Arch. Environ. Contam. Toxicol. 18, 452–467 (1989)

Archives of Environmental Contamination and Toxicology

The Connection between the Penicillia and Aspergilli and Mycotoxins with Special Emphasis on Misidentified Isolates

Jens C. Frisvad

Department of Biotechnology, Food Technology, The Technical University of Denmark, DK-2800 Lyngby, Denmark

Abstract. Species of *Penicillium* and *Aspergillus* are the most potent mycotoxin producers, but the connection between species and profiles of mycotoxins has been obscured by many misidentifications of fungal isolates, especially in *Penicillium*. Available producers of known mycotoxins in the two important genera were examined concerning identity and production of secondary metabolites using thin-layer chromatography and high performance liquid chromatography with diode array detection. 152 isolates of *Penicillium* were reclassified, leaving the connection between species and mycotoxin profiles much clearer in this genus. Earlier data on mycotoxin production by different taxa were confirmed by analyzing several isolates of each taxon.

An accurate identification of toxigenic fungi is very important in preventing mycotoxin contamination of foods and feedstuffs and knowledge of the mycoflora of these commodities under known environmental conditions is very important in the analysis of mycotoxins. To be able to restrict the number and the complexity of mycotoxin analysis, it is thus important to determine the connection between fungal taxa and profiles of mycotoxins. Unfortunately, these connections have been obscured by many misidentifications of either the fungi or the mycotoxins (Marasas *et al.* 1984; Pitt 1979a; Frisvad 1986). One of the reasons for the misidentification of especially the Penicillia, the Aspergilli and the Fusaria is the very difficult taxonomy of these genera (Marasas *et al.* 1984; Samson and Pitt 1985), another problem is that reported producers are quite seldomly placed in major culture collections or the identity of the producers are not confirmed by experts. The identity of the mycotoxins is often only based on comparison with standards in one-dimensional thin-layer chromatography (TLC), whereas the first report on new mycotoxins are often based on several spectroscopic, physical, chemical, and analytical data.

The problems mentioned above have resulted in many mycotoxins being named after fungi which do not produce them either because of misidentifications or less seriously because of synonomy of fungal names. Examples of this are neosolaniol which is not produced by *Fusarium solani* (Marasas *et al.* 1984), deoxynivalenol which is not produced by *F. nivale* (*Microdochium nivale*), viridicatumtoxin which is not produced by *Penicillium viridicatum* (Frisvad 1986), cyclopiazonic acid which is not produced by *P. cyclopium* (or its synonym *P. aurantiogriseum*) (Hermansen *et al.* 1984), verruculogen which is not produced by *P. verruculosum* (Pitt 1979a), and cyclopaldic acid which is not produced by *P. cyclopium* (Polonelli *et al.* 1987).

The purpose of this paper is to compile correct producers of the most important mycotoxins with a strong emphasis on misidentified toxigenic isolates of *Penicillium* and *Aspergillus*. Misidentified isolates of *Fusarium* are treated by Marasas *et al.* (1984).

Materials and Methods

Producers of known mycotoxins were obtained from major culture collections or directly from the authors of papers concerning new producers of known mycotoxins. The cultures were identified by a variety of morphological, physiological, and chemical criteria (Pitt 1979b; Frisvad and Filtenborg 1983; Frisvad 1985a; Samson and Pitt 1985) on several media and compared to ex type and authentic cultures. The identity of the mycotoxins produced were confirmed by comparing standards to the metabolites produced by the fungi in at least two eluents (Filtenborg *et al.* 1983) by TLC and in a standardized reversed phase high-performance liquid chromatography (HPLC) system using alkylphenone indices and diode array detection (Frisvad and Thrane 1987).

Results and Discussion

Misidentified toxigenic isolates of *Penicillium* are listed in Table 1. Most of the Penicillia are members of subgenus *Penicillium,* which abundantly occur in foods and feeds, but very difficult to identify (Onions and Brady 1987; Cruickshank and Pitt 1987; Samson and Gams 1984; Frisvad 1986). By comparison to the Penicillia, the Aspergilli have only seldomly been misidentified (Table 2).

Isolates of many of the penicillia and aspergilli reported to produce particular mycotoxins were not available for study. In these cases, cultures ex type, authentic isolates, and fresh isolates from foods, soil and other substrata were examined for production of the particular mycotoxin, provided the standard mycotoxins were available, on a variety of different media. In many cases, the production of a particular mycotoxin by a certain species could not be confirmed. The production of ochratoxin A by *P. chrysogenum* could not be detected in any isolates of 230 tested, f.ex., even though this has been reported by independent groups of researchers (Leistner and Pitt 1977; Mills and Abramson 1982). The report of ochratoxin A production by among others *P. expansum* and *P. brevicompactum* (Paterson *et al.* 1987) is probably also caused by spots on TLC plates which look like ochratoxin A, but are other compounds. This emphasizes the importance of confirming new reports of toxin production by particular fungi by several chemical and/or physical methods! Misidentifications of mycotoxins were also noted for *P. brunneostoloniferum* (=*P. brevicompactum*) and *P. viridicyclopium* (=*P. aurantiogriseum*) (originally reported by Udagawa and Abe 1961) (see Table 1). In the report of ochratoxin A production by *P. purpurescens* and citrinin production by *P. granulatum* (Lillehøj and Göransson 1980), both toxins and fungal isolates were misidentified.

The difficulty in identifying the terverticillate toxigenic penicillia correctly may be caused by morphological similarity, overreliance on colony texture in the book of Raper and Thom (1949) (Pitt 1979b), the lack of adequate reference material, by ignorance of the many confirmatory tests that are available for many of these fungi (Pitt 1979a, 1979b; Frisvad 1985a, 1985b, 1985c, 1986), and by disagreement among *Penicillium* taxonomists. Better keys for the identification of the penicillia are certainly needed, based on a variety of criteria (synoptic keys) or on easily recorded consistent criteria (analytical keys). Unfortunately, many existing analytical keys in recent books starts with inconsistent characters. F.ex. the key on subgenus *Aspergilloides* in the *Penicillium* manual by Pitt (1979b) starts with the quite inconsistent character vesiculation and non-vesiculation of the conidiophore stipe and later uses colony diameter on CYA, a character which was later shown to be quite dependent on the type of yeast extract employed in the CYA medium (Pitt, personal communication and our observations).

Some of the misidentified isolates of *Penicillium* and *Aspergillus* listed in Table 1 and 2 have been reidentified by other taxonomists. The identification of *A. candidus* NRRL 1955 as a citrinin producer (Timonin and Rouatt 1944) was rejected by Raper and Fennell (1965) and reidentified to *A. niveus* (anamorphic state of *Fennellia nivea*). *A. candidus* was later cited as a citrinin-producer (Tandan *et al.* 1969) again. A comparative study of the aspergilli in the *Candidi, Flavipedes* and *Terrei* sections have shown that NRRL 1955 is an isolate of *A. carneus* (Frisvad, unpublished). Pitt (1979a) showed that isolates of *P. cyclopium* and *P. palitans* producing penitrem A were indeed *P. crustosum* and that isolates of *P. verruculosum, P. piscarium, P. paraherquei* and *P. estinogenum* producing verruculogen were all representative of his concept of *P. simplicissimum*. Later work by Stolk and Samson (1983) and Frisvad (unpublished) have shown that *P. simplicissimum* sensu Pitt contains two or three species: *P. piscarium, P. pulvillorum* and *P. brasilianum* and that the name *P. simplicissimum* should be reserved for the anamorph of *Eupenicillium javanicum* (making *P. janthinellum* a synonym of *P. simplicissimum*). *P. brasilianum* (=*P. paraherquei*) is therefore a good producer of penicillic acid, verruculogen and viridicatumtoxin, whereas *P. simplicissimum* (=*P. janthinellum*) is a producer of xanthomegnin, viomellein, brefeldin A and janthitrems. The citreoviridin producing isolate NRRL 13013 was first identified as *P. charlesii,* but reidentified as *P. citreonigrum* by Wicklow (1984), even though the isolate produced vesiculate metulae and I concur with the decision of Wicklow that this isolate is *P. citreonigrum*. The very closely related species *P. citreonigrum, P. miczynskii* and *P. manginii* are all producers of citreoviridin and occasionally have vesiculate stipes or metulae. An isolate of *Aspergillus versicolor* was reported as a producer of cyclopiazonic acid (Ohmomo *et al.* 1973), but this isolate was examined by Domsch *et*

Table 1. Misidentified toxigenic strains of *Penicillium* and their correct identity

Misidentified strain Culture collection number	Reported mycotoxin	Reference	Correct identity
P. aurantiogriseum var. *poznaniense*			
IMI 92235	Penicillic acid		*P. aurantiogriseum* v. *aurantiogriseum*
P. aurantiovirens			
ATCC 32000	Chaetoglobosin C	Springer *et al.* 1976	*P. echinulatum* v. *discolor*
ATCC 32002			
P. australicum			
NRRL 935	Cyclopiazonic acid		*P. commune* chemotype I
P. biforme			
NRRL 6497	Rugulovasine A & B	Dorner *et al.* 1980	*P. commune* chemotype I
P. brunneostoloniferum			
CBS 317.59	Griseofulvin (not prod.)	Udagawa and Abe 1961	*P. brevicompactum*
P. canescens			
FRR 1708	Mycophenolic acid		*P. raciborskii*
IMI 166199	Mycophenolic acid		*P. raciborskii*
V76/170A/28	Penitrem A	Patterson *et al.* 1979	*P. crustosum*
P. carneolutescens			
Fujimoto 1 & 2	Botryodiploidin and mycophenolic acid	Fujimoto *et al.* 1980	*P. brevicompactum*
NRRL 2035	Terrestric acid		*P. hirsutum*
P. casei			
CBS 302.48	Ochratoxin A		*P. verrucosum*
CBS 483.75	Penitrem A	Engel and Teuber 1978	*P. crustosum*
IMI 92238	Ochratoxin A		*P. verrucosum*
P. casei var. *compactum*			
CBS 427.65	Viridicatin		*P. melanochlorum* (=*P. solitum*)
P. charlesii			
NRRL 13013	Citreoviridin	Cole *et al.* 1981	*P. citreonigrum*
P. chrzaszczii			
NRRL 906	Citrinin	Pollock 1947	*P. westlingii*
P. citreoviride			
ATCC 42743	Viomellein		*E. javanicum* (an. *P. simplisissimum*)
P. citrinum			
LKF ZL 17	Roquefortine C		*P. chrysogenum*
Sp. 340 & 865	Citreoviridin	Leistner and Eckardt 1979	*P. miczynskii*
P. citrinum var. *pseudopaxilli*			
CBS 688.77	Citrinin		*P. citrinum* chemotype II
P. claviforme			
IMI 297557	Penitrem A		*P. clavigerum*
P. commune			
AUA 827	Penitrem A	Wagener *et al.* 1980	*P. crustosum*
P. concentricum			
Sp 831	Patulin	Leistner and Eckardt 1979	*P. glandicola* v. *glaucovenetum*
P. crustosum			
ATCC 48414	Xanthomegnin viomellein	Hald *et al.* 1983	*P. aurantiogriseum* v. *aurantiogriseum*
CCM F-389	Griseofulvin	Kocur 1975	*P. aethiopicum*
IMI 291543	Cyclopiazonic acid		*P. commune* chemotype II
Sp 607	Cyclopiazonic acid	Leistner and Eckardt 1979	*P. commune*
P. crustosum var. *spinulosporum*			
FRR 1621	Viridicatin		*P. echinulatum*
P. cyclopium			
ATCC 32014	Penitrem A	Wells and Payne 1976	*P. crustosum*
CBS 202.57	Cyclopiazonic acid		*P. commune*
CSIR 1399, CSIR 1082	Cyclopiazonic acid	Holzapfel 1968	*P. griseofulvum*

Table 1. (cont'd)

Misidentified strain Culture collection number	Reported mycotoxin	Reference	Correct identity
E. Marth 25	Cyclopiazonic acid		*P. camemberti*
E. Marth 40	Cyclopiazonic acid		*P. commune*
E. Marth 8, 13	Cyclopiazonic acid		*P. commune*
IMI 281919	Penitrem A		*P. crustosum*
IMI 297550			*P. flavogenum*
IMI 297556	Viridicatin		*P. melanochlorum* (= *P. solitum*)
IMI 89373	Emodic acid, roquefortine, penicillin	Anslow *et al.* 1940	*P. chrysogenum*
IMI 89374	Cyclopenin	Luckner 1980	*P. melanochlorum* (= *P. solitum*)
IMI 89375	Cyclopaldic acid	Birch and Kocor 1960	*P. commune*
LC 3239	Cyclopiazonic acid		*P. commune*
NRRL 3476	Penitrem A	Wilson *et al.* 1968	*P. crustosum*
NRRL 3477			
NRRL 6065	Ochratoxin A	Ciegler *et al.* 1972	*P. verrucosum*
NRRL 6093	Penitrem A	Vesonder *et al.* 1980	*P. crustosum*
Sp 603, 605, 607	Cyclopiazonic acid	Leistner and Eckardt 1979	*P. commune*
Sp 608, 613	Cyclopiazonic acid	Leistner and Pitt 1977	*P. commune*
P. cyclopium var. *album*			
CBS 343.51	Cyclopolic acid	Birch and Kocor 1960	*P. commune*
P. estinogenum			
76S9FC9	Verruculogen	Di Menna and Mantle 1978	*P. brasilianum*
P. expansum			
CSIR 1375	Griseofulvin, viridicatum-toxin		*P. aethiopicum*
FRR 1347	Xanthomegnin & viomellein	Pitt 1979b	*P. aurantiogriseum* v. *viridicatum*
P. farinosum			
IMI 174717	Roquefortine C	Kozlovsky *et al.* 1981	*P. crustosum*
P. fellutanum			
	Citreoviridin	Locci *et al.* 1965	*P. citreonigrum*
IMI 89896	Gliotoxin, carolic acid	Bracken and Raistrick 1947	*P. palmense*
P. frequentans			
CBS 345.51	Frequentin	Sigg 1963	*P. spinulosum*
CBS 290.53			
P. granulatum			
FRR 343	Penicillic acid		*P. aurantiogriseum* v. *aurantiogriseum*
P. granulatum			
IMI 296059	Penitrem A		*P. crustosum*
NRRL 974		Raper and Thom 1949	*P. hirsutum* v. *albocoremium*
NRRL A-23324	Citrinin not prod.	Lillehøj and Goransson 1980	*P. griseofulvum*
P. griseum			
ATCC 26068	Penitrem A, roquefortine C		*P. crustosum*
P. hirsutum			
FRR 1403	Griseofulvin, roquefortine C		*P. coprophilum*
FRR 48	Roquefortine C, terrestric acid		*P. expansum*
P. implicatum			
CBS 232.38	Citrinin	Pollock 1947	*P. citrinum*
P. janthinellum			
CCM F-391	Citrinin	Betina and Binowska 1979	*P. citrinum*
P. janthogenum			
CBS 348.48	Roquefortine C		*P. expansum*
NRRL 2034	Patulin	Raper and Thom 1949	*P. glandicola* v. *glaucovenetum*
P. japonicum			
QM 7298			*P. italicum*
P. lanosocoeruleum			
ATCC 32017	Roquefortine C	Wells and Payne 1976	*P. crustosum*

Table 1. (cont'd)

Misidentified strain Culture collection number	Reported mycotoxin	Reference	Correct identity
ATCC 32032			
Dragoni 1	Roquefortine C		*P. chrysogenum*
P. lanosogriseum			
NRRL 894	Cyclopiazonic acid		*P. commune*
NRRL 886			
P. lanosoviride			
E. Marth 44	Cyclopiazonic acid		*P. commune*
NRRL 879	Cyclopiazonic acid		*P. commune*
P. lanosum			
	Verruculogen	Dix *et al.* 1972	*P. brasilianum*
Dragoni 2			*P. chrysogenum* v. *nalgiovense*
T. S. Nelson	Citrinin	Nelson *et al.* 1980	*P. citrinum*
P. lapidosum			
IMI 99085	Citreoviridin		*P. manginii*
P. manginii			
CBS 350.51			*P. soppii*
P. marneffei			
CBS 334.59	Citrinin	Van Eijk, unpubl.	*P. citrinum* chemotype II
P. martensii			
IMI 297891	Penitrem A		*P. crustosum*
P. mediolanensis			
IJFM 7812	Ochratoxin A		*P. verrucosum*
P. meleagrinum			
ATCC 32021	Penitrem A	Wells and Payne 1976	*P. crustosum*
P. melinii			
Sp 2061	Griseofulvin	Leistner and Eckardt 1979	*P. janczewskii*
P. nalgiovense			
CBS 105.71	Atramentin		*P. atramentosum*
CBS 581.70	Penicillin		*P. chrysogenum*
P. nordicum			
IJFM 7813	Ochratoxin A		*P. verrucosum*
P. notatum			
CCM F-391	Citrinin	Betina *et al.* 1964	*P. citrinum*
P. ochraceum			
Fujimoto 3	Penicillic acid	Tsunoda *et al.* 1978	*P. aurantiogriseum* v. *polonicum*
IMI 92264	Penicillic acid		*P. aurantiogriseum* v. *aurantiogriseum*
NRRL 870'	Brevianamide A	Robbers *et al.* 1975	*P. aurantiogriseum* v. *viridicatum*
NRRL 882			
NRRL 873	Cyclopiazonic acid		*P. commune*
P. olivinoviride			
CCF 1444	Penicillin, roquefortine		*P. chrysogenum*
P. palitans			
CBS 223.71	Ochratoxin A, citrinin	Scott *et al.* 1972	*P. verrucosum*
H. K. Frank 604	Roquefortine C		*P. chrysogenum*
IMI 89378	Palitantin	Chaplan and Thomas 1960	*P. commune* chemotype II
NRRL 2033	Palitantin	Polonelli *et al.* 1987	*P. commune* chemotype II
NRRL 3468	Penitrem A	Ciegler 1969	*P. crustosum*
NRRL 3672	Penicillic acid	Ciegler and Kurtzman 1970	*P. aurantiogriseum* v. *aurantiogriseum*
P. paraherquei			
FRR 1859	Verruculogen	Yoshizawa *et al.* 1976	*P. brasilianum*
FRR 1930			
P. paxilli			
CBS 276.75	Citrinin		*P. citrinum* chemotype II
FRR 1973	Verruculogen	Giesecke *et al.* 1979	*P. graminicola*

Table 1. (cont'd)

Misidentified strain Culture collection number	Reported mycotoxin	Reference	Correct identity
IMI 96506	Penicillic acid		*P. matriti*
P. phaeojanthinellum			
IMI 92267	Citrinin	Pollock 1947	*P. citrinum*
P. piceum			
V76/170A/28	Penitrem A	Patterson *et al.* 1979	*P. crustosum*
V76/170C/14	Penitrem A	Patterson *et al.* 1979	*P. clavigerum*
P. piscarium			
NRRL A-14996	Verruculogen	Gallagher and Latch 1977	*P. brasilianum*
P. psittacinum			
NRRL 932	Cyclopiazonic acid	—	*P. commune*
P. puberulum			
CCF 1280	Viridicatin		*P. melanochlorum* (=*P. solitum*)
E. Marth 33 & 37	Cyclopiazonic acid		*P. commune*
FRR 168 FRR 1703 FRR 2014	Cyclopiazonic acid		*P. commune*
IMI 17456	Mycophenolic acid		*P. brevicompactum*
LC 218	Cyclopiazonic acid		*P. commune*
NRRL 845	Cyclopiazonic acid		*P. commune*
Sp 524	Cyclopiazonic acid	Leistner and Pitt 1977	*P. commune*
P. pulvillorum			
IMI 216543	Citreoviridin	Nagel *et al.* 1972	*P. manginii*
P. purpurescens			
NRRL A-23305 NRRL A-23309	Ochratoxin A (not prod.)	Lillehoj and Goransson 1980	*P. glabrum*
P. raciborskii			
CBS 215.71	Griseofulvin		*P. raistrickii*
P. raistrickii			
IMI 214120	Verruculogen	Patterson *et al.* 1979	*P. graminicola*
NRRL A-23325			*P. soppii*
P. resticulosum			
NRRL 2021	Roquefortine C		*P. expansum*
P. roqueforti			
ATCC 32027	Penitrem A	Wells and Payne 1976	*P. crustosum*
P. roqueforti var. *punctatum*			
IMI 68234	Cyclopiazonic acid		*P. commune*
P. simplicissimum			
FRR 1695	Mycophenolic acid		*P. raciborskii*
Sp. 863	Verruculogen, viridicatum-toxin	Leistner and Eckardt 1979	*P. brasilianum*
P. spinulosum			
IMI 281920	Citromycetin	Onions 1982	*P. glabrum*
P. terrestre			
ATCC 32028	Cyclopiazonic acid		*P. commune*
P. toxicarium			
CBS 351.51			*P. spinulosum*
NRRL 2579	Citreoviridin	Hirata 1947	*P. citreonigrum*
P. verrucosum			
FRR 1830	Cyclopiazonic acid		*P. commune*
FRR 1963	Viridicatin		*P. echinulatum*
NRRL 948	Cyclopiazonic acid		*P. commune*
P. verrucosum var. *album*			
CBS 203.57	Viridicatin		*P. echinulatum*

Table 1. (cont'd)

Misidentified strain Culture collection number	Reported mycotoxin	Reference	Correct identity
P. verrucosum var. *corymibiferum*			
Sp. 1448	Griseofulvin, viridicatum-toxin	Leistner and Eckardt 1979	*P. aethiopicum*
P. verrucosum var. *cyclopium*			
IJFM 7791			*P. aethiopicum*
P. verrucosum var. *melanochlorum*			
Sp 2309	Penitrem A, roquefortine	Leistner and Eckardt 1979	*P. crustosum*
P. verrucosum var. *verrucosum*			
Sp. 931	Xanthomegnin & viomellein	Leistner and Eckardt 1979	*P. aurantiogriseum* v. *viridicatum*
P. verrucosum var. *cyclopium*			
Sp 458, Sp 119	Penitrem A	Leistner and Eckardt 1979	*P. crustosum*
P. verruculosum			
NRRL 5881	Verruculogen	Fayos *et al.* 1974	*P. brasilianum*
P. viridicatum			
CSIR 1375	Griseofulvin, viridicatum-toxin	Hutchinson *et al.* 1973	*P. aethiopicum*
P. viridicatum			
IMI 154731	Viridicatin		*P. melanochlorum* (= *P. solitum*)
LC 212	Penitrem A		*P. crustosum*
NRRL 5570	Penicillic acid	Ciegler *et al.* 1973	*P. aurantiogriseum* v. *aurantiogriseum*
NRRL 5880	Griseofulvin, viridicatum-toxin		*P. aethiopicum*
Q. 464, Q. 1407	Cyclopaldic acid	Quintanilla 1983	*P. commune*
Sp 119	Cyclopiazonic acid	Leistner and Pitt 1977	*P. commune*
P. viridicyclopium			
QM 7314	Griseofulvin (not prod.)	Udagawa and Abe 1961	*P. aurantiogriseum* v. *aurantiogriseum*

Table 2. Misidentified toxigenic strains of *Aspergillus* and their correct identity

Misidentified strain Culture collection number	Reported mycotoxins	Reference	Correct identity
A. candidus			
NRRL 1955	Citrinin	Timonin and Rouatt (1944)	*A. carneus*
A. niveus			
NRRL 1955	Citrinin	Raper and Fennell (1965)	*A. carneus*
A. versicolor	Cyclopiazonic acid	Ohmomo *et al.* (1973)	*A. oryzae*

al. (1980) and reidentified as *A. oryzae*, a known producer of the toxin (Orth 1977).

A major problem concerning producers of the individual mycotoxins is that once reported these producers have been cited in several reviews and papers even though they may not be correct in the first place. A high number of non-producers of citrinin, such as *P. claviforme, P. viridicatum, P. cyclopium, P. implicatum, P. fellutanum, P. janthinellum, P. lanosum, P. palitans, P. corylophilum, P. aurantioviolaceum, P. steckii, P. velutinum, P. canescens, P. roqueforti, P. purpurescens, P. camemberti* (Binder 1954), *P. granulatum* (Lillehoj and Göransson 1980), *P. notatum, A. candidus* and *A. niveus* have been cited again and again as producers of this important nephrotoxin (Krogh 1974; Saito *et al.* 1971; Leistner and Pitt 1977; Moreau 1973; Betina 1984). The situation is further complicated when some of the originally cited producers are "incorrectly" synonymized and cited under a new name. Pollock (1947) listed *P. phaeojanthinellum* and *P. chrzaszczii* as producers of citrinin f.ex. These species were regarded as synonyms of *P. fellutanum* and *P. jensenii* respectively by Pitt (1979b) and therefore cited as citrinin producers by f.ex. Mantle (1987). Our investigations have shown, however, that the two original producers were indeed good citrinin producers but synonymous with *P. citrinum* and *P. westlingii* respectively. This is further confirmed by the fact that all other isolates of the latter two species produce large amounts of citrinin.

The most important mycotoxins are listed below with a compilation of their producers. Bibliographic details on all reported producers are given elsewhere (Betina 1984; Turner 1971; Turner and Aldridge 1983; Cole and Cox 1981; Frisvad 1986) and details on the mycotoxin production of individual strains of *Penicillium* and *Aspergillus* will also be reported elsewhere. The production of the mycotoxins in a given taxon was confirmed by examining ex type cultures, authentic cultures and several culture collection and freshly collected cultures.

Aflatoxins

The aflatoxins are only produced consistently by *A. flavus, A. parasiticus, A. nomius* and aflatoxin B_2 by *A. flavus* var. *columnaris*. The culture ex type of *A. flavus* NRRL 1957 does not produce aflatoxin. A number of other aflatoxin producers have been reported, but these data have later been questioned (Rehm 1972; Frank 1972) and not confirmed by us. The most interesting reports have been those claiming that *Emericella rugulosa* (Schroeder and Kelton 1975) and *A. wentii* (Schroeder and Verrett 1977) could produce trace amounts of aflatoxin, either because these fungi produce the aflatoxin precursor sterigmatocystin (see below) or because they seem to be closely related to section *Flavi* of subgenus *Circumdati*. We have not been able to detect aflatoxin in any sterigmatocystin-producer or members of section *Wentii*.

Aflatrem

This mycotoxin have been found in sclerotium-producing cultures of *A. flavus* (NRRL 3251 and CBS 121.62) but we have also found it in *A. clavato-flavus* (Frisvad and Liljegren, unpublished), a species which does not produce sclerotia.

Ascladiol

Ascladiol has been reported to be produced by *A. clavatus* (Suzuki *et al.* 1971).

Aspergillic Acid

Aspergillic acid has been found in *A. flavus, A. parasiticus, A. subolivaceus, A. thomii* and *A. nomius*. Aspergillic acid or neoaspergillic acid is also produced by members of subgenus *Circumdati* section *Circumdati* such as *A. sclerotiorum* and *A. fresenii*. The production of the toxin by *A. alutaceus, A. auricomus* and *A. melleus* has not been confirmed.

Asteltoxin

Asteltoxin is produced by *Emericella variecolor*.

Asterric acid, asteriquinone, acetylaranotin, mevinolin, pulvinon, quadrone, terreic acid, terredionol, terretonin, territrems. All these toxins have been reported to be produced by *Aspergillus terreus*. Asterric acid has also been reported from *P. citrinum* and *P. glabrum*.

Austamide, Austdiol, Austin, Austocystins

These toxins are produced by *A. ustus*, but members of the austin biosynthetic family are also produced by *Emericella variecolor* and *P. diversum* (Turner and Aldridge 1983).

Avenaciolide

Avenaciolide is produced by *A. avenaceus* (Brookes *et al.* 1963) and *Neosartorya fischeri*.

Botryodiploidin

Botryodiploidin is produced by *P. roqueforti* chemotype II and *P. brevicompactum*, but it is not known whether this toxin is sporadically produced. As can be seen in Table 1, botrydiploidin was reported from the neutral fraction of an extract of *P. carneolutescens*. The two isolates of *P. carneolutescens* received from Y. Fujimoto were typical of *P. brevicompactum*, but they produced a high amount of red pigments in Yeast extract sucrose (YES) agar.

Brefeldin A

Apart from being produced by *Nectria radicicola, Phoma herbarum* var. *medicaginis* (=*Phyllosticta medicaginis* = *Ascochyta imperfecta*), *Curvularia subulata* and *Curvularia lunata*, brefeldin A production has been reported from *P. decumbens* (Singleton *et al.* 1958), *P. cyaneum* (Betina *et al.* 1965), *P. simplicissimum* (Betina *et al.* 1966), *P. brefeldianum* (Härri *et al.* 1963), *P. cremeogriseum* and *P. janthinellum* (Turner and Aldridge 1983). We have not examined *P. decumbens* for brefeldin A production, but all the other isolates were typical of *E. javanicum* (anamorphic state *P. simplicissimum*). The isolate of *P. cyaneum* investigated (CCM F-376) was growing much faster than typical isolates of *P. cyaneum* and was a typical, but quite colourless, culture of *P. simplicissimum*. This strongly confirms the opinion of Stolk and Samson (1983) that *E. javanicum* and *E. brefeldianum* are synonyms and that *P. simplicissimum* sensu Stolk and Samson = *P. janthinellum* are synonyms of the anamorphic state of this common *Eupenicillium* species, a taxonomic decision that is further confirmed by data on xanthomegnin and viomellein production (see below).

Brevianamide A

Brevianamide A is produced by *P. brevicompactum* (a major part of all isolates investigated) and *P. aurantiogriseum* var. *viridicatum*. The isolate of *P. ochraceum* reported to produce brevianamide A (Robbers *et al.* 1975) (NRRL 870 (and NRRL 882)) was a typical (brown mutant) of the latter variety. Only quite few of the Danish isolates of *P. aurantiogriseum* var. *viridicatum* produced brevianamide A (Frisvad and Filtenborg 1983).

Candidulin, Terphenyllin, Xanthoascin

These toxins are produced by *A. candidus*.

Carolic Acid, Carlosic Acid

This family of closely related secondary metabolites is produced by *P. fellutanum* sensu Pitt, the possible synonym *P. cinerascens, P. palmense* and *P. hordei*. The production of carolic acid in *P. fellutanum* and *P. hordei* has been confirmed by HPLC with diode array detection.

Chaetoglobosin C

Chaetoglobosin C was reported to be produced by *P. aurantiovirens* by Springer *et al.* (1976). Two authentic isolates (ATCC 32000 and 32002) were examined. They had both echinulate conidia, quite divaricate structures and they produced synnemata. For this reason they will be described as a new variety of *P. echinulatum* (*P. echinulatum* var. *discolor*).

Citreoviridin

Citreoviridin is produced by *A. terreus* and its varieties (var. *africanus* and var. *aureus)* (but only by quite few isolates), *P. citreonigrum =? P. miczynskii, P. manginii, P. smithii* (synonym *P. corynephorum*) and *Eupenicillium ochrosalmoneum*. The Penicillia and Eupenicillia mentioned are consistent and very good producers of this mycotoxin (confirmed by HPLC with diode array detection).

Citrinin

Citrinin is consistently produced (i.e. by more than 80% of all isolates investigated) by *P. verrucosum* chemotype II, *P. expansum, P. citrinum, P. westlingii, P. lividum* and *A. carneus*, and by some isolates of *A. terreus, P. citreonigrum =? P. miczynskii, P. spinulosum* and *P. manginii* (Frisvad, manuscript in preparation). Many misidentified isolates of *Penicillium* and *Aspergillus* have been reported to produce citrinin (see Table 1 and 2).

Citromycetin

This mycotoxin is consistently produced by *P. glabrum*.

Costaclavin

Costaclavin is produced by *P. chermesinum*.

Curvularin

Curvularin is produced by *P. steckii* (confirmed for 7 isolates) and maybe by *P. expansum* and *P. restrictum*.

Cyclochlorotin = Islanditoxin, Simatoxin and Erythroskyrin

These very toxic compounds are all produced by *P. islandicum*.

Cyclopaldic Acid, Cyclopolic acid and the Chromanols

These secondary metabolites are produced by *P. commune* (chemotype I) and *A. duricaulis, A. puniceus* and *Neosartorya quadricincta*.

Cyclopenin, Cyclopenol, Viridicatin, Viridicatol

These compounds are consistently produced by *P. aurantiogriseum* and its varieties (var. *aurantiogriseum*, var. *polonicum*, var. *neoechinulatum* and var. *viridicatum*), *P. crustosum, P. echinulatum, P. echinulatum* var. *discolor, P. hirsutum* and its varieties, *P. melanochlorum* (=*P. solitum* sensu Raper and Thom), *P. scabrosum* and *P. vulpinum*.

Cyclopiazonic Acid

Cyclopiazonic acid is consistently produced by *A. flavus, A. oryzae* (not all isolates however), *A. tamarii, P. griseofulvum, P. camemberti* and *P. commune*. Recently we have found cyclopiazonic acid in *A. subolivaceus* (Frisvad and Liljegren, unpublished). Isolates referable to *P. commune* have often been misidentified (see Table 1). *A. versicolor* is not a producer of cyclopiazonic acid (Domsch *et al.* 1980), but it has been cited very often as such. The original cultures was an *A. oryzae*. El-banna *et al.* (1987) have reported on cyclopiazonic acid production by *P. chrysogenum, P. nalgiovense, P. crustosum, P. hirsutum* and *P. viridicatum*. This could not be confirmed by us in any culture of these taxa.

Cytochalasin E

A. clavatus and *A. terreus* are reported to produce cytochalasin E. We have not been able to confirm this yet.

3,7-Dimethyl-8-hydroxy-6-methoxy Isochroman (Isochromantoxin)

This toxin is produced by *P. steckii*.

Duclauxin, "Naphthalic Anhydride", Herqueinone

These toxins are produced by *P. herquei, P. duclauxii* and *Talaromyces stipitatus*.

Emodin

Emodin has been reported from *A. aculeatus, A. alutaceus, A. wentii, Eurotium chevalieri, Eurotium cristatum, Eurotium* *echinulatum, P. brunneum, P. islandicum, P. tardum, Talaromyces avellaneus* (*Hamigera avellanea*) and *Talaromyces stipitatus*.

Emodic Acid and Omega-hydroxyemodic Acid

These metabolites were reported to be produced by *P. cyclopium*. The isolate investigated, IMI 89373, was a typical *P. chrysogenum*, however.

Fumagillin, Fumigatin, Fumitoxins

These toxins are reported to be produced by *A. fumigatus*. The fumitoxins are also produced by *A. fumigatus* var. *ellipticus* (Debeupis and Lafont 1978). Fumigatin and spinulosin are also reported from *P. spinulosum*, but this has not been confirmed.

Fumigaclavines

These ergotalkaloid like compounds are produced by *A. fumigatus, A. tamarii* and many other members of section *Flavi* and *Wentii* of subgenus *Circumdati* (Frisvad and Liljegren, unpubl.).

Fumitremorgins and Verruculogen

These tremorgenic mycotoxins are produced by *A. caespitosus, A. fumigatus, Neosartorya fischeri, Eupenicillium crustaceum, Eupenicillium tularense* (Horie *et al.* 1985), *P. brasilianum* and *P. graminicola* (new species to be described elsewhere). Several fungi representing *P. brasilianum* (=*P. paraherquei*) have been called *P. estinogenum, P. verruculosum, P. simplissisimum, P. janthinellum* (see Table 1), but as stated by Pitt (1979a), all these isolates are representative of *P. simplicissimum* sensu Pitt = *P. brasilianum*. The name *P. simplicissimum* is here regarded to represent the anamorph of *E. javanicum* based on Oudemans iconotype (Stolk and Samson 1983). Other strains producing verruculogen, FRR 1973 and IMI 214120, have been identified as *P. paxilli* and *P. raistrickii* respectively, but they are representatives of a new species in *Penicillium*.

Gladiolic Acid and 3,5-Dimethyl-6-hydroxyphthalide

These metabolites are produced by *Eupenicillium crustaceum*.

Gliotoxin

Gliotoxin has been reported from many different Penicillia and Aspergilli, but the exact identity of the isolates is still not known, because of different opinions on synonomy. *P. bilaii* and *A. fumigatus* seem to be well confirmed producers of the toxin. Other isolates, with rough conidia, reported to produce *gliotoxin* (such as *P. terlikowskii, P. spinulosum* and *P. vinaceum*) are probably also includable in *P. bilaii*. At least one other species of *Penicillium* is able to produce gliotoxin, because several isolates with smooth walled conidia (are reported producers: *P. jensenii, P. obscurum, P. cinerascens, P. waksmanii* and *P. adametzii*. Further species reported to produce gliotoxin are *Eurotium chevalieri, A. terreus* and *A. ustus*.

Griseofulvin

Griseofulvin is consistently produced by the following species: *P. griseofulvum, P. griseofulvum* var. *dipodomyicola, P. coprophilum, P. aethiopicum* (new species to be described elsewhere, the former *P. viridicatum* group IV, (Frisvad and Filtenborg 1983)), *P. sclerotigenum, P. raistrickii, P. janczewskii, P. canescens, P. jensenii, P. lanosum* (all confirmed by both TLC and reversed phase HPLC with diode array detection) and *E. javanicum* (reported from *P. brefeldianum*) and *A. versicolor*. Griseofulvin production by the last two species has not been confirmed, but preliminary results show that *A. sydowii* and not *A. versicolor* may be a griseofulvin producer.

Janthitrem

The janthitrems are produced by *Eupenicillium javanicum*, but only by some isolates.

Kojic Acid

Kojic acid has been found by us in *P. lanosum* and section *Flavi, Wentii*, and *Circumdati* of *Aspergillus*, but it is probably produced by many other species.

Malformin

The malformins are produced by *Aspergillus niger* (and its proposed varieties).

Maltoryzin

Maltoryzin is produced by a strain of *A. oryzae*. It is not known whether other isolates of section *Flavi* can produce this toxin.

Marcfortins

The marcfortins are produced by *P. roqueforti* chemotype I. It is not known whether these toxins are produced by chemotype II of *P. roqueforti*.

Monorden

P. resedanum is a reported producer of monorden.

Mycelianamide

This secondary metabolite is produced by *P. griseofulvum*.

Mycophenolic Acid

Mycophenolic acid is produced by most isolates of *P. roqueforti,* both chemotype I and II, *P. brevicompactum* and *P. raciborskii.* Mycophenolic acid has been detected in all fresh strains of *P. raciborskii* but not in the old ex type culture. The closely related mycochromenic acid is produced by *P. soppii.* The production of mycophenolic acid in these species has been confirmed by TLC and HPLC with diode array detection. The strain of *P. carneolutescens* producing mycophenolic acid (Fujimoto *et al.* 1980) was misidentified, it was a typical *P. brevicompactum.*

Naptho-γ-pyrones

The toxic naptho-γ-pyrones are produced by *A. niger.*

Nidulotoxin

This toxin is produced by *Emericella nidulans, A. versicolor* and *A. sydowii* (Lafont and Lafont 1970).

3-Nitropropionic acid

This toxin is produced by *P. atrovenetum* and members of section *Flavi, Wentii* and *Candidi* in *Aspergillus.* We have confirmed the production of 3-nitropropionic acid in *P. atrovenetum* and nearly all species in section *Flavi* and *Wentii* (Frisvad and Liljegren, unpublished).

Ochratoxin A

A high number of species in both *Penicillium* and *Aspergillus* have been reported to produce ochratoxin A. Most of these are misidentified fasciculate *Penicillium* species (Table 1). The only confirmed producer of ochratoxin A in *Penicillium* is *P. verucosum* chemotype I and II (Frisvad and Filtenborg 1983), this has been further confirmed by HPLC with diode array detection and by checking the original producers of the nephrotoxin. Ochratoxin production by *P. purpurescens* and *P. variabile,* reported several times could not be confirmed in any isolate of these species. The isolates of *P. purpurescens* producing ochratoxin A has been examined and they were all members of *P. glabrum.* Further isolates of *P. glabrum,* a very common species, did not produce ochratoxin A in our assays.

Ochratoxin A is produced by many members of section *Circumdati* in *Aspergillus: A. alutaceus, A. fresenii, A. melleus, A. ostianus, A. petrakii* and *A. sclerotiorum.* This has been confirmed in our laboratory. Recently, Chelkowski *et al.* (1987) reported on the production of ochratoxin A in some isolates of *Eurotium,* a very important discovery.

Oryzacidin

Oryzacidin is produced by *A. oryzae* (Shimoda 1951).

Oosporein

Oosporein has been reported from *P. rubrum* (Curtin *et al.* 1940).

Oxalin

Oxalin is produced by *P. oxalicum.*

Palitantin and Frequentin

These metabolites are produced by *P. commune, P. spinulosum* (see Table 1) and *E. javanicum.*

Paraherquamide

This toxin is produced by *P. brasilianum* (called *P. simplicissimum* by Pitt (1979a)).

Paspalinin

This tremorgen is produced by *A. flavus.* We have recently found this mycotoxin also in *A. leporis* and *A. clavatoflavus* (Frisvad and Liljegren, unpublished).

Patulin

Patulin has been reported from a high number of species in *Penicillium* and *Aspergillus,* but many of these seem to be misidentified (Table 1). In *Penicillium* the following species are good producers of the toxin: *P. griseofulvum, P. expansum, P. vulpinum, P. glandicola, P. glandicola* var. *glaucovenetum, P. griseofulvum* var. *dipodomyicola, P. coprophilum* var. *ribesolens, P. roqueforti* chemotype II, *P. novaezeelandiae, P. melinii* and *P. selandiae* (new species to be described elsewhere). *Patulin* is also produced by *Eupenicillium lapidosum* and *A. clavatus, A. giganteus* and *A. terreus.* Apart from *P. melinii* and *E. lapidosum,* patulin production in the other species have been confirmed by both TLC and HPLC with diode array detection.

Paxillin

Paxillin was originally found in *P. paxilli.* This has been confirmed in three isolates and the culture ex type. Recently, we have found that *A. clavato-flavus* is very good producer of paxillin (Frisvad and Liljegren, unpublished).

Penicillic Acid

As in the case of patulin many isolates of *Penicillium* and *Aspergillus* have been reported to produce penicillic acid, but quite a lot of these reported producers are misidentified (Table 1). Good producers of penicillic acid are *P. aurantiogriseum* and all its varieties (var. *aurantiogriseum*, var. *polonicum*, var. *melanoconidium*, var. *neoechinulatum* and var. *viridicatum*), *P. roqueforti* chemotype II (only few isolates), *P. fennelliae*, *P. hirsutum* var. *albocoremium* (new variety to be described elsewhere), *P. brasilianum*, *P. janczewskii*, *P. matriti*, *P. rolfsii* (Frisvad and Filtenborg, unpublished), *P. lividum* (not confirmed), *P. hispanicum* (not confirmed), *Eupenicillium baarnense*, *E. ehrlichii*, *Petromyces alliaceus*, *A. alutaceus*, *A. auricomus*, *A. fresenii*, *A. melleus* and *A. sclerotiorum*.

Penicillin

We have confirmed the production of penicillin (Frisvad *et al.* 1987) in *P. chrysogenum*, *P. chrysogenum* var. *dipodomyis*, *P. chrysogenum* var. *nalgiovense* (new combination to be proposed elsewhere), *P. turbatum*, *P. castellonense* (=*P. sizovae*), and members of the genus *Emericella* and section *Nidulantes* in *Aspergillus*.

Penitrems

The penitrems are produced by *P. crustosum*, *P. clavigerum* and *P. glandicola* (confirmed by TLC and HPLC with diode array detection). It has also been found in a few isolates of *P. aurantiogriseum* var. *aurantiogriseum* in trace amounts (only confirmed by TLC). A high number of penitrem A producers have been misidentified (Pitt 1979a; Frisvad 1986; Table 1). Isolates of *P. crustosum* have often been given the name *P. commune* or *P. cyclopium*. *P. crustosum* is recognizable by its good growth on creatine-sucrose agar (Frisvad 1985b), its high growth rates, its ability to produce an apple rot, its production of conidial crusts and its grey green quite large conidia (Frisvad, 1985c)

Physicon

Physicon is produced by *A. flavus*, *A. wentii*, *Eurotium chevalieri*, *E. amstelodami*, *E. echinulatum*, *E. herbariorum*, *E. cristatum* and *E. repens*, but we have not been able to confirm this.

PR-toxin

PR-toxin is produced by *P. roqueforti* chemotype I only.

Puberulic Acid and Puberulonic Acid

This metabolite is produced by *P. aurantiogriseum* var. *aurantiogriseum*, but we have only been able to confirm the identity of the original producers (IMI 92199 and IMI 34846ii).

Purpurogenone

Purpurogenone is produced by *P. purpurogenum*.

Questin and Questinol

These metabolites have been reported from *A. flavus*, *A. terreus*, *Eurotium cristatum* and *P. glabrum*. A producer of these metabolites and sulochrin, asterric acid and bischlorogeodin (IMI 96659) was a typical *P. glabrum*.

Roquefortine A and B (Isofumigaclavine A and B)

These metabolites have been found in *P. roqueforti* and *P. commune* chemotype II and *P. clavigerum*.

Roquefortine C

Consistent production of roquefortine C by several species besides *P. roqueforti* was first reported by Frisvad and Filtenborg (1983). This has been further confirmed by analytical HPLC with diode array detection for the following species: *P. roqueforti* chemotype I and II, *P. crustosum*, *P. chrysogenum*, *P. griseofulvum*, *P. coprophilum* var. *coprophilum*, *P. expansum*, *P. glandicola* var. *glandicola*, *P. glandicola* var. *glaucovenetum*, *P. hirsutum* var. *hirsutum*, *P. hirsutum* var. *albocoremium*, *P. hirsutum* var. *allii*, *P. hordei*, *P. oxalicum* (traces), *P. sclerotigenum* and *P. vulpinum*. Roquefortine C is thus produced by a very high number of terverticillate Penicillia including the closely related biverticillate Penicillia with an asymmetrically appressed branch (*P. sclerotigenum* and *P. oxalicum*).

Roquefortine D

Roquefortine D is produced by *P. atramentosum*, *P. chrysogenum*, *P. glandicola* (var. *glandicola* and var. *confertum*) (Frisvad and Filtenborg, unpublished).

Rubratoxin

Rubratoxin A and B are produced by *P. rubrum* and maybe by *P. purpurogenum*.

Rugulosin

Rugulosin is produced by *P. islandicum* (the (−) form), *P. rugulosum* and *T. wortmannii*. Recent results from our laboratory indicate that *P. variabile*, *P. brunneum*, *P. concavorugulosum* and *P. tardum* are synonyms of the anamorph of *T. wortmannii!*

Rugulovasine A & B and Chlororugulovasines

P. commune and *T. wortmannii* (anamorph *P. variabile*) are good producers of rugulovasines. *P. corylophiloides* and *P. rubrum* has also been reported to produce the alkaloid, but this has not been checked.

Secalonic Acid A

This toxin has been rapported from *A. alutaceus*.

Secalonic Acid D

This toxin has been reported from *P. oxalicum* and this has been confirmed for 10 freshly isolated strains. The production of the toxin by *P. atramentosum* (Fujimoto *et al.* 1983) could not be confirmed.

Secalonic Acid F

Secalonic acid F has been reported from *A. aculeatus.*

Sterigmatocystin

The precursor to the aflatoxins, sterigmatocystin, is produced by a high number of *Aspergillus* species. It has been reported from species in subgenus *Circumdati,* section *Flavi,* subgenus *Aspergillus,* section *Aspergillus* (*Eurotium* is the teleomorphic state), subgenus *Nidulantes* section *Nidulantes* (*Emericella* is the teleomorph), section *Versicolores,* section *Usti,* section *Terrei* and section *Flavipedes.* The production of sterigmatocystin has been confirmed in the following species (Frisvad 1985d, 1986): *A. flavus, A. parasiticus* (small amounts), *A. versicolor, E. nidulans* (and its varieties *lata, dentata, echinulata, acristata* and *quadrilineata*), *E. rugulosa, E. claistominuta, E. corrugata, E. foveolata, E. spectabilis, E. heterothallica, E. bicolor, E. fructiculosus, E. navahoensis, A. multicolor* and *A. egyptiacus* (not the type however). Sterigmatocystin production by *E. parvathecia, E. purpurea, E. unguis, E. striata, E. variecolor* var. *variecolor, A. ustus, A. sydowii, A. terreus, A. flavipes* (*Fennellia flavipes*), *A. niveus* (*Fennellia nivea*), *A. carneus* and *A. tamarii* could not be confirmed. Sterigmatocystin production has also been rapported from *Eurotium rubrum* (*Eurotium herbariorum*), *Eurotium repens, Eurotium chevalieri* and *Eurotium amstelodami* (trace amounts) (Karo & Hadlok 1982; Schroeder and Kelton, 1975; Szebiotko *et al.* 1981). As these fungi are very widespread in foods, these findings should be further examined.

Tardin

Tardin has been reported from *P. tardum* (= ? *P variabile*) (Borodin *et al.* 1947).

Terrein

Terrein production has been confirmed in all isolates examined of *A. terreus,* including strains used in the industry, food strains, soil strains and pathogenic strains (J. C. Frisvad, unpublished results). The toxin has also been reported from *P. raistrickii* and *Neosartorya fischeri.*

Terrestric Acid and Viridicatic Acid

Terrestric acid is produced by *P. crustosum, P. hordei, P. hirsutum* (and its varieties) consistently and by some isolates of *P. aurantiogriseum* var. *aurantiogriseum* (ca. 5%).

Tryptiquivalins

The tryptiquivalins has been reported from *A. clavatus* and *A. fumigatus.*

Verrucosidin

Verrucosidin (= S-toxin) (El-Banna *et al.* 1987) is produced by *P. aurantiogriseum* var. *polonicum.*

Verruculotoxin

The toxin is produced by *P. brasilianum.* The original producer was called *P. verruculosum,* but it was a *P. brasilianum* (= *P. simplicissimum* sensu Pitt) (see Table 1).

Viomellein, Xanthomegnin, Vioxanthin

These nephrotoxins are produced by *P. aurantiogriseum* var. *aurantiogriseum* and var. *viridicatum, P. mariaecrucis, E. javanicum* (J. C. Frisvad, unpublished), *A. alutaceus* (= *A. ochraceus*), *A. fresenii* (= *A. sulphureus*), *A. auricomus* and *A. melleus.* The production of viomellein and xanthomegnin by the ex type culture of both *P. janthinellum* (NRRL 2016) and *E. javanicum* further supports the opinion of Stolk and Samson (1983) that *P. janthinellum* (= *P. simplicissimum* sensu Stolk and Samson) is the anamorph of *E. javanicum.* The culture of *P. citreoviride* (ATCC 42743) producing xanthomegnin and viomellein was misidentified and represents a typical anamorphic state of *E. javanicum.*

Viridamine

Viridamine is produced by *P. aurantiogriseum* var. *viridicatum.*

Viridicatumtoxin

This toxin is produced by *P. aethiopicum* (new species to be described elsewhere) and *P. brasilianum* (= *P. simplicissimum* sensu Pitt). Strains of *P. aethiopicum* has been given a variety of names (see Table 1), but it can be distinguished from these by its (albeit poor) growth at 37 C and smooth stipes on Czapek yeast extract agar.

Viriditoxin

Viriditoxin is reported to be produced by *A. viridi-nutans* and *A. brevipes* in subgenus *Aspergillus* section *Fumigati.*

Wentilacton

Wentilacton has been reported from *A. wentii.*

Xanthocillins

Xanthocillins has been reported from *P. chrysogenum*, *Eurotium chevalieri*, *A. clavatus*, *A. ustus* and *Eupenicillium egyptiacum* (=? *E. crustaceum*).

References

Anslow WK, Breen J, Raistrick H (1940) Studies in the biochemistry of microorganisms 64. Emodic acid (4:5:7-trihydroxyanthraquinone-2-carboxylic acid) and w-hydroxyemodin (4:5:7-trihydroxy-2-(hydroxymethyl)-anthraquinone), metabolic products of *Pennicillium cyclopium* Westling. Biochem J 34:159–165

Betina V, Nemec P, Kutková M, Balan J, Kovác S (1964) The isolation of citrinin from *Penicillium notatum* Westling. Chem Cvesti 18:128–139

Betina V, Nemec P, Kovác S, Kjaer A, Shapiro RH (1965) The identity of cyanein and brefeldin A. Acta Chem Scand 19:579

Betina V, Fuska J, Kjaer A, Kutkova M, Nemec P, Shapiro RH (1966) Production of cyanein by *Penicillium simplicissimum*. J Antibiotics, Ser A (Tokyo) 19:115–117

Betina V (ed) (1984) Mycotoxins. Production, isolation, separation and purification. Elsevier, Amsterdam, 528 pp

Betina V, Binowská Z (1979) Diphasic production of citrinin by *Penicillium janthinellum* and its regulation. Biológia (Bratislava) 34:461–469

Binder W (1955) The formation of antibiotic substance in molds of the Camembert, Gorgonzola and Roquefort types of cheese. Milschwiss Ber 4:88–129

Birch AJ, Kocor M (1960) Studies in relation to biosynthesis Part XXII. Palitantin and cyclopaldic acid. J Chem Soc 1960:866–871

Borodin N, Philpot FJ, Florey HW (1947) An antibiotic from *Penicillium tardum*. Brit J Exp Pathol 28:31–34

Bracken A, Raistrick H (1947) Studies in the biochemistry of microorganisms 75. Dehydrocarolic acid, a metabolic product of *Penicillium cinerascens* Biorge. Biochem J 41:569–575

Brookes D, Kidd BK, Turner WB (1963) Avenaciolide, an antifungal lactone from *Aspergillus avenaceus*. J Chem Soc 1963:5385–5391

Chaplan P, Thomas R (1960) Studies in the biosynthesis of fungal metabolites. The biosynthesis of palitantin. Biochem J 77:91–96

Chelkowski J, Samson RA, Wiewiórowska M, Golinski P (1987) Ochratoxin A formation by isolated dtrains of the conidial stage of *Aspergillus glaucus* Link ex Gray (=*Eurotium herbariorum* (Wiggers) Link ex Gray) from cereal grains. Nahrung 31:267–269

Ciegler A (1969) A tremorgenic toxin from *Penicillium palitans*. Appl Microbiol 18:128–129

Ciegler A, Kurtzman CP (1970) Penicillic acid production by blue-eye fungi on various agricultural commodities. Appl Microbiol 20:761–764

Ciegler A, Fennell DI, Mintzlaff H-J, Leistner L (1972) Ochratoxin synthesis by *Penicillium* species. Naturwissenschaften 59:365–366

Ciegler A, Fennell DI, Sansing GA, Detroy RW, Bennett GA (1973) Mycotoxin producing strains of *Penicillium viridicatum:* classification into subgroups. Appl Microbiol 26:271–278

Cole, RJ, Cox RH (1981) Handbook for toxic fungal metabolites. Academic Press, New York, 874 pp

Cole RJ, Dorner JW, Cox RH, Hill RA, Cluter HG, Wells JM (1981) Isolation of citreoviridin from *Penicillium charlesii* cultures and molded pecan fragments. Appl Environ Microbiol 42:677–681

Cruickshank RH, Pitt JI (1987) Identification of species in *Penicillium* subgenus *Penicillium* by enzyme electrophoresis. Mycologia 79:614–620

Curtin TP, Fitzgerald G, Reilly J (1940) Production of phoenicine on synthetic media. Biochem J 34:1605–1610

Debeaupuis JP, Lafont P (1978) Fumitoxins, new mycotoxins from *Aspergillus fumigatus* Fres. Appl Environ Microbiol 36:8–10

Di Menna ME, Mantle PG (1978) The role of Penicillia in ryegrass staggers. Res Veterin Sci 24:347–351

Dix DT, Martin J, Moppett CE (1972) Molecular structure of the metabolite lanosulin. J Chem Soc Chem Commun 1972:1168–1169

Domsch KH, Gams W, Anderson T-M (1980) Compendium of soil fungi. Academic Press, New York, 859 + 405 pp

Dorner JW, Cole RJ, Hill R, Wicklow DT (1980) *Penicillium rubrum* and *Penicillium biforme,* new sources of rugulovasine A and B. Appl Environ Microbiol 40:685–687

El-Banna AA, Pitt JI, Leistner L (1987) Production of mycotoxins by *Penicillium* species. System Appl Microbiol 10:42–46

Engel G, Teuber M (1978) Simple aid in the identification of *Penicillium roqueforti* Thom. Growth in acetic acid. Eur J Appl Microbiol 6:107–111

Fayos J, Lokensgard D, Clardy J, Cole RJ, Kirksey JW (1974) Structure of verruculogen, a tremor producing peroxide from *Penicillium verruculosum*. J Amer Chem Soc 96:6785–6787

Filtenborg O, Frisvad JC, Svendsen JA (1983) Simple screening method for molds producing intracellular mycotoxins in pure cultures. Appl Environ Microbiol 45:581–585

Frank HK (1972) Zweifel über das Vorkommen von Aflatoxin bei der Gattung *Penicillium*. Z Lebensm Unters-Forsch 150:151–153

Frisvad JC (1985a) Profiles of primary and secondary metabolites of value in classification of *Penicillium viridicatum* and related species. In: Samson & Pitt (1985) pp. 311–325

——— (1985b) Creatine sucrose agar, a differential medium for mycotoxin producing terverticillate *Penicillium* species. Lett Appl Microbiol 1:109–113

——— (1985c) Classification of asymmetric penicillia using expressions of differentiation. In: Samson & Pitt (1985) pp. 327–333

——— (1985d) Secondary metabolites as an aid to *Emericella* classification. In: Samson & Pitt (1985) pp. 437–443

——— (1986) Taxonomic approaches to mycotoxin identification. In Cole RJ (ed) Modern methods in the analysis and structural elucidation of mycotoxins. Academic Press, New York, London, pp 415–457

Frisvad JC, Filtenborg O (1983) Classification of terverticillate penicillia based on profiles of mycotoxins and other secondary metabolites. Appl Environ Microbiol 46:1301–1310

Frisvad JC, Thrane U (1987) Standardized high-performance liquid chromatography of 182 mycotoxins and other fungal metabolites based on alkylphenone retention indices and UV-VIS spectra (diode array detection). J Chromatogr 404:195–214

Frisvad JC, Filtenborg O, Wicklow DT (1987) Terverticillate penicillia isolated from underground seed caches and cheek pouches of banner-tailed kangaroo rats (Dipodomys spectabilis). Can J Bot 65:765–773

Fujimoto Y, Kamiya M, Tsunoda H, Ohtsubo K, Tatsuno T (1980) Recherch toxicologique des substances metabolique de *Penicillium carneo-lutescens*. Chem Pharm Bull 28:1062–1066

Fujimoto Y, Yokoyama E, Morooka N, Tsunoda H, Tatsuno T (1983) Studies on the metabolite of *Penicillium atramentosum*. Proc Jap Assoc Mycotoxicol 17:52–54

Gallagher RT, Latch GCM (1977) Production of tremorgenic mycotoxins verruculogen and fumitremorgin B by *Penicillium piscarium* Westling. Appl Environ Microbiol 33:730–731

Giesecke PR, Lanigan GW, Payne AL (1979) Fungal tremorgens associated with ryegrass staggers in South Australia. Austr Vet J 55:444

Hald B, Christensen DH, Krogh P (1983) Natural occurrence of the mycotoxin viomellein in barley and the associated quinone-producing penicillia. Appl Environ Microbiol 46:1311–1317

Härri E, Loeffler W, Sigg HP, Stähelin H, Tamm C (1963) Uber die Isolierung neuer Stoffwechselprodukte aus *Penicillium brefeldianum* Dodge. Helv Chim Acta 46:1235–1246

Hermansen K, Frisvad JC, Emborg C, Hansen J (1984) Cyclopiazonic acid production by submerged cultures of *Penicillium* and *Aspergillus* strains. FEMS Microbiol Lett 21:253–261

Hirata Y (1947) On the products of mould. I. Poisonous products from mouldy rice (Part I). Extraction. J Chem Soc Japan 68:63 + 74

Holzapfel CW (1968) The isolation and structure of cyclopiazonic acid, a toxic product of *Penicillium cyclopium* Westling. Tetrahedron 24:2101–2119

Horie Y, Maebayashi Y, Yamazaki M (1985) Survey of productivity of tremorgenic mycotoxin, verruculogen by *Eupenicillium* spp. Proc Jap Assoc Mycotoxicol 22:35–37

Hutchinson RD, Steyn PS, van Rensburg SJ (1973) Viridicatumtoxin, a new mycotoxin from *Penicillium viridicatum* Westling. Toxicol Appl Pharmacol 24:507–509

Karo M, Hadlok RM (1982) Investigations on sterigmatocystin production by fungi of the genus *Eurotium*. In: Krogh P (ed) Proc Int IUPAC Symp Mycotoxins Phycotoxins, 5th, Techn. Univ. Vienna, Vienna, pp 178–181

Kocur M (1975) Czechoslovak collection of microorganisms. Catalogue of cultures 3. ed, JE Purkyne University, Brno, 628 pp

Kozlovsky AG, Solovieva TF, Reschetilova TA, Skruabin GK (1981) Biosynthesis of roquefortine and 3,12-dihydroroquefortine by the culture *Penicillium farinosum*. Experientia 37:472

Krogh P (1974) Mycotoxic nephropathy. In: Purchase IFH (ed) Mycotoxins. Elsevier, Amsterdam, pp. 419–428

Lafont P, Lafont J (1970) Production de nidulotoxin par des aspergilli apparteneant a diverse especes. Experientia 26:807–808

Leistner L, Eckardt C (1979) Vorkommon toxinogener Penicillien bei Fleischerzeugnisse. Fleischwirtschaft 59:1892–1896

Leistner L, Pitt JI (1977) Miscellaneous *Penicillium* toxins. In: Rodricks JV, Hesseltine CV, Mehlmann MA (eds) Mycotoxins in human and animal health. Pathotox, Park Forest South, pp 639–653

Lillehøj EG, Göransson B (1980) Occurrence of ochratoxin- and citrinin-producing fungi on developing danish barley grain. Acta Path Microbiol Scand Sect B88:133–137

Locci R, Merlini L, Nasini G, Locci JR (1965) On a strain of *Penicillium fellutanum* Biourge producing a yellow fluorescent substance. Giorn Microbiol 13:271–277

Luckner M (1980) Alkaloid biosynthesis in *Penicillium cyclopium*—does it reflect general features of secondary metabolism? J Nat Prod 43:21–40

Mantle PG (1987) Secondary metabolites of *Penicillium* and *Acremonium*. In: Peberdy JF (ed) *Penicillium* and *Acremonium*. Plenum, New York & London, pp 161–243

Marasas WFO, Nelson PE, Toussoun TA (1984) Toxigenic *Fusarium* species. Identity and mycotoxicology. Pennsylvania State University Press, University Park, London, 328 pp

Mills JT, Abramson D (1982) Ochratoxigenic potential of *Penicillium* spp. isolated from stored rapeseed and cereals in western Canada. Can J Plant Sci 4:37–41

Moreau C (1973) Moulds, toxins and food (transl. Moss MO). John Wiley and Sons, Chichester, New York, Brisbane, Toronto, 477 pp

Nagel DW, Steyn PS, de Scott B (1972) Production of citreoviridin by *Penicillium pulvillorum*. Phytochem 11:627–630

Nelson TS, Beasley JN, Kirby LK, Johnson ZB, Ballam GC (1980) Isolation and characterisation of citrinin produced by *Penicillium lanosum*. Poultry Sci 59:2055–2059

Ohmomo S, Sugita M, Abe M (1973) Isolation of cyclopiazonic acid, cyclopiazonic acid imine and bissecodehydro-cyclopiazonic acid from the cultures of *Aspergillus versicolor* (Vuill.) Tiraboschi. J Agric Chem Soc Japan 47:57–93

Onions AHS (1982) Catalogue of the culture collection of the Commonwealth Mycological Institute, 8 ed, CAB International Mycological Institute, Kew, 298 pp

Onions AHS, Brady BL (1987) Taxonomy of *Penicillium* and *Acremonium*. In: Peberdy JF (ed) Penicillium and Acremonium. Plenum, New York, London, pp. 1–36

Orth R (1977) Mycotoxins of *Aspergillus oryzae* strains for use in the food industry as starters and enzyme producing molds. Ann Nutr Aliment 31:617–624

Paterson RRM, Simmonds MSJ, Blaney WM (1987) Mycopesticidal effects of characterized extracts of *Penicillium* isolates and purified secondary metabolites (Including mycotoxins) on *Drosophila melanogaster* and *Spodoptora littoralis*. J Invert Pathol 50:124–133

Patterson DSP, Roberts BA, Shreeve BJ, McDonald SM, Hayes AW (1979) Tremorgenic toxins produced by soil fungi. Appl Environ Microbiol 37:172–173

Pitt JI (1979a) *Penicillium crustosum* and *Penicillium simplicissimum*, the correct names for two common species producing tremorgenic mycotoxins. Mycologia 71:1166–1177

——— (1979b) The genus *Penicillium* and its teleomorphic states *Eupenicillium* and *Talaromyces*. Academic Press, London, 634 pp

Pollock AV (1947) Production of citrinin by five species of *Penicillium*. Nature 160:331–332

Polonelli L, Morace G, Rosa R, Castagnola M, Frisvad JC (1987) Antigenic characterization of *Penicillum camemberti* and related common cheese contaminants. Appl Environ Microbiol 53:872–878

Quintanilla JA (1983) Un nuovo productor de ácido ciclopáldico: *Penicillium viridicatum* Westling. Avan Nutr Mej Anim 24:405–410

Raper KB, Fennell DI (1965) The genus *Aspergillus*. Williams and Wilkins, Baltimore, 686 pp

Raper KB, Thom C (1949) A manual of the penicillia. Williams and Wilkins, Baltimore, 875 pp
Rehm H-J (1972) Mycotoxine in Lebensmitteln. VI. Mitteilung. Aflatoxinbildung verschiedener Pilzarten. Z Lebensm Unters -Forsch 150:146–151
Robbers JE, Strauss JW, Tuite J (1975) The isolation of brevianamide A from *Penicillium ochraceum*. J Nat Prod 38:355–356
Saito M, Enomoto M, Tatsuno T (1971) Yellowed rice toxins. Luteoskyrin and related compounds, chlorine containing compounds, and citrinin. In: Ciegler A, Kadis S, Ajl SJ (eds) Microbial toxins. Vol. VI. Fungal toxins. Academic Press, New York, London, pp 299–380
Samson RA, Gams W (1984) The taxonomic situation in the hyphomycete genera *Penicillium, Aspergillus* and *Fusarium*. Antonie van Leeuwenhoek 50:815–824
Samson RA, Pitt JI (1985) Advances in *Penicillium* and *Aspergillus* systematics. Plenum, New York, London, 483 pp
Schroeder HW, Kelton WH (1975) Production of sterigmatocystin by some species of the genus *Aspergillus* and its toxicity to chicken embryos. Appl Environ Microbiol 30:589–591
Schroeder HW, Verrett MJ (1969) Production of aflatoxin by *Aspergillus wentii* Wehmer. Can J Microbiol 15:895–899
Scott PM, van Walbeek W, Kennedy BRC, Anyeti D (1972) Mycotoxins (ochratoxin A, citrinin, and sterigmatocystin) and toxigenic fungi in grains and other agricultural products. J Agric Food Chem 20:1103–1109
Shimoda C (1951) An antibiotic substance, oryzacidin, against saké-putrefying bacteria, produced by *Aspergillus oryzae*. I. Isolation of oryzacidin. J Agr Chem Soc Japan 25:254–260
Sigg HP (1963) Die Konstitution von Frequentin. Helv Chim Acta 46:1061–1065
Singleton VL, Bohonos N, Ullstrup AJ (1958) Decumbin, a new compound from a species of *Penicillium*. Nature 181:1072–1073
Springer JP, Clardy J, Wells JM, Cole RJ, Kirksey JW, MacFarlane RD, Torgeson DF (1976) Isolation and structure determination of the mycotoxin chaetoglobosin C, a new (13) cytochalasin. Tetrahedron Lett 1976:2531–2534
Stolk AC, Samson RA (1983) The ascomycete genus *Eupenicillium* and related *Penicillium* anamorphs. Stud Mycol (Baarn) 23:1–149
Suzuki T, Takeda M, Tanabe H (1971) A new mycotoxin produced by *Aspergillus clavatus*. Chem Pharm Bull 19:1786–1788
Szebiotko K, Chelkowski J, Dopierala B, Godlewska B, Radomyska W (1981) Mycotoxins in cereal grain Part I. Ochratoxin, citrinin, sterigmatocystin, penicillic acid and toxigenic fungi in cereal grain. Nahrung 25:415–421
Tandan RN, Nigam SS, Agarwall PN (1969) Biosynthesis of citrinin by the fungus *Aspergillus candidus*. Lab J Sci Technol 7-B:263–265
Timonin MI, Rouatt JW (1944) Production of citrinin by *Aspergillus* species of the *Candidus* group. Can J Publ Health 35:80–88
Tsunoda H, Kishi K, Okubo K, Tatsuno T, Ohtsubo K (1977) Morphology and culture of *Penicillium ochraceum* and *P. carneolutescens* in *Penicillium,* Asymmetrica-Fasciculata group I. Proc Jap Assoc Mycotoxicol 5/6:11–13
Turner WB (1971) Fungal metabolites. Academic Press, London, New York, 446 pp
Turner WB, Aldridge DC (1983) Fungal metabolites II. Academic Press, London, New York, 631 pp
Udagawa K, Abe S (1961) Production of griseofulvin by some strains of the genus *Penicillium*. J Antibiot ser A 14:215–220
Vesonder RF, Tjarks L, Rohwedder W, Kieswetter DO (1980) Indol metabolites from *Penicillium cyclopium* NRRL 6093. Experientia 36:1308
Wagener RE, Davis ND, Diener UL (1980) Penitrem A and roquefortine production by *Penicillium commune*. Appl Environ Microbiol 39:882–887
Wells JM, Cole RJ (1977) Production of penitrem A and of an unidentified toxin by *Penicillium lanosocoeruleum* isolated from weevil-damaged pecans. Phytopathology 67:779–782
Wells JM, Payne JA (1976) Toxigenic species of *Penicillium, Fusarium* and *Aspergillus* from weevil-damaged pecans. Can J Microbiol 22:281–285
Wicklow DT (1984) A citreoviridin-producing fungus, NRRL 13013, from pecan fragments is not *Penicillium charlesii*. Mycologia 76:943–944
Wilson BJ, Wilson CH, Hayes AW (1968) Tremorgenic toxin from *Penicillium cyclopium* grown on food materials. Nature 220:77–78
Yoshizawa T, Morooka N, Sawada Y, Udagawa S-I (1976) Tremorgenic mycotoxin from *Penicillium paraherquei*. Appl Environ Microbiol 32:441–442

Manuscript received March 26, 1988.