.3
acetates	1	0.2	0.5	0.5
esters	2	0.4	6	5.5
free acids	103	22.4	23	21.1
free alcohols	107	23.3	24	22.0
lost on column	160	34.8	31	28.4
wax	460 = 0.34% dry wt		109 = 0.1% dry wt	

Table II. Composition (peak area %) of hydrocarbon fractions from *Jojoba* leaves and stems.

No. of C-atoms	Leaves			Stems		
	n-alkanes	br. alkanes	alkenes	*n*-alkanes	br. alkanes	alkenes
17	+			+		
18	+		+	+		+
19	+		+	0.7		0.9
20	+		1.5	0.8		1.6
21	+		+	2.6		1.2
22	+		+	1.3		1.6
23	2.1		+	3.7		1.5
24	2.4		1.5	2.1		1.9
25	7.6		1.4	6.0		1.8
26	5.7		3.7	4.1		3.7
27	20.2	0.4	1.4	16.4	0.8	1.4
28	6.2	0.2	3.5	4.2	+	2.6
29	13.4	0.7	1.3	13.6	2.0	0.9
30	3.2	0.4	5.3	2.9	0.8	2.6
31	17.4	0.5	+	13.9	1.7	+
32	+		+	+	+	+
33	+			0.7		
34	+			+		
35	+			+		
$\sum$	78.2	2.2	19.6	73.0	5.3	21.7

+ = < 0.1%.

high purity. In *n*-alkanes odd-carbon-numbered homologues are dominating with chain lengths ranging from C_{17} to C_{35} in branched alkanes with chain lengths from C_{27} to C_{31}. Compared to these the alkenes show dominating even-carbon-numbered chain lengths ranging from C_{18} to C_{32}. The proportions of the hydrocarbon fractions are listed in Table II. Branched alkanes from *Jojoba* leaves and stems reach only a few percent (2.2–5.3%) while they are present in *Jojoba* pericarp in amounts of 30% and in seed coats of 44.5%.

Alkenes are found in leaves and stems but could not be identified in pericarp and seed coats. These results demonstrate the organ specific composition of epicuticular hydrocarbons.

Wax esters

Wax esters and in lower proportions aldehydes, acetates of long chain alcohols and esters of long chain fatty acids were eluted from silica gel columns with 2-chloropropane. These substances could be separated by TLC on silica gel plates with benzene as solvent.

Wax esters (R_f 0.61) from *Jojoba* leaves and stems consisted of straight long chain fatty acids and alcohols. These wax esters show predominantly even-numbered homologues with chain lengths ranging from C_{38} to C_{56} with C_{44} as main component (Table III). 1% to 5.5% of wax esters could not classified as members of these homologues. Saponification of the wax esters results in mainly saturated long chain fatty acids and alcohols with chain lengths from C_{16} to C_{32}. Only traces of unsaturated

Table III. Composition (peak area %) of wax esters from *Jojoba* leaves and stems.

No. of C-atoms	Leaves	Stems
38	+	+
39	+	+
40	0.9	0.9
41	+	+
42	10.9	13.6
43	1.3	1.2
44	31.1	34.0
45	1.8	1.6
46	21.7	21.6
47	1.6	0.9
48	13.3	12.4
49	0.9	+
50	7.8	8.8
51	+	+
52	3.5	4.0
53	+	+
54	+	+
55	+	+
56	+	+
unidentified	5.5	1.0

+ = < 0.1%.

Table IV. Composition of epicuticular wax components (peak area %) from *Jojoba* leaves and stems.

No. of C-atoms	Aldehydes		Alcohols of acetates		Acids of esters		Saponification fatty acids		Saponification alcohols		Free fatty acids		Free alcohols	
	leaves	stems	leaves	stems	leaves	stems	leaves	stems	leaves	stems	leaves	stems	leaves	stems
16							2.7	2.9			+	+	+	+
17							+	+			+	+		
18							1.5	+	5.5	+	+	+	+	+
18:1							+	+			+	+		
19							+	+	+	+	+	+	+	+
20							27.8	24.5	3.8	+	1.0	3.0	+	+
20:1							+	1.5						
21							1.6	+	+	+	+	+	+	+
22	+	+			+	+	40.6	44.5	57.3	42.5	14.1	37.1	1.1	6.3
22:1							0.5	+						
23	+	+			+	+	1.2	+	+	+	+	1.0	+	+
24	+	2.3	18.8	3.5	32.8	29.2	16.5	22.0	23.3	23.9	41.1	39.1	3.1	5.9
24:1							+	+						
25	+	2.8	+	3.3	+	2.4	+	+	+	+	3.4	1.1	+	+
26	5.6	9.0	31.3	18.6	44.9	41.1	4.5	4.6	4.9	14.7	24.8	11.9	19.0	16.1
27	3.6	4.5	+	3.3	+	0.5	+	+	+	+	+	+	2.4	+
28	25.4	29.5	47.0	46.9	22.3	25.5	3.2	+	4.8	18.9	15.6	6.8	50.3	49.9
29	4.5	4.4	+	1.8	+	+	+	+	+	+	+	+	+	+
30	26.1	22.9	2.9	14.7	+	1.3	+	+	0.4	+	+	+	15.9	16.2
31	2.8	1.4	+	+	+	+	+	+			+	+	+	+
32	32.0	23.2	+	7.9	+	+	+	+			+	+	8.2	5.6
33	+	+											+	
34	+	+									+	+	+	+

fatty acids were observed. Docosanoic acid and docosanol (Table IV) are definitely dominating. These results are in contrast to the wax esters from *Jojoba* seed coats and pericarp. Wax esters from these parts of *Jojoba* consist exclusively of monounsaturated long chain acids and alcohols. This result demonstrates again organ specific compositions of epicuticular waxes in *Jojoba* plants.

Aldehydes

Aldehydes (R_f 0.45) were found to represent a homologous series with chain lengths ranging from C_{22} to C_{34}. The aldehydes C_{28}, C_{30} and C_{32} are present always in more than 20% (Table IV). They were identified by reduction with $NaBH_4$. Aldehydes were found in *Jojoba* seed coats too, with octacosanal (58.4%) dominating.

Acetates

In fraction R_f 0.45 were also acetates of long chain alcohols. These primary alcohols could be obtained by saponification. Alcohols ranging from C_{24} to C_{32} were analysed after derivatization again to the corresponding acetates. Octacosanol acetate (47%) was the dominating component in both leaves and stems (Table IV).

Esters

Further esters (R_f 0.45) of long chain acids and unidentified short chain alcohols could be analysed. The fatty acids were identified by saponification yielding the corresponding methylesters. Similar patterns of homologous series of acids ranging from C_{22} to C_{32} are found in leaves and stems (Table IV).

Free acids and alcohols

Free acids and alcohols were the main components in epicuticular waxes from *Jojoba* leaves and stems, each representing more than 20% (Table I). They were separated by TLC on silica gel plates with benzene as solvent after esterification. Analysis by GLC showed homologous series of long chain even-carbon-numbered acids and primary alcohols ranging from C_{16} to C_{34}. Saturated acids and alcohols were prevailing, unsaturated acids are present only in traces. The main components were tetracosanoic acid (~ 40%) and octacosanol (~ 50%) (Table IV).

Leaves and stems showed the same qualitative composition of alcohols and acids. The quantitative composition of the alcohols from leaves and stems was similar, too. The acids showed different patterns, the main components being identical though. Sterols as found in *Jojoba* seed coat or triterpenols could not be identified in this fraction.

Free acids and alcohols from leaves and stems are of longer chain lengths than those from *Jojoba* seed coats.

Epicuticular waxes from *Jojoba* leaves and stems show nearly the same qualitative composition of the various compounds analysed and also nearly identical quantitative composition for most wax components. Variations in distribution patterns are found only in free acids and acetates. All other values are found to be within the normal standard deviations.

The composition of epicuticular waxes from *Jojoba* leaves and stems are on the other hand quite different from those of *Jojoba* pericarp and seed coat and demonstrate the organ specific nature of epicuticular waxes according to the different functions of these plant organs.

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