TABLE IV

ULTRAVIOLET ABSORPTION DATA IN CYCLOHEXANE OF PURE ALKYL PHENYL KETONES

Alkyl moiety	λ_{max}, mμ	$\epsilon \times 10^{-4}$
n-Propyl	240	1.11
n-Butyl	240	1.12
n-Pentyl	239	1.30
n-Hexyl	239	1.34
n-Heptyl	240	1.20
n-Octyl	240	1.16
n-Nonyl	236	1.80
n-Undecyl	239	1.29
n-Tridecyl	236	1.72
n-Pentadecyl	240	1.26
n-Heptadecyl	240	1.09

Preparation of Pure Alkyl Phenyl Ketones as Analytical Standards.—Table IV lists the alkyl phenyl ketones prepared by the Friedel–Crafts procedure of Breusch and Oguzer.[5]

Preparation of Alkyl Phenyl Ketones.—The apparatus has been described.[1] One tenth mole of benzoic acid, 0.1 mole of aliphatic acid, and 0.11 mole of iron were used in reactions with aliphatic carboxylic acids of less than five carbon atoms; twice these quantities were utilized in reactions involving aliphatic acids of five or more carbon atoms. The reaction flask was heated to 250° until hydrogen evolution (100% yield in all cases) ceased—approximately 45 min. If the expected alkyl phenyl ketone had less than nine carbon atoms in the side chain, the condenser was set for downward distillation, and the flask heated until distillation ceased. Evolution of carbon dioxide and distillation occurred at a pot temperature of 280–300°; only a few drops of black tar distilled at higher temperatures. The volatile distillate was diluted with ether, washed with saturated sodium bicarbonate solution, dried, concentrated, and weighed. An accurately weighed sample of 10 mg. of crude product was dissolved in 1 l. of cyclohexane and compared at the wave length of maximum absorption with the spectrum of the corresponding pure ketone. The alkyl phenyl ketone was then distilled to separate it from possible lower boiling dialkyl ketones. From the appropriate ketones no acetone, no 3-pentanone, no 2,4-dimethylpentanone-3, 12% of 4-heptanone, no 3,5-dimethylheptanone-4, and 8% yields of 5-nonanone were obtained. The tarry, nonvolatile, red residue remaining after twenty-five different distillations were combined to give 50 g. of material. Chromatographic study of the small amount of tar (about 4 g.) boiling at 300–400° indicated (infrared spectrum) some benzophenone to be present; no other materials were identified in the tar. (Parenthetically, it was observed that when only benzoic acid and powdered iron were treated, a pot temperature of 350–400° was required to decompose the iron(II) benzoate; yields of 13% benzene, 17% benzophenone, a trace of benzaldehyde, and much tar resulted.)

If the expected alkyl phenyl ketone had nine or more carbon atoms in the side chain, ketonic decarboxylation of the iron salts was effected with the condenser attached vertically to the decarboxylation flask. After decarboxylation, the impure ketone was dissolved in 200 ml. of ether, filtered through a pad of Celite to remove particles of iron and iron oxide, washed with sodium bicarbonate solution, dried, concentrated, weighed, and analyzed for alkyl phenyl ketone. The crude red residue was dissolved in cyclohexane (10 ml./g.) and passed through a 2.5 × 20 cm. column of alumina, eluting the column with a double volume of cyclohexane. After the removal of solvent, the colorless, solid residue was recrystallized one to three times from 95% ethanol to give pure alkyl phenyl ketone.

The identity and purity of products were established by boiling and/or melting points, melting points of 2,4-dinitrophenylhydrazones and/or semicarbazones, and quantitative ultraviolet absorption spectra.

Semimicro Preparation of Ethyl Substituted Phenyl Ketones.—Into a 200-cm. test tube equipped with condenser, drying tube, and bubble counter were placed 0.05 mole of propanoic acid, 0.05 mole of substituted benzoic acid, and 0.054 mole of powdered iron. The tube was heated in an electric coil at 280–300° until all gas evolution ceased. No attempt was made to distil ketone as it formed. The cooled tube was broken directly into a steam distillation flask containing 500 ml. of water and 10 g. of sodium bicarbonate. After steam distillation, the distillate was extracted with chloroform, then dried, concentrated, and distilled and/or recrystallized, depending upon the properties of the expected ketone.

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[5] F. L. Breusch and M. Oguzer, *Chem. Ber.*, **87**, 1227 (1954).

Occurrence of the Isoflavone Afromosin in Cabreuva Wood[1]

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During a study of the extractives of "cabreuva" or "oleo pardo" wood (*Myrocarpus fastigiatus* Fr. Allem.), a companion substance to cabreuvin (7,3′,4′-trimethoxyisoflavone) was isolated and designated as C-2.[2] It has subsequently been found also in "cabreuva vermelha" or "oleo vermelho" (*Myroxylon balsamum* (L.) Harms).[3] Elementary, functional group and infrared spectral analyses revealed C-2 to be a hydroxydimethoxyflavone or isoflavone. A comparison of its chromatographic properties (Table I) with those of known representatives of these two classes[4] indicated that C-2 was probably an isoflavone. This was confirmed by demethylating it with aluminum chloride in dry ether and acetylating the product. The acetate thus produced had a spectrum which was almost identical with those of isoflavone and various acetylated hydroxyisoflavones, but which differed from the spectrum of flavone (Table II).

Up to the present, only one natural hydroxydimethoxyisoflavone has been described in the literature. This is afromosin, whose isolation from *Afrormosia elata* Harms was reported by McMurry and Theng[5] Mixed melting point, spectral and chromatographic comparisons (Tables I and III) of samples of afromosin (7-hydroxy-6,4′-dimethoxyisoflavone), its methyl ether and 6,7,4′-trihydroxyisoflavone[6] with C-2 and its appropriate derivatives showed that these two isoflavones were identical.

It has been mentioned several times in the literature that isoflavones may be distinguished from flavones by the absence of absorption maxima between 320 and 380 mμ, ascribed to the chalcone chromophore of the latter. Nevertheless, it is now appreciated that the substitution pattern of the flavonoids has a profound influence on their ultraviolet spectrum.[7] Thus'

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[1] This paper is part IV in the series "The Chemistry of Brazilian Leguminosae." Part III: W. B. Eyton, W. D. Ollis, I. O. Sutherland, L. M. Jackman, O. R. Gottlieb, and M. Taveira Magalhães, *Proc. Chem. Soc.*, 301 (1962).

[2] O. R. Gottlieb and M. Taveira Magalhães, *Anais Assoc. Brasil. Quim.*, **18**, 89 (1959).

[3] For references to the botanical literature, see ref. 2.

[4] J. B. Harborne, *J. Chromatog.*, **2**, 581 (1959).

[5] T. B. H. McMurry and C. Y. Theng, *J. Chem. Soc.*, 1491 (1960). These authors spell the species *Afromosia elata* Harms. See, however, "Index Kewensis," suplementum quintum, Oxonii e prelo Clarendoniano, 1921, p. 6.

[6] Kindly donated by Dr T B. H. McMurry.

[7] For references see O. R. Gottlieb and M. Taveira Magalhães, *J. Org. Chem.*, **26**, 2449 (1961).

TABLE I. R_f VALUES AND COLORS OF ISOFLAVONES[a]

Isoflavone	R_f value in solvent[b] A	B	C	D	E	Color in ultraviolet light In air	In ammonia
C-2 7-OH-6,4′-diOMe (afromosin)	0.92	0.06	0.87	0.42	0.28	Colorless[c]	Light blue
C-2 methyl ether 6,7,4′-TriOMe	0.91	0.07	0.87	0.83	0.39	Colorless	Dull mauve
C-2, demethylated 6,7,4′-TriOH	0.80	0.05	0.76	0.12	0.24	Colorless	Light blue
6,7-DiOH-4′-OMe	0.89	0.05	0.83	0.22	0.23	Colorless	Light blue
7,3′,4′-TriOH	0.82	0.09	0.81	0.14	0.30	Colorless	Light blue
7,3′,4′-TriOMe (cabreuvin)	0.91	0.09	0.88	0.83	0.43	Mauve	Dull mauve
7,4′-DiOH (daidzein)	0.88	0.10	0.87	0.42	0.37	Colorless	Light blue
7-OH-4′-OMe (formononetin)	0.89	0.07	0.88	0.57	0.35	Colorless	Light blue

[a] Flavones, by comparison with isoflavones, appear on paper chromatograms as purple spots, which change to yellow-brown in ammonia, and have much lower R_f values in solvent A (*e.g.*, quercetin R_f 0.64, apigenin 0.87) and in solvent D (*e.g.*, quercetin R_f 0.03, apigenin 0.08). [b] Solvents: A, butanol–acetic acid–water (4:1:5, top layer); B, water; C, butanol–ethanol–water (4:1:2); D, butanol-2N NH_3 (1:1, top layer); E, acetic acid–water (15:85). [c] All these isoflavones can be seen as dull purple on a fluorescent paper background in ultraviolet light of 253 mμ.

TABLE II

ABSORPTION SPECTRA OF ACETOXYISOFLAVONES, ISOFLAVONE, AND FLAVONE

Compound	λ_{max}	mμ	E_{300}/E_{250}, %
Acetate of demethylated C-2	250	~302	35
7,3′,4′-Triacetoxyisoflavone	250	300	25
7,4′-Diacetoxyisoflavone	251	305	15
5,6,7,3′,4′,5′-Hexaacetoxyisoflavone	250	308	26
Isoflavone	245	307	12
Flavone	251	291	126

TABLE III. ABSORPTION SPECTRA OF 6,7,4′-OXYGENATED ISOFLAVONES

	λ_{max} in mμ (log ε) 95% EtOH	95% EtOH-NaOEt	95% EtOH cont. $AlCl_3$	95% EtOH satd. with AcONa
C-2	260 (4.49), 320 (4.11)	260 (4.49), 352 (4.29)	260, 320	260, 350
Afromosin	258 (4.37), 320 (4.0)	256 (. . .), 348 (. . .)	259, 320	260, 350
C-2 methyl ether	260 (4.47), 320 (4.04)	260 (4.47), 320 (4.04)	No shift	No shift
6,7,4′-TriOMe	261 (4.70), 320 (4.30)	261 (. . .), 320 (. . .)	No shift	No shift
C-2, demethylated	261 (. . .), 325 (. . .)	270 (. . .), 373 (. . .)	261, 325	255, 348
6,7,4′-TriOH	262 (. . .), 325 (. . .)	272 (. . .), 378 (. . .)	260, 330	254, 348
6,7-DiOH-4′-OMe	261 (. . .), 326 (. . .)	258 (. . .), 382 (. . .)	258, 336	258, 345

afromosin and its derivatives give rise to a well pronounced long wave length band at 320–325 mμ, which is not shown by any of the other known naturally occurring isoflavones,[8,9] but is present also in the spectrum of the synthetic 6,7-dihydroxy-4′-methoxyisoflavone[10] (Table III). This band is apparently characteristic of compounds derived from 2,4,5-trihydroxyacetophenone; the spectrum of 6,7,3′,4′-tetrahydroxyflavanone also contains a pronounced long wave length band, which is not present in the spectra of the majority of other flavanones.[11]

The occurrence of 7-hydroxy-6,4′-dimethoxyisoflavone in three timbers belonging to the same tribe (*Sophoreae*) of the *Leguminosae-Papilionatae* family is of systematic interest. Isoflavones lacking a 5-oxygen function have up to now been found only in species of this family.

Experimental[12]

7-Hydroxy-6,4′-dimethoxyisoflavone.—Cabreuva wood (5 kg.) was reduced to saw dust and then extracted with benzene in a Soxhlet apparatus. The benzene solution was washed with dilute hydrochloric acid and concentrated sodium carbonate solutions. Subsequently it was extracted with 3% sodium hydroxide solution. The alkaline liquid was acidified and extracted with chloroform. After evaporation of the solvent a brown mass remained which was dissolved in hot methanol. The crystalline material, separated on cooling, was purified by chromatography on alumina (activity IV), elution with benzene, vacuum sublimation, and recrystallization from methanol. Colorless needles (40 mg. *ex-Myroxylon balsamum;* 29 mg. *ex-Myrocarpus fastigiatus*), m.p. 236–237°. Ultraviolet spectrum: Table III. Infrared spectrum (Nujol mull): λ_{max} (*inter al.*) 3.12, 6.12, 6.33, 6.56, 7.79, 7.99, 8.23, 11.91 μ.

Anal. Calcd. for $C_{17}H_{14}O_5$: C, 68.45; H, 4.73; 2 OCH_3, 20.81. Found: C, 68.11; H, 4.85; OCH_3, 20.65.

6,7,4′-Trimethoxyisoflavone.—7-Hydroxy-6,4′-dimethoxyisoflavone was treated at room temperature with an ethereal solution of diazomethane. After 5 hr. the solution was evaporated and the residue purified by chromatography on alumina (activity I). Colorless crystals, m.p. 178–179°. Ultraviolet spectrum: Table III. Infrared spectrum (Nujol mull): λ_{max} (*inter al.*) 6.16, 6.63, 7.78, 7.88, 8.09 μ.

Anal. Calcd. for $C_{18}H_{16}O_5$: C, 69.22; H, 5.16; 3 OCH_3, 29.81. Found: C, 69.03; H, 5.14; OCH_3, 29.90.

6,7,4′-Trihydroxyisoflavone and Its Acetate.—7-Hydroxy-6,4′-dimethoxyisoflavone in dry benzene and powdered anhydrous aluminum chloride were boiled for 2 hr. The benzene was evaporated and the aluminum complex was decomposed with dilute hydrochloric acid and the product extracted into ethyl acetate. Evaporation of this extract gave 6,7,4′-trihydroxyisoflavone. Ultraviolet spectrum: Table III. This substance was acetylated with acetic anhydride and pyridine in the usual way to give 6,7,4′-triacetoxyisoflavone. Ultraviolet spectrum: Table II.

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(8) T. A. Geissman, "Modern Methods of Plant Analysis," Vol. III, K. Paech and M. V. Tracey, ed., Springer Verlag, Berlin, 1955, p. 450.

(9) W. D. Ollis "The Chemistry of Flavonoid Compounds," T. A. Geissman, ed., Pergamon Press, Oxford, 1962, p. 367.

(10) For the preparation of this model compound we are indebted to Drs. W. D. Ollis and M. Sainsbury.

(11) J. B. Harborne and T. A. Geissman, *J. Am. Chem. Soc.*, **78**, 829 (1956).

(12) Melting points were determined using a Kofler hot stage. Ultraviolet absorption spectra were taken on a Beckman model DU quartz spectrophotometer and infrared spectra on a Perkin–Elmer Infracord, Model 137 spectrophotometer. Microanalyses were performed by Dr. A. Bernhardt, Muehlheim (Ruhr), Germany.