CHROM. 6043

QUANTITATIVE DETERMINATION OF THE METHYL ESTER OF 2-CHLORO-3-(4-CHLOROPHENYL)PROPIONIC ACID IN TECHNICAL PRODUCTS AND FORMULATIONS BY GAS CHROMATOGRAPHY

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(Received February 22nd, 1972)

SUMMARY

A method is described for the quantitative determination of the methyl ester of 2-chloro-3-(4-chlorophenyl)propionic acid (common name chlorphenprop-methyl), the active ingredient of herbicide formulations known under the trade-name Bidisin. The method is proposed for the determination of both technical and formulated products. On a poly neopentyl glycol succinate–phosphoric acid column it is possible to determine also the following by-products: free 2-chloro-3-(4-chlorophenyl)propionic acid, its nitrile and its amide, and other impurities derived from raw materials and other reactions as well, either simultaneously or after modification of the operating conditions. The conditions for the qualitative analysis of the methyl ester of 2-chloro-3-(4-chlorophenyl)propionic acid samples and for the qualitative and quantitative analyses of the nitrile of 2-chloro-3-(4-chlorophenyl)propionic acid (a by-product from the preparation of the methyl ester) are described.

INTRODUCTION

The methyl ester of 2-chloro-3-(4-chlorophenyl)propionic acid (CPCPM) is the active ingredient of a herbicide that provides specific post-emergence control of wild oats *(Avena fatua)*, known until now under the trade-name Bidisin (Bayer, Leverkusen, G.F.R.).

The only published work on the analysis of CPCPM by gas–liquid chromatography (GLC) is that by JARCZYK[1], who described the determination of residues of Bidisin in plant matter on a column of SE-30. Other possible methods for the determination of CPCPM and the nitrile of 2-chloro-3-(4-chlorophenyl)propionic acid (CPCPN) in technical products include IR spectroscopy[2] and an argentometric method[3] based on the titration of the hydrolyzable chlorine derived from the carbon chain. By this latter method it is possible to determine CPCPM even in formulated products.

The analysis of free acids and their derivatives (esters, nitriles, amides) by GLC is described adequately in the literature. In the analysis of free acids, difficulties

arise as a result of the formation of associated molecules (dimers), which do not elute from the column. This problem occurs mainly with acids with higher boiling points (above 250°). The associated compounds decompose even at 180–200°. Highly polar liquid phases (*e.g.*, Carbowax 20M) also cause the decomposition of associated compounds. The support has a great influence on the extent of the separation of free acids achieved, and must be inert (PTFE, glass beads) or deactivated by the use of silanes and phosphoric acid[4].

The analysis of the esters has been studied thoroughly. Polyester liquid phases have been mentioned as being the most suitable for the analysis of esters[5,6]. The retention behaviour of the esters of saturated and unsaturated carboxylic acids on polar and non-polar liquid phases of the polysiloxane type (OV-1, OV-17, OV-25, OV-210, F-61, XE-60) has also been described[7,8].

Work has also been published on the analysis of the nitriles and amides of aliphatic carboxylic acids. The use of polyesters[9,10], polyglycols[11] and Apiezon L[12] has been recommended.

ARAD-TALMI *et al.*[9] discussed the possibility of the quantitative determination of the nitriles of several aliphatic carboxylic acids in aqueous solutions of hydrochloric acid on diethylene glycol adipate (DEGA) polyester with phosphoric acid.

EXPERIMENTAL

Preparation and physical properties of the methyl ester of 2-chloro-3-(4-chlorophenyl) propionic acid and other derivatives of the 2-chloro-3-(4-chlorophenyl)propionic acid

CPCPM (a colourless viscous liquid, boiling point 110–113° at 0.1 mm Hg; $n_D^{20} = 1.532$; $D_4^{20} = 1.273$ (ref. 1)) was prepared as follows. CPCPN (a colourless viscous liquid, boiling point 128–129° at 6 mm Hg (ref. 13); $n_D^{20} = 1.551$) was obtained by the reaction of *p*-chlorobenzenediazonium chloride with acrylonitrile in acetone with cupric chloride as catalyst[13]; subsequent hydrolysis of CPCPN with sulphuric acid gave 2-chloro-3-(4-chlorophenyl)propionic acid (CPCPA) (a white crystalline substance, melting point 103° (ref. 14)), and by esterification with methanol, CPCPM was obtained[15].

The amide of 2-chloro-3-(4-chlorophenyl)propionic acid (CPCPAm) (a white crystalline substance, melting point 90° (ref. 14)) was prepared by the hydrolysis of CPCPN with 85% sulphuric acid and by subsequent neutralization with sodium hydroxide[16].

The prepared substances were purified by distillation or crystallization from benzene. Their purity was controlled according to the physical constants and by GLC and paper chromatography (PC).

All the above compounds have good solubilities in acetone, diethyl ether and aromatic hydrocarbons.

Apparatus and chemicals

A Fractovap Model C gas chromatograph (Carlo Erba, Italy) was used, equipped with a flame ionization detector and a Speedomax Model G recorder (Leeds and Northrup, U.S.A.) with a range of 1 mV f.s.d. The chart speed was 38 cm/h. For the calculation of the surface area of the peaks a Model 72 integrator (Carlo Erba) was used.

The following standard preparations and chemicals were used: CPCPM, CPCPN, CPCPA, CPCPAm, *p*-chloroaniline, *p*-chlorophenol, *p*-dichlorobenzene, benzene, 2,3,4-trichloronitrobenzene and 2,4,5-trichloronitrobenzene.

The purity of these compounds was controlled by GLC and PC.

Operating conditions

Column A. A glass column, 80 × 0.3 cm, packed with 5% poly neopentyl glycol succinate (NPGS) + 1% phosphoric acid on Chromosorb W (60–80 mesh) was used. The column temperature was 220° and the injection temperature 230°. The gas pressures used were: carrier gas (nitrogen), 0.5 kp/cm^2; hydrogen, 0.3 kp/cm^2; and air, 1.5 kp/cm^2.

Column B. A glass column, 240 × 0.3 cm, packed with 1.5% NPGS + 0.5% phosphoric acid on Chromosorb W (60–80 mesh) was used. The column temperature was 200° and the injection temperature 230°. Flow-rates and gas pressures used were: carrier gas (nitrogen), 24 ml/min (200°) and 1.0 kp/cm^2; hydrogen, 65 ml/min and 0.5 kp/cm^2; and air, 320 ml/min and 1.0 kp/cm^2.

Column C. A glass column, 240 × 0.3 cm, packed with 1.5% NPGS + 0.5% phosphoric acid on Chromosorb W (60–80 mesh) was used. The column temperature was 185° and the injection temperature 230°. Flow-rates and gas pressures used were: carrier gas (nitrogen), 26 ml/min and 1.0 kp/cm^2; hydrogen, 65 ml/min and 0.5 kp/cm^2; and air, 320 ml/min and 1.0 kp/cm^2.

Qualitative analysis of CPCPM technical products

Column A was used for qualitative analysis. A 0.1 μl sample of CPCPM was injected directly (without weighing and dissolution) with a 10-μl Hamilton microsyringe. For identification, the particular peaks were compared with the peaks of the standards, which were recorded under the same operating conditions and were of approximately the same concentration (Fig. 1).

Quantitative analysis of CPCPM technical and formulated products (50% emulsifiable concentrates)

Column C and a method with an internal standard were used for quantitative analysis. About 150 mg of the sample and about 150 mg of 2,4,5-trichloronitrobenzene (internal standard) were weighed into a 2-ml glass flask, 0.7 ml of benzene was added, the contents were mixed and 0.5 μl of the solution was injected at an attenuation of 10–256.

The samples of the emulsifiable concentrates of CPCPM (50%) were analysed on column C under the same operating conditions as for the technical samples, except that a sample weight of about 300 mg was used. The peak surfaces were evaluated with an integrator.

Quantitative analysis of CPCPN technical products

Column B and a method with an internal standard were used for quantitative analysis. About 140 mg of 2,4,5-trichloronitrobenzene (internal standard) and 150–200 mg of the sample (according to the concentration) were weighed into a 2-ml glass flask and dissolved in 0.7 ml of benzene. A 0.5 μl volume of the solution was injected at an attenuation of 10–256.

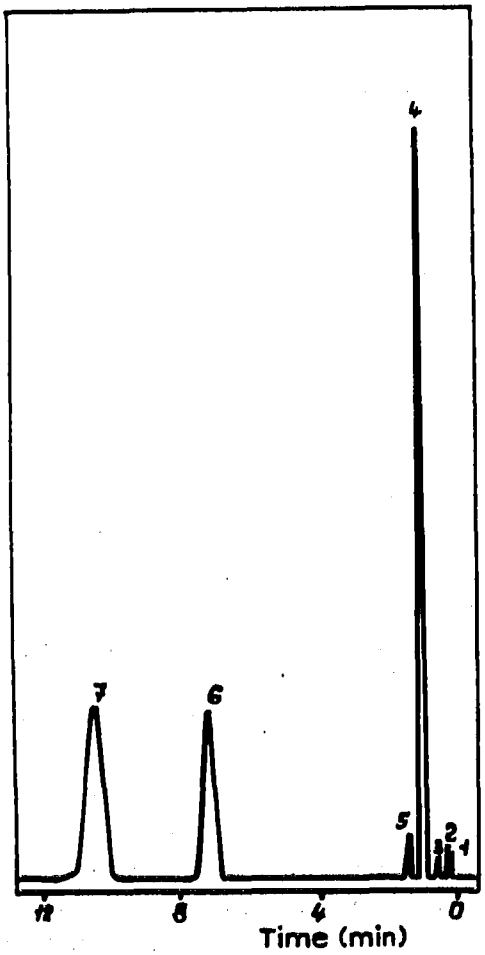

Fig. 1. Chromatogram of the synthetic mixture (column A). 1 = Benzene (1.40%); 2 = *p*-dichlorobenzene (1.60%); 3 = *p*-chloroaniline (1.00%); 4 = CPCPM (88.00%); 5 = CPCPN (4.50%); 6 = CPCPAm (1.50%); 7 = CPCPA (2.00%); (1–5 at attenuation 256, 6 and 7 at attenuation 4).

The precision and accuracy of the methods

The accuracy of the methods was verified by the analysis of the standard mixtures having compositions approximately the same as those of the analysed samples. The above procedures for CPCPM and CPCPN were followed. The precision was determined by the analysis of one sample and expressed by the standard deviation. The results are given in Table I.

TABLE I

PRECISION AND ACCURACY IN THE DETERMINATION OF CPCPM AND CPCPN

CPCPM			*CPCPN*		
Weighed (%)	*Found (%)*	*Relative error (%)*	*Weighed (%)*	*Found (%)*	*Relative error (%)*
50.98	51.51	+1.04	85.91	85.08	−0.96
89.42	90.47	+1.17	89.97	90.51	+0.60
98.90	99.36	+0.46	95.13	94.82	−0.33
s = 0.1662			s = 0.1533		

DISCUSSION AND CONCLUSIONS

Different liquid phases of the polyester type were tested, and the poly neopentyl glycol succinate phase was shown to be the most suitable on Chromosorb W with the addition of phosphoric acid for obtaining good distribution and symmetrical peaks.

The by-products in the preparations of GPCPM and CPCPN have different elution times, those for CPCPA and CPCPAm being substantially longer than those for the other compounds. Consequently, for the analysis of these two substances, the shorter column A was used, and for their quantitative evaluation the internal standard method with 4,5,6-trichloro-1,2-dinitrobenzene was used.

In the comparison of the results of the analyses of the technical products of CPCPM (content of active material about 85%) and CPCPN, obtained by GLC, IR spectroscopy and by the titrimetric method, conformity was obtained only between the results obtained by GLC and IR spectroscopy. The results obtained by the titrimetric method were higher by 5–7% on average. This anomaly can be explained only by the presence of other substances that contain hydrolyzable chlorine. In fact, by titimetry the total hydrolyzable chlorine is determined. With active material contents of about 97% (distilled products), there is no difference between the results obtained by GLC and by the titrimetric method. Similar discrepancies in the latter method have been found also in the analysis of the formulated products.

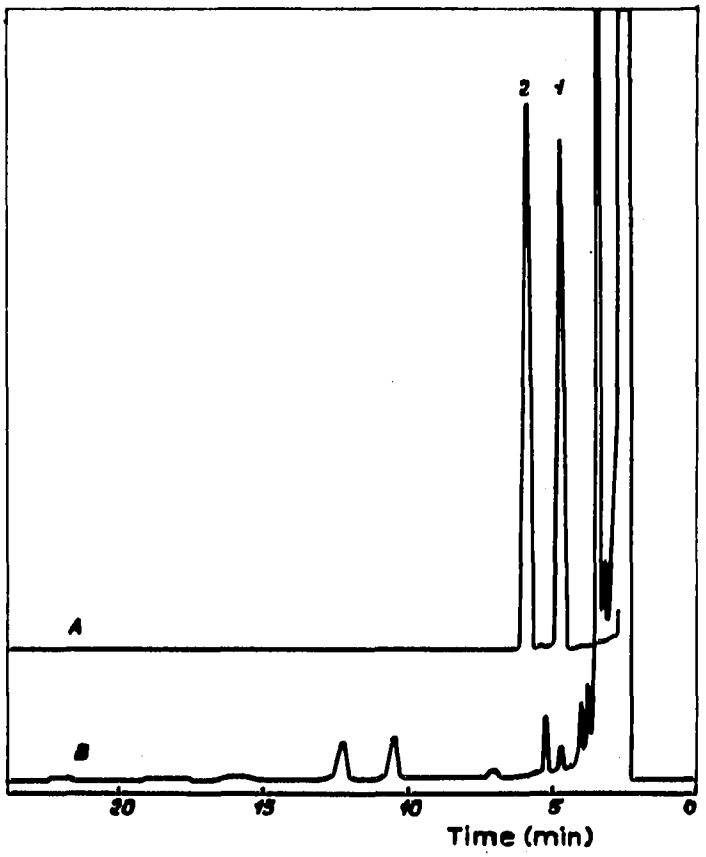

Fig. 2. (A) Chromatogram of the formulated sample of CPCPM (emulsifiable concentrate, 50%). 1 = Internal standard; 2 = CPCPM. (B) Chromatogram of a complete emulsifying mixture for preparing emulsifiable concentrate (column C).

The conditions for the determination of CPCPM in technical products are also suitable for the simultaneous quantitation of unreacted (free) CPCPN in the same sample and by the same internal standard.

It is possible to analyse the formulated CPCPM products under the same conditions as those for the technical products. This is possible because the emulsifiers and the solvents used for the final formulation do not interfere with the peaks of the internal standard or those of CPCPM and CPCPN (Fig. 2).

When choosing a suitable internal standard for the analysis of CPCPM and CPCPN, we tested also the ethyl, propyl and isopropyl esters of 2-chloro-3-(4-chlorophenyl)propionic acid. The results obtained were not satisfactory because of the insufficient purity of the compounds tested.

For the analysis of CPCPN, 2,3,4-trichloronitrobenzene, 4,5,6-trichloro-1,2-dinitrobenzene and hexachlorobenzene are also suitable as internal standards. Hexachlorobenzene is useful also for the analysis of CPCPM, but it is difficult to dissolve it in common solvents. It is most soluble in benzene. Benzoic acid methyl ester was also shown to be a very suitable internal standard for CPCPM.

The methods described for the determination of CPCPM and CPCPN are rapid, sufficiently precise and accurate, and are equally suitable for the intermediate analysis of technical products between two operations and for the analysis of formulated products without any prior isolation procedure being necessary.

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