It has been shown by Desai and co-workers\(^1\) that resacetophenone as well as 5-ethyl-2:4-dihydroxy-acetophenone condense with aceto-acetic ester, not in the presence of concentrated sulphuric acid, but phosphoryl chloride with the formation of 7-hydroxy-coumarin derivatives. Limaye and Shenolikar,\(^2\) on the other hand, have found that 2-acetylresorcinol undergoes the usual coumarin condensation in the presence of concentrated sulphuric acid. Desai and Ekhlas\(^3\) who happened to synthesise 4-ethyl-2-acetylresorcinol in course of some other work observed that it resembled 2-acetylresorcinol in its capacity for coumarin condensation in the presence of concentrated sulphuric acid. To make sure that this was not an isolated case, we have now condensed 4-ethyl-2-acetylresorcinol with C-alkylated aceto-acetic esters of the general formula CH\(_3\)CO—CHR COOEt, where R = methyl, ethyl, propyl, butyl and allyl groups. Thus methylaceto-acetic ester gave 3:4-dimethyl-6-ethyl-7-hydroxy-8-acetyl coumarin (I) while its higher homologues behaved in an analogous manner.

The constitution of the resulting coumarin was proved by its rational synthesis from 4-ethylresorcinol and methylaceto-acetic ester which gave 3:4-dimethyl-6-ethyl-7-hydroxy-coumarin, the acetoxy derivative of which underwent Fries migration with the formation of 3:4-dimethyl-6-ethyl-7-hydroxy-8-acetyl coumarin. The constitution of other coumarins was similarly proved, and this proof is conclusive as Desai and Ekhlas\(^4\) have shown that the Pechmann condensation of 4-ethylresorcinol and aceto-acetic ester gives exclusively 6-ethyl-7-hydroxy-4-methylcoumarin.

Desai and Miss Vakil\(^5\) have recently shown that 5-methyl-2-acetylresorcinol (II) undergoes de-acetylation during the course of the Pechmann Reaction. When this observation is compared with those recorded in this communication it becomes quite apparent how profoundly similar substituents situated in different places affect the course of the same reaction.
Finally 4-ethyl-2-acetylresorcinol was condensed with benzoyl acetic ester, when 4-phenyl-6-ethyl-7-hydroxy-8-acetylcoumarin (III) was obtained. The poor yield obtained in this reaction shows that this ester is less reactive than aceto-acetic ester.

**Experimental**

4-Ethyl-2-acetylresorcinol was prepared by Limaye’s Process the details of which have been described by Desai and Ekhlas\(^3\) (loc. cit.). These have been recently repeated and confirmed by Limaye and Limaye.\(^5\)

**Condensation of 4-ethyl-2-acetylresorcinol with ethyl \(\alpha\)-methylaceto-acetate and formation of 3:4-dimethyl-6-ethyl-7-hydroxy-8-acetyl-coumarin.**—A clear solution of the dihydroxy ketone (2.5 g.) and the ester (2 g.) in 73 per cent. sulphuric acid (25 c.c.) was kept at the room temperature for 36 hours, and poured over ice. The resulting solid crystallised from colourless needles, m.p. 121° (yield = 75 per cent.).

[Found: C, 69·1; H, 6·2; \(\text{C}_{15}\text{H}_{16}\text{O}_4\) requires C, 69·2; H, 6·2 per cent.]

The coumarin was easily soluble in chloroform, acetone, alcohol and acetic acid, sparingly soluble in benzene but almost insoluble in petroleum ether. Its alkaline solution was yellow and devoid of any fluorescence, and its alcoholic solution gave green colouration with alcoholic ferric chloride.

**Condensation of 4-ethylresorcinol with ethyl \(\alpha\)-methylaceto-acetate and formation of 3:4-dimethyl-6-ethyl-7-hydroxycoumarin.**—A mixture of 4-ethylresorcinol (3 g.), \(\alpha\)-methylaceto-acetic ester (3 g.) and 73 per cent. sulphuric acid (30 c.c.), after being kept for 12 hours was poured over rice. The solid crystallised from alcohol in colourless needles, m.p. 240° (yield = 90 per cent.).

[Found: C, 71·4; H, 6·55; \(\text{C}_{13}\text{H}_{14}\text{O}_3\) requires C, 71·5; H, 6·5 per cent.]

It dissolved in alkali giving green fluorescence. The acetyl derivative prepared by heating the mixture of the coumarin (2 g.), acetic anhydride (10 c.c.) and fused sodium acetate (2 g.) for four hours crystallised from alcohol in lustrous needles, m.p. 150°.

[Found: C, 69·0; H, 6·3; \(\text{C}_{15}\text{H}_{16}\text{O}_4\) requires C, 69·2; H, 6·2 per cent.]
Fries Transformation of 3:4-dimethyl-6-ethyl-7-acetoxy-coumarin to 3:4-dimethyl-6-ethyl-7-hydroxy-8-acetylcoumarin.—An intimate mixture of the acetoxy coumarin (1 g.) and anhydrous aluminium chloride (2 g.) was gradually heated in an oil-bath to 140° for one hour. The solid obtained by decomposing the excess of aluminium chloride with ice-cold hydrochloric acid was purified through alkali, and crystallised from alcohol when colourless needles, m.p. 121°, were obtained. Its m.p. was not depressed by the specimen prepared from 4-ethyl-2-acetyltresorcinol and α-methylacetocacetate.

Condensation of α-ethylacetoacetate with 4-ethyl-2-acetyltresorcinol and formation of 3:6-diethyl-4-methyl-7-hydroxy-8-acetylcoumarin.—This was carried out as above. The Coumarin which was obtained in 70 per cent. yield crystallised from alcohol in colourless needles, m.p. 147°. Its alkaline solution was yellow and non-fluorescent, while its alcoholic solution gave green colouration with alcoholic ferric chloride.

[Found: C, 69.8; H, 6.8; C_{16}H_{18}O_{4} requires C, 70.0; H, 6.8 per cent.]

3:6-Diethyl-4-methyl-7-hydroxycoumarin was obtained by the usual method by condensing 4-ethylresorcinol with α-ethylaceto-acetic ester, and crystallised from alcohol in needles, m.p. 216°; (yield = 75 per cent.). Its alkaline solution was yellowish and gave green fluorescence.

[Found: C, 72.2; H, 7.0; C_{14}H_{16}O_{3} requires C, 72.4; H, 7.1 per cent.]

The Acetyl Derivative crystallised from alcohol in lustrous needles, m.p. 131°.

[Found: C, 70.1; H, 6.8; C_{16}H_{18}O_{4} requires C, 70.0; H, 6.6 per cent.]

When subjected to the Fries Transformation in the usual manner, the above acetyl-derivative gave 3:6-diethyl-4-methyl-7-hydroxy-8-acetylcoumarin, m.p. 147°, and undepressed by the sample prepared from 4-ethyl-2-acetyltresorcinol and α-ethy laceto-acetic ester.

Condensation of α-propyl-acetoacetate with 4-ethyl-2-acetyltresorcinol and formation of 3-propyl-4-methyl-6-ethyl-7-hydroxy-8-acetylcoumarin.—This coumarin (70 per cent. yield) crystallised from alcohol in colourless needles, m.p. 129°, and had the usual properties of its analogues.

[Found: C, 70.6; H, 7.2; C_{17}H_{20}O_{4} requires C, 70.8; H, 7.0 per cent.]

3-Propyl-4-methyl-6-ethyl-7-hydroxy-coumarin obtained from 4-ethylresorcinol and α-propylacetoc-acetic ester (65 per cent. yield) crystallised from alcohol in yellowish needles, m.p. 189°.

[Found: C, 72.9; H, 7.5; C_{15}H_{18}O_{3} requires C, 73.1; H, 7.4 per cent.]
The Acetyl Derivative crystallised from alcohol in needles, m.p. 133°.

[Found: C, 70·6; H, 7·2; C_{17}H_{29}O_{4} requires C, 70·9; H, 7·3 per cent.]

When this was subjected to the Fries migration it gave the coumarin m.p. 129°, which was proved to be 3-propyl-4-methyl-6-ethyl-7-hydroxy-8-acetylcoumarin.

Condensation of 4-ethyl-2-acetylresorcinol with α-butylacetoacetate and formation of 3-butyl-4-methyl-6-ethyl-7-hydroxy-8-acetylcoumarin.—As the α-butylaceto-acetic ester was slightly contaminated with the original unsubstituted aceto-acetic ester, the crude coumarin was fractionally crystallised from alcohol. The first fraction, m.p. 135°, was identified as 4-methyl-6-ethyl-7-hydroxy-8-acetylcoumarin while the second fraction, m.p. 100-105°, when recrystallised from benzene, melted at 124°. Its alcoholic solution gave green colouration with ferric chloride, and was identified to be 3-Butyl-4-methyl-6-ethyl-7-hydroxy-8-acetylcoumarin.

[Found: C, 71·2; H, 7·5; C_{18}H_{22}O_{4} requires C, 71·5; H, 7·3 per cent.]

The coumarin obtained by condensing 4-ethylresorcinol with α-butylacetoacetic ester was a mixture of 3-butyl-4-methyl-6-ethyl-7-hydroxy-coumarin and 4-methyl-6-ethyl-7-hydroxy-coumarin. The former was more soluble in warm benzene than the latter. The soluble fraction on recrystallisation from alcohol gave colourless needles, m.p. 159°.

[Found: C, 73·5; H, 7·9; C_{18}H_{20}O_{3} requires C, 73·8; H, 7·8 per cent.]

The Acetyl Derivative crystallised from alcohol in lustrous needles, m.p. 114°.

[Found: C, 71·3; H, 7·5; C_{18}H_{22}O_{4} requires C, 71·5; H, 7·3 per cent.]

When subjected to the Fries Transformation, it gave a product, m.p. 124°, identified by the mixed m.p. as 3-butyl-4-methyl-6-ethyl-7-hydroxy-8-acetyl-coumarin which has been described before.

Condensation of α-allyl-aceto-acetic ester with 4-ethyl-2-acetylresorcinol and formation of 3-allyl-4-methyl-6-ethyl-7-hydroxy-8-acetyl-coumarin.—This coumarin crystallised from alcohol in yellowish needles, m.p. 106° (yield = 50 per cent.).

[Found: C, 71·0; H, 6·5; C_{17}H_{18}O_{4} requires C, 71·3; H, 6·4 per cent.]

4-Ethylresorcinol condensed with α-allyl-aceto-acetic ester in the usual manner giving 3-allyl-4-methyl-6-ethyl-7-hydroxy-coumarin which crystallised from alcohol in needles, m.p. 202° (yield = 45 per cent.).

[Found: C, 73·5; H, 6·4; C_{18}H_{16}O_{3} requires C, 73·7; H, 6·6 per cent.]
The Acetyl Derivative crystallised from alcohol in needles, m.p. 123°.

[Found: C, 71·1; H, 6·6; C_{17}H_{18}O_{4} requires C, 71·3; H, 6·3 per cent.]

The Fries migration of this acetyl derivative gave the coumarin, m.p. 106° and identified as 3-allyl-4-methyl-6-ethyl-7-hydroxy-8-acetylcoumarin.

Condensation of benzoylecetic ester with 4-ethyl-2-acetyltresorcinol and formation of 4-phenyl-6-ethyl-7-hydroxy-8-acetylcoumarin.—The condensation carried out as usual was worked up after 36 hours when the resulting coumarin crystallised from alcohol in lustrous, prismatic needles, m.p. 154° (yield = 180 per cent.). Its alkaline solution was yellow and non-fluorescent while the alcoholic solution gave deep-violet colouration with alcoholic ferric chloride.

[Found: C, 73·8; H, 5·4; C_{19}H_{16}O_{4} requires C, 74·0; H, 5·2 per cent.]

4-Phenyl-6-ethyl-7-hydroxycoumarin, obtained from 4-ethylresorcinol and benzoylecetic ester, crystallised from alcohol in colourless lustrous needles, m.p. 232° (yield = 90 per cent.). Its yellowish, alkaline solution gave green fluorescence.

[Found: C, 76·5; H, 5·5; C_{17}H_{14}O_{3} requires C, 76·6; H, 5·3 per cent.]

The Acetyl Derivative crystallised from alcohol in lustrous needles, m.p. 151°.

[Found: C, 73·7; H, 5·4; C_{19}H_{16}O_{4} requires C, 74·0; H, 5·2 per cent.]

When this acetyl derivative was subjected to the usual Fries migration, 4-phenyl-6-ethyl-7-hydroxy-8-acetylcoumarin, m.p. 154°, was obtained.

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Summary

The condensation of 4-ethyl-2-acetyltresorcinol with α-methyl, α-ethyl, α-propyl, α-butyl and α-allylaceto-acetic esters as well as benzoylecetic ester has shown that this ketone is much reactive as contrasted with resaceto-phenone, thus showing that the Pechmann Reaction is not hindered by negative groups in the γ-position of the resorcinol molecule. The constitution of each coumarin was established by its rational synthesis from 4-ethylresorcinol, acetylating the resulting coumarin, and subjecting it to the Fries migration.

REFERENCES

   ——— and Ekhlas .. Ibid., 1938, 8, 571.
2. Limaye and Shenolikar .. Rasayanam, 1937, 1, 99.
4. ——— and (Miss) Vakil .. Ibid., 1940, 12, 357.
5. Limaye and Limaye .. Rasayanam, 1941, 1, 201.