CLX. THE CHEMISTRY OF THE WHITE ROTS OF WOOD.

IV. THE EFFECT ON WOOD SUBSTANCE OF *USTULINA VULGARIS* TUL.

By WILLIAM GEORGE CAMPBELL AND JAN WIERTELAK.

From the Section of Chemistry, Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.

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In connection with his studies of the parasitism of the genus *Ustulina* on the timbers of temperate regions Wilkins [1934, and in the press] identified *U. vulgaris* Tul. as the causal organism of a disease of lime (*Tilia vulgaris* Hayne). In view of the facts that this constituted the first experimental evidence of the parasitism of this particular fungus on lime wood in temperate climates and that doubt has frequently been expressed with regard to its injurious effect on trees, it seemed desirable to supplement the mycological study by determining the ultimate chemical effect of the fungus on the wood substance. This has now been carried out on material supplied by Mr W. H. Wilkins of the Mycology Laboratory, University Department of Botany, Oxford, and also on a sample of freshly felled beech wood, which is the usual host of the fungus.

Experimental.

(1) *Lime wood decayed by* U. vulgaris.

The material consisted of a 6-in. disc cut from the bole of the diseased tree. Three distinct zones were clearly discernible in the sample as follows: (1) Outer sound wood. (2) Intermediate "red wood", a dark brown-coloured zone. (3) Inner decayed wood. The appearance of the specimen suggested that the causal fungus was of the white rot type.

The wood from each of the three zones was air-dried to a moisture content of approximately 6 % and converted into a series of more or less regularly shaped pieces measuring approximately $4 \times 1\frac{1}{4} \times 1\frac{1}{4}$ in. The volume of each piece was determined by the method described in previous work [Campbell, 1932] and each piece was weighed after oven-drying at 105°. Accepting the outermost zone as sound wood the approximate percentage loss in weight sustained by the inner zones during decay was calculated by comparing the average ratio $\frac{\text{oven-dry weight}}{\text{air-dry volume}}$ for each group of decayed specimens with that for the group of sound specimens. Each group of specimens was now converted to sawdust and ground to pass a 60-mesh screen. In each case the portion remaining on the 80-mesh screen was reserved for analysis (Table I).

Table I. *The effect of* Ustulina vulgaris *on the chemical composition of lime wood* (Tilia vulgaris *Hayne*).

Results expressed as % by weight of oven-dry material.

		Intermediate "red wood"		Decayed wood I		Decayed wood II	
	Sound wood	% of sample	% of sound wood	% of sample	% of sound wood	% of sample	% of sound wood
Moisture content	6·07	5·07	—	6·01	—	7·09	—
Average oven-dry wt./air-dry vol.	0·50	0·477		0·389		0·343	
Approximate loss in wt. (calculated)	—	—	4·6	—	22·2	—	31·4
Cold water-soluble	2·59	2·64	2·52	3·09	2·40	3·64	2·50
Hot water-soluble	3·63	3·71	3·54	4·56	3·56	5·85	4·01
1 % NaOH-soluble	27·03	27·66	26·39	26·68	20·76	29·45	20·20
Alcohol : benzene (1 : 2)-soluble	7·05	9·07	8·75	4·44	3·50	6·37	4·37
Cellulose	54·55	52·66	50·24	65·48	43·16	52·77	36·20
Lignin	23·74	24·21	23·10	24·21	18·84	25·55	17·53
Total methoxyl	5·75	5·36	5·11	5·71	4·44	5·62	3·86
Methoxyl in lignin	4·07	3·90	3·72	4·02	3·13	4·15	2·85
Methoxyl in lignin as % of lignin	17·13	16·10		16·61		16·24	
Total pentosans	20·41	21·76	20·76	21·84	16·99	20·17	13·84
Pentosans in cellulose	12·34	12·55	11·97	12·59	9·79	12·51	8·58
Pentosans not in cellulose	8·07	9·21	8·79	9·25	7·20	7·66	5·26

(2) *Beech wood decayed by* U. vulgaris *in pure culture.*

A sample of freshly felled beech wood (*Fagus sylvatica* L.) was converted to sawdust and air-dried. A sample of 60–80 mesh material prepared from this was sterilised by steaming at 100° for 30 minutes on each of three consecutive days, inoculated with a pure culture of *U. vulgaris* and incubated at 20°. The authors are indebted to Mr W. P. K. Findlay for carrying out the inoculation. After 14 months the decayed wood was washed free from acid with cold water, dried at 105°, weighed and analysed (Table II).

Table II. *Analysis of 60–80 mesh beech wood decayed by* Ustulina vulgaris.

Results expressed as % by weight of oven-dry sound wood.

	Sound wood	Decayed wood
Duration of decay	—	14 months
Loss in wt.	—	3·17
Cold water-soluble	0·32	0·75
Hot water-soluble	1·23	0·72
1 % NaOH-soluble	14·88	15·12
Cellulose	59·89	55·26
Lignin	21·38	21·14
Total pentosans	25·10	23·15
Pentosans in cellulose	14·95	12·55
Pentosans not in cellulose	10·15	10·60
Total methoxyl	6·48	6·28
Methoxyl in lignin	4·73	4·50

Discussion.

The results in Table I indicate that in the living tree *U. vulgaris* produces a typical white rot. Both lignin and carbohydrates are attacked and the alkali-solubility, when calculated as a percentage of sound wood, decreases steadily as decay proceeds.

The results for the intermediate zone of so-called "red wood" are of considerable interest. From a visual examination it was doubtful whether the fungus had penetrated into this zone to any appreciable extent although the wood was stained a reddish brown colour, which suggested that at least part had undergone chemical change. The analytical data make it abundantly clear that the wood substance in question was in an early stage of decay. A loss in weight of approximately 4·6 % was sustained and this is almost wholly accounted for by depletion of the Cross and Bevan cellulose. The furfuraldehyde-yielding complexes associated with the cellulose only exhibit the faintest indication of decomposition. At this early stage of decay the lignin is also attacked to a slight extent. Both the methoxyl groups and the main portion of the lignin complex would appear to be involved. With regard to extractives it is noteworthy that the decayed wood contains less water- and alkali-soluble material than sound wood when the results are all expressed on the same basis. At the same time the fraction soluble in alcohol: benzene is greater in the decayed than in the sound wood. It is therefore suggested that the increment to the alcohol: benzene-soluble fraction is derived from transition products in the break-down of the wood substance. The red-brown colour of the intermediate zone may thereby be explained.

As the decay becomes more advanced the nature of the ultimate chemical changes is in all respects similar to certain other white rots which have been studied [Campbell, 1932; Wiertelak, 1932]. At the most advanced stage examined approximately one-third of the cellulose and one-quarter of the lignin were decomposed. Depletion of the furfuraldehyde-yielding complexes was also well marked. It is therefore apparent that the fungus derives the greater part of its nourishment from the carbohydrates of the cell wall substance of the wood. It is observed that as decay proceeds the solubility of the wood in alcohol: benzene exhibits a decline. This would appear to indicate that the by-products formed in the early stages of decay are ultimately decomposed.

Turning now to the data in Table II it can be seen that although the saprophytic attack of *U. vulgaris* on wood substance is slow it closely resembles, in its early stages at least, the parasitic action (Table I).

As before, attack is concentrated on the cellulose from the outset. In this case there is more definite indication of early attack on the furfuraldehyde-yielding complexes associated with the cellulose, and the attack on lignin at this stage has been confined to methoxyl groups.

Summary.

Ustulina vulgaris Tul. as a parasite on lime wood (*Tilia vulgaris* Hayne) produces a type of decomposition which must be characterised as a white rot. The chief source of fungal nourishment, however, is the carbohydrate portion of the cell wall. Lignin is also decomposed but not to the same extent as the Cross and Bevan cellulose.

The saprophytic action of the fungus on beech wood, although slow, is chemically of the same order as the parasitic action.

The experimental data obtained from decayed lime wood suggest that this fungus must have a pronounced detrimental effect on the mechanical properties of the wood.

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