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Biocidal Activity of the Esterification Products of Polyfluoroalkyl Alcohols and Pentafluorophenol with Resin Acids

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Abstract—Esterification products of polyfluoroalkyl alcohols and pentafluorophenol with resin acids were synthesized and tested for bactericidal activity against *Bacillus mucilaginosus* and *Bacillus coagulans* and fungicidal activity against *Aspergillus niger*, *Aspergillus terreus*, *Alternaria alternata*, *Trichoderma viride*, *Rhizopus oryzae*, *Rhizopus nigricans*, *Mucor mucedo*, *Penicillium funiculosum*, *Penicillium ochro-chloron*, and *Botrytis cinerea*.

Keywords: Resin acids, polyfluoroalkyl esters, bactericidal activity, fungicidal activity.

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INTRODUCTION

In view of increase in hydrocarbon price, additional impetus has been given to studies directed toward integrated utilization of plant raw materials. For example, wood rosin and tall oil rosin are abundant sources of tricyclic carboxylic acids and are therefore promising from the viewpoint of synthesis of new biologically active compounds.

Esterification is a possible way of rosin modification. Depending on the initial rosin type and alcohol nature, the esterification products attract interest as materials for the manufacture of environmentally safe synthetic resins, ester plasticizers, hot melt adhesives, lacquers, paints, and food container adhesives [1]. Taking into account that compounds containing long-chain fluoroalkyl groups possess surfactant properties [2], esters derived from rosin and fluorinated alcohols may be expected to act as good film-forming agents in the manufacture of paint-and-lacquer materials, as well as adhesive additives.

Specific structure of resin acids makes them valuable starting compounds for the synthesis of various biologically active substances. A number of pharmacologically active abietane diterpenoids were synthesized on the basis of resin acids. For example, dehydroabietic acid and their derivatives were found to exhibit antiphlogistic, spasmolytic, sedative, antitumor, immunomodulating, adaptogenic, antiulcer, and antioxidant activity [3–5].

Many authors have shown that resin acids and their derivatives are capable of acting as insecticides, fungicides, and bactericides. Dehydroabietic acid (DAA) at a concentration of 39.7 μg/mL inhibited the growth of *Aspergillus terreus*. Derivatives of dehydroabietic acid were active against *A. fumigates* and *A. niger*, the minimum inhibitory concentrations being 50 and 63 μg/mL, respectively [3]. Bardyshev et al. [6] studied biological properties of resin acid salts with amines and found that abietic acid diethylammonium and morpholinium salts exhibited a considerable stimulating activity and accelerated metabolism. Abietic acid ammonium salt inhibited the growth of *Botrytis cinereae* and *Fusarium moniliforme* by 67 and 53%, respectively. Resin acids isolated from the bark of *Buddleja globosa* were active against the

dermatophytes *Trichophyton rubrum* and *Epidermophyton floccosum*. 11,12-Dihydroxyabieta-8,11,13-triene derivatives obtained from dehydroabietic acid displayed a high activity against *Microsporium canis* and *Trichophyton mentagrophytes*.

Pisiferic acid and its derivatives are active against *Proteus vulgaris*, *Staphylococcus aureus*, and *Bacillus subtilis*. Quinones showed a high activity toward *S. aureus*. Plants of the genus *Salvia* (sage) produce metabolites of the abietane series, some of which were found to act as antitubercular agents and bactericides against beta-hemolytic streptococcus.

Antimicrobial activity of resin acids originates from the presence in their molecules of hydroxy, aldehyde, ketone, and other functional groups and is determined by their configuration (*cis* or *trans*). The presence of carboxy and hydroxy groups is in important factor responsible for the activity of resin acids isolated from cypress against gram positive bacteria. Alkylation of the phenolic hydroxyl favors enhanced antimicrobial activity, and its magnitude is related to the alkyl chain length. However, replacement of the carboxy group by CH_3, CHO, CHOH, or CHOR does not increase antibacterial activity [3]. Oxidized dehydroabietic acid showed a stronger antifungal effect as compared to abietic, levopimaric, and palustric acids.

Various resin acid preparations may find wide application for protection of commercial products from biodeterioration, conservation of wood varieties, and modification of paint-and-lacquer materials [7]. Esters derived from resin acids and fluorine-containing alcohols [8–11] may also be valuable products, in particular as biocides for protection of construction materials from biodeterioration.

The goal of the present work was to synthesize esters from resin acids, on the one hand, and polyfluoroalkyl alcohols and pentafluorophenol, on the other, and test the products for bactericidal and fungicidal activity.

EXPERIMENTAL

As starting compounds we used wood rosin (GOST 18–12345) and telomer alcohols, 2,2,2-trifluoroethanol, 2,2,3,3-tetrafluoropropan-1-ol, 1*H*,1*H*,5*H*-octafluoropentan-1-ol, 1*H*,1*H*,7*H*-dodecafluoroheptan-1-ol, and 1*H*,1*H*,9*H*-hexadecafluorononan-1-ol.

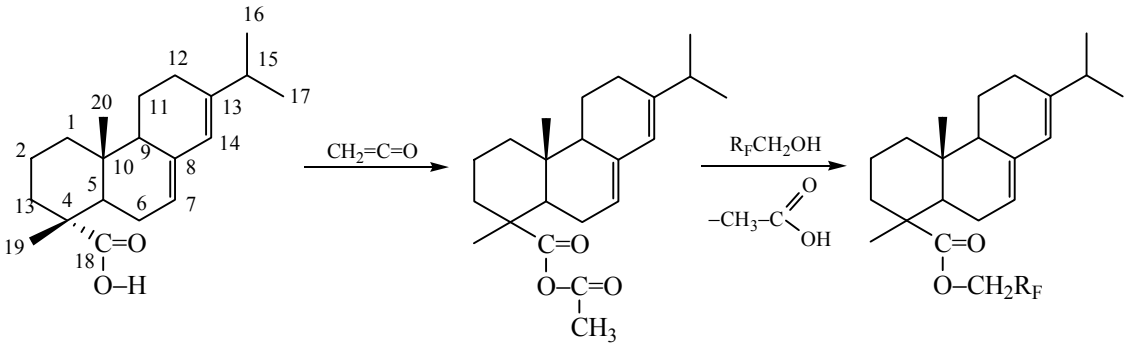
The IR spectra were recorded on a Shimadzu IR Prestige-2 instrument from solutions in carbon tetrachloride placed between KBr plates. The UV spectra of solutions in ethanol with a concentration of 10^{-4} M were measured on an SF-2000 spectrophotometer (cell path length 1 cm). The ^{1}H and ^{19}F NMR spectra were obtained on a Bruker 500 spectrometer at 500 MHz for ^{1}H and 470 MHz for ^{19}F using $CDCl_3$ as solvent and CCl_3F as external reference for ^{19}F. The progress of reactions and the purity of the initial compounds and products were monitored by TLC on Sorbfil plates using hexane–methylene chloride–acetone (1 : 1 : 0.5) as eluent. Solvents were purified according to standard procedures [8].

Isolation of abietic acid (I) from wood rosin [9]**.** Wood rosin, 25 g, was dissolved in 75 mL of ethanol, 5 mL of concentrated aqueous HCl was added, and the mixture was heated for 2 h at 80°C. The solvent was distilled off, the residue was washed with water, and the isomerized rosin was dissolved in diethyl ether. The ether extract was dried over $MgSO_4$, 8 mL of diethylamine was added to the solution, and the precipitate of abietic acid diethylammonium salt was filtered off and recrystallized twice from petroleum ether. The pure salt was treated with acetic acid, and abietic acid thus formed was recrystallized from ethanol. Yield 40%, mp 170–172°C. IR spectrum, ν, cm^{-1}: 1694 (C=O), 2936 (C–H), 3418 (O–H). UV spectrum: λ 242 nm (log ε 4.02). ^{1}H NMR spectrum, δ, ppm: 0.86 ($C^{20}H_3$), 1.01 and 1.02 ($C^{16}H_3$, $C^{17}H_3$), 1.26 ($C^{19}H_3$), 2.24 m (15-H, J = 6.89 Hz), 5.36 (7-H), 5.78 (14-H). Iodine number 173, acid number 183.

2,2,2-Trifluoroethanol was dried over NaX zeolite and then distilled. IR spectrum, ν, cm^{-1}: 947–1160 (C–F), 2963 (C–H), 3363 (O–H). ^{1}H NMR spectrum, δ, ppm: 3.4 (OH), 3.92 q (1H, CH_2, J = 8.4 Hz), 3.86 q (1H, CH_2, J = 9.2 Hz), 5.16 (OH). ^{19}F NMR spectrum: δ_F –76.35 ppm, t (CF_3, J = 8.5 Hz).

2,2,3,3-Tetrafluoropropan-1-ol (telomer, *n* = 1) was distilled once under atmospheric pressure, a fraction boiling at 120–121°C being collected. IR spectrum, ν, cm^{-1}: 1107 (C–F), 2959 (C–H), 3387 (O–H). ^{1}H NMR spectrum, δ, ppm: 2.59 (OH), 3.98 t.t (1H, CH_2, J = 13.5, 1.6 Hz), 5.93 t.t. (1H, CF_2H, J = 53.2, 4.3 Hz). ^{19}F NMR spectrum, δ_F, ppm: –127 t (2-F, J = 12.7 Hz), –138.80 d (3-F, J = 53.86 Hz).

1*H*,1*H*,5*H*-Octafluoropentan-1-ol (telomer, *n* = 2) was distilled once under atmospheric pressure, a fraction boiling at 140–142°C being collected. IR spectrum, ν, cm^{-1}: 1171 (C–F), 2953 (C–H), 3402 (O–H). ^{1}H NMR spectrum, δ, ppm: 3.03 t (CH_2, J = 14.28 Hz),



I **II**

R_F: CF_3 (**III**)
CF_2CF_2H (**IV**)
$(CF_2CF_2)_2H$ (**V**)
$(CF_2CF_2)_3H$ (**VI**)
$(CF_2CF_2)_4H$ (**VII**)

III, $R_F = CF_3$; **IV**, $R_F = CHF_2CF_2$; **V**, $R_F = H(CF_2CF_2)_2$; **VI**, $R_F = H(CF_2CF_2)_3$; **VII**, $R_F = H(CF_2CF_2)_4$.

3.75 (OH), 4.99 t.t (CF_2H, J = 51.69, 4.92 Hz). ^{19}F NMR spectrum, δ_F, ppm:–119.09 m (2-F), –122.07 (3-F), –126.83 (4-F), –134.34 d (5-F, J = 53.86 Hz).

1*H*,1*H*,7*H*-Dodecafluoroheptan-1-ol (telomer, *n* = 3) was distilled once under reduced pressure, a fraction boiling at 140–142°C (5 mm) being collected. IR spectrum, ν, cm^{-1}: 1200 (C–F), 2951 (C–H), 3388 (O–H). ^1H NMR spectrum, δ, ppm: 4.11 t (CH_2, J = 14.8 Hz), 5.2 (OH), 6.6 t.t (CF_2H, J = 51.2, 5.4 Hz). ^{19}F NMR spectrum, δ_F, ppm:–121.5 m (2-F, 3-F), –122.9 and –123 (4-F, 5-F), –129.3 (6-F), –137.75 d (7-F, J = 49.6 Hz).

1*H*,1*H*,9*H*-Hexadecafluorononan-1-ol (telomer, *n* = 4) was dried in a vacuum desiccator over $CaCl_2$, IR spectrum, ν, cm^{-1}: 1200 (C–F), 2959 (C–H), 3387 (O–H). ^1H NMR spectrum, δ, ppm: 4.17 m (CH_2, J = 7.29 Hz), 5.21 t (OH, J = 6.89 Hz), 6.90 t.t (CF_2H, J = 50.7, 4.92 Hz). ^{19}F NMR spectrum, δ_F, ppm: –120.77, –121.07, –122.29, –122.43, –128.52 (2-F, 3-F, 4-F, 5-F, 6-F, 7-F, 8-F); –137.55 d (9-F, J = 51.5 Hz).

Generation of ketene CH_2=C=O [14]**.** Ketene was generated according to Williams and Hurd. A still flask was charged with a required amount of acetone, the setup was filled with an inert gas (argon), and the still flask was heated so that to maintain acetone smoothly boiling. Acetone valor contacted with a red-hot tungsten filament and underwent pyrolysis to produce ketene which passed through a reflux condenser into a reactor. The yield of ketene attained 90%.

Abietic acetic anhydride (II) [10]**.** A solution of 5.0 g (17 mmol) of abietic acid in 50 mL of diethyl ether was cooled with ice, and gaseous ketene was bubbled through the solution until persistent yellow color (reaction time ~1 h, TLC). When the reaction was complete, the solvent was removed under reduced pressure to isolate anhydride **II** as a yellow oily substance (yield quantitative). IR spectrum, ν, cm^{-1}: 1737 and 1808 (C=O), 2937 (C–H). ^1H NMR spectrum, δ, ppm: 0.88 ($C^{20}H_3$), 1.04 and 1.05 ($C^{16}H_3$, $C^{17}H_3$), 1.32 ($C^{19}H_3$), 2.23 [$C(O)CH_3$], 2.25 m (15-H, J = 6.9 Hz), 5.37 (7-H), 5.8 (14-H).

Reaction of abietic acetic anhydride with 2,2,2-trifluoroethanol. Abietic acetic anhydride prepared from 5.0 g (17 mmol) of abietic acid was dissolved in 30 mL of hexane, 3.43 g (35 mmol) of 2,2,2-trifluoroethanol and a few drops of concentrated sulfuric acid were added, and the mixture was heated for 6 h under reflux. When the reaction was complete (TLC), the mixture was cooled, washed with cold water, a 15% solution of $NaHCO_3$, and water again to pH 7, dried over $MgSO_4$, and evaporated under reduced pressure. The residue was 2,2,2-trifluoroethyl abietate (**III**) as a brown transparent tarry material. Yield 75%, softening point 55°C. IR spectrum, ν, cm^{-1}: 1082–1167 (C–F), 1692 (C=O), 2917 (C–H). ^1H NMR spectrum, δ, ppm: 0.86 ($C^{20}H_3$), 1.01 and 1.03 ($C^{16}H_3$, $C^{17}H_3$), 1.26 ($C^{19}H_3$), 2.24 (15-H), 4.67 q (OCH_2, J = 8.5 Hz), 5.35 (7-H); dehydroabietate: 5.78 (14-H), 6.89 s (14-H), 7.01 d and 7.19 d (11-H, 12-H). ^{19}F NMR spectrum: δ_F –72.33 ppm, t (CF_3, J = 9.5 Hz).

Compounds **IV**–**VII** were synthesized in a similar way.

2,2,3,3-Tetrafluoropropyl abietate (IV). Yield 80%, yellow amorphous powder. softening point ~70°C. IR spectrum, ν, cm^{-1}: 1109 (C–F), 1694 (C=O), 2937 (C–H). ^1H NMR spectrum, δ, ppm: 0.86 ($C^{20}H_3$), 1.01 and 1.03 ($C^{16}H_3$, $C^{17}H_3$), 1.27 ($C^{19}H_3$), 2.24 (15-H), 4.59 m (OCH_2, J = 12.8 Hz), 5.36 (7-H), 5.78 (14-H), 6.39 t.t (CF_2H, J = 53.4 Hz); dehydroabietate: 6.89 s (14-H), 7.01 d and 7.18 d (11-H, 12-H). ^{19}F NMR spectrum, δ_F, ppm: –140.02 d (3′-F, J = 53.4 Hz), –124.5 t (2′-F, J = 12.8 Hz).

1*H*,1*H*,5*H*-Octafluoropentyl abietate (V). Yield 85%, yellow–brown amorphous substance. IR spectrum, ν, cm^{-1}: 1173 (C–F), 1693 (C=O), 2941 (C–H). ^1H NMR spectrum, δ, ppm: 0.85 ($C^{20}H_3$), 1.01 and 1.02 ($C^{16}H_3$, $C^{17}H_3$), 1.26 ($C^{19}H_3$), 2.23 m (15-H, J = 6.64 Hz), 2.86 (??), 4.12 t and 4.75 t (1H each, OCH_2, J = 14.8 Hz), 5.36 (7-H), 5.77 (14-H), 6.71 t.t and 6.75 t.t (CF_2H, J = 51.2, 5.91 Hz); dehydroabietate: 6.88 s (14-H), 7.01 d and 7.20 d (11-H, 12-H). ^{19}F NMR spectrum, δ_F, ppm: –137.56 d (CF_2H, J = 45.78 Hz); –129.62, –129.21, –124.81, –124.37, –121.11 m (J = 12.88 Hz), –118.83.

1*H*,1*H*,7*H*-Dodecafluoroheptyl abietate (VI). Yield 80%, brown tarry substance. IR spectrum, ν, cm^{-1}: 1200 (C–F), 1695 (C=O), 2934 (C–H). ^1H NMR spectrum, δ, ppm: 0.85 ($C^{20}H_3$), 1.01 and 1.03 ($C^{16}H_3$, $C^{17}H_3$), 1.20, 1.22, 1.26 ($C^{19}H_3$), 2.24 (15-H), 2.86, 4.79 t (OCH_2, J = 14.3 Hz), 5.36 (7-H), 5.78 (14-H), 6.87 t.t (CF_2H, J = 50.7, 5.17 Hz); dehydroabietate: 6.89 (14-H), 7.01 and 7.19 (11-H, 12-H). ^{19}F NMR spectrum, δ_F, ppm: –137.51 d (J = 49.59 Hz), –128.65, –122.49, –121.31, –118.53 m (J = 12.86 Hz).

1*H*,1*H*,9*H*-Hexadecafluorononyl abietate (VII). Yield 80%, brown tarry substance. IR spectrum, ν, cm^{-1}: 1214 (C–F), 1693 (C=O), 2932 (C–H). ^1H NMR spectrum, δ, ppm: 0.86 ($C^{20}H_3$), 1.01 and 1.03 ($C^{16}H_3$, $C^{17}H_3$), 1.26 ($C^{19}H_3$), 2.23 (15-H), 2.86, 4.80 t (OCH_2, J = 14.3 Hz), 5.37 (7-H), 5.78 (14-H), 6.91 t.t (CF_2H, J = 50.2, 5.4 Hz); dehydroabietate: 7.02 and 7.19 (11-H, 12-H). ^{19}F NMR spectrum, δ_F, ppm: –137.55 d (J = 51.5 Hz), –128.5, –122.32, –121.04, –118.48.

We synthesized esters of abietic and dehydroabietic acids with fluorinated telomer alcohols (n = 1–4) and pentafluorophenol [11–14]. Polyfluoroalkyl esters were prepared by reaction of resin acids [8] or acid chlorides with sodium alkoxides [10], as well as by reaction of tall oil rosin with telomer alcohols (n = 2–4; 150°C, 6 h) [10]. Some abietic acid esters with polyfluoroalkyl alcohols were also obtained by another method, via reaction of abietic acetic anhydride with polyfluoroalkanols. Abietic acetic anhydride (**II**) was synthesized by treatment of abietic acid (**I**) with gasoues ketene under mild conditions (diethyl ether, 0°C) [14].

The reactions of anhydride **II** with fluorinated telomer alcohols CF_3CH_2OH, $H(CF_2CF_2)_n{\cdot}CH_2OH$ (n = 1–4) were carried out under acid catalysis (in the presence of H_2SO_4) on heating for 6 h in boiling hexane, and the corresponding polyfluoroalkyl esters **III**–**VII** were isolated in 75–85% yield. The progress of reactions was monitored by TLC.

The reaction of abietic acid with gaseous ketene in diethyl ether gave a compound whose ^1H NMR spectrum contained signals typical of methyl protons in the abietane fragment at δ 0.88 ($C^{20}H_3$), 1.04 and 1.05 ($C^{16}H_3$, $C^{17}H_3$), and 1.32 ppm ($C^{19}H_3$). The 15-H proton in the isopropyl group resonated as a multiplet signal at δ 2.25 ppm (J = 6.9 Hz). The presence of signals at δ 5.37 (7-H) and 5.8 ppm (14-H) indicated conservation of the number and position of double bonds. Protons in the acetyl group gave a singlet at δ 2.23 ppm. In the IR spectrum of **II** we observed absorption bands at 1737 and 1808 cm^{-1} typical of anhydride moiety. These findings allowed us to assign the structure of abietic acetic anhydride (**II**) to the isolated compound.

Esters **III**, **IV**, **VI**, and **VII** displayed in the ^1H NMR spectra multiplet signals from the OCH_2 protons in the fluorinated alkyl groups, δ, ppm: **III**, 4.67 q (J = 8.5 Hz); **IV**, 4.59 m (J = 12.8 Hz); **VI**, 4.79 t (J = 14.3 Hz); **VII**, 4.80 t (J = 14.3 Hz). It should be noted that the corresponding protons in **V** gave rise to two triplets at δ 4.12 and 4.5 ppm with equal coupling constants (J = 14.8 Hz).

Analogous pattern was observed for the terminal proton in the fluoroalkyl residue. In the ^1H NMR spectrum of **V**, the CF_2H signal appeared as two triplets at δ 6.71 and 6.75 ppm with equal ^1H–^{19}F coupling constants through two and three bonds, 51.3 and 5.91 Hz. In the spectra of **IV**, **VI**, and **VII**, the corresponding signals were triplets of triplets located at δ 6.39 (J = 53.4 Hz), 6.87 (J = 50.7, 5.17 Hz), and 6.91 ppm (distorted, J = 50.2, 5.4 Hz), respectively.

The reaction of abietic acetic anhydride with fluorinated alcohols was accompanied by disproportionation of the diterpene moiety with formation of the corresponding dehydroabietic acid esters, as followed

Tabe 1. Compounds tested for biocidal activity and their concentrations

Run no.	Compound	Concentration, wt %	Method of synthesis
SK-1	Wood rosin	0.14	–
SK-2	Tall oil rosin	0.10	–
SK-3	2,2,2-Trifluoroethyl abietate (sort 2)	0.08	[10]
SK-4	2,2,2-Trifluoroethyl abietate (sort 1)	0.13	This work
SK-5	2,2,3,3-Tetrafluoropropyl abietate (sort 1)	0.10	This work
SK-6	2,2,3,3-Tetrafluoropropyl abietate (sort 2)	0.12	[10]
SK-7	1*H*,1*H*,5*H*-Octafluoropentyl abietate	0.11	This work
SK-8	1*H*,1*H*,5*H*-Octafluoropentyl dehydroabietate	0.10	[8]
SK-9	Abietic acid	0.11	This work
IO-1	Pentafluorophenyl abietate	1.99	[9]
IO-2	1*H*,1*H*,9*H*-Hexadecafluorononyl abietate	1.25	[9]
IO-3	1*H*,1*H*,7*H*-Dodecafluoroheptyl abietate	2.47	[9]
IO-4	1*H*,1*H*,7*H*-Dodecafluoroheptyl dehydroabietate	2.23	This work
IO-5	1*H*,1*H*,9*H*-Hexadecafluorononyl dehydroabietate (sort 1)	2.59	[9]
IO-6	1*H*,1*H*,9*H*-Hexadecafluorononyl dehydroabietate (sort 2)	2.59	This work
IO-7	Pentafluorophenyl dehydroabietate	1.00	[9]

from the presence of signals at δ 6.89 (s, 14-H), 7.01 (d), and 7.18 ppm (d) (11-H, 12-H). In the reactions with 2,2,2-trifluoroethanol and 2,2,3,3-tetrafluoropropan-1-ol, the contribution of the disproportionation process was insignificant (~5%), whereas compounds **VI** and **VII** contained up to 75% of the dehydroabietic acid derivative.

The ^{19}F NMR spectra of compounds **III**–**VII** were consistent with the assumed structures. The products were isolated as yellow to brown viscous glassy transparent materials.

Biocidal Activity of the Synthesized Compounds

As test cultures for the evaluation of bactericidal and fungicidal activity of the synthesized compounds we used bacterial strains *Bacillus mucilaginosus* and *Bacillus coagulans* and micromycetes *Aspergillus niger*, *Aspergillus terreus*, *Alternaria alternata*, *Trichoderma viride*, *Rhizopus oryzae*, *Rhizopus nigricans*, *Mucor mucedo*, *Penicillium funiculosum*, *Penicillium ochro-chloron*, and *Botrytis cinerea* from the collection of microorganisms at the Technology of Microbiological Synthesis Department of the St. Petersburg State Institute of Technology.

Samples of SK-1–SK-9 were dissolved in petroleum ether, and IO-1–IO-7, in ethanol. Fungicidal activity was assessed by the disk or well diffusion method in Petri dishes charged with the Czapek-Dox or wort agar medium. The inhibition zone diameter was measured after incubation for 7 days at 28°C.

To develop recommendations for practical use of one or another bioactive agent, it is necessary to known its minimum concentrations at which it exerts inhibitory or biocide effect. The minimum inhibitory concentration (MIC) and minimum biocidal concentrations (MBC) of the compounds under study were determined by serial dilution and subsequent inoculation first in liquid and then in solid nutrient medium.

Antibacterial activity was estimated by the well diffusion method in a medium containing sprat hydrolyzate. The inhibition zone was measured after incubation for 24 h at 28°C.

Tabe 2. Antibacterial activity of SK-1–SK-9 and IO-1–IO-7 (inhibition zone diameter, mm)

Comp. no.	*B. mucilaginosus*	Comp. no.	*B. mucilaginosus*	*B. coagulans*
SK-1	19.3±6.3	IO-1	9.8±0.3	12.5±1.0
SK-2	17.8±5.3	IO-2	9.2±0.2	12.5±1.5
SK-3	0	IO-3	9.8±0.3	13.5±1.5
SK-4	10.8±2.2	IO-4	8.9±0.4	10.9±1.1
SK-5	10.5±1.5	IO-5	8.9±0.3	12.8±1.8
SK-6	9.5±0.5	IO-6	10.3±0.3	16.0±2.5
SK-7	11.7±4.5	IO-7	9.1±0.4	11.3±1.3
SK-8	20.8±8.7			
SK-9	19.8±10.8			

As follows from the data in Table 2, all compounds, except for SK-3, inhibited the growth of *B. mucilaginosus*. The highest antibacterial effect was observed for SK-1 SK-2, SK-8, and SK-9. All compounds displayed a moderate activity against *B. coagulans*.

None of compounds of the SK series showed pronounced antifungal effect toward *T. viride* or *B. cinerea*. Such fungal strains as *A. niger*, *A. terreus*, *R. oryzae*, *M. mucedo*, and *P. funiculosum* turned out to be tolerant to compounds of the IO series. However, IO-4, IO-5, and IO-6 were active against *A. alternata*, IO-7 was active against *A. terreus*, IO-1 and IO-7 were active against *R. nigricans*, IO-2, IO-4, and IO-6 were active against *P. ochro-chloron*, and IO-1, IO-2, and IO-6 were active against *B. cinerea*. Table 3 contains the minimum biocidal concentrations of fungicides of the IO series with respect to the most sensitive test cultures. These data indicate that IO-5 is the most active against *A. alternata*; IO-7 is the most active against *R. nigricans*, and IO-2 is the most active against *P. ochro-chloron*.

CONCLUSIONS

(1) Abietic (dehydroabietic) acid polyfluoroalkyl esters have been synthesized in 75–85% yield by acid-catalyzed reaction of abietic acetic anhydride with the corresponding polyfluorinated telomer alcohols (n = 1–4).

(2) Resin acid preparations (16 samples) have been tested for fungicidal activity in 10 fungal strains and for bactericidal activity against two bacterial strains. Among 9 preparations of the SK series, eight showed bactericidal activity against *B. mucilaginosus*, and only one preparation of the IO series (IO-3) turned out to be inactive.

(3) Preparations of the SK series are inactive toward the fungi *T. viride* and *B. cinerea*. *Alternaria alternata* is most sensitive to IO-4, IO-5, and IO-6; *A. terreus* is most sensitive to IO-7; *R. nigricans* is most sensitive to IO-1 and IO-7; *P. ochro-chloron* is most sensitive to IO-2, IO-4, and IO-6; and *B. cinerea* is most sensitive to IO-1, IO-2, and IO-6.

(4) The minimum biocidal concentrations are as follows: 0.0125% IO-2, 0.1% IO-4, and 0.5% IO-6 for *P. ochro-chloron*; 0.5% IO-4, 0.01% IO-5, and 0.5% IO-6 for *A. alternata*; and 0.1% IO-5 for *T. viride*.

Table 3. Minimum fungicidal concentrations of IO-2–IO-7 toward

Comp. no.	Fungus	MFC, mg/mL
IO-2	*P. ochro-chloron*	0.125
IO-4	*P. ochro-chloron*	1.000
IO-4	*A. alternata*	5.000
IO-5	*A. alternata*	0.100
IO-5	*T. viride*	1.000
IO-6	*P. ochro-chloron*	5.000
IO-6	*A. alternata*	5.000
IO-7	*R. nigricans*	0.050

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