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Cellular Neutral Sugar Compositions and Ubiquinone Systems of the Genus *Candida*

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Cellular neutral sugar compositions and ubiquinone systems of the type strains of 196 species and 9 varieties of the genus *Candida* were examined. One hundred sixty-two species and 7 varieties contained glucose and mannose in the whole cells, while 34 species and 2 varieties contained glucose, mannose, and galactose. As the major ubiquinone, the genus *Candida* was clearly demonstrated to have four ubiquinone types of Q-6, Q-7, Q-8, and Q-9, i.e., 8 species had Q-6, 50 species had Q-7, 20 species had Q-8, and 118 species and 9 varieties had Q-9. On the basis of cellular neutral sugar compositions and ubiquinone systems, *Candida* species were divided into six groups. Group Ia (8 species) has glucose, mannose, and Q-6 type of ubiquinone. Group Ib (50 species) has glucose, mannose, and Q-7 type of ubiquinone. Group Ic (17 species) has glucose, mannose, and Q-8 type of ubiquinone. Group Id (87 species and 7 varieties) has glucose, mannose, and Q-9 type of ubiquinone. Group IIa (3 species) has glucose, mannose, galactose, and Q-8 type of ubiquinone. Group IIb (31 species and 2 varieties) has glucose, mannose, galactose, and Q-9 type of ubiquinone. Each of the six groups is assumed to be still an assembly of phylogenetically different species because each group contains several teleomorphic genera and is heterogeneous in cellular fatty acid compositions.

Key words : sugar compositions, ubiquinone, chemotaxonomy, *Candida*

INTRODUCTION

Anamorphic genera *Candida* and *Torulopsis* had long been known as the most heterogeneous taxa of yeasts. In 1978, Yarrow and Meyer (41) merged *Torulopsis* to *Candida* because the presence or absence of pseudomycelium formation was an unstable differential character for distinguishing *Torulopsis* from *Candida*. This classification was adopted in The Yeasts, a Taxonomic Study, 3rd. edition, 1984. The combined genus *Candida* includes both of ascomycetous and basidiomycetous yeast species (6). In 1981, van der Walt et al. (33) established the genus *Myxozyma* for mucoid extracellular polysaccharides-producing ascomycetous yeast species, *Candida mucilagina* and *Cryptococcus melibiosum* (≡*Torulopsis melibiosum*). Later, Weijman et al. (38) amended the definition of the genus *Candida* to permit the inclusion of only ascomycetous species, and transferred basidiomycetous species to the genera *Cryptococcus* and *Rhodotorula* based on the ultrastructure of cell walls and the ultrastructure of hyphal septal pores, cellular carbohydrate compositions, and physiological characteristics, after the emendation of the latter two genera. However, even after excluding *Myxozyma* species and basidiomycetous yeast species, *Candida* is the biggest genus of yeasts and comprises about one-third of all yeast species, and is still considered to be the most heterogeneous genus. It is considered that reclassification of the genus *Candida* is urgently required using modern technology for microbial systematics.

Cellular sugar (or carbohydrate) compositions and ubiquinone systems have been considered to be important chemotaxonomic characters as criteria of genus or higer taxa of yeasts (35~39). Hence, these two characters are essential for reclassification of the genus *Candida* from chemotaxonomic point of view. However, the whole features of cellu-

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Table 1. Grouping of species of the genus *Candida* based on whole cell sugar compositions and ubiquinone system

Group	Number of species and varieties	Whole cell sugar compositions	Ubiquinone system
Ia	8	Glc, Man	Q-6
Ib	50	Glc, Man	Q-7
Ic	17	Glc, Man	Q-8
Id	94	Glc, Man	Q-9
IIa	3	Glc, Man, Gal	Q-8
IIb	33	Glc, Man, Gal	Q-9

lar sugar compositions and ubiquinone systems of *Candida* species is still unclear.

In this study, cellular neutral sugar compositions and ubiquinone systems of type strains of all species available in the genus *Candida* were examined to clarify their whole features, and it was attempted to group *Candida* species based on these two characters.

MATERIALS AND METHODS

Strains employed. The type strains of 196 species and 9 varieties of the genus *Candida* and their sources were shown in Tables 2~6.

Cellular neutral sugar analysis. Yeasts were incubated on YM agar plates at 25°C for 4 days. *Candida austromarina* and *Candida psychrophila* were incubated at 10°C for 4 days and at 17°C for 4 days, respectively. *Candida glucosophila* was incubated on 25 % glucose-YM agar plates at 25°C for 4 days. Yeast cells grown on the surface of agar were harvested and suspended in deionized water. The suspension was transferred to centrifuge tubes using a pipette. After centrifugation at 3,000 rpm for 10 min, yeast cells were washed twice with deionized water, then washed with acetone three times, and dried at 37°C overnight. Dried yeast cells (50 to 100 mg) were hydrolyzed with 1 m*l* of 2 M trifluoroacetic acid at 100°C for 3 hours. After paper filtration, filtrates were evaporated to dryness at 55 °C. The residue was dissolved in 0.5 m*l* of deionized water, and neutralized immediately with ion-exchange resins (Amberlite IRA 410, OH form). After removal of ion-exchange resins using a disposal filter unit (Sodex DT ED-13, Showa Denko, K. K., Tokyo, Japan), the filtrates were subjected to high-performance liquid chromatography (HPLC) for analysis of neutral sugars. HPLC analysis of neutral sugars was carried out by the method of Suzuki and Nakase (30).

Ubiquinone analysis. Yeasts were incubated, with shaking, in YM broth at 25°C for 4 days. *Candida austromarina* and *Candida psychrophila* were incubated at 10°C for 4 days and at 17°C for 4 days, respectively. *Candida glucosophila* was incubated in 25 % glucose-YM broth at 25°C for 4 days. After saponification of wet yeast cells by the modified method of Yamada and Kondo (39) described by Suzuki and Nakase (31), ubiquinones were extracted with hexane and purified by preparative thin layer chromatography using Merck Kieselgel 60 F254 plates and with benzene as a solvent system. Ubiquinones were extracted with acetone and evaporated to dryness. Purified ubiquinone isoprenologues were analyzed by the HPLC method previously reported (19, 31).

RESULTS AND DISCUSSION

The strains of the genus *Candida* studied were classified into two categories based on cellular neutral sugar compositions. The one had glucose and mannose (called glucose-mannose below) and comprised 162 species and 7 varieties, and the other had glucose, mannose and galactose (called glucose-mannose-galactose below) and comprised 34 species and 2 varieties. The strains of the genus *Candida* employed were classified into four ubiquinone types. As major ubiquinone, eight species had Q-6, 50 species had Q-7, 20 species had Q-8, and 118 species and 9 varieties had Q-9.

As a result, species and varieties of the genus *Candida* were divided into two groups, I and II based on the presence or absence of galactose in the

Table 2. Cellular neutral sugar compositions and ubiquinone systems of Group Ia in the genus *Candida*

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. castellii	JCM 9550^T	IFO 10270^T	31.1	68.9	—	100	—	—	—	—
C. glabrata	JCM 3761^T	CBS 138^T	37.1	62.9	—	98.8	0.3	0.9	—	—
C. holmii	JCM 9554^T	IFO 1629^T	40.0	60.0	—	100	trace	—	—	—
C. humilis	JCM 9852^T	IFO 10280^T	33.1	66.9	—	100	trace	—	—	—
C. kefyr	JCM 9556^T	IFO 10287^T	37.3	62.7	—	99.2	—	0.3	0.5	—
C. milleri	JCM 9613^T	NRRL Y-7245^T	43.9	56.1	—	97.5	1.0	1.5	—	—
C. sphaerica	JCM 9563^T	IFO 0648^T	41.5	58.5	—	98.9	trace	0.6	0.4	—
C. tannotolerans	JCM 9564^T	IFO 10314^T	48.6	51.4	—	99.6	trace	—	0.4	—

—, Not detected
T, Type strain

cellular neutral sugar compositions. Based on the type of the ubiquinone systems, groups I and II were further divided into four subgroups, Ia, Ib, Ic, and Id and two subgroups, IIa and IIb, respectively (Table 1). In this paper, the ubiquinone isoprenologue containing the largest amount in five isoprenologues was designated as the major ubiquinone.

Group Ia (glucose-mannose, Q-6)

Eight species are included in this group (Table 2). Four species were reported to have teleomorphs of genera *Saccharomyces* and *Kluyveromyces*. *Candida holmii, Candida kefyr, Candida sphaerica*, and *Candida tannotolerans* are anamorphs of *Saccharomyces exiguus, Kluyveromyces marxianus, Kluyveromyces lactis*, and *Kluyveromyces yarrowii*, respectively (1, 6). Group Ia is heterogeneous in the cellular fatty acid compositions according to the data of Viljoen and Kock (34). They reported that *Candida glabrata, Candida humilis*, and *Candida holmii* were included in Group I-B ; *Candida castellii* was included in Group II-C ; and *Candida kefyr* was included in Group III-D.

Group Ib (glucose-mannose, Q-7)

This group comprises 50 species (Table 3). Nine species in this group were reported to have teleomorphs of genera *Issatchenkia* and *Pichia*. *Candida krusei* and *Candida sorbosa* are anomorphs of *Issatchenkia orientalis* and *Issatchenkia occidentalis*, respectively (1, 6). *Candida pelliculosa, Candida melinii, Candida lambica, Candida valida, Candida utilis, Candida norvegensis*, and *Candida nitrativorans* are anamorphs of *Pichia anomala, Pichia canadensis, Pichia fermentans, Pichia membranaefaciens, Pichia jadinii, Pichia norvegensis*, and *Pichia sydowiorum*, respectively (1, 6).

Group Ib is heterogeneous in cellular fatty acid compositions according to the data of Viljoen and Kock (34). They reported that *Candida boidinii* belonged to group II-A ; *Candida freyschussii, Candida inconspicua, Candida norvegica, Candida peltata, Candida sonorensis, Candida utilis, Candida vini*, and *Candida wickerhamii* belonged to III-A ; *Candida rugopelliculosa* and *Candida solani* belonged to III-B ; *Candida pelliculosa* belonged to III-C ; *Candida berthetii, Candida diversa, Candida krusei*, and *Candida nitratophila* belonged to III-E ; *Candida norvegensis* and *Candida succiphila* belonged to III-H ; and that *Candida methanosorbosa* and *Candida vartiovaarai* belonged to III-J and III-K, respectively.

Lee and Komagata (14～16) and Kumamoto et al. (7) reported that fifteen methanol-assimilating *Candida* species had Q-7 as the major ubiquinone. Their results were confirmed in this study. These are *Candida boidinii, Candida cariosilignicola, Candida methanolophaga, Candida methanosorbosa, Candida methylica, Candida ooitensis, Candida ovalis, Candida succiphila, Candida nemodendra, Candida nitratophila, Candida pini, Candida maris, Candida pignaliae, Candida nanaspora*, and *Candida sonorensis*. Lee et al. (9) reported that *Candida methylica* was a synonym of *Candida boidinii* and *Candida methanolophaga* was a synonym of *Candida succiphila*. Yamada et al. (40) showed that *Candida*

Table 3. Cellular neutral sugar compositions and ubiquinone systems of Group Ib in the genus *Candida*

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. berthetii	JCM 9594^T	ATCC 18808^T	44.3	55.7	—	3.7	96.3	—	—	—
C. boidinii	JCM 9604^T	NRRL Y-2332^T	60.6	39.4	—	6.0	91.3	2.7	—	—
C. cariosilignicola	JCM 9438^T	IAM 12484^T	31.0	69.0	—	3.4	94.5	2.1	—	—
C. cellulolytica	JCM 9397^T	T. Hatano KO-27	25.7	74.3	—	3.1	96.9	trace	—	—
C. citrea	JCM 1503^T	AJ 4769^T	25.6	74.4	—	6.8	92.4	0.8	—	—
C. dendrica	JCM 9605^T	NRRL Y-7775^T	33.0	67.0	—	2.7	92.9	trace	4.4	—
C. diversa	JCM 1848^T	AJ 4648^T	17.4	82.6	—	3.1	95.8	0.9	0.2	—
C. ethanolica	JCM 9588^T	CBS 8041^T	23.9	76.1	—	1.4	96.9	1.4	0.3	—
C. freyschussii	JCM 9850^T	IFO 10235^T	34.9	65.1	—	1.1	98.9	trace	—	—
C. inconspicua	JCM 9555^T	IFO 0621^T	50.7	49.3	—	2.2	96.6	1.2	—	—
C. krusei	JCM 1609^T	IAM 12186^T	32.0	68.0	—	0.8	97.8	1.4	trace	—
C. lambica	JCM 9557^T	IFO 10289^T	43.0	57.0	—	3.2	94.9	1.9	—	—
C. llanquihuensis	JCM 8918^T	CBS 8182^T	49.3	50.7	—	4.6	92.8	1.3	1.3	—
C. maris	JCM 9853^T	IFO 10003^T	29.1	70.9	—	0.5	96.5	3.0	—	—
C. maritima	JCM 9612^T	NRRL Y-7899^T	30.6	69.4	—	1.6	97.6	0.8	—	—
C. melinii	JCM 2276^T	AJ 4696^T	30.6	69.4	—	trace	99.2	0.8	—	—
C. methanolophaga	JCM 9441^T	IAM 13156^T	31.1	68.9	—	6.4	92.0	1.6	—	—
C. methanolovescens	JCM 9442^T	IAM 12878^T	29.2	70.8	—	4.5	94.8	0.7	—	—
C. methanosorbosa	JCM 9620^T	CBS 7029^T	39.9	60.1	—	2.2	96.6	1.2	—	—
C. methylica	JCM 9854^T	IFO 10329^T	57.9	42.1	—	2.8	95.9	1.3	—	—
C. montana	JCM 2323^T	S. Goto No. 865	29.9	70.1	—	1.4	92.5	0.6	5.5	—
C. nanaspora	JCM 9590^T	CBS 7200^T	24.6	75.4	—	5.8	93.0	1.2	—	—
C. nemodendra	JCM 9855^T	IFO 10299^T	35.2	64.8	—	3.7	94.7	1.6	—	—
C. nitrativorans	JCM 9591^T	CBS 6152^T	50.1	49.9	—	1.2	96.7	2.1	—	—
C. nitratophila	JCM 9856^T	IFO 10300^T	21.3	78.7	—	1.6	96.4	2.0	—	—
C. norvegensis	JCM 2307^T	AJ 5001^T	49.0	51.0	—	2.1	97.1	0.8	—	—
C. norvegica	JCM 8897^T	IFO 10301^T	46.8	53.2	—	2.5	96.3	0.6	0.6	—
C. odintsovae	JCM 9838^T	CBS 6026^T	35.3	64.7	—	2.2	96.1	1.7	—	—
C. ooitensis	JCM 9443^T	IAM 13158^T	59.4	40.6	—	1.3	95.8	2.9	—	—
C. ovalis	JCM 9444^T	IAM 13157^T	34.2	65.8	—	3.0	95.7	1.3	—	—
C. pelliculosa	JCM 9847^T	CBS 605^T	50.3	49.7	—	trace	100	trace	—	—
C. peltata	JCM 9829^T	CBS 5576^T	14.7	85.3	—	6.9	93.1	trace	—	—
C. pignaliae	JCM 9836^T	CBS 6071^T	26.1	73.9	—	—	94.9	5.1	trace	—
C. pini	JCM 9826^T	CBS 970^T	17.8	82.2	—	trace	98.3	1.7	—	—
C. pseudolambica	JCM 9830^T	CBS 2063^T	43.2	56.8	—	0.8	86.2	4.1	8.9	—
C. quercuum	JCM 1587^T	AJ 4781^T	39.0	61.0	—	1.9	98.1	trace	—	—
C. rugopelliculosa	JCM 1593^T	AJ 4656^T	29.5	70.5	—	2.7	95.9	1.4	—	—
C. silvae	JCM 6352^T	IFO 10310^T	29.6	70.4	—	3.9	95.1	0.9	0.1	—
C. silvicultrix	JCM 9831^T	CBS 6269^T	59.4	40.6	—	8.8	89.7	0.4	1.1	—
C. solani	JCM 2339^T	AJ 4664^T	46.5	53.5	—	2.8	97.2	trace	trace	—
C. sonorensis	JCM 1827^T	UCD 71-148^T	38.0	62.0	—	2.2	90.5	1.4	5.9	—
C. sorbosa	JCM 9843^T	CBS 1910^T	31.2	68.8	—	3.0	95.9	1.1	—	—
C. sorboxylosa	JCM 1536^T	AJ 4437^T	28.6	71.4	—	10.4	89.1	0.5	trace	—
C. stellimalicola	JCM 3546^T	M. Suzuki T-53	26.9	73.1	—	3.8	95.9	0.3	—	—
C. succiphila	JCM 9445^T	IAM 12489^T	29.8	70.2	—	6.5	92.4	1.1	—	—

Table 3. continued

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. utilis	JCM 9624^T	CBS 621^T	48.9	51.1	—	trace	93.3	trace	6.7	—
C. valida	JCM 1455^T	CBS 638^T	26.5	73.5	—	1.4	97.2	1.4	—	—
C. vartiovaarai	JCM 3759^T	CBS 4289^T	40.9	59.1	—	3.2	96.5	0.3	trace	—
C. vini	JCM 1456^T	CBS 639^T	28.1	71.9	—	1.4	96.9	1.7	—	—
C. wickerhamii	JCM 9568^T	IFO 10322^T	35.7	64.3	—	4.9	93.4	1.7	trace	—

—, Not detected
T, Type strain

Table 4. Cellular neutral sugar compositions and ubiquinone systems of Group Ic in the genus *Candida*

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. anatomiae	JCM 9547^T	IFO 10259^T	37.4	62.6	—	—	15.0	85.0	—	—
C. entomophila	JCM 9607^T	NRRL Y-7783^T	33.6	66.4	—	0.4	7.8	91.5	0.3	—
C. ernobii	JCM 9848^T	IFO 0654^T	29.8	70.2	—	0.9	15.1	84.0	—	—
C. fennica	JCM 9849^T	IFO 10276^T	36.6	63.4	—	2.0	1.9	94.5	1.6	—
C. fructus	JCM 1513^T	AJ 4401^T	17.9	82.1	—	—	10.1	88.0	1.9	—
C. globosa	JCM 9609^T	NRRL Y-1506^T	44.1	55.9	—	1.3	13.7	82.6	2.4	—
C. homilentoma	JCM 1507^T	AJ 14322^T	37.3	62.7	—	2.9	3.6	89.6	3.9	—
C. ishiwadae	JCM 9451^T	IFO 1495^T	18.0	82.0	—	0.6	15.4	81.7	2.3	—
C. karawaiewii	JCM 8067^T	IFO 10286^T	34.7	65.3	—	—	2.8	92.8	4.4	—
C. lusitaniae	JCM 1814^T	AJ 4938^T	41.9	58.1	—	1.0	11.3	87.7	trace	—
C. molischiana	JCM 1997^T	IAM 12810^T	26.8	73.2	—	0.5	4.1	92.7	2.7	—
C. musae	JCM 1598^T	AJ 4408^T	22.5	77.5	—	—	18.4	81.2	0.4	—
C. populi	JCM 9833^T	CBS 7351^T	32.4	67.6	—	—	3.4	93.3	3.3	—
C. rhagii	JCM 9839^T	CBS 4237^T	32.2	67.8	—	2.0	7.6	88.9	1.5	—
C. sequanensis	JCM 9841^T	CBS 8118^T	46.6	53.4	—	2.9	4.5	91.0	1.6	—
C. silvanorum	JCM 1804^T	AJ 14314^T	38.8	61.2	—	—	2.5	95.2	2.3	—
C. stellata	JCM 9476^T	IFO 0703^T	52.4	47.6	—	—	3.7	74.0	22.3	—

—, Not detected
T, Type strain

maris, *Candida boidinii*, *Candida methylica*, and *Candida methanosorbosa* had a phylogenetically close relation to methanol-assimilating species of the genera *Pichia* and *Ogataea* based on 18S ribosomal RNA and 26S ribosomal RNA partial sequences.

Montrocher (17) divided *Candida* species into ten groups based on physiological characteristics, soluble cell protein antigenic structures, and cytochrome absorption spectra. Montrocher's "norvegensis" group (17) was divided into two groups, species having Q-7 and species having Q-9. Species having Q-7 included in this group are *Candida norvegensis*, *Candida solani* and *Candida quercuum*. Seven species included in Montrocher's "krusei" group (17) had Q-7. They are *Candida krusei*, *Candida sorbosa*, *Candida sorboxylosa*, *Candida lambica*, *Candida citrea*, *Candida rugopelliculosa*, and *Candida diversa*.

Candida montana was described by Goto and Oguri (4) in 1983 and reported to have Q-7 as the major ubiquinone which was confirmed in this study.

Group Ic (glucose-mannose, Q-8)

This group comprises 17 species (Table 4). Three species were reported to have teleomorphs of genera *Pichia, Citeromyces*, and *Clavispora*. *Candida molischiana* is anamorph of *Pichia capsulata* and is known as a methanol-assimilating yeast (1, 6, 16). *Candida globosa* and *Candida lusitaniae* are anamorphs of *Citeromyces matritensis* and *Clavispora lusitaniae*, respectively (6).

Group Ic is heterogeneous in cellular fatty acid compositions according to the data of Viljoen and Kock (34). They reported that *Candida entomophila, Candida ernobii*, and *Candida lusitaniae* belonged to group III-A and *Candida homilentoma* belonged to group III-C.

Montrocher et al. (18) reported that *Candida silvanorum, Candida entomophila*, and *Candida homilentoma* belonging to "diddensii" group (17) had Q-8 as the major ubiquinone which was confirmed in this study.

Hagler et al. (5) described *Candida populi* in 1989 and reported the ubiquinone type of Q-8 though they did not show quantitative data. This species physiologically resembles *Candida molischiana*, a Q-8-equipped species, but is distinguished by its habitat, G+C content of DNA and maximum growth temperature.

Candida stellata was reported to have Q-6 or Q-8 (39). In this study, the type strain of this species had Q-8 as the major ubiquinone. *Candida stellata* having Q-6 is considered to belong to a separate species.

Among Group Ic species, six species, *Candida entomophila, Candida fennica, Candida homilentoma, Candida rhagii, Candida sequanensis*, and *Candida stellata*, were reported to exist in phylogenetically different clusters from each other based on partial sequences at 5'-end of 26S ribosomal RNA genes (8).

Group Id (glucose-mannose, Q-9)

Group Id is the biggest group comprising 87 species and 7 varieties (Table 5). *Candida vulgaris* (=*Candida tropicalis*), the type species of the genus *Candida* was included in this group.

Two varieties and four species were reported to have teleomorphs of genera *Debaryomyces, Pichia*, and *Metschnikowia*. *Candida famata* var. *famata* and *Candida famata* var. *flareri* are anamorphs of *Debaryomyces hansenii* var. *hansenii* and *Debaryomyces hansenii* var. *fabryi*, respectively (1, 19). *Candida guilliermondii* is anamorph of *Pichia guilliermondii* (6). *Candida pulcherrima* and *Candida reukaufii* are anamorphs of *Metschnikowia pulcherrima* and *Metschnikowia reukaufii*, respectively (6). Lee et al. (12) showed *Candida cacaoi* to be an anamorph of *Pichia farinosa* having Q-9 based on DNA-DNA reassociation.

Group Id is heterogeneous in cellular fatty acid compositions according to the data of Viljoen and Kock (34). They reported that *Candida bombicola, Candida geochares*, and *Candida intermedia* were included in their group I-A ; *Candida cacaoi, Candida membranaefaciens, Candida schatavii*, and *Candida torresii* were included in their group II-A ; *Candida pseudointermedia* was included in their group II-B ; *Candida chiropterorum* was included in their group II-D ; *Candida maltosa, Candida albicans, Candida beechii, Candida diddensiae, Candida natalensis, Candida parapsilosis, Candida quercitrusa, Candida rugosa, Candida sake, Candida shehatae* var. *shehatae, Candida tropicalis, Candida viswanathii,* and *Candida zeylanoides* were included in their group III-A ; *Candida tenuis* was included in their group III-B ; *Candida fermenticarens, Candida glaebosa*, and *Candida insectamans* were included in their group III-C ; *Candida atmospherica* was included in their group III-F ; *Candida entomaea* and *Candida mogii* were included in their group III-G ; and *Candida oregonensis* was included in their group III-H.

Candida albicans, Candida tropicalis, Candida viswanathii, and *Candida maltosa* were included in this group. These species belonged to Montrocher's "albicans-tropicalis" group (17). Four species belonging to Montrocher's "parapsilosis" group (17) were included in this group. They are *Candida parapsilosis, Candida sake, Candida oleophila*, and *Candida natalensis*. *Candida intermedia* belonging to Montrocher's "pseudotropicalis" group (17) was included in this group. Montrocher's "norvegensis" group (17) was divided into species having Q-7 and species having Q-9. Species having Q-9 were included in this group. They are *Candida bombi, Candida boleticola, Candida catenulata, Candida conglobata, Candida santamariae* var. *santamariae*, and *Candida santamariae* var. *membranifaciens*. In Montrocher's "guilliermondii" group (17), *Candida guilliermondii,*

Table 5. Cellular neutral sugar compositions and ubiquinone systems of Group Id in the genus *Candida*

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. aaseri	JCM 1689^T	CBS 1913^T	43.9	56.1	—	—	2.3	2.5	95.2	—
C. agrestis	JCM 2321^T	S. Goto No. 611	26.8	73.2	—	—	1.1	4.7	93.7	0.5
C. akabanensis	JCM 9115^T	T. Nakse NK-4	27.9	72.1	—	—	—	14.3	85.7	—
C. albicans	JCM 1542^T	IFO 1385^T	54.1	45.9	—	—	—	15.4	84.4	0.2
C. apicola	JCM 9592^T	ATCC 24616^T	51.1	48.9	—	1.7	—	10.5	87.8	—
C. atlantica	JCM 9548^T	IFO 10263^T	30.5	69.5	—	2.6	1.6	14.0	81.7	trace
C. atmospherica	JCM 9549^T	IFO 1969^T	31.9	68.1	—	—	0.7	5.2	93.8	0.3
C. austromarina	JCM 8894^T	IFO 10265^T	65.6	34.3	—	—	0.1	1.3	98.0	0.6
C. beechii	JCM 1802^T	AJ 14312^T	29.3	70.7	—	0.3	1.0	9.0	89.7	trace
C. boleticola	JCM 1500^T	AJ 4703^T	22.0	78.0	—	—	trace	10.6	89.4	—
C. bombi	JCM 9595^T	ATCC 18811^T	48.0	52.0	—	—	2.0	17.9	80.1	—
C. bombicola	JCM 9596^T	ATCC 22214^T	42.9	57.1	—	1.0	—	7.7	91.3	—
C. buinensis	JCM 9453^T	IFO 1642^T	20.0	80.0	—	0.6	1.0	3.1	95.3	—
C. butyri	JCM 1501^T	AJ 4668^T	22.2	77.8	—	—	trace	5.4	94.6	trace
C. cacaoi	JCM 8895^T	IFO 10231^T	51.5	48.5	—	—	0.2	1.8	97.0	1.0
C. catenulata	JCM 1604^T	IAM 12182^T	42.8	57.2	—	—	1.3	5.7	92.3	0.7
C. chilensis	JCM 1693^T	CBS 5719^T	24.7	75.3	—	—	0.4	8.1	91.5	trace
C. chiropterorum	JCM 9597^T	ATCC 22291^T	52.9	47.1	—	—	—	3.4	96.6	—
C. coipomensis	JCM 8916^T	CBS 8178^T	21.5	78.5	—	3.7	0.4	7.5	88.4	trace
C. conglobata	JCM 2373^T	AJ 4701^T	37.9	62.1	—	trace	0.1	4.8	95.1	—
C. cylindracea	JCM 9586^T	CBS 6330^T	35.5	64.5	—	—	—	16.5	83.5	—
C. dendronema	JCM 1803^T	AJ 14313^T	43.3	56.7	—	—	—	3.0	97.0	—
C. diddensiae	JCM 9598^T	ATCC 15541^T	24.0	76.0	—	—	0.5	6.2	93.3	—
C. drymisii	JCM 9587^T	CBS 8185^T	59.9	40.1	—	trace	0.5	9.6	89.6	0.3
C. entomaea	JCM 9606^T	NRRL Y-7785^T	32.6	67.4	—	0.2	1.0	7.8	91.0	trace
C. famata var. *famata*	JCM 1521^T	AJ 4342^T	43.5	56.5	—	—	—	5.2	94.8	trace
C. famata var. *flareri*	JCM 2166^T	CBS 1796^T	39.6	60.4	—	0.2	0.5	7.0	91.8	0.5
C. fermenticarens	JCM 9589^T	CBS 7040^T	43.2	56.8	—	1.1	0.9	6.0	91.4	0.6
C. fluviatilis	JCM 9552^T	IFO 10234^T	44.3	55.7	—	—	0.6	7.6	91.5	0.3
C. fragi	JCM 1791^T	AJ 4616^T	21.0	79.0	—	0.2	1.0	7.2	91.3	0.3
C. friedrichii	JCM 9553^T	IFO 10277^T	29.7	70.3	—	—	0.4	3.9	94.8	0.9
C. fukuyamanensis	JCM 9396^T	T. HatanoKO-15	43.2	56.8	—	—	—	5.1	94.9	—
C. geochares	JCM 9851^T	IFO 10278^T	54.7	45.3	—	—	2.0	12.1	85.2	0.7
C. glaebosa	JCM 1590^T	AJ 4754^T	32.3	67.3	—	—	—	2.2	96.2	1.6
C. glucosophila	JCM 9440^T	IAM 13112^T	42.8	57.2	—	—	trace	2.0	97.8	0.2
C. guilliermondii	JCM 1539^T	T. Shinoda	19.8	80.2	—	—	1.6	1.7	96.1	0.6
C. haemulonii	JCM 3762^T	CBS 5149^T	54.7	45.3	—	0.4	0.5	0.8	96.7	1.6
C. insectalens	JCM 9610^T	NRRL Y-7778^T	42.3	57.7	—	—	0.7	3.4	95.9	—
C. insectamans	JCM 9611^T	NRRL Y-7786^T	63.3	36.7	—	—	0.3	6.4	93.2	0.1
C. insectorum	JCM 9457^T	IFO 10283^T	25.0	75.0	—	—	—	2.6	97.4	—
C. intermedia	JCM 1607^T	IAM 12185^T	19.7	80.3	—	—	—	14.2	85.8	—
C. krissii	JCM 9454^T	IFO 1663^T	45.3	54.7	—	trace	4.4	6.0	88.7	0.9
C. kruisii	JCM 1779^T	CCY 26-19-7^T	20.8	79.2	—	—	—	15.7	84.1	0.2

Table 5. continued

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. laureliae	JCM 8917^T	CBS 8180^T	19.4	80.6	—	—	—	15.0	85.0	—
C. lodderae	JCM 1601^T	AJ 5122^T	46.9	53.1	—	—	0.7	1.8	97.5	—
C. lyxosophila	JCM 7532^T	CBS 8194^T	48.1	51.9	—	trace	0.8	8.2	90.6	0.4
C. maltosa	JCM 1504^T	AJ 4718^T	57.2	42.8	—	0.3	1.2	4.5	94.0	trace
C. melibiosica	JCM 9558^T	IFO 10238^T	31.7	68.3	—	—	0.9	15.5	83.6	trace
C. membranae-faciens	JCM 9450^T	IFO 1246^T	30.1	69.9	—	—	0.4	2.6	97.0	trace
C. mesenterica	JCM 2368^T	AJ 4990^T	36.6	63.4	—	—	0.7	5.9	93.4	trace
C. mogii	JCM 1611^T	IAM 4979^T	39.6	60.4	—	—	0.8	4.5	94.2	0.5
C. mutisgemmis	JCM 9559^T	IFO 10247^T	32.5	67.5	—	—	—	3.8	96.2	—
C. naeodendra	JCM 1509^T	AJ 14324^T	35.2	64.8	—	—	0.7	3.0	96.3	trace
C. natalensis	JCM 1445^T	CBS 2935^T	19.5	80.5	—	0.5	1.0	6.0	92.1	0.4
C. oleophila	JCM 1620^T	IAM 12200^T	24.7	75.3	—	—	—	9.3	90.3	0.4
C. oregonensis	JCM 1811^T	AJ 5111^T	21.1	78.9	—	1.2	3.7	4.9	90.2	trace
C. palmioleophila	JCM 5218^T	T. Kodama Y-128	58.3	41.7	—	—	—	9.8	89.9	0.3
C. parapsilosis	JCM 1785^T	AJ 5970^T	45.6	54.4	—	—	0.4	2.3	97.0	0.3
C. polymorpha	JCM 9449^T	IFO 0836^T	56.0	44.0	—	—	0.3	4.3	95.0	0.4
C. pseudoglaebosa	JCM 2168^T	CBS 6715^T	69.9	30.1	—	—	—	8.0	92.0	—
C. pseudointermedia	JCM 1592^T	AJ 4481^T	44.0	56.0	—	—	1.6	14.6	83.8	—
C. psychrophila	JCM 2388^T	CBS 5956^T	74.9	25.1	—	—	0.3	1.3	96.8	1.6
C. pulcherrima	JCM 9846^T	CBS 610^T	34.1	65.9	—	—	0.4	13.8	85.8	trace
C. quercitrusa	JCM 9832^T	CBS 4412^T	30.3	69.3	—	—	6.5	4.2	88.6	0.7
C. ralunensis	JCM 8923^T	CBS 8179^T	27.8	72.2	—	—	0.4	3.6	96.0	trace
C. reukaufii	JCM 9845^T	CBS 1903^T	36.0	64.0	—	—	1.3	3.7	94.5	0.5
C. rugosa	JCM 1619^T	IAM 12198^T	38.1	61.9	—	trace	2.1	2.9	94.6	0.4
C. saitoana	JCM 1438^T	CBS 940^T	58.8	41.2	—	—	—	4.6	94.9	0.5
C. sake	JCM 2951^T	IFO 0435^T	38.0	62.0	—	0.5	1.0	7.5	90.4	0.6
C. santamariae										
var. *santamariae*	JCM 1816^T	AJ 4466^T	21.2	78.8	—	0.7	1.8	9.8	87.4	0.3
var. *membranifaciens*	JCM 9844^T	CBS 5838^T	31.5	68.5	—	—	0.6	7.5	91.4	0.5
C. savonica	JCM 9561^T	IFO 10309^T	31.1	68.9	—	0.4	1.0	4.6	93.5	0.5
C. shehatae var. *shehatae*	JCM 9840^T	CBS 5813^T	26.4	73.6	—	0.8	2.1	17.4	79.7	trace
C. shehatae var. *insectosa*	JCM 9842^T	CBS 4286^T	30.4	69.6	—	—	0.3	8.7	91.0	trace
C. shehatae var. *lignosa*	JCM 9837^T	CBS 4705^T	38.9	61.1	—	0.7	0.4	6.9	92.0	trace
C. silvatica	JCM 9828^T	CBS 6277^T	30.2	69.8	—	—	0.7	4.9	94.4	trace
C. sojae	JCM 1644^T	AJ 4787^T	45.7	54.3	—	—	—	4.2	95.4	0.4
C. sophiaereginae	JCM 8925^T	CBS 8175^T	42.1	57.9	—	0.8	0.4	3.0	95.2	0.6
C. suecica	JCM 7530^T	CBS 5724^T	31.0	69.0	—	—	trace	3.3	96.1	0.6
C. tanzawaensis	JCM 1648^T	AJ 4916^T	32.5	67.5	—	—	—	12.3	87.6	0.1
C. tenuis	JCM 9827^T	CBS 615^T	24.0	76.0	—	trace	trace	4.7	95.3	trace
C. terebra	JCM 9452^T	IFO 1497^T	25.5	74.5	—	0.7	—	2.4	96.9	—

Table 5. continued

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. torresii	JCM 1845^T	AJ 4937^T	28.6	71.4	—	—	trace	5.4	92.7	1.9
C. tropicalis	JCM 1541^T	IFO 1400^T	49.3	50.7	—	—	—	11.8	87.8	0.4
C. tsuchiyae	JCM 1638^T	AJ 4911^T	23.7	76.3	—	—	—	10.9	87.9	1.2
C. veronae	JCM 9566^T	IFO 10320^T	35.1	64.9	—	—	0.8	5.5	93.5	0.2
C. viswanathii	JCM 9567^T	IFO 10321^T	32.8	67.2	—	—	1.0	6.8	91.5	0.7
C. xestobii	JCM 9569^T	IFO 10323^T	46.7	53.3	—	—	1.0	4.0	94.1	0.9
C. zeylanoides	JCM 1627^T	IAM 12204^T	35.6	64.4	—	0.6	1.7	3.2	93.6	0.9

—, Not detected
T, Type strain

Table 6. Cellular neutral sugar compositions and ubiquinone systems of Group IIa in the genus *Candida*

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. galacta	JCM 8257^T	IFO 10031^T	36.7	46.1	17.2	0.3	2.0	95.2	2.5	—
C. incommunis	JCM 8258^T	IFO 10228^T	39.1	60.1	0.8	0.4	4.1	93.5	2.0	—
C. lactiscondensi	JCM 9472^T	IFO 1286^T	34.4	55.0	10.6	—	1.2	57.8	41.0	—

—, Not detected
T, Type strain

Candida membranaefaciens, and *Candida tenuis* were included in this group, but *Candida steatolytica* was included in our Group IIb, which contains galactose, and *Candida rhagii* was included in our Group Ic. Montrocher et al. (18) reported that 14 out of 17 species of the "diddensii" group (17) had Q-9 as the major ubiquinone. These species were included in this group. They are *Candida atmosphaerica, Candida butyri, Candida dendronema, Candida diddensiae, Candida entomaea, Candida ergastensis, Candida fluviatilis, Candida insectorum, Candida naeodendra, Candida polymorpha, Candida shehatae* var. *shehatae, Candida tenuis, Candida terebra*, and *Candida veronae*. Lee et al. (10) showed that *Candida entomaea* and *Candida veronae* were synonyms of *Candida terebra* based on DNA-DNA hybridization.

Among the species described by Ramírez and González (20~26) in 1984, the six species, *Candida coipomensis, Candida drymisii, Candida laureliae, Candida llanquihuensis, Candida ralunensis*, and *Candida sophiaereginae*, were included in this group.

Candida glucosophila was described by Tokuoka et al. (32) in 1987 as a new species of sugar tolerant yeast having Q-9. The ubiquinone system of this species was confirmed in this study. Goto and Oguri (4) reported that the major ubiquinone of *Candida agrestis* was Q-7, but its major ubiquinone was Q-9 in this study.

Group IIa (glucose-mannose-galactose, Q-8)

Group IIa comprised three species as shown in Table 6.

Candida galacta was formerly dealt with as a variety of *Candida apis* (6). In 1993, however, Lee et al. (13) proposed a new combination, *Candida galacta*, by separating it from *Candida apis*. We confirmed that *Candida galacta* had Q-8 as the major ubiquinone whereas *Candida apis* had Q-9 as the major ubiquinone. Viljoen and Kock (34) reported that these two species were similar to each other in cellular fatty acid composition.

Although Gorin and Spencer (3) reported that *Candida incommunis* had galactomannan in their cell wall polysaccharide, only a small amount of galactose was detected in the whole cell of this

Table 7. Cellular neutral sugar compositions and ubiquinone systems of Group IIb in the genus *Candida*

Species	Strain	Source	Neutral sugars (mol %)			Ubiquinone isoprenologues (mol %)				
			Glucose	Mannose	Galactose	Q-6	Q-7	Q-8	Q-9	Q-10
C. ancudensis	JCM 8915^T	CBS 8184^T	45.7	44.3	10.0	—	0.5	13.3	86.1	0.1
C. antillancae	JCM 9581^T	CBS 9170^T	45.5	38.9	15.6	0.6	—	3.5	95.3	0.5
C. apis	JCM 8256^T	IFO 10262^T	45.8	39.3	14.9	—	0.8	9.3	89.2	0.7
C. auringiensis	JCM 9593^T	ATCC 58430^T	22.2	51.2	26.6	—	3.1	2.9	94.0	trace
C. azyma	JCM 1691^T	CBS 6826^T	29.1	65.9	5.0	trace	trace	6.8	92.6	0.6
C. bertae var. *bertae*	JCM 9582^T	CBS 8169^T	41.4	47.0	11.6	—	1.0	23.7	75.3	—
C. bertae var. *chiloensis*	JCM 9583^T	CBS 8168^T	35.0	49.4	15.6	—	—	33.4	66.6	—
C. blankii	JCM 8259^T	IFO 10230^T	38.1	51.7	10.2	trace	0.4	4.0	95.1	0.5
C. bondarzewiae	JCM 9584^T	CBS 8171^T	51.5	31.4	17.1	—	—	5.3	94.7	—
C. cantarellii	JCM 8260^T	IFO 10269^T	43.6	24.7	31.7	—	trace	0.7	98.7	0.6
C. castrensis	JCM 9585^T	CBS 8172^T	40.1	33.9	26.0	—	—	2.3	97.7	—
C. ciferrii	JCM 9551^T	IFO 10192^T	48.1	46.2	5.7	—	0.6	3.8	94.5	1.1
C. edax	JCM 9470^T	IFO 10273^T	33.9	54.4	11.7	trace	0.8	5.3	93.2	0.7
C. etchellsii	JCM 8066^T	IFO 1592^T	31.9	54.3	13.8	—	3.5	5.9	90.0	0.6
C. floricola	JCM 9439^T	IAM 13115^T	48.0	46.2	5.8	—	1.9	13.0	84.2	0.9
C. gropengiesseri	JCM 8255^T	IFO 0659^T	39.3	48.3	12.4	—	1.1	6.1	91.7	1.2
C. ingens	JCM 9471^T	IFO 10057^T	38.0	44.4	17.6	0.2	0.3	2.8	96.0	0.7
C. inositophila	JCM 1508^T	AJ 5000^T	35.8	43.8	20.4	—	—	7.9	92.1	—
C. magnoliae	JCM 1446^T	CBS 166^T	46.8	48.6	4.6	—	1.7	10.5	86.8	1.0
C. paludigena	JCM 9614^T	NRRL Y-12697^T	29.0	55.5	15.5	—	0.4	6.3	92.5	0.8
C. pararugosa	JCM 1512^T	AJ 4645^T	43.4	45.3	11.3	—	0.8	4.0	94.6	0.6
C. petrohuensis	JCM 8922^T	CBS 8173^T	71.8	23.8	4.4	—	trace	7.0	93.0	trace
C. salmanticensis	JCM 8896^T	IFO 10242^T	34.5	40.7	24.8	—	0.6	7.7	91.0	0.7
C. santjacobensis	JCM 8924^T	CBS 8183^T	44.4	45.6	10.0	—	0.5	4.0	95.0	0.5
C. sorbophila	JCM 1514^T	AJ 4995^T	36.7	48.6	14.7	0.4	0.7	5.4	93.3	0.2
C. spandovensis	JCM 9562^T	IFO 10249^T	31.4	53.7	14.9	—	1.2	7.9	90.3	0.6
C. steatolytica	JCM 1698^T	CBS 5839^T	32.6	53.7	13.7	—	2.7	15.5	81.5	0.3
C. tepae	JCM 10265^T	NRRL Y-17670^T	53.1	31.7	15.2	—	trace	2.9	95.1	2.0
C. vaccinii	JCM 9446^T	IAM 13117^T	37.7	52.0	10.3	trace	1.1	8.1	90.1	0.7
C. valdiviana	JCM 9565^T	IFO 10317^T	22.4	66.2	11.4	1.7	0.8	10.6	86.4	0.5
C. vanderwaltii	JCM 9615^T	CBS 5524^T	24.4	59.1	16.5	—	trace	1.2	96.9	1.9
C. versatilis	JCM 8065^T	IFO 10056^T	49.7	29.5	20.8	—	3.5	2.7	92.9	0.8
C. vinaria	JCM 1813^T	AJ 4676^T	19.3	45.0	35.7	—	0.7	9.8	89.5	—

—, Not detected
T, Type strain

species in this study. Further analysis is needed to clarify the presence or absence of galactose in cell wall polysaccharide of this species.

Kurtzman and Robnett (8) reported that *Candida galacta, Candida incommunis*, and *Candida lactis-condensi* existed in different clusters from each other in the phylogenetic tree based on partial sequences at 5'-end of 26S ribosomal RNA gene.

Group IIb (glucose-mannose-galactose, Q-9)

Group IIb comprised 31 species and 2 varieties as shown in Table 7.

The following 19 species and 2 varieties of *Candida* were newly found to contain galactose in addition to glucose and mannose in the whole cells in this study : They were *Candida azyma, Candida auringiensis, Candida paludigena, Candida vinaria, Candida floricola, Candida vaccinii, Candida ingens, Candida sorbophila, Candida spandovensis, Candida pararugosa, Candida valdiviana, Candida ciferrii, Candida castrensis, Candida santjacobensis, Candida antillancae, Candida bondarzewiaei, Candida ancudensis, Candida petrohuensis, Candida bertae* var. *bertae*, and *Candida bertae* var. *chiloensis*.

Gorin and Spencer (3) reported that twelve species, *Candida apis, Candida magnoliae, Candida etchellsii, Candida edax, Candida steatolytica, Candida tepae, Candida vanderwaltii, Candida versatilis, Candida salmanticensis, Candida blankii, Candida cantarellii*, and *Candida gropengiesseri*, contained galactomannan in their cell wall.

Candida steatolytica and *Candida inositophila* are allotypes of teleomorhic *Zygoascus hellenicus* (28). *Candida ciferrii* is an anamorph of *Stephanoascus ciferrii* (6). Giménez-Jurado et al. (2) reported that *Candida edax* was an anamorph of *Stephanoascus smithiae*.

Group IIb is heterogeneous in cellular fatty acid compositions according to the data of Viljoen and Kock (34). They reported that *Candida pararugosa, Candida sorbophila, Candida vanderwaltii*, and *Candida versatilis* belonged to group I-A ; *Candida blankii, Candida ingens, Candida paludigena*, and *Candida steatolytica* belonged to group II-A ; *Candida apis* and *Candida azyma* belonged to group II-B ; and *Candida edax* and *Candida ciferrii* belonged to group II-D and group III-F, respectively.

Lee et al. (11) reported that *Candida etchellsii* and *Candida versatilis* had Q-9 as the major ubiquinone which was confirmed in this study.

Candida floricola and *Candida vaccinii* were described as new species of sugar tolerant yeasts by Tokuoka et al. (32) in 1987. Ubiquinone systems of these species were confirmed in this study.

Recently, Shin et al. (27) reported ubiquinone systems and ITS-RFLP of 32 species of the genus *Candida* and divided them into five groups (group I, II, III, IV, and V). The results of ubiquinone systems agreed with our results.

Their group V (*Candida glabrata*) was included in our Group Ia. Their groups I (*Candida lambica, Candida sorbosa*), II (*Candida krusei*), and IV (*Candida vartiovaarai*) were included in our Group Ib. Their groups I (*Candida intermedia, Candida melibiosica*), II (*Candida maltosa, Candida parapsilosis, Candida albicans*), and IV (*Candida xestobii, Candida glaebosa, Candida ergastensis, Candida terebra, Candida diddensiae, Candida santamariae, Candida famata, Candida aaseri, Candida friedrichii, Candida insectorum*) were included in our Group Id. Their groups II (*Candida vinaria*) and III (*Candida steatolytica, Candida inositophila*) were included in our Group IIb.

Taxonomic position of Candida species containing galactose in the whole cells.

Spencer and Gorin (29) and Gorin and Spencer (3) reported the existance of *Candida* species containing galactose in their cell wall polysaccharides. However, it has not been reported how many species of the genus *Candida* contain galactose. In this study, it was clarified that 34 species and 2 varieties of the genus *Candida* contained galactose in the whole cells. Namely, about 17 % of *Candida* species was found to have galactose, suggesting that galactose-containing *Candida* species are not rare in nature. The presence of galactose suggests the close relationships between galactose-containing *Candida* species and ascomycetous genera containing galactose, e.g., *Stephanoascus, Zygoascus, Yarrowia, Dipodascus, Galactomyces, Lipomyces*, and *Dipodascopsis* (3, 36).

In conclusion, each of the six groups of the genus *Candida* based on cellular neutral sugar compositions and ubiquinone systems is assumed to be an assembly of phylogenetically different species because each group contained several genera in anamorph-teleomorph relationships and was heterogeneous in cellular fatty acid compositions. More detailed chemotaxonomic and molecular phylogenetic analyses, i.e., 18S ribosomal RNA gene sequences, codon usage, and structural analyses of cell wall polysaccharides, are required to establish a rational taxonomic system of the genus *Candida*.

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REFERENCES

1. Barnett, J.A., Payne, R.W. and Yarrow, D. (ed.) Yeasts : characteristics and identification, 2nd edition, Cambridge University Press, Cambridge (1990).
2. Giménez-Jurado, G., Cidadão, A.J. and Beijn-van der Waaij, A. A novel heterothallic ascomycetous yeast species : *Stephanoascus smithiae*, teleomorph of *Candida edax*. Syst. Appl. Microbiol. **17** : 237-246 (1994).
3. Gorin, P.A.J. and Spencer, J.F.T. Proton magnetic resonance spectroscopy—An aid in identification and chemotaxonomy of yeasts. Adv. Appl. Microbiol. **13** : 25-89 (1970).
4. Goto, S. and Oguri, H. Two new species of the genus *Candida* from wild grapes. J. Gen. Appl. Microbiol. **29** : 85-90 (1983).
5. Hagler, A.N., Mendonça-Hagler, L.C. and Phaff, H. J. *Candida populi*, a new species of yeast occurring in exudates of *Populus* and *Betula* species. Int. J. Syst. Bacteriol. **39** : 97-99 (1989).
6. Kreger-van Rij, N.J.W. (ed.) The yeasts, a taxonomic study, 3rd edition, Elsevier Science Publishers B. V., Amsterdam (1984).
7. Kumamoto, T., Yamamoto, M., Seriu, Y., Koiuno, K., Okamoto, R., Ishikura, T. and Takamatsu, A. Four new species of methanol-assimilating yeasts : *Candida methaolophaga, Candida ovalis, Candida ooitensis* and *Pichia methlovora*. Trans. Mycol. Soc. Japan **27** : 387-397 (1986).
8. Kurtzman, C.P. and Robnett, C.J. Identification of clinically important Ascomycetous yeasts based on nucleotide divergence in the 5' end of the large-subunit (26S) ribosomal DNA gene. J. Clin. Microbiol. **35** : 1216-1223 (1997).
9. Lee, C.-F., Lee, F.-L. and Hsu, W.-H. Synonymy of *Candida methylica* with *Candida boidinii* and of *Candida methanolophaga* with *Candida succiphila*. Int. J. Syst. Bacteriol. **44** : 839-841 (1994).
10. Lee, C.-F., Lee, F.-L., Hsu, W.-H. and Hsu, W.H. DNA reassociation and electrokaryotype study of some *Candida* species and synonymy of *Candida terebra, Candida entomaea*, and *Candida veronae*. Can. J. Microbiol. **39** : 864-867 (1993).
11. Lee, F-L., Lee, C-F., Okada, S., Hsu, W.-H. and Kozaki, M. Chemotaxonomic comparison of osmotolerant yeasts isolated from "Inyu" (black soybean sauce) mash in Taiwan and "Shoyu" (soybean sauce) mash in Japan. Bull. JFCC 8 : 11-17 (1992).
12. Lee, F-L., Lee, C-F., Okada, S., Uchimura, T. and Kozaki, M. Chemotaxonomic comparison of *Pichia farinosa, Pichia sorbitophila* and *Candida cacaoi*. Bull. JFCC 8 : 71-78 (1992).
13. Lee, F-L., Lee, C-F., Okada, S., Uchimura, T., Komagata, K. and Kozaki, M. *Candida galacta* comb. nov., a new combination for *Candida apis* var. *galacta*. Int. J. Syst. Bacteriol. **43** : 183-184 (1993).
14. Lee, J.D. and Komagata, K. Further taxonomic study of methanol-assimilating yeasts with special references to electrophoretic comparison of enzymes. J. Gen. Appl. Microbiol. **29** : 395-416 (1983).
15. Lee, J.D. and Komagata, K. *Pichia cellobiosa, Candida cariosilignicola*, and *Candida succiphila*, new species of methanol-assimilating yeasts. Int. J. Syst. Bacteriol. **30** : 514-519 (1980).
16. Lee, J.D. and Komagata, K. Taxonomic study of methanol-assimilating yeasts. J. Gen. Appl. Microbiol. **26** : 133-158 (1980).
17. Montrocher, R. Etude des affinites interspecifiques dans le genre *Candida* (Levures asporogenes). Approches serologique, biochimique et mathematique. Thesis (1984).
18. Montrocher, R., Billon-Grand, G. and Claisse, M. Analysis of cytochromes and co-enzymes Q in the yeast genus *Candida*. J. Gen. Appl. Microbiol. **36** : 151-161 (1990).
19. Nakase, T. and Suzuki, M. Taxonomic studies on *Debaryomyces hansenii* (Zopf) Lodder et Kreger-van Rij and related species. I. Chemotaxonomic investigations. J. Gen. Appl. Microbiol. **31** : 49-69 (1985).
20. Ramírez, C. and González, A. Two new species and one variety of nitrate-utilizing mycelial *Candida* isolated from decayed wood in the evergreen rainy Valdivian forest of southern Chile. Mycopathologia **88** : 55-60 (1984).
21. Ramírez, C. and González, A. Five new filamentous, glucose-fermenting *Candida* isolated from decayed wood in the evergreen rainy Valdivian forest of

southern Chile. Mycopathologia **88** : 83-92 (1984).

22. Ramírez, C. and González, A. Three new filamentous, fermenting *Candida* isolated from decayed wood in the evergreen rainy Valdivian forest of southern Chile. Mycopathologia **88** : 93-98 (1984).
23. Ramírez, C. and González, A. Two new amycelial *Candida* isolated from decayed wood in the evergreen rainy Valdivian forest of southern Chile. Mycopathologia **88** : 99-103 (1984).
24. Ramírez, C. and González, A. *Candida santjacobensis* and *Candida ancudensis*, two new species of yeasts isolated from decayed wood in the evergreen rainy Valdivian forest of southern Chile. Mycopathologia **88** : 105-109 (1984).
25. Ramírez, C. and González, A. Two new filamentous, non fermenting *Candida* and a new *Schizoblastosporion* isolated from decayed wood in the evergreen rainy Valdivian forest of southern Chile. Mycopathologia **88** : 165-171 (1984).
26. Ramírez, C. and González, A. Three new, non-fermenting, and nitrate-negative *Candida* species isolated from decayed wood in the evergreen rainy Valdivian forest of southern Chile. Mycopathologia **88** : 175-180 (1984).
27. Shin, K-S., Hong, S-D. and Bae, K.S. The significance of ITS-RFLPs and coenzyme Q system in determing taxonomic relationships among *Candida* species. J. Gen. Appl. Microbiol. **42** : 481-491 (1996).
28. Smith, M. Th. Zygoascus hellenicus gen. nov., sp. nov., the teleomorph of *Candida hellenica* (=*C. inositophila*=*C. steatolytica*). Antonie van Leeuwenhoek **52** : 25-37 (1986).
29. Spencer, J.F.T. and Gorin, P.A.J. Systematics of the genus *Candida* Berkhout : proton magnetic resonance spectra of the mannans and mannose-containing polysaccharides as an aid in classification. Antonie van Leeuwenhoek **35** : 33-44 (1969).
30. Suzuki, M. and Nakase, T. The distribution of xylose in the cells of ballistosporous yeasts—Application of high performance liquid chromatography without derivatization to the analysis of xylose in whole cell hydrolysates. J. Gen. Appl. Microbiol. **34** : 95-103 (1988).
31. Suzuki, M. and Nakase, T. Heterogeneity of ubiquinone systems in the genus *Sporothrix*. J. Gen. Appl. Microbiol. **32** : 165-168 (1986).
32. Tokuoka, K., Ishitani, T., Goto, S. and Komagata, K. Four new yeast species belonging to the genus *Candida*. J. Gen. Appl. Microbiol. **33** : 1-10 (1987).
33. Van der Walt, J.P., Weijman, A.C.M. and von Arx, J.A. The anamorphic yeast genus *Myxozyma* gen. nov. Sydowia. Ann. Mycol. Ser. II., **34** : 191-198 (1981).
34. Viljoen, B.C. and Kock, J.L.F. A taxonomic study of the yeast genus *Candida* Berkhout. Syst. Appl. Microbiol. **12** : 91-102 (1989).
35. Von Arx, J.A. and Weijman, A.C.M. Conidiation and carbohydrate composition in some *Candida* and *Torulopsis* speices. Antonie van Leeuwenhoek **45** : 547-555 (1979).
36. Weijman, A.C.M. and Golubev, W.I. Carbohydrate patterns and taxonomy of yeasts and yeast-like fungi. Studies in Mycology **30** : 361-371 (1987).
37. Weijman, A.C.M. and Rodrigues de Miranda, L. Carbohydrate patterns of *Candida, Cryptococcus* and *Rhodotorula* species. Antonie van Leeuwenhoek **54** : 535-543 (1988).
38. Weijman, A.C.M., Rodrigues de Miranda, L. and van der Walt, J.P. Redefinition of *Candida* Berkhout and the consequent emendation of *Cryptococcus* Kutzing and *Rhodotorula* Harrison. Antonie van Leeuwenhoek **54** : 545-553 (1988).
39. Yamada, Y. and Kondo, K. Taxonomic significance of coenzyme Q system in yeasts and yeast-like fungi (1). *In* Kocková-Kratochvílová, A. and Minarik. E. (eds.), Yeasts Models in Science and Technics. Proceedings of the First Specialized International Symposium on Yeasts, p. 363-372, Publishing House of the Slovak Academy of Sciences, Bratislava, (1972).
40. Yamada, Y., Matsuda, M., Maeda, K. and Mikata, K. The phylogenetic relationships of methanol-assimilating yeasts based on the partial sequences of 18S and 26S ribosomal RNAs : The proposal of *Komagataella* gen. nov.(Saccharomycetaceae). Biosci. Biotech. Biochem. **59** : 439-444 (1995).
41. Yarrow, D. and Meyer, S.A. Proposal for amendment of the diagnosis of the genus *Candida* Berkhout nom. cons. Int. J. Syst. Bacteriol. **28** : 611-615 (1978).

Candida 属酵母の菌体糖組成とユビキノン系

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Candida 属酵母 196 種 9 変種の基準株の菌体糖組成およびユビキノン系について調べた．その結果，菌体糖組成(中性糖)においては，162 種 7 変種の基準株がグルコースおよびマンノースであり，34 種 2 変種の基準株がグルコース，マンノースおよびガラクトースであった．主要ユビキノンにおいては，8 種の基準株が Q-6，50 種の基準株が Q-7，20 種の基準株が Q-8，118 種 9 変種の基準株が Q-9 であった．*Candida* 属のユビキノン系は Q-6，Q-7，Q-8，Q-9 の 4 つのタイプをもつことが明確にされた．また，菌体糖組成およびユビキノン系に基づいてグルーピングを行った結果，6 つのグループ (Ia，Ib，Ic，Id，IIa および IIb) に分かれた．グループ Ia はガラクトースを含まず，主要キノンが Q-6 であり，8 種からなった．グループ Ib はガラクトースを含まず，主要キノンが Q-7 であり，50 種からなった．グループ Ic はガラクトースを含まず，主要キノンが Q-8 であり，17 種からなった．グループ Id はガラクトースを含まず，主要キノンが Q-9 であり，基準種を含む 87 種 7 変種からなった．グループ IIa はガラクトースを含み，主要キノンが Q-8 であり，3 種からなった．グループ IIb はガラクトースを含み，主要キノンが Q-9 であり，31 種 2 変種からなった．菌体糖組成およびユビキノン系に基づくこれら 6 つのグループは，テレオモルフ-アナモルフ関係において複数の属を含むこと，菌体脂肪酸組成において不均一な群であることから，各グループはそれぞれ，系統的に異なった種を含んでいるものと推定される．