Quantitative Determination of Polyethylene Glycols in Nonionic Surfactants by High Pressure Liquid Chromatography

L.P. TURNER, D. McCULLOUGH, and **A. JACKEWITZ,** Alcolac Inc., Baltimore, Mayland 21226

ABSTRACT

A method employing high pressure liquid chromatography has been developed for the quantitative determination of polyethylene glycols in ethoxylated fatty alcohols and alkylphenols. This technique overcomes many of the limitations encountered in previously-reported methods. The polyethylene glycols are separated from the ethoxylated product and other sample components using a 65/35 acetonitrile/water mobile phase and a Bondapak C_{18}/Corasil reverse-phase column system. The response factor of the differential refractometer detector is determined using Carbowax standards of appropriate molecular weights. The molecular weight of the polyethylene glycols in each sample is approximated using thin layer chromatography prior to the high pressure liquid chromatography calibration and analysis. The precision of this method for the determination of polyethylene glycols is ± 4% relative or better, and the recovery of added polyethylene glycols is quantitative. Application of this method to a wide variety of commercial ethoxylated fatty alcohols and alkylphenols is presented.

INTRODUCTION

The presence of glycols and polyglycols in nonionic surfactants is widely recognized. The level and nature of these components exert a significant influence upon the physicochemical and performance characteristics of the product mixture. Therefore, the quantitative determination of polyglycols in these products is of utmost importance. Methods reported for the quantitative determination of polyethylene glycols in nonionic surfactants include paper chromatography (1), adsorption chromatography (2), partition chromatography (3), gas chromatograpny (4,5), thin layer chromatography (6,7), solvent extraction (8), sedimentation (9,10), and organic analysis (11). The primary problems often encountered with these methods are long analysis time, lack of specificity, difficulty of quantitation, limited application, and poor precision and accuracy.

A method employing high pressure liquid chromatography (HPLC) has been developed for the quantitative determination of polyethylene glycols in ethoxylated fatty alcohols and alkylphenols. This technique overcomes many of the limitations encountered in previously-reported methods. The primary factors considered in the development of this method were adequate separation of the polyethylene glycols from other known product components, sensitivity, ease of calibration, consistency of detector response for polyethylene glycols having a wide molecular weight range, and ease of quantitation.

EXPERIMENTAL PROCEDURES

Ethoxylated Products

The ethoxylated fatty alcohols and alkylphenols used in this study were commercial products made by Alcolac Inc. (Baltimore, MD) or obtained from other sources. Those products made at Alcolac Inc. were made from commercially-available fatty alcohols or alkylphenols, which were ethoxylated without further purification. The approximate mole ratio of ethylene oxide to fatty alcohol or alkylphenol was determined by hydroxyl number and/or hydrogen iodide (HI) cleavage (12).

Thin Layer Chromatography (TLC)

TLC was used to estimate the molecular weight range of polyglycols present in each sample type analyzed. Developing-solvent mixtures employed were prepared from individual solvents which were reagent (ACS) grade or better. The chromatograms were obtained using silica gel plates (250-micron thickness) purchased from Brinkmann Instruments (Cantiague, NY), Analtech (Newark, DE) or Quantum Industries (Fairfield, NJ). The samples were spotted

[1] Presented at the Meeting of the American Oil Chemists' Society, April 1976, New Orleans.

TABLE I

Thin Layer Chromatography[a]
Determination of Polyethylene Glycol Molecular Weight

Product	Developing solvent	Plates (250-micron thickness)
Lauryl Alcohol + 12 EO	Acetone/Chloroform/Methanol 30/ 47/ 23	Silica Gel
Lauryl Alcohol + 50 EO	Chloroform/Methanol/Water 3/ 25/ 12	Silica Gel
	Butanol/Ethanol/Ammonia (aq.) 14/ 3/ 5	Silica Gel
Dodecyl Phenol + 40 EO Cetyl-Stearyl Alcohol + 40 EO	Acetone/Water/Ethyl Acetate 45/ 25/ 10	Silica Gel
Tridecyl Alcohol + 6 EO	Acetone/Chloroform/Methanol 30/ 47/ 23	Silica Gel
Octylphenol + 25-35 EO	Acetone/Water/Ethyl Acetate 45/ 25/ 10	Silica Gel
Octylphenol + 60 EO	Chloroform/Methanol/Water 3/ 25/ 12	Silica Gel

[a] All chromatograms visualized with iodine vapor.

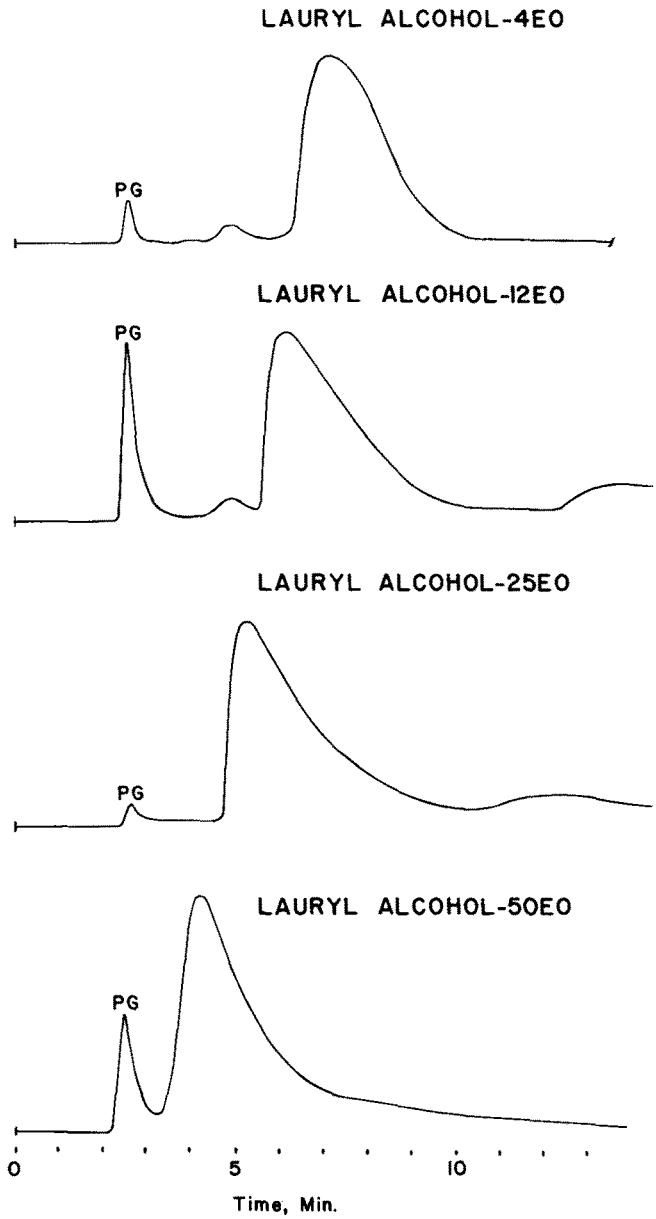

FIG. 1. Typical high pressure liquid chromatography chromatograms of lauryl alcohol ethoxylates. 4 ft x 2 mm Bondapak C_{18}/Corasil, 65/35 v/v acetonitrile/water, 1.0 ml/min.

from ca. 10% (w/v) methanol solutions, and the Carbowax standards (Union Carbide, New York, NY) were spotted from ca. 1% (w/v) methanol solutions on the same chromatographic plate. Conventional spotting techniques were employed.

After visualization of the developed chromatogram with iodine vapor, the molecular weight range of the polyglycols in the sample was estimated by comparison of the spot position of the polyglycols in the sample with those of known standards. This estimated polyglycol molecular weight was then used to calibrate the HPLC system for the quantitative determination of the polyglycol content in the sample as described later in this presentation. The TLC conditions employed are shown in Table I.

High Pressure Liquid Chromatography

A Waters model ALC 202 liquid chromatograph equipped with a M6000 pumping system and a Waters model 401 differential refractometer was employed. Also employed was a comparable instrument consisting of a Milton Roy model 709 pumping system (with pulse damp-

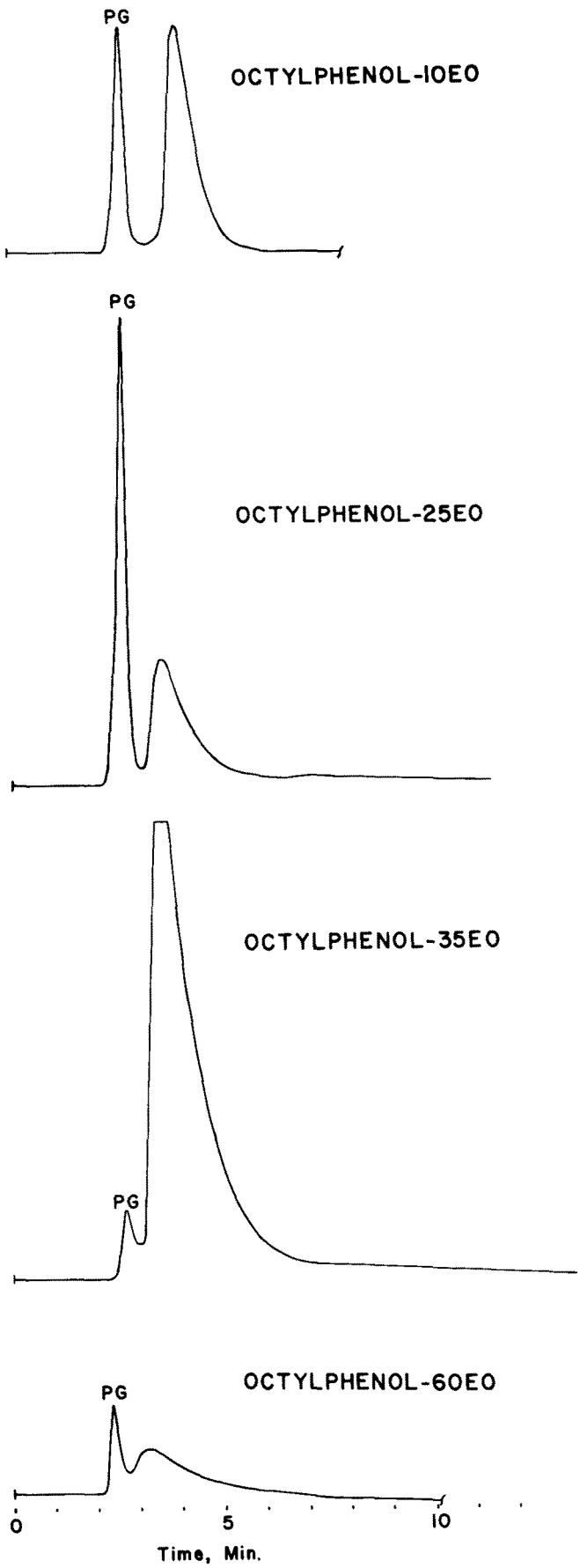

FIG. 2. Typical high pressure liquid chromatography chromatograms of octylphenol ethoxylates. Conditions same as in Figure 1, except 60/40 v/v acetonitrile/water mobile phase was used for octylphenol–60 EO.

TABLE II

High Pressure Liquid Chromatography Response Factors (Carbowax Standards)

Carbowax molecular weight	Response factor (arbitrary units)[a]
600	1.96
1450	1.97
1500	2.13
4000	2.13
6000	1.97
Average Response Factor: 2.03 ± 0.09	

[a]Differential Refractometer, 65/35 v/v Acetonitrile/Water Mobile Phase.

ener) and a Waters model 401 differential refractometer. The column system used with each instrument was two 2 ft x 2 mm inside diameter stainless steel columns each packed with Bondapak C_{18}/Corasil (Waters Associates, Milford, MA). A mixture of 65/35 v/v acetonitrile/water was used as the mobile phase. Acetonitrile was Mallinckrodt (St. Louis, MO) Nanograde (distilled in glass) and the water was deionized and distilled in glass. The mobile phase flow rate was 1.0 ml/min. This flow rate was verified by measuring the time required for the system to deliver a precise volume of mobile phase. Sample volumes of 10 microliters were injected, using either a 25-microliter Pressure Lok Syringe (Precision Sampling, Baton Rouge, LA) or a Valco six-port sampling valve equipped with a 10-microliter sampling loop. The chromatograms were recorded on a 10-millivolt recorder and the polyglycol peak areas were either hand calculated by triangulation or automatically computed with an Autolab System IV Integrator (Spectra-physics, Autolab Division, Santa Clara, CA).

Calibration and Analysis

The response factor (RF) of the HPLC system for the polyglycols present in the sample was first determined. A solution of the appropriate Carbowax standard (as determined by TLC) was accurately prepared using the mobile phase as the solvent. In cases where the estimated molecular weight of the polyglycols in the sample was found to be between those of two Carbowax standards, two such solutions were prepared for calibration, with an average interpolated response factor ($\overline{RF}$) determined. Ten microliters of the standard solution (or solutions) were injected in duplicate and chromatographed. The RF or $\overline{RF}$ was calculated as follows:

$$RF = \frac{\text{Weight \%* of Carbowax in Injected Solution}}{\text{Peak Area}}$$

$$\overline{RF} = \frac{RF\ \#1 + RF\ \#2}{2}$$

*or grams/milliliter

A solution of the sample was accurately prepared using the mobile phase as the solvent. Ten microliters of this solution was chromatographed in duplicate and the polyglycol content of the sample was calculated as follows:

$$\text{\% Polyglycols (w/w)} = \frac{\text{(Peak Area) (RF or } \overline{RF}\text{) (100)}}{\text{Weight \%* of Sample in Injected Solution}}$$

*or grams/milliliter

Both the standards and samples were melted (if necessary) and thoroughly mixed before preparation of the solutions to be injected. If the sample to be analyzed contains water, the sample must be dried prior to analysis. For best results the weight percents of standard(s) and sample in the injected solutions were adjusted so that the absolute amounts of injected polyglycols were nearly identical between standard(s) and sample. This procedure minimizes nonlinearity of system response and is possible only if the anticipated polyglycol level in the sample can be accurately approximated. Injection of the standard and sample solutions in duplicate confirms the validity of the run and serves to monitor the general condition of the chromatographic system.

RESULTS AND DISCUSSION

General Considerations

The chromatographic system employed was designed to separate the polyglycols and the ethoxylated products of a wide variety of fatty alcohols and alkylphenols. Polyglycols

TABLE III

High Pressure Liquid Chromatography Determination of Polyethylene Glycols in Nonionic Surfactants

Product	Range, %	Standard deviation, %	Relative standard deviation, %
Lauryl Alcohol + 12 EO	8 - 11	0.31	3.2
Lauryl Alcohol + 50 EO	6 - 15	0.36	3.9
Tridecyl Alcohol + 6 EO	0.3-0.4	0.01	2.8
Cetyl-Stearyl Alcohol + 40 EO	6 - 20	0.39	2.6
Octylphenol + 25 EO	7 - 20	0.40	3.0
Octylphenol + 35 EO	4 - 22	0.49	3.3
Octylphenol + 60 EO	11 - 19	0.25	1.6
Dodecylphenol + 40 EO	5 - 11	0.26	3.2

TABLE IV

Recovery
High Pressure Liquid Chromatography Determination of Polyethylene Glycols in Nonionic Surfactants

Product	% Polyethylene glycol added	% Polyethylene glycol found	% Recovery
Lauryl Alcohol + 50 EO	7.87[a]	8.14	103
Octylphenol + 35 EO	16.83[b]	15.77	94

[a]Mol wt ca. 4000.
[b]Mol wt ca. 1000.

are entirely hydrophilic, while the hydrophilicity of the ethoxylated products varies with the extent of ethoxylation. As the extent of ethoxylation increases, the ethoxylated product becomes more hydrophilic, due to the decreasing influence of the hydrophobic (fatty) portion of the molecule on its physical and chemical properties. Furthermore, the ethoxylated product consists of a mixture of molecules, each with a different degree of ethoxylation and a different chromatographic retention time.

The acetonitrile/water mobile phase and the Bondapak C_{18}/Corasil column were chosen to achieve this separation. The use of water enables the polyglycols to migrate readily through the column. The addition of acetonitrile to the mobile phase improves the sensitivity of the differential refractometer for the detection of polyglycols. The Bondapak C_{18}/Corasil is a pellicular packing (particle size 37-50 microns) prepared by the chemical bonding of octadecyltrichlorosilane to a rigid, spherical core of silica gel. The octadecyl group retards the migration of the ethoxylated product relative to the polyglycols. Figures 1 and 2 illustrate typical separations obtained for commercial lauryl alcohol and octylphenol ethoxylates, respectively. The retention time of the polyglycols is constant, while the retention times of the ethoxylated products relative to that of the polyglycols decrease as the extent of ethoxylation increases in each series. In each chromatogram the ethoxylated product is the major component eluting after the polyglycols. The lauryl alcohol used to produce the lauryl ethoxylates is a commercial blend of C_{12}, C_{14}, and C_{16} alcohols. This alkyl distribution contributes to the broadness of the ethoxylate peaks in this series. The octylphenol −60 EO ethoxylate does not readily separate from the polyglycols using the 65/35 acetonitrile/water mobile phase. Adjusting the mobile phase to 60/40 acetonitrile/water achieves the separation shown in Figure 2.

The invariant polyglycol retention time obtained for all the products studied is due to the use of water in the mobile phase. The rapid elution of the polyglycols in the molecular weight range of ca. 600-6000 results in a single chromatographic peak, which facilitates the quantitative determination of polyglycols in these products.

Response Factors vs. Molecular Weight

Table II shows the system response factors obtained for the Carbowax standards employed. Even though the response factor varies somewhat in the Carbowax molecular weight range of 600-6000, the standard deviation of the response factor in this range is less than 5% relative. This indicates that the same response factor may be used to determine polyglycols in the molecular weight range of 600-6000 with a maximum of 5% relative error. However, maximum accuracy is achieved through determination of the polyglycol molecular weight (TLC), followed by the determination of the system response factor using the Carbowax standard appropriate for the sample analyzed. If the source of starting materials and reaction conditions are invariant for a particular type of ethoxylated product, the polyglycol molecular weight, and thus the response factor, will be invariant for each sample of that product analyzed. Without the TLC analysis, the total analysis time is less than 1 hr.

Precision and Accuracy

Table III shows some typical products analyzed and the range of polyglycol content and precision obtained for each product. The products listed represent materials produced both in laboratory and in large-scale production facilities. In some cases, products were obtained from other commercial sources. The exact polyglycol content for a given product was found to depend upon initial moisture content of the starting material, the extent of ethoxylation, the ethoxylation conditions, the source of the product, and the anticipated product use(s). The relative standard deviation of this method is 4% or less for each product studied.

The accuracy of the method was determined by the analysis of a selected product, followed by the addition of a known amount of a Carbowax standard and re-analysis. Table IV shows typical results for the recovery of polyglycols in two different commercial products. The data represent recovery experiments showing the effect of sample type, percent polyglycol added, and the molecular weight of polyglycol added. The average recovery shown is 98.5%, which is quantitative within the precision of the method.

REFERENCES

1. Ginn, E., C.L. Church, Jr., and J.C. Harris, Anal. Chem. 33:143 (1961).
2. Voogt, P., "Program of the International Congress on Surface-Active Agents IV," Vol. 1, pp. 399-411, Brussels, Sept., 1964.
3. Koniski, K. and S. Yamaguchi, Anal. Chem. 40:1720 (1968).
4. Tornquist, J., Acta Chem. Scand. 21:2095 (1967).
5. Horbatch, W., Ph.D. Dissertation, Univ. of Detroit, 1975.
6. Obruda, J., Coll. Czech. Chem. Comm. 27:2968 (1962).
7. Walczyk, C., M. Jaworski, and H. Szewczyk, Chemia Anal. 16:775 (1971).
8. Weibull, B., "Program of the International Congress on Surface-Active Agents III," Vol. 3, pp. 121-124, Cologne, 1960.
9. Burger, K., Z. Anal. Chem. 196:251 (1963).
10. Burger, K., Ibid. 199:434 (1964).
11. Elworthy, P., J. Pharm. Pharmacol. 15:216 (1963).
12. Rosen, M.J., and H.A. Goldsmith, "Systematic Analysis of Surface-Active Agents," 2nd Edition, Wiley-Interscience, New York, 1972, pp. 336-337, 360-362.

[Received June 9, 1976]