Nomenclatural Problems of the *Pediococci*

Request for an Opinion

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Information is presented to show that the name *Pediococcus cerevisiae* Balcke was not validly published, and, furthermore, that it has been a source of confusion, having been used to refer to two different species of pediococci. Therefore, there is no identifiable species that can be selected as the type of the genus *Pediococcus* in accordance with the rules of the International Code of Nomenclature of Bacteria, because *P. cerevisiae* was the only species placed in this genus by Balcke. However, the name *Pediococcus* has been used subsequently for a genus containing several recognizable species, and one of these may be designated by international agreement as the type species. The name of the genus would then be ascribed to the author of the name of the species designated as the type. Therefore, it is requested that the Judicial Commission of the International Committee on Systemic Bacteriology issue an Opinion designating *Pediococcus damnosus* Claussen as the type species of *Pediococcus*, a genus of gram-positive, lactic acid-producing bacteria which divide in two planes, and Claussen as the author of this generic name. Neotype strains are designated for *P. damnosus*, *P. pentosaceus*, and *P. acidi-lactici*; these are NCDO 1832, NCDO 990, and NCDO 1859, respectively.

In 1962 Günther and White (9) proposed that ATCC 8081 be designated the type strain of *Pediococcus cerevisiae* Balcke. Unfortunately, at this time the name *P. cerevisiae* was in use for two different species of pediococci. In 1949, Pederson (15) had applied it to pediococci from plants, and, in 1959, Nakagawa and Kitahara (14) applied it to pediococci from beer, despite the fact that the name was established in modern usage for a different organism. Opinions on the correct application of the name *P. cerevisiae* were divided, with the result that the status of the name *P. cerevisiae* has been considered by subcommittees of the International Committee on Systematic Bacteriology (ICSB) for the past 10 years. By 1970 it was on the agenda of the subcommittee on the Taxonomy of Lactobacilli and Closely Related Organisms, and this Subcommittee established a study group to advise on the choice of a neotype strain for *P. cerevisiae* (10). During this time, the name *P. cerevisiae* has continued to be used for two species of pediococci. The resulting difficulties are obvious.

MATERIALS AND METHODS

The information on species characters has been compiled from papers by Coster and White (4),

Günther and White (8), Mundt, Beattie, and Weiland (13), Nagakawa and Kitahara (14), and Whittenbury (16). The strains used by these workers came from a variety of sources, and these are given in the respective papers.

The methods used to determine the properties given in Table 2 are those of these different workers, and the methods used to determine the properties of the proposed neotype strains were those of Coster and White (4) and Günther and White (8), with the exception of the method for the determination of lactic acid, which was that of Garvie (6).

RESULTS AND DISCUSSION

Balcke (2), in 1884, first used the name *P. cerevisiae*, but it was not validly published (Rule 12 [2] of the Bacteriological Code [5]); it was only proposed in anticipation of the future acceptance of the organism as a distinct species.

Balcke stated: "Unser Spaltpilz gehört zu einer in neuerer Zeit von 'Sarcina' abgezweigten Gattung mit Namen 'Pediococcus' d.h. Kugelbakterie, die sich in einer Ebene theilt, und würde, falls er eine eigene Art ist, den Namen 'Pediococcus' cerevisiae verdienen." ("Our schizomycete belongs to a genus 'Pediococcus' that is a spherical bacterium, separated recently from 'Sarcina.' It divides in one plane and would, in case that it is an independent species,

deserve the name *Pediococcus cerevisiae*”). Moreover, Balcke’s organism cannot be recognized with certainty. He did not isolate any cultures and only saw cocci in tetrads under the microscope. The observation of tetrads means that the bacteria were dividing in two planes and not in one plane as Balcke stated. As stated above, Pederson (15) and Nakagawa and Kita-

hara (14) used the name *P. cerevisiae* Balcke for different organisms. As Balcke saw pediococci not only in sarcina-soured beer but also in washing of the malt, it is probable that both species to which the name *P. cerevisiae* is now applied were seen by Balcke.

The modern concept of a beer pediococcus is a low-temperature, anaerobic organism, but in

TABLE 1. *Characteristics of species of the genus Pediococcus listed historically*

Scientist	Pediococcus species			
	<i>P. cerevisiae</i>	<i>P. damnosus</i>	<i>P. pentosaceus</i>	<i>P. acid-lactici</i>
Balcke (1884)	Only observed microscopically. Present in yeast, yeast water, malt, green malt, on the threshing floor, and in sarcina-sick beer.			
Lindner (1888)	Source: beer clouded with sarcina. Grew at 20 to 25 C. Grew better aerobically; probably acid sensitive.			Source: malt mash. Grows at 41 C. Strong acid former. Hop sensitive.
Claussen (1903)		Causes fault in beer. Grows at 15 to 25 C. Prefers anaerobic conditions. Forms acid in nutrient medium plus carbohydrate. Does not grow under alkaline conditions.		
Mees (1934)	? = <i>P. damnosus</i>	More information than given by Clausen. Considered to be the same as that above.	Will not grow in beer. Carbohydrate fermentations given.	
Pedersen (1949)	Plant pediococci examined. Considered to be the same as the organism in sarcina-sick beer. <i>P. cerevisiae</i> became widely used for plant pediococci as a result of Pedersen’s work.			
Nakagawa and Kitahara (1959)	Used the name <i>P. cerevisiae</i> for acid-tolerant beer pediococci. These preferred anaerobic conditions.		Strains called <i>P. cerevisiae</i> by Pedersen now called <i>P. pentosaceus</i> . Not hop tolerant.	The name <i>P. acidilactici</i> was used for strains with high optimum temperature. Not hop tolerant.

1888 Lindner (11) reported isolating cocci from beer clouded with sarcina and called them *P. cerevisiae*. These bacteria were low-temperature organisms, but they were aerobic. Later, in 1903, Claussen (3), again working with beer, rejected the name *P. cerevisiae* for his cultures and called them *P. damnosus* as he did not

consider his organisms to be the same as those seen by Balcke. Mees, in his dissertation of 1934 (12), accepted *P. damnosus* of Claussen and again queried if it was the same as *P. cerevisiae* of Balcke.

Gram-positive cocci dividing in two planes so that they occur as single cells, pairs, and tetrads

TABLE 2. Characters of established species of the genus *Pediococcus* showing the principal differentiating factors^a

Property	Pediococcus species			
	<i>P. damnosus</i>	<i>P. acidi-lactici</i>	<i>P. pentosaceus</i>	<i>P. parvulus</i>
Morphology	Cocci occurring singly, in pairs, and in tetrads			
Gram stain	+	+	+	+
Optimum pH for growth initiation	5.0-5.5	6.0	7.0	not known
Maximum pH for growth initiation	6.5	8.0	8.2	not known
Growth at pH 9.0	—	—	—	—
Final pH in glucose broth	3.5-3.8	3.5-3.8	3.5-3.8	3.9-5.5
Growth at pH 8.0	—	+	+	not known
Optimum temperature	25-30	40	35	30
Maximum temperature	<35	<55	42-45	40-42
Growth at 45 C	—	+	+	—
Growth at 50 C	—	+	—	—
Growth in 8.0% NaCl	—	+	+	—
Tolerance of hop antiseptic	+	—	—	not known
CO ₂ requirement	+	—	—	—
O ₂ requirement	facultative	facultative	facultative	facultative
Type of lactic acid produced	DL	DL	DL	DL
Hydrolysis of arginine	—	+	+	—
aesculin	+	+	+	+
Acid produced from arabinose	—	±	+	—
xylose	—	±	±	—
fructose	+	+	+	±
galactose	±	+	+	—
glucose	+	+	+	+
mannose	+	+	+	—
rhamnose	—	±	±	—
cellobiose	+	±	+	—
lactose	±	± (slow)	± (slow)	±
maltose	± (slow)	±	+	±
melibiose	—	±	±	—
melezitose	—	±	—	—
sucrose	±	±	±	—
trehalose	+	±	+	±
raffinose	—	—	—	—
glycerol	—	slow	slow	—
mannitol	—	—	—	—
sorbitol	—	—	—	—
salicin	±	+	+	±
Mol % G + C in DNA ^b	Considerable variation between laboratories, but ranges from 35 to 43			not known

^a Compiled from published data (4, 7, 12, 13, 15).

^b G + C, guanine plus cytosine; DNA, deoxyribonucleic acid.

TABLE 3. *Characters of the proposed neotype strains of species of the genus Pediococcus and of the type strain of P. parvulus*

Property	Pediococcus species			
	<i>P. damnosus</i> ^a NCDO 1832	<i>P. acidi-lactici</i> ^a NCDO 1859	<i>P. pentosaceus</i> ^a NCDO 990	<i>P. parvulus</i> ^b NCDO 1634
Morphology	Cocci occurring singly, in pairs, and in tetrads			
Gram stain	+	+	+	+
Growth at pH 9.0	—	—	—	—
Final pH in glucose broth	not known	3.8	3.8	5.3 ^c
Growth at 12 C	+	+	+	+
37 C	—	—	+	—
40 C	—	+	+	+
45 C	—	+	—	—
Growth in 4% NaCl	—	+	+	+
6.5% NaCl	—	+	+	—
O ₂ requirement	anaerophilic	facultative	facultative	anaerophilic
Type of lactic acid produced	DL	DL	DL	DL
Diacetyl from glucose	+	+	—	—
Hydrolysis of arginine	—	+	+	—
aesculin	+	+	+	+
Acid produced from arabinose	—	+	+	—
xylose	—	+	—	—
fructose	+	+	+	+
galactose	—	+	+	—
glucose	+	+	+	+
mannose	+	+	+	—
sorbose	—	—	—	—
rhamnose	—	—	—	—
cellobiose	+	+	+	—
lactose	—	+	—	—
maltose	—	+	slow	+
melibiose	—	—	slow	—
sucrose	—	—	slow	—
trehalose	+	+	+	—
raffinose	—	—	slow	—
dextrin	—	—	—	—
starch	—	—	—	—
glycerol	—	+	slow	—
mannitol	—	—	—	—
sorbitol	—	—	—	—
salicin	+	+	slow	±

^a Compiled from an examination of strains at NCDO.^b Compiled from Günther et al. (6) and NCDO.^c Glucose yeastrel broth.

are considered to belong to a separate genus in the family *Lactobacillaceae* and are commonly known as pediococci. These bacteria are catalase-negative or, if they produce catalase, they show only weak gas production from H₂O₂. They require a fermentable carbohydrate for growth, and their amino acid and vitamin requirements are complex. Carbon dioxide is not formed from the fermentation of glucose, and lactic acid is the major end-product of

glucose fermentation. It is requested that the Judicial Commission issue an Opinion designating *P. damnosus* Claussen as the type species of the genus *Pediococcus* and conserving the generic name *Pediococcus*, with attribution of this name to Claussen [Rule 9c(3)(c)].

The names which have been used for some species of pediococci are summarized in Table 1. By age, *P. acidi-lactici* Lindner 1888 (11) has priority over *P. damnosus* Claussen 1903 (3).

The information given by Lindner about *P. acidi-lactici* is scanty. It was a pediococcus with an optimum temperature of growth of 41 C, but little more is known. The name was not used again until it was revived by Nagakawa and Kitahara (14) in 1959. The organism described under this name by these workers is easily recognizable, and strains included in it are available for study, but Nagakawa and Kitahara separated *P. acidi-lactici* from another species, which they named *P. pentosaceus*. Other workers studying these same bacteria do not agree that they form two species. Mundt et al. (13) agreed with Nagakawa and Kitahara, Günther and White (8) put both species into one, and Whittenbury (16) thought the difference between *P. acidi-lactici* and *P. pentosaceus* so small that future work might well show that they were only one species. On the other hand, the name *P. damnosus* Claussen has been used only for pediococci growing in beer. It was used by Mees (12) and subsequently by other workers (1, 4). There is no disagreement that all of the studies involving *P. damnosus* dealt with the same organism. For these reasons, *P. damnosus* Claussen is proposed as the type species of the genus *Pediococcus* rather than *P. acidi-lactici* Lindner.

Table 2 gives the differential characteristics of *P. damnosus*, *P. pentosaceus*, *P. acidi-lactici*, and *P. parvulus* Günther et al. (7).

Other species have been described and named in the literature, but they are not included here because their true position in classification is still in doubt. These comprise the salt-tolerant species and bacteria sometimes called aerococci.

The following are proposed as neotype strains for the species listed in Table 2. The characteristics of these strains are given in Table 3. The strains all possess properties which are typical of the species for which they are the proposed neotypes.

1. *P. damnosus* NCDO 1832 (Be.1). As far as can be ascertained, none of Claussen's strains, on which the original description of this species was based, exist. NCDO 1832 is proposed as a typical pediococcus from beer which has been studied in detail. It was isolated from lager beer yeast by D. H. Williamson, Brewing Industry Research Foundation, Nutfield, England. It was sent by Williamson to Dr. Coster and by her to the NCDO. It is designated here as the neotype strain.

2. *P. pentosaceus* NCDO 990 (P. C.) This strain was isolated from dried American beer yeast in 1931 by C. B. van Niel. It was sent to the Technische-Hoogeschool, Delft, and from there to Dr. Gunther, who sent it to the NCDO.

It is possible, but not certain, that this strain was included by Mees in his work. It is designated here as the neotype strain of *P. pentosaceus*.

3. *P. acidi-lactici* NCDO 1859 (IFO 3884). None of the strains on which Lindner based his original description of this organism exist. The name *P. acidi-lactici* was revived in modern times by Nagakawa and Kitahara. Therefore, one of their strains which is already deposited in culture collections is here designated as the neotype strain. This strain was sent to the NCDO from the IFO as *P. hennebergii* and was renamed *P. acidi-lactici* by Nagakawa and Kitahara.

NCDO 1634 (S182; ATCC 19371; NCIB 9447) is the type strain of *P. parvulus* (6).

REPRINT REQUESTS

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