NOTES

Streptococcus lactis subsp. *cremoris* (Orla-Jensen) comb. nov. and *Streptococcus lactis* subsp. *diacetilactis* (Matuszewski et al.) nom. rev., comb. nov.

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Streptococcus lactis (Lister 1873) Löhnis 1909 and *Streptococcus cremoris* Orla-Jensen 1919 have a number of significant properties in common and belong to the same DNA homology group. *S. cremoris* is here regarded as a subspecies of *S. lactis*. The name of the subspecies is *S. lactis* subsp. *cremoris* (Orla-Jensen) comb. nov. *Streptococcus diacetilactis* Matuszewski et al. 1936 does not appear on the approved lists of bacterial names (Int. J. Syst. Bacteriol. 30:225-420, 1980). However, it is here regarded as a recognizable taxon, for which the name *S. lactis* subsp. *diacetilactis* (Matuszewski et al.) nom. rev., comb. nov. is proposed. The type strain of this subspecies is NCDO 176.

The status of *Streptococcus cremoris* Orla-Jensen 1919 as a species different from *Streptococcus lactis* (Lister 1873) Löhnis 1909 (12) has been questioned (4, 7, 10). Lawrence et al. (10) stated, "It remains to be seen if differences in genetic homology can be used to distinguish between the three species." (The third was called *Streptococcus diacetilactis*.) The specific epithet *lactis* dates back to Lister (11), and the name *S. cremoris* dates to Orla-Jensen (14). The criteria then available permitted differentiation of the two species, and it is only in recent years, as knowledge of the metabolism and the structure and function of cell components of bacteria has increased, that doubts have arisen about the classification of these organisms. The status of *S. lactis* subsp. *diacetilactis* is different. It was first named in 1936 (13), but studies by Swartling (17) and Zielinska and Hiscox (18) in the early 1950s showed many similarities to *S. lactis*. Thus, Deibel and Seeley (3) gave subspecies rank to the bacterium previously named *S. diacetilactis*. This was, however, not on the approved lists of bacterial names (16).

The question posed by Lawrence et al. (10) has been answered recently, and it is now known that *S. lactis*, *S. lactis* subsp. *diacetilactis*, and *S. cremoris* belong to a single DNA homology group (5, 6). The DNAs of *S. cremoris* strains are 75 to 100% homologous with the DNA of the type strain of *S. lactis*, NCDO 604, and a starter strain, NCDO 712. The percentage of homology between the DNAs of *S. lactis* NCDO 604 and the type strain of *S. cremoris*, NCDO 607, is 78%. Similarly, there is over 80%

homology between strains of *S. lactis* subsp. *diacetilactis* and the type strain of *S. lactis* (5, 6).

There is no universally accepted definition of a bacterial species, and the criteria generally used are uneven, but strains with a high DNA homology form a natural unit. Within a DNA homology group, strains differentiated by physiological properties should be subspecies. On this basis, *S. cremoris* would be a subspecies of *S. lactis*. Table 1 shows properties of the three above-mentioned taxa as previously described (3, 5, 17, 18). Other characters presently used in bacterial taxonomy have failed to separate *S. lactis* from *S. cremoris* and have supported the subspecies rank of *S. lactis* subsp. *diacetilactis*. Schleifer and Kandler (15) found that the interpeptide bridges of the cell walls of *S. lactis* and *S. cremoris* contain L-lysine D-asparagine, a composition rarely found in streptococci, except for *Streptococcus faecium*. The lactate dehydrogenases of *S. lactis*, *S. lactis* subsp. *diacetilactis*, and *S. cremoris* have similar properties (5) which have not been found in any other species, not even in some which are phenotypically similar to *S. lactis* but which belong to a different DNA homology group. The structures of the isoprenoid quinones found in *S. lactis*, *S. lactis* subsp. *diacetilactis*, and *S. cremoris* are similar but are not found in many streptococcal species (2). As would be expected within a DNA homology group, the guanine plus cytosine contents of the DNAs of the members of the group come within a narrow range; the values for strains NCDO 604 and NCDO 607 are 35.8 and

TABLE 1. Selected properties of *S. lactis* subsp. *lactis*, *S. lactis* subsp. *diacetilactis*, and *S. cremoris*

Determination	<i>S. lactis</i>				<i>S. cremoris</i>	
	Type strain NCDO 604	Nondairy strains	Dairy strains	<i>S. lactis</i> subsp. <i>diacetilactis</i>	Type strain NCDO 607	Species
Growth at 10°C	+	+	+	+	+	+
40°C	+	+	+	+	—	+
45°C	—	—	—	—	—	—
Growth in 2% NaCl	+	+	+	+	+	+
4%	+	+	+	+	—	—
6.5%	—	—	—	—	—	—
Hydrolysis of arginine	+	+	+	±	—	—
Utilization of citrate	—	—	—	+	—	±
Acid from: ^a						
Arabinose	—	—	—	—	—	—
Ribose	+	+	+	+	+	—
Xylose	+	+	—	—	—	—
Cellobiose	+	+	+	+	+	—
Lactose	+	±	+	+	+	+
Maltose	+	+	+	+	—	—
Sucrose	—	±	±	—	—	±
Trehalose	+	±	+	±	—	±
Raffinose	—	±	—	—	—	—
Dextrin	+	+	+	+	—	—

^a All strains fermented fructose, galactose, glucose, and usually aesculin and salicin. No strains fermented sorbose, rhamnose, melibiose, melezitose, polysaccharides, or alcohols, except mannitol, which was not fermented by *S. cremoris* but which was fermented by some strains of *S. lactis*. Results with NCDO 604 were variable. Symbols: +, positive; —, negative; ±, most strains positive, but some negative; ±, most strains negative, but some positive.

35.4 mol% (5), respectively. (The type strain of *S. lactis* subsp. *diacetilactis* has not been examined.) These values are at the lower end of the guanine plus cytosine range for streptococci.

These properties, common to *S. lactis* and *S. cremoris*, might be considered more significant taxonomically than the phenotypic differences. For commercial reasons it is important to distinguish *S. cremoris* as a distinct entity, and its many differences from *S. lactis* subsp. *lactis* must be taken into account. It is proposed, therefore, that *S. cremoris* be reclassified as *S. lactis* subsp. *cremoris* (Orla-Jensen) comb. nov.

S. lactis subsp. *lactis* resembles *S. lactis* subsp. *diacetilactis* more closely than it resembles *S. cremoris*. The main difference is that *S. lactis* subsp. *diacetilactis* can use citrate (1). This property is so important commercially that the identity of *S. lactis* subsp. *diacetilactis* should be retained. The ability to use citrate is a variable property and is plasmid linked, but only the permease and not the citritase is coded as a plasmid (5, 8).

S. lactis is a typical streptococcus, i.e., it is a gram-positive, catalase-negative coccus or coccoid rod dividing in one plane to form chains of cells. The chains are often short. *S. lactis* can be

distinguished from other streptococci because it grows at 10°C but not at 45°C. The temperature for optimum growth is 22 to 30°C. It does not grow in the presence of 6.5% NaCl or at pH 9.6. Lactose-fermenting strains reduce litmus in litmus milk before acidifying and clotting the milk. Its lactate dehydrogenase has a high affinity for fructose-1,6-diphosphate and a wide range of pH activity; the enzyme is inhibited by phosphate, giving a typical reaction curve in vitro tests (4, 5). The interpeptide bridge of the cell wall consists of L-lysine D-asparagine. Isoprenoid quinone structures have been identified in cells. The guanine plus cytosine content of the DNA is 34.4 to 35.8 mol%. The properties of *S. lactis* subsp. *lactis* are given in Table 1. It differs from *S. lactis* subsp. *cremoris* in that it grows at 40°C and in the presence of 4% NaCl, hydrolyzes arginine, and ferments maltose and dextrin. It is found in milk and dairy products and also on vegetable matter. *S. lactis* subsp. *cremoris* is less active than the type subspecies. Its properties are presented in Table 1. It is found in dairy starter and dairy products and probably does not exist outside of these habitats.

Descriptions of *S. lactis* subsp. *diacetilactis* have been given by Swartling (17) and by Zie-

linska and Hiscox (18); the latter include the type strain, NCDO 176, as strain 2. According to rule 46 of the Bacteriological Code (9), the valid publication of the names of *S. lactis* subsp. *diacetilactis* (Matuszewski, Pikanowski, and Supinska) comb. nov. and *S. lactis* subsp. *cremoris* (Orla-Jensen) comb. nov. automatically creates the subspecies *S. lactis* subsp. *lactis*. The type strains of these subspecies are NCDO 176, NCDO 607, and NCDO 604, respectively.

REPRINT REQUESTS

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