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Proposal of *Salmonella paratyphi* sp. nov., nom. rev. and Request for an Opinion to conserve the specific epithet *paratyphi* in the binary combination *Salmonella paratyphi* as *nomen epitheton conservandum*

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We propose *Salmonella paratyphi* sp. nov., nom. rev., by raising *Salmonella choleraesuis* subsp. *choleraesuis* serovar Paratyphi A to species status and request an Opinion to include the specific epithet *paratyphi* in the binary combination of *Salmonella paratyphi* in the list of *epitheta specifica conservanda*.

Keywords: *Salmonella paratyphi*, *nomen epitheton conservandum*, serovar Paratyphi A

INTRODUCTION

Kelterborn (1967) described a case of enteric fever, resembling typhoid fever, whose blood culture yielded 'paracolonbacillus', which was first reported by Gwyn in 1898. Kayser (1902) isolated an organism from the blood of a patient suffering from a typhoid-fever-like disease and named it '*Bacterium paratyphi*'. Soon after, Brion & Kayser (1902) described the clinical features of the patients and the serological differentiation of '*Bacterium paratyphi*' from '*Bacillus typhi*'. Both '*Bacillus typhi*' and '*Bacterium paratyphi*' were later transferred to the genus *Salmonella*. Though *Salmonella typhi* (Schroeter 1886) Warren and Scott 1930 retained its nomenclatural position by being listed in the Approved Lists of Bacterial Names (Skerman *et al*., 1980), *Salmonella paratyphi* (Kayser 1902) Castellani and Chalmers 1919 was not included in the Approved Lists and lost its standing in nomenclature. Furthermore, the generic name '*Bacterium*' was cited in the list of *nomina generum rejicienda* by Opinion 4 (revised) (Judicial Commission, 1954), thus '*Bacterium paratyphi*' Kayser was recognized as a validly published illegitimate name according to Buchanan *et al*. (1966) and cannot be the basonym of *Salmonella paratyphi* (International Committee on Bacteriological Nomenclature, 1958; Lapage *et al*., 1975).

Kauffmann (1960, 1963) and Kauffmann & Edwards (1952) divided species in the genus *Salmonella* into 'sub-genera' I, II, III and IV based on their biochemical characteristics. Strains which inhabit in the intestinal tract of warm-blooded animals were in 'sub-genus' I. Le Minor & Rhode (1974) described eight types of *Salmonella* in 'sub-genus' I, e.g. '*Salmonella cholerae-suis*' (sic), '*Salmonella hirschfeldii*' (*Salmonella paratyphi*-C), *Salmonella typhi*, *Salmonella paratyphi*-A, '*Salmonella schottmuelleri*', *Salmonella typhimurium*, *Salmonella enteritidis* and '*Salmonella gallinarum*'. Four of these, '*S. hirschfeldii*', *S. paratyphi*-A, '*S. schottmuelleri*' and '*S. gallinarum*' were excluded from the Approved Lists and lost their standing in nomenclature. According to Buchanan *et al*. (1966), *S. paratyphi*-A was not a validly published name according to Rule 14a(1) of the International Code of Nomenclature of Bacteria and Viruses (International Committee on Bacteriological Nomenclature, 1958). Rule 14a(1) reads, 'The name of a species is validly published only when its publication conforms to the following requirements. (1) It must be published as a binary combination consisting of a generic name followed by a single specific epithet.' Rule 14a(1) of the 1958 Code corresponds to Rule 30(2) of the revised Code (Lapage *et al*., 1975, 1992).

Le Minor & Popoff (1982) and Le Minor *et al*. (1982) studied 88 *Salmonella* reference strains, including Kauffmann's 'sub-genera' I–IV (Kauffmann, 1966) together with the bongor group, and performed numerical analysis and DNA–DNA hybridization. They proposed *S. choleraesuis* as the type and only species of the genus and five new subspecies corresponding to the former 'sub-genera' I–IV and the bongor group. *S. choleraesuis* subsp. *choleraesuis*

Table 1. DNA/DNA similarities among selected *Salmonella* strains

Hybridization was carried out at the temperature shown in 2× SSC containing 50% formamide using *S. paratyphi* NCTC 5702^T DNA as label DNA. Similarity values are shown ± SD. CV, coefficient of variation.

Organism*	Description	Hybridization at 46 °C		Hybridization at 36 °C	
		Similarity value (%)	CV (%)	Similarity value (%)	CV (%)
S. paratyphi NCTC 5702^T	Kauffmann 1939	100·0 ± 0·0	0·0	100·0 ± 0·0	0·0
S. paratyphi GIFU 3P-430	Human clinical	91·1 ± 2·4	2·7	96·0 ± 3·8	4·0
S. paratyphi NCTC 13	Schottmueller 1920	86·4 ± 5·2	6·0	89·2 ± 5·5	6·1
S. paratyphi GIFU 3P-426	Human clinical	85·9 ± 2·5	2·9	93·9 ± 3·6	3·9
S. typhi ATCC 19430^T(Ty2)	Type strain	90·6 ± 0·1	0·1	93·8 ± 1·6	1·7
S. choleraesuis NCTC 5735^T	Type strain	85·9 ± 0·8	0·9	83·3 ± 1·0	1·2
S. enteritidis ATCC 13076^T	Type strain	81·9 ± 8·4	10·3	89·7 ± 11·7	13·0
S. typhimurium ATCC 13311^T	Type strain	78·3 ± 5·6	7·1	88·5 ± 8·5	9·6
Herring sperm DNA		0·0 ± 0·0	–	0·0 ± 0·0	–

* GIFU 3P, Gifu University Level Three collection of human pathogens, Japan.

Table 2. Differential characteristics of *S. paratyphi* from other *Salmonella* species

Characteristic	*S. choleraesuis* NCTC 5735^T	*S. enteritidis* ATCC 13076^T	*S. typhimurium* ATCC 13311^T	*S. typhi* ATCC 19430^T	*S. paratyphi* NCTC 5702^T	*S. paratyphi* (eight strains)
Conventional tests						
Lysine decarboxylase	+	+	+	+	−	−
Ornithine decarboxylase	+	+	+	−	+	+
H_2S on TSI agar	+	+	+	Weak	−	Weak or −
Simmons' citrate	+	+	+	−	−	−
Gas from glucose	+	+	+	−	+	+
Antigenic formula	6,7:c:1,5	1,9,12:g,m:−	1,4,(5),12:b:1,2	9,12,Vi:d:−	1,2,12:a,−	1,2,12:a,−
API tests						
D-Xylose	+	+	+	+	−	−
Glycerol	−	−	+	+	+	−
L-Arabinose	−	+	+	−	+	+
L-Rhamnose	+	+	+	−	+	+
Dulcitol	−	+	+	−	+	+*
i-Inositol	−	−	+	−	−	−
Trehalose	−	+	+	+	+	+
D-Tagatose	−	−	+	−	+	+
L-Fucose	+	+	+	−	+	+
5-Ketogluconate	+	+	+	−	+	+

* Only seven of the eight strains were positive.

corresponds to the former 'sub-genus' I and contains human and animal pathogens, including those species listed in the Approved Lists by ranking them down to infrasubspecific serovars (*International Journal of Systematic Bacteriology*, 1985; Le Minor *et al.*, 1986).

In 1987, Le Minor & Popoff published a Request for an Opinion to designate *Salmonella enterica* sp. nov., nom rev. as the type and only species of the genus *Salmonella* (Le Minor & Popoff, 1987; *International Journal of Systematic Bacteriology*, 1987). They intended to replace the species name *S. choleraesuis* with *S. enterica* because of nomenclatural confusion due to identity of the specific epithet *choleraesuis* with the serovar name Choleraesuis. Such replacement of the earliest legitimate specific epithet by another epithet is one of the reasons for which the name is illegitimate according to Rule 51b(2). Rule 51b(2) reads, 'If the author did not adopt for a binary or ternary combination the earliest legitimate generic name, specific epithet, or subspecific epithet available for the taxon with its particular circumscription, position, and rank.' *S. enterica* was originally proposed by Kauffmann & Edwards (1952) to replace the

species name '*Salmonella kauffmannii*' and was cited in *Index Bergeyana* as an illegitimate name according to Rule 24b of the Code (International Committee on Bacteriological Nomenclature, 1958).

The Judicial Commission of the International Committee of Systematic Bacteriology did not award the Opinion requested by Le Minor & Popoff (1987) to designate *S. enterica* sp. nov. as the type and only species of the genus *Salmonella* (Wayne, 1994). Le Minor *et al.* (1982) proposed placing pathogenic *Salmonella* serovars in *S. choleraesuis* subsp. *choleraesuis*. Thus, *S. paratyphi* became *S. choleraesuis* subsp. *choleraesuis* serovar Paratyphi A. Concerning the rejection of names, an item was added to Rule 56a(5) in the Code (Lapage *et al.*, 1992). It reads, 'A perilous name (*nomen periculosum*), i.e. a name whose application is likely to lead to accidents endangering health or life or both or of serious economic consequences.' Because *S. paratyphi* is a contagious organism causing typhoid-fever-like disease (paratyphoid fever) in humans, Rule 56a(5) must be applicable to the inclusion of *S. paratyphi* in *S. choleraesuis* subsp. *choleraesuis* as one of the serovars, because the organism is widely recognized as contagious and virulent and cited in the list of Class 3 pathogens. At the end of Rule 56a(5) (Lapage *et al.*, 1975), Note 1 states that 'If the Judicial Commission recognizes a high order of risk to health, or of serious economic consequences, an Opinion may be issued that the taxon be maintained as a separate nomenspecies, without prejudice to the recognition or acceptance of its genetic relatedness to another taxon.'

From the reasons described above, we herein propose to raise *Salmonella choleraesuis* subsp. *choleraesuis* serovar Paratyphi A to species status and request that this organism be designated as *Salmonella paratyphi* sp. nov., nom. rev. and conserve the specific epithet *paratyphi* in the binary combination *Salmonella paratyphi*.

Description of *Salmonella paratyphi* (Kayser 1902) sp. nov., nom. rev.

Salmonella paratyphi (pa.ra.ty′phi. Gr. prep. *para* alongside; Gr. n. *typhus* a stupor; M.L. n. *paratyphi* of paratyphoid).

Gram-negative, motile with peritrichous flagella and fermentative rods, consistent with the definition of the genus *Salmonella* as described by Le Minor & Rohde (1974) and Le Minor (1984). Strains of *S. paratyphi*, however, characteristically fail to utilize citrate as sole carbon source, to produce black iron sulfide compound and have weakly positive or negative lysine decarboxylase activity (Smith, 1948). Antigenic formula is 1,2,12:a:[1,5]. Strain NCTC 5702^T (= KI 1015^T) is designated as the type strain for the species. The antigenic formula for this strain is 1,2,12:a:−. DNA–DNA similarity values for the type strain to other *Salmonella* species at different stringency levels (Ezaki *et al.*, 1989) are listed in Table 1 and differential biochemical and serological characteristics of this species are indicated in Table 2.

Among more than 2000 serovars of *S. choleraesuis* subsp. *choleraesuis*, two serovars carry the name Paratyphi: serovars Paratyphi B and Paratyphi C. They are not causative agents of typhoid or paratyphoid fever. Therefore, their name might cause confusion to medical microbiologists. However, serovar Paratyphi B is now called serovar Schottmuelleri. Serovar Paratyphi C was once called serovar Hirschfeldii (Le Minor & Rohde, 1974). If enterobacteriologists promote the use of serovar names Schottmuelleri and Hirschfeldii for serovars Paratyphi B and Paratyphi C, respectively, confusion will be avoided.

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