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Polyamine Profiles of Some Members of the Gamma Subclass of the Class *Proteobacteria* : Polyamine Analysis of Twelve Recently Described Genera

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Cellular polyamines of 65 recently described species (12 genera) belonging to the gamma subclass of the class *Proteobacteria* were analyzed by HPLC. *Thiothrix* species belonging to the gamma-1 subgroup and *Xanthomonas* species belonging to the gamma-2 subgroup ubiquitously contained spermidine alone. A gamma-2 proteobacterium, *Stenotrophomonas*, contained cadaverine and spermidine. In the gamma-3 subgroup, *Photorhabdus* and *Xenorhabdus* located in the family *Enterobacteriaceae*, ubiquitously contained putrescine and spermidine and sporadically contained cadaverine. Putrescine and spermidine were the major polyamines in all 21 authentic species of *Pseudomonas* and cadaverine was found in a half of them. *Psychrobacter* and *Moraxella* species are located in the family *Moraxellaceae* and the former ubiquitously contained spermidine as the major polyamine, however, the polyamine patterns within the latter were heterogeneous, showing the occurrence of diaminopropane and / or norspermidine as the major polyamine in seven species among the 13 species tested. Putrescine alone, spermidine alone, 2-hydroxyputrescine / putrescine, putrescine / cadaverine, and putrescine / spermidine were found as the polyamine profiles of *Shewanella* species, indicating heterogeneous polyamine patterns within the genus. *Oceanomonas baumannii* and *O. doudoroffi* contained putrescine, cadaverine and spermidine. *Cardiobacterium* and *Suttonella* belonging to the family *Cardiobacteriaceae* contained diaminopropane and spermidine. The present data serve for the polyamine catalogues of gamma proteobacteria, as a chemotaxonomic marker.

Key words : polyamine, 2-hydroxyputrescine, cadaverine, spermidine, proteobacteria

INTRODUCTION

Cellular polyamine compositions have been shown to serve as chemotaxonomic markers within the alpha, beta, gamma, delta and epsilon subclasses of the class *Proteobacteria* (6, 7, 12-18, 20-22). The polyamine profiles of the gamma proteobacteria, which is composed of three subgroups based on the 16S rDNA phylogenetic analysis, were correlated with their phylogenetic classifications, however, they were more complicated than the polyamine patterns within other subclasses (12, 13, 15, 17, 18, 22).

In the present study, we analyzed polyamines of 65 recently established or reclassified gamma proteobacteria belonging to the 12 genera, *Thiothrix* (subgroup-1), *Xanthomonas*, *Stenotrophomonas* (subgroup-2), *Photorhabdus*, *Xenorhabdus*, *Pseudomonas*, *Psychrobacter*, *Moraxella*, *Oceanomonas*, *Shewanella*, *Cardiobacterium* and *Suttonella* (subgroup-3), to elucidate variations in their polyamine profiles, and to evaluate the usefulness of polyamine pattern as a

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phenotypic marker.

MATERIALS AND METHODS

The gamma proteobacteria analyzed are shown in Table 1. They were grown at the optimum growth temperature in the media designated by the culture collections as shown by Medium No., organic complex media such as Marine broth (MB) (DIFCO Ltd, Detroit, USA), Nutrient broth (NB) (Nissui Pharmaceutical Co Ltd., Tokyo, Japan), Brain heart infusion broth (BHIB) (Nissui), Trypticase soy broth (TSB) (BBL, Bectone Dickinson and Company, Cockeysville, MD, USA) or peptone-yeast extract medium (PY). Stationary growing cells were harvested by centrifugation. The pellets of organisms were homogenized in 0.5 M perchloric acid ($HClO_4$) at 2 ℃. Polyamines were extracted into $HClO_4$ and analyzed by high-performance liquid chromatography (HPLC) on an L6000 High-Speed Liquid Chromatograph (Hitachi Ltd., Tokyo, Japan) (14, 18).

RESULTS AND DISCUSSION

Typical chromatograms of the polyamine fraction by HPLC are shown in Fig. 1. 2-Hydroxyputrescine, 1,3-diaminopropane (diaminopropane), putrescine, cadaverine, spermidine, norspermidine, homospermidine, agmatine and spermine were separately eluted in the HPLC. Estimated cellular concentrations of the polyamines are listed in Table 1.

Gamma subgroup-1

Filamentous sulfur bacteria of the families *Chromatiaceae, Thiothrix unzii, T. fructosivorans* and *T. eikelboomii*, ubiquitously contained spermidine as the major polyamine. This pattern is similar to that found in four other genera (*Allochromatium*, *Thermochromatium*, *Thiocapsa* and *Thiohalocapsa*) of the family *Chromatiaceae* (22). In other gamma proteobacteria of subgroup-1, *Halorhodospira* and *Ectothiorhodospira* belonging to the family *Ecthothiorhodospiraceae* (of purple sulfur bacteria) contained spermidine and spermine, *Thiomicrospira* (of sulfur-oxidizing bacteria) contained putrescine and spermidine, and *Beggiatoa* belonging to the family *Beggiatoaceae* (a group of sulfur-depositing bacteria) contained putrescine, spermidine and homospermidine (18, 22).

Gamma subgroup-2

The phytopathogenic genus *Xanthomonas* is phylogenetically divided into three clusters (23, 30). Except for *X. oryzae* IAM 1657, all the *Xanthomonas* strains examined contained spermidine alone as the major polyamine, as previously reported in some species (16, 33). *X. oryzae* IAM 1657 showed the occurrence of 2-hydroxyputrescine and putrescine, and the pattern was the typical profile of beta proteobacteria. Therefore, precise taxonomic investigation is necessary for the correct assignment of the strain IAM 1657. *Xanthomonas* species was distinguished from a related gamma proteobacterium, *Stenotrophomonas maltophilia* (formerly *X. maltophilia*), which contains cadaverine and spermidine in its polyamine profiles.

Gamma subgroup-3

Photorhabdus and *Xenorhabdus* species belong to the family *Enterobacteriaceae* and form entomopathogenic symbioses with soil nematodes (10, 11). Putrescine and spermidine were the major polyamines in the three *photorhabdus* species and five *Xenorhabdus* species. A significant amount of cadaverine distributed in *X. japonicus* and *X. poinarii* among them. Although *Photorhabdus* and *Xenorhabdus* are located in a branch together with the genus *Proteus*, the *Proteus* species lack spermidine (12). Sporadic occurrence of spermidine in the family *Enterobacteriaceae* has been reported (11). Diaminopropane, which is widespread within this family (11, 33), was not detected in the *Photorhabdus* and *Xenorhabdus* species.

Pseudomonas species are phylogenetically divided into seven subclusters, *P. aeruginosa* group, *P. chlororaphis* group, *P. fluorescens* group, *P. pertucinogena* group, *P. putida* group, *P. stuzeri* group and *P. syringae* group (1,34). The *Pseudomonas* strains of 21 species distributing over the seven subclusters ubiquitously contained putrescine and spermidine. Cadaverine was sporadically detected in 12 species but was widely distributed within the seven sub-

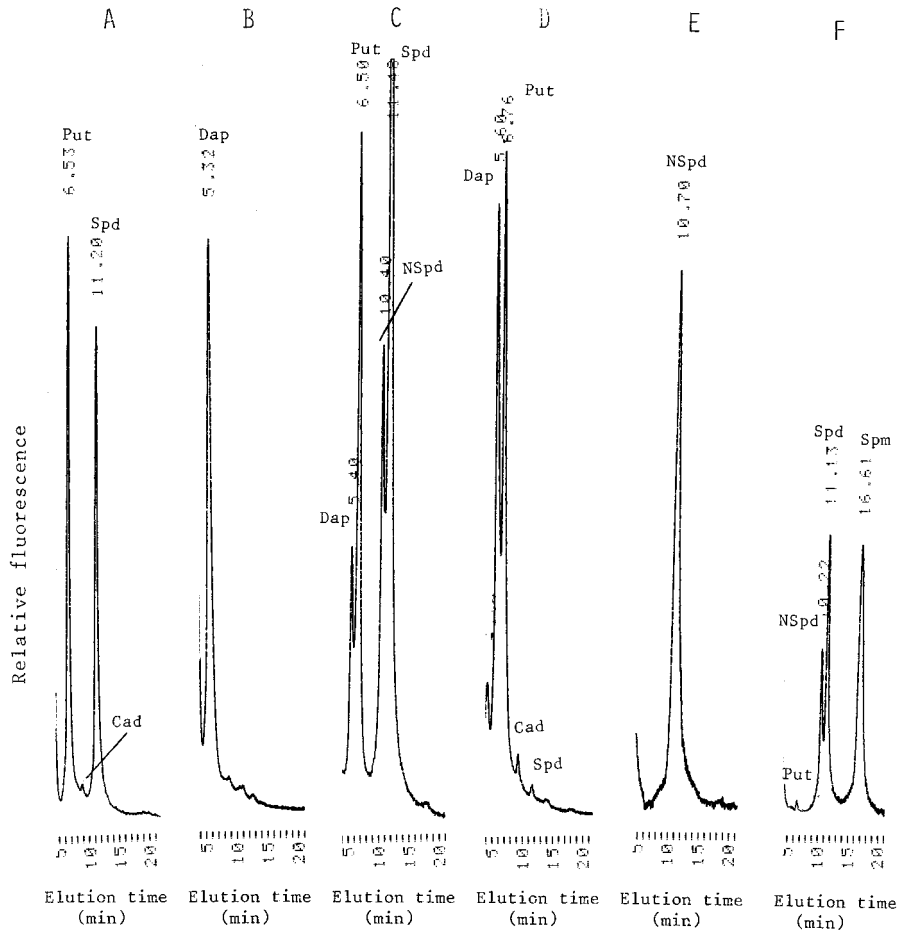

Fig. 1. HPLC analysis of polyamines extracted from *Moraxella lincolnii* ATCC 51388(A), *M. caprae* ATCC 700019(B), *M. catarrhalis* ATCC 25238(C), *M. osloensis* ATCC 19976(D), *M. ovis* ATCC 33078(E) and *M. cuniculi* ATCC 14688 (F).

Printed numbers on elution peaks indicate the elution time (min) of the peak. Abbreviations for polyamines are shown in Table 1.

clusters.

The family *Moraxellaceae* formed a distinct clade consisting of four phylogenetic groups, I (*Moraxella osloensis*, *Moraxella atlantae*), II (nine species of *Moraxella*), III (*Psychrobacter* species) and IV (*Acinetobacter* species) (2, 4, 8, 25, 27-29). Polyamine profiles among 13 species of the genus *Moraxella* were heterogeneous, as shown in Fig. 1 and Table 1. Seven members contained diaminopropane and some of them contained norspermidine as a major triamine. Two *Moraxella* species belonging to group I and *Moraxella lincolnii*, located in another separate group within the family (28), contained putrescine and spermidine. Four species of the eight *Moraxella* species of group II (*M. canis*, *M. catarrhalis, M. nonliquefaciens, M. equi, M. lacunata, M. caviae, M. ovis, M. cuniculi*), analyzed in this study, contained norspermidine in addition to putrescine and spermidine. In *Moraxella cuniculi* in group II, a significant amount of spermine was found. *Moraxella* species of group II are phylogenetically separated into two clusters (28). *M. boevrei* contained diaminopropane and spermidine, and *M. caprae* contained diaminopropane alone, however, a phylogenetic analysis of the two has not been conducted. *Acinetobacter* species (group IV) contained

Table 1. Polyamine concentration within the gamma subclass of *Proteobacteria*

Organism		Medium−Temp (℃)	Polyamines (μmol/g wet cell)							
			Dap	H−Put	Put	Cad	Spd	NSpd	Spm	Agm
Gamma proteobacteria subgroup−1										
Thiothrix eikelboomii	ATCC 49788^T	1820−20	−	−	−	−	1.10	−	−	−
Thiothrix fructosivorans	ATCC 49748^T	1820−20	−	−	−	−	1.12	−	−	−
Thiothrix unzii	ATCC 49747^T	1820−10	−	−	−	−	1.10	−	−	−
Gamma proteobacteria subgroup−2										
Xanthomonas arboricola	IFO 13557	(b)	−	−	−	−	0.93	−	−	−
Xanthomonas campestris	IFO 13551	(b)	−	−	−	−	0.76	−	−	−
"Xanthomonas physalidicola"	IFO 13555	(b)	−	−	−	−	1.36	−	−	−
Xanthomonas pisi	IFO 13556	(b)	−	−	−	−	1.04	−	−	−
Xanthomonas axonopodis	IFO 12213	PY−30	−	−	−	−	1.40	−	−	−
	IFO 13553	PY−30	−	−	−	−	1.28	−	−	−
Xanthomonas oryzae	IFO 3312	NB−25	−	−	−	−	1.66	−	0.01	−
	IFO 3510	NB−25	−	−	−	−	1.63	−	0.01	−
	IFO 3827	NB−25	−	−	−	−	1.57	−	0.02	−
	IFO 3828	NB−25	−	−	−	−	1.65	−	0.06	0.03
	IFO 3895	NB−25	−	−	−	−	1.40	−	−	−
	IAM 1657	NB−25	−	0.50	0.98	−	−	−	−	−
Xanthomonas translucens	IFO 13559	PY−30	−	−	−	−	1.10	−	−	−
	IFO 13558	(b)	−	−	−	−	0.55	−	−	−
Stenotrophomonas maltophilia (*Xanthomonas maltophilia*)	IAM 12423^T	(b)	−	−	−	0.70	4.00	−	−	−
Gamma proteobacteria subgroup−3										
Photorhabdus asymbiotica	ATCC 43950^T	PY−26	−	−	1.74	−	0.08	−	−	−
Photorhabdus luminescens	NCIMB 12670	BHIB−30	−	−	0.85	0.01	0.02	−	−	−
Photorhabdus temperata	ATCC 29304^T	NB−26	−	−	1.30	−	0.05	−	−	−
Xenorhabdus beddingii	ATCC 49542^T	NB−26	−	−	1.40	0.02	0.27	−	−	−
Xenorhabdus bovienii	ATCC 35271^T	PY−26	−	−	1.45	−	0.37	−	−	−
Xenorhabdus japonicus	IAM 14265^T	NB−28	−	−	1.40	0.08	0.45	−	−	−
Xenorhabdus nematophilus	NCIMB 9965^T	NB−25	−	−	0.57	0.01	0.28	−	−	−
Xenorhabdus poinarii	ATCC 35272^T	PY−26	−	−	1.50	0.95	0.55	−	−	−
Pseudomonas aeruginosa group										
Pseudomonas aeruginosa	IAM 1514^T	NB−30	−	−	0.80	0.51	0.40	−	−	−
Pseudomonas alcaligenes	IAM 12411^T	NB−30	−	−	0.92	0.25	0.40	−	−	−
Pseudomonas alcaliphila	IAM 14884^T	NB−25	−	−	1.25	0.34	1.02	−	−	−
Pseudomonas mendocina	JCM 5966^T	NB−37	−	−	0.74	0.50	1.46	−	−	−
Pseudomonas nitroreducens	IAM 1439^T	NB−25	−	−	0.85	−	0.70	−	−	−
Pseudomonas oleovorans	IAM 1508^T	NB−25	−	−	0.90	−	0.80	−	−	−
Pseudomonas pseudoalcaligenes	IAM 12410	NB−25	−	−	0.54	−	0.46	−	−	−
Pseudomonas straminea	IAM 1598^T	NB−25	−	−	0.27	0.28	0.62	−	−	−
Pseudomonas chlororaphis group										
Pseudomonas chlororaphis	IAM 12354^T	NB−25	−	−	1.02	0.26	0.57	−	−	−
Pseudomonas fragi	IAM 1650	NB−25	−	−	0.45	−	0.27	−	−	−
Pseudomonas taetrolens	IAM 1653^T	NB−25	−	−	0.60	−	0.50	−	−	−
Pseudomonas fluorescens group										
Pseudomonas fluorescens	IAM 12022^T	NB−25	−	−	0.90	−	0.58	−	−	−
Pseudomonas azotoformans	IAM 1603^T	NB−25	−	−	0.76	0.04	0.52	−	−	−
Pseudomonas mucidolens	IAM 12406^T	NB−25	−	−	0.82	−	0.84	−	−	−
Pseudomonas pertucinogena group										
Pseudomonas pertucinogena	IFO 14163^T	PY−30	−	−	1.10	1.05	0.35	−	−	−
Pseudomonas putida group										
Pseudomonas putida	IAM 1236^T	NB−25	−	−	0.72	−	0.52	−	−	−
Pseudomonas fluva	IAM 1529^T	NB−25	−	−	0.50	−	0.50	−	−	−
Pseudomonas stutzeri group										
Pseudomonas stutzeri	IAM 12668^T	NB−25	−	−	0.69	0.05	0.60	−	−	−

Pseudomonas syringae group										
Pseudomonas syringae	IFO 3310	PY−30	−	−	0.90	−	0.40	−	−	−
Pseudomonas ficuserectae	JCM 2440^T	NB−28	−	−	0.56	−	− 0.44	−	−	−
Pseudomonas synxantha	IAM 12356^T	NB−25	−	−	0.72	0.02	0.42	−	−	−
Psychrobacter phenylpyruvicus (*Moraxella phenylpyruvica*)	IAM 12282^T	(d)	−	−	−	0.20	1.35	−	−	−
Psychrobacter urativorans (“*Micrococcus cryophilus*”)	ATCC 15174^T	(a)	−	−	0.61	0.14	0.07	−	−	−
Psychrobacter frigidicola	ATCC 700361^T	1849−15	−	−	−	−	1.08	−	−	−
Psychrobacter glacincola	ATCC 700754^T	MB−15	−	−	0.01	0.06	0.86	−	0.02	−
Psychrobacter immobilis	IAM 12280^T	NB−25	−	−	0.25	−	1.30	−	−	−
Psychrobacter pacificensis	IFO 16270	MB−25	−	−	0.10	−	1.15	−	−	−
Psychrobacter sp. (“*Micrococcus cryophilus*”)	IAM 12030	PY−10	−	−	0.10	0.04	0.85	−	0.04	−
Psychrobacter sp. (“*Iizukaella psychrophila*”)	IFO 15753	PY−30	−	−	0.37	0.04	0.60	−	0.01	−
Moraxella atlantae	IFO 14588^T	(d)	−	−	0.15	−	2.88	−	−	−
Moraxella equi (*Moraxella bovis*)	IAM 12313^T	(d)	−	−	−	−	1.10	−	−	−
Moraxella nonliquefaciens	IAM 12281^T	(d)	−	−	−	−	1.30	−	−	−
Moraxella boevrei	ATCC 700022^T	BHIB−30	0.32	−	−	−	0.84	−	−	−
Moraxella canis	ATCC 51391^T	BHIB−30	0.20	−	0.50	−	1.35	−	−	−
Moraxella caprae	ATCC 700019^T	BHIB−30	1.10	−	−	−	−	−	−	−
Moraxella catarrhalis	ATCC 25238^T	BHIB−30	0.35	−	0.75	−	0.96	0.35	−	−
Moraxella caviae	ATCC 14659^T	BHIA−30	0.20	−	0.01	−	0.02	0.75	0.04	−
Moraxella cuniculi	ATCC 14688^T	BHIA−30	−	−	0.02	−	0.32	0.57	0.52	−
Moraxella lacunata	ATCC 17967^T	260−30	0.56	−	0.02	−	0.04	−	−	−
Moraxella lincolnii	ATCC 51388^T	260−30	−	−	1.15	0.01	0.95	−	−	−
Moraxella osloensis	ATCC 19976^T	BHIB−30	1.05	−	1.25	0.03	0.02	−	−	−
Moraxella ovis	ATCC 33078^T	BHIB−30	−	−	−	−	−	1.05	−	−
Oceanomonas baumannii	NCIMB 13685^T	TSB−25	−	−	0.20	0.01	0.46	−	−	−
Oceanomonas doudoroffii (*Pseudomonas doudoroffii*)	IAM 14168^T	MB−25	−	−	0.38	0.04	0.90	−	−	−
Shewanella algae	IAM 14159^T	(c)	−	−	1.45	0.50	−	−	−	−
Shewanella baltica	NCIMB 1733	(e)	−	−	1.20	1.50	−	−	−	−
Shewanella bentica	JCM 10176	(e)	−	0.25	0.45	−	−	−	−	−
	JCM 10264	(a)	−	−	0.77	−	−	−	−	−
	ATCC 43992^T	(e)	−	−	0.25	−	−	−	−	−
Shewanella frigidimarina	NCIMB 400	(e)	−	−	0.80	−	0.02	−	−	−
Shewanella hanedai	IAM 12641^T	(c)	−	−	1.50	−	−	−	−	−
Shewanella putrefaciens	IAM 12079^T	(c)	−	−	3.00	−	−	−	−	−
Shewanella violacea	JCM 10179^T	(e)	−	0.60	0.45	−	−	−	−	−
Shewanella woodyi	NCIMB 13526^T	(e)	−	−	0.50	−	0.25	−	−	−
Shewanella amazonensis	ATCC 700329^T	1065−30	−	−	1.05	−	0.08	−	−	−
Shewanella pealeana	ATCC 700345^T	MB−30	−	−	0.67	−	−	−	−	−
Shewanella oneidensis	ATCC 700550^T	TSB−30	−	−	1.50	1.10	−	−	−	−
Shewanella gelidimarina	ATCC 700752^T	MB−30	−	−	0.01	0.01	1.12	−	−	−
Cardiobacterium hominis	ATCC 15826^T	BHIB−37	0.02	−	−	−	0.40	−	−	−
Suttonella indologenes	ATCC 25869^T	BA−37	0.18	−	0.04	−	0.52	−	−	−

Note : Dap, 1, 3−diaminopropane ; H−Put, 2−hydroxyputrescine ; Put, putrescine ; Cad, cadaverine ; Spd, spermidine ; NSpd, norspermidine ; Spm, spermine ; Agm, agmatine ; IAM, IAM Culture Collection, Institute of Molecular and Cellular Biosciences, The University of Tokyo, Tokyo, Japan ; IFO, Institute for Fermentation, Osaka, Japan ; JCM, Japan Collection of Microorganisms, RIKEN, Saitama, Japan ; NCIMB, The National Collections of Industrial and Marine Bacteria, Aberdeen, Scotland, UK ; ATCC, American Type Culture Collection, Manassas, Virginia, USA ; ^{T}, Type strain ; −, not detectable (<0.005). Former names are shown in parentheses. Quotation marks indicate the scientific name has not been validly published. Abbreviations for media are shown in MATERIALS AND METHODS. a, cited from Hamana et al. (18). b, cited from Hamana and Matsuzaki (15). c, cited from Hamana et al. (12). d, cited from Hamana and Takeuchi (17). e, cited from Hamana et al. (21).

diaminopropane alone (15). Spermidine was ubiquitously detected in the six psychrophilic *Psychrobacter* species (group III). Cellular concentration of putrescine and cadaverine as well as spermidine level varied among the six species.

Reclassification of *Pseudomonas doudoroffii* into a new genus *Oceanomonas* and a description of *Oceanonomas baumannii* were presented (5). The genus *Oceanomonas* is phylogenetically located near the three families *Vibrionaceae, Enterobacteriaceae* and *Aeromonadaceae* (5) and contained putrescine, cadaverine and spermidine. This polyamine pattern is different from the profiles of the three families containing diaminopropane in addition to spermidine and/or norspermidine.

Since four different polyamine patterns have been reported in eight *Shewanella* species (13, 18, 22), polyamine profiles of four newly validated species (3, 26, 31) were analyzed. In the previous studies, putrescine and cadaverine were found in *S. algae* and *S. baltica*, 2−hydroxyputrescine and putrescine in *S. bentica* and *S. violacea*, putrescine alone in *S. frigidimarina, S. hanedai* and *S. putrefaciens*, and putrescine and spermidine in *S. woodyi*. In the four new species, *S. amazonensis* and *S. pealeana* contained putrescine alone, *S. oneidensis* putrescine and cadaverine, and *S. gelidimarina* contained spermidine alone. Thus, variation in polyamine profile has been observed within the genus *Shewanella*; however, diaminopropane, norspermidine and homospermidine have never been found in the genus.

Cardiobacterium hominis and *Suttonella indologenes* contained diaminopropane in addition to spermidine. Norspermidine was not produced from diaminopropane in the organisms. They are phylogenetically placed near the branching point between the beta and gamma subclasses, however, 2−hydroxyputrescine, a good chemotaxonomic marker for beta proteobacteria, was not detected in the two gamma proteobacteria.

Polyamine profiles as a chemotaxonomic marker

In the previous studies on gamma proteobacterial polyamines, homospermidine was selectively distributed in *Legionella* and *Beggiatoa* species (18, 22) and norspermidine was selectively distributed within the genera *Vibrio* and *Photobacterium* of the family *Vibrionaceae* and the genus *Moritella* (13, 22). The occurrence of norspermidine in some *Moraxella* species was first found in the present study. In contrast to these triamines, diaminopropane was widely distributed, although sporadically, within the genera *Moraxella, Cardiobacterium* and *Suttonella*, as shown in this study, and the families *Enterobacteriaceae* (12, 35), *Pasteurellaceae* (13, 17), *Aeromonadaceae* (13) and *Vibrionaceae* (14, 22), and the genus *Acinetobacter* (15) of the gamma subclass of *Proteobacteria*. Although norspermidine is produced from diaminopropane, norspermidine has not been found in gammma proteobacteria other than the families *Vibrionaceae* and *Moraxellaceae*. The distribution of the two triamines, norspermidine and homospermidine, may be idiosyncratic, however, it may serve as a phenotypic marker for certain genera within the gamma subclass of *Proteobacteria*.

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γサブクラスに属する数種のプロテオバクテリアにおけるポリアミン構成：近年記載された12属のポリアミン分析

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γサブクラスに属するプロテオバクテリアとして近年記載された65種（12属）のポリアミンをHPLCにより分析し，分析済みの同属および近縁属の種と比較し，γプロテオバクテリア内のポリアミン構成を考察した．

γ-1サブグループに属する *Thiothrix* 属3種およびγ-2サブグループに属する *Xanthomonas* 属7種は，スペルミジンのみを有していた．γ-2サブグループの *Stenotrophomonas* 属1種はカダベリンとスペルミジンを含有した．γ-3サブグループでは以下のような結果であった．*Enterobacteriaceae* 科の *Photorhabdus* 属と *Xenorhabdus* 属では全8種がプトレスシンとスペルミジンを有し，カダベリンは一部の種に含まれていた．プトレスシンとスペルミジンが *Pseudomonas* 属の21種の全てにおける主ポリアミンとなっていたが，カダベリンはその半数の種にのみしか含まれていなかった．*Moraxellaceae* 科を構成する *Psychrobacter* 属と *Moraxella* 属では，*Psychrobacter* 全8種と6種の *Moraxella* の主ポリアミンはスペルミジンであった．他7種の *Moraxella* は，主ポリアミンとしてジアミノプロパンとノルスペルミジンの両方か，どちらか一つを含むことから，*Moraxella* 種のポリアミン構成は不均一であった．*Shewanella* 属12種では，プトレスシンのみ，スペルミジンのみ，2-ヒドロキシプトレスシンとプトレスシン，プトレスシンとカダベリン，プトスシンとスペルミジン，のいずれかとなり，ポリアミン構成は種間で異なっていた．*Oceanomonas baumannii* と *O. doudoroffii* はプトレスシン，カダベリン，スペルミジンを含有していた．*Cardiobacteriaceae* 科の *Cardiobacterium* 属1種と *Suttonella* 属1種はジアミノプロパンとスペルミジンを含んでいた．

上記のデータはγプロテオバクテリアにおける化学分類マーカーとしてのポリアミン構成をカタログ化する上で役立つものである．