BACTERIOLOGICAL NOMENCLATURE
AND TAXONOMY

THE YEASTS= A TAXONOMIC STUDY

A Review

R. E. Buchanan, Ames, Iowa, U. S. A.

This volume of 713 pages by Dr. J. Lodder, mycologist of Koninklijke Nederlandsche Gist- en Spiritusfabriek of Delft and Dr. N. J. W. Kreger van Rij, mycologist of the Centraalbureau voor Schimmelcultures, Yeast Division, Delft, is a highly welcome and authoritative summary of our knowledge of the yeasts. It may be regarded as a revision and condensation of the several volumes on taxonomy and nomenclature of the yeasts previously prepared by the staffs at Baarn and at Delft.

The introduction notes that specific epithets previously given to yeast species by earlier authors have in general been corrected in this text when not formed in conformity to the articles and recommendations of the revised International Botanical Rules of Nomenclature.

After a survey of literature and experience, the authors, for purposes of genera and species differentiation, fix upon six morphological characters (characteristics of vegetative reproduction, shape and size of cells, ascospore formation, ballistospores, and colony characteristics) and twelve physiological properties (pellicle formation, fermentation, sugar assimilation, utilization of nitrate, utilization of ethanol as a sole source of carbon, splitting of arbutin, production of carotenoid pigments, production of starch-like compounds, production of esters, reaction in litmus milk, splitting of fat, and acid production). These are clearly defined and the methods for laboratory determination outlined.

The taxonomic problems related to yeast variability are reviewed with understanding and discrimination. The artificial nature of the group called yeasts is satisfactorily emphasized, as well as the practical utility of this grouping.

Three families are recognized, the Endomycetaceae including yeasts which form asci and ascospores, the Sporobolomycetaceae which produce so-called ballistospores on sterigmata from which they are forcibly dis-

charged, (resembling the spores of the Basidiomyces), and the asporogenous yeasts placed in the Cryptococcaceae.

The ascogenous yeasts are included in the fungus class Ascomycetes, the subclass Protascales and the order Endomycetales. A single ascogenous yeast family is recognized, the Endomycetaceae which in turn includes five subfamilies, as follows:

Eremascoideae, with one genus Eremascus
Endomycetoideae, with two genera, Endomyces
 and Schizosaccharomyces.

Saccharomycetoideae, with three tribes

Endomycopseae, with one genus Endomycopsis

Saccharomycetaceae, with five genera, Saccharomyces, Pichia, Hansenula, Schwanniomyces and Debaryomyces.

Nadsonieae, with three genera, Saccharomycodes, Hanseniaspora and Nadsonia.

Nematosporoideae, with three genera, Monosporella, Nematospora, and Coccidiascus.

Lipomycetoideae, with one genus, Lipomyces.

There are several anomalies in the above nomenclature that deserve comment. On the basis of the directives of the Botanical Code, the name of the family Endomycetaceae is derived from the name of the contained genus, Endomyces. The inappropriateness of the family name is evident from the footnote (p. 53) which states:- "This genus does not belong to the yeasts in the proper sense". The authors do not discuss in detail the priorities of the names Endomycetales and Saccharomycetales for the order, nor of Endomycetaceae and Saccharomycetaceae for the family. This failure on the part of the authors to justify the use of names of taxa higher than the genus is unfortunate. The recognition of Endomycetaceae as the family name is apparently based upon the statement of Stelling-Dekker (1931, p. 522) who says:-

"Unter diesen Umständen empfiehlt es sich, die in dieser Abhandlung beschriebenen Organismen - also neben den

BACTERIOLOGICAL NOMENCLATURE AND TAXONOMY

typischen Hefearten auch die Vertreter der Gattung Endomyces - in einer Familie wofür dann der ältere Namen Endomycetaceae angebracht ist, vereinigt zu halten. "

A hasty examination of the literature seems to indicate that the Stelling-Dekker statement may be incorrect. The first definite use of Saccharomycetaceae as a family name found by the writer is that of DeToni (1889, p. 916) in Saccardo's *Sylloge Fungorum*. He ascribes the name to Reess (1870). A study of the paper by Reess fails to confirm such use of the name; the family name was not given by Reess. The first use of the name Endomycetaceae found is that of Schroeter (1897 p.154) in the *Pflanzenfamilien* of Engler and Prantl. If all of the yeast genera are to be included in a single family, it would seem that the family name should be Saccharomycetaceae.

It is of interest to note that the authors list three species of Endomyces, describe none of them, and in effect, remove them from consideration as yeasts.

The writer believes that nomenclatural confusion and taxonomic difficulties will be minimized if the older differentiation of the two families, Saccharomycetaceae and Endomycetaceae is maintained. The apparent nomenclatural centering of the whole group of yeasts around an ascus-bearing mold (Endomyces decipiens) parasitic upon the gills of a single species of mushroom makes for confusion.

Beginning with the description of the genus Schizosaccharomyces (p.81) the format is a model for microbiological systematic monographs. The fifteen genera of the Endomycetaceae are differentiated in a well-organized dichotomous key. For each genus there is included a generic diagnosis, the designation of the type species of the genus, an historical survey of the generic name, a list of the species recognized, and a dichotomous key to the species. This is followed by a systematic discussion of each species, including synonyms, original description and historical survey, standard description (morphological and

physiological characters), origin and characterization of strains studied and designation of the type strain of the species. Drawings of the vegetative and sporulating cells are generally included.

One may question the author's ascription for some of the genera, as for example, (p. 116) the genus Saccharomyces (Meyen) Reess. It would seem that this should be Saccharomyces Meyen, for this author named both the genus and the type species. Possibly the authors intended Saccharomyces Meyen emend. Reess.

Inasmuch as the type species must be one of those included in the first publication of the genus, the type should probably be designated Saccharomyces cerevisiae Meyen emend. Hansen. In several other cases the name of the emending author has been substituted for the name of the original proponent of the name.

The following comments as to other unresolved nomenclatural problems may be made.

1. Clements and Shear (1931 p. 246) apparently designated Saccharomycopsis capsularis Schiöning as the type species of the genus Saccharomycopsis. Lodder and van Rij (1952) designate S. guttulata as the type species and recognize the transfer of S. capsularis to the new genus Endomycopsis Dekker (1931) and designate (1952) this as the type species of the genus Endomycopsis. A careful review should be made to determine whether by virtue of the designation of the same type species for each of the two genera, the genus Endomycopsis is not in fact a later synonym of Saccharomycopsis. It would appear that Saccharomycopsis guttulata is the type species of a nameless genus.
2. On page 96, and on later pages, the recognized species of each genus are listed "in chronological sequence", that is, in the order in which they were described. The format used is one that may give rise to a misinterpretation. The name "Endomycopsis capsularis

BACTERIOLOGICAL NOMENCLATURE AND TAXONOMY

- (Schiönning) Dekker 1913" would usually be interpreted as meaning that Dekker placed the organism in the genus Endomycopsis in 1913, and not that Schiönning originally described it in that year.
3. The type species of Saccharomyces was designated as S. cerevisiae by Clements and Shear (1931 p. 246).
 4. (p.122) Should not the type species have been listed as Saccharomyces cerevisiae Meyen emend. Hansen?
 5. Reess (not Hansen) named Saccharomyces ellipsoideus, as also S. exiguus and S. pastorianus.
 6. The genus Debaryomyces was founded by Klöcker upon a single species D. globosus. This would normally, therefore, be regarded as the type species. However, the authors place this first named species in the genus Saccharomyces, and as type species designate Debaryomyces hansenii (Saccharomyces hansenii Zopf 1889). They further recommend that the emended genus be made a nomen genericum conservandum. This recommendation is made to avoid the necessity of erecting a new name to replace Debaryomyces. Careful consideration should be given to the question of the conservation of the name, such action may raise more problems than it will settle. The matter is somewhat further complicated by the fact that Clements inferentially fixed the type species in his designation of Isomyces globosus (Klöcker) Clements as the type of the genus Isomyces proposed as a replacement for Debaryomyces.
 7. The authors state that Derx (1948) designated Sporobolomyces roseus Kluyver and van Niel as the type species of the genus. This ignores the earlier (1931) designation of S. salmonicolor Kluyver and van Niel as the type species.
 8. The authors accept Bullera alba (Hanna) Derx as

designated by Derx (1948) as the type species of Bulle-ra rather than the Bullera grandispora proposed by Clements and Shear (1931).

9. The "asporogenous" yeasts are placed in the Fungi Imperfecti, with the establishment of a new order, the Cryptococcales containing the single family Cryptococcaceae. Unfortunately there is not given adequate consideration of historical background and reasons. No synonymy is given for the names of these higher taxa. Some careful nomenclatural study seems called for.
10. The frank recognition of the generic status of Cryptococcus is helpful, it may assist in clearing up some of the problems in medical mycology. However, the authors have somewhat oversimplified the problem of such recognition. The type species of Cryptococcus was designated by Clements and Shear (1931) as Cryptococcus fermentum Kuetzing. But the only species described in the original publication by Kuetzing is C. mollis which would be presumed to be the type rather than the later C. fermentum. The designation by the authors of Cryptococcus neoformans (Sanfelice) Vuillemin has much to commend it, without serious question it would bring some much needed stability. But it would seem that for this typification to be accepted some international sanction is needed. Perhaps the simplest, though not the only method of achieving the desired goal, would be for the authors to recommend to the International Committee on the Nomenclature of the Fungi that Cryptococcus Kuetzing be placed in the list of nomina generica rejicienda and that the generic name Cryptococcus Vuillemin be recognized as a nomen genericum conservandum with the type species the Cryptococcus neoformans (Sanfelice) Vuillemin as several times proposed in the literature. Some study also needs to be given to the alternative name C. hominis.
11. The legitimacy of the name Torulopsis Berlese, as used by the authors, is questioned by themselves. The

BACTERIOLOGICAL NOMENCLATURE AND TAXONOMY

implications of discarding Torulopsis rosea as the type and of replacing it by Torulopsis colliculosa (Hartmann) Saccardo should be carefully reviewed, and any desirable international action recommended.

12. The status of Candida as a generic name is indicated as problematical and tentative. One may hope for a prompt decision from the Committee on the Nomenclature of the Fungi appointed by the Stockholm Botanical Congress, to which Committee the problem has been referred.
13. The type species is designated as Candida albicans (Robin) Berkhout. However, C. vulgaris Berkhout was chosen by Clements and Shear (1931). The authors note that C. vulgaris Berkhout is to be regarded as a synonym of C. tropicalis (Castellani) Berkhout. Should C. tropicalis be regarded, therefore, as the type species?
14. The great amount of work done by the various groups of yeast specialists in bringing order out of zymological chaos is illustrated by the listing of ninety-one synonyms for the species Candida albicans.
15. An interesting complication arises in the discussion of Candida mycoderma by the authors. The statement is made (p. 483):- "Pichia membrifaciens Hansen has to be regarded as the perfect stage of this species". The implications of this assertion require careful exploration in the light of Article 57 of the International Rules of Botanical Nomenclature, which seems to indicate that the name of the perfect form should be used when known.
16. The reasons for the designation of Trichosporon cutaneum as the type species of the genus Trichosporon are not sufficiently documented. Behrend (1890) is stated to have "created the genus Trichosporon" with the single species T. ovoides. This species would therefore seem to be the type; however, the authors state "according to Article 18 of the International

Rules of Botany Nomenclature Trichosporon cutaneum (de Beurmann, Gougerot et Vaucher) Ota is the type species of the genus". The writer can find nothing in Article 18 to justify this conclusion. The authors (p. 641) regard T. ovoides Behrend as a nomen dubium and reject it. This reasoning would seem to make the generic name Trichosporon Behrend questionable. Might T. ovoides Behrend be identified with one of the more recently described species, thus making the later description an emendation of that of Behrend? Or the generic name Trichosporon Behrend might be rejected and replaced by some later synonym. The authors are probably right in concluding that the acceptance of T. cutaneum as the type species would cause the least confusion in nomenclature. If this is done a suitable request for international approval should be formulated.

17. In this review Clements and Shear are several times quoted as having designated the type species in certain fungus genera. It should be noted that these authors definitely stated that they were designating the types in accordance with the well recognized rules of botanical nomenclature, but that the validity of their designations in many cases has been called into question as by Seaver (1932). The fact of these designations must be recognized by later workers, but their legitimacy may require careful checking. A ruling by the appropriate Committee on the legitimacy of the many designations thus made would be of material mycological assistance.

The Latin diagnoses required under the Botanical Code to make legitimate the names of new taxa are given as follows:

Saccharomyces four species (pp. 668-669).

Lipomyces genus and one species (p. 669).

Cryptococcus one variety (p. 670).

Torulopsis six species and one variety (pp. 670-671).

Candida three species and two varieties (p. 672).

Trichosporon one species (p. 673).

BACTERIOLOGICAL NOMENCLATURE AND TAXONOMY

The author and taxonomic indices are adequate and admirable.

In the opinion of the writer, the time has come when a series of well formulated recommendations relative to the unsettled nomenclatural problems of the yeasts should be prepared and submitted to the International Committee on Mycological Nomenclature.

REFERENCES

- Behrend, G. Ueber Trichomycosis nodosa' (Juhel-Rénoy); Piedra (Osorio). Berlin. klin. Wochenschr. 27:464- 467 1890.
- Clements, F. E. and C. L. Shear. The Genera of Fungi second ed. 1931.
- DeToni, J. B. Saccharomycetaceae. In Saccardo, P. A., Sylloge Fungorum 8: 916. 1889.
- Derx, H. G. Itersonilia, nouveau genre de Sporobolomycètes à mycélium bouclé. Bull. bot. Gardens, Buitenzorg. ser. III, 17 (4): 465-72. 1948.
- Lodder, J. and N. J. W. Kreger-van Rij. The Yeasts. A Taxonomic Review. pp. XI, 713. Amsterdam and New York. 1952.
- Reess, Max. Botanische Untersuchungen über die Alkoholgährungspilze. Leipzig. 1870.
- Stelling-Dekker, N. M. Die sporogenen Hefen. Erhandel koninkl. Akad. Wetenschap. af. Naturkunde. Sect. II. 28' 1931.