Mycological Fat Production in India. I. A Preliminary Survey of Fat Producing Moulds

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Abstract

A comparative assessment of 96 species of moulds: 21 of *Aspergillus*, 14 of *Penicillium*, 2 of *Paecilomyces*, 3 of *Cunninghamella*, 2 of *Circinella*, 1 of *Actinomucor*, 2 of *Mortierella*, 35 of *Mucor*, 6 of *Absidia*, 1 of *Gongronella*, 3 of *Helicostylum*, 4 of *Rhizopus*, 1 of *Syncephalastrum*, and 1 of *Chaetocladium*, for fat production was undertaken. These species fell into five broad categories on the basis of fat production. The fat content of eight species was above 40 percent; 18 species between 30—40 percent; 9 species between 20—30 percent; 41 species about 10—20 percent, and 19 species between 0—10 percent. Mucoraceous fungi were found to be good fat synthesizers in comparison to other groups of moulds.

Introduction

An adequate supply of fat is essential for all advanced countries of the world. It is, therefore, necessary that all possible sources of fat must be explored especially in countries where there is scarcity of fat from usual sources. Among the microorganisms that can produce sufficient fat are: algae, actinomycetes, bacteria, and moulds. Several surveys on fat producing fungi have been made in countries where there is normally no dearth of fat. Sometimes the work of this nature has been taken up, at such places, at the time of emergency, during World Wars, as in Germany.

Among 18 moulds, Kordes (1923) found fat in the spores or old hyphae of *Mucor circinelloides*, *M. mucedo*, *M. hiemalis*, *M. jansseni*; *Rhizopus nigricans*; *Absidia cylindrospora*; *Aspergillus glaucus*, *A. clavatus*; *Claviceps purpurea*; *Pleospora herbarum*; *Sclerotinia tuberosa* and *Daedalea quercina*, with the highest fat content (20 percent) in the last named fungus. Pruess, Eichinger and Peterson (1934) tested some species of *Aspergillus* and *Penicillium* and found highest percentage of fat (24.4 percent) in *Aspergillus flavipes*. Lockwood, Ward, May and Herrick (1935) tested species of moulds which included 39 species of *Penicillium* and 22 species of *Aspergillus* and found one species of *Aspergillus*, viz., *A. flavus*, producing 16.0 percent of fat and 9 species of *Penicillium* producing over 20 percent of fat. Fifty

strains of *Geotrichum candidum* were tested by Schnell (1912) and Fink, Haesler and Schmidt (1934), out of which 10 were found to be the most promising ones. Bernhauer, Niethammer and Rauch (1948) got much better yield of fat in four of their organisms: *Mucor circinelloides* (54.2 percent), *Fusarium bulbigenum* (45.6 percent), *Zygorhynchus moelleri* (39.9 percent), and *Endomyces vernalis* (31.1 percent). More recently, Woodbine, Gregory and Walker (1951) studied fat production of some strains of moulds, representing 10 genera on 5 different media and they found *Aspergillus nidulans*; *Penicillium spinulosum*, *P. javanicum*, *P. piscarium*, *P. flavo-cinearum*, *P. oxalicum*; *Aspergillus flavus* and *A. flavipes* to be promising.

In India, there is acute shortage of fats, hence a survey of micro-organisms for microbial fat is of great potential value. The present study was undertaken with this aim in view.

Materials and Methods

Ninety six species, belonging to 14 genera of moulds were obtained from the BSM Culture Collection, Botany Department, University of Allahabad, and are listed in Table I.

Cultures and inoculum — Species of the order Mucorales were grown on oat-meal agar slant (oat-meal, 20 g, boiled for 10 minutes in 700 ml. water, strained through porous cloth; agar agar 20 g; enough water to bring the volume to 1 litre) and the rest of the organisms were grown on Czapek's solution agar slant (KH_2PO_4, 1.0 g; $MgSO_4$. $7H_2O$, 0.5 g; $NaNO_3$, 3.0 g; KCl, 0.5 g; sucrose, 30 g; distilled water, 1000 ml. and pH, 6.5) and were incubated at 28° C for 10 days. A spore suspension for inoculation was prepared by adding 4 ml. of sterilized distilled water to each slant and shaking vigorously for 1 minute.

Preparation and Collection of fungal crop — The capacity of all organisms to produce fat was tested on two media. 1. (SMA): KH_2PO_4, 0.5 g; $MgSO_4$. $7H_2O$, 0.25 g; asparagine, 2.0 g; thiamin chloride, 0.5 mg; glucose, 25 g; distilled water, 1000 ml and pH, 6.5; 2: NH_4NO/, 3.0 g; KCl, 0.2 g; $MgSO_4$. $7H_2O$, 0,2 g; Na_2SO_4, 0.1 g; NaH_2PO_4, 0.2 g; $ZnSO_4$. $7H_2O$, 4.5 mg; $FeSO_4$. $7H_2O$, 5.0 mg; $CuSO_4$. $5H_2O$, 0.08 mg; sucrose 25 g; distilled water, 1000 ml; and pH, 6.5. The hydrogen-ion concentration of the nutrient solution was determined by using Merck's Reagenzien pH paper before autoclaving for 15 minutes at 15 lbs pressure. For the adjustment of pH values, $\frac{N}{10}$ NaOH solution was used. Purest available chemicals supplied by B. D. H. or Merck and glass wares, exclusively of Jena make, were used. Thirty ml. of the medium was poured in 150 ml. Erlenmeyer flasks. Flasks were inoculated with spore suspension and incubated at 25° C for 16 days. Thereafter, mycelial crops were collected on filter

papers. After 2—3 washings, they were subsequently dried in an incubator at 80° C for three consecutive days and cooled at room temperature in a desiccator. Then the felts were weighed and ground to fine powder. All cultures were set in triplicates.

Extraction and determination of fat — The homogenous mat of three flasks was transferred to Whatman ether extracted thimbles' and 'hot extracted' in Soxhlet apparatus (quickfit with ground joint) for 12 hours using petroleum ether (boiling point 60° C). The extracted fatty material was concentrated over a steam bath, dried at 103°—105° C for 75 minutes, cooled to toome temperature in a desiccator (charged with calcium chloride) and weighed.

Determination of sugar — Sugar was estimated according to the method of Somogyi (1945).

Fat coefficient — Rippel's (1940) following formula was used:

$$\text{Fat coefficient} = \frac{\text{mg sugar utilized} \times 100}{\text{mg fat formed}}$$

Economic coefficient — Foster's (1949) following formula was used:

$$\text{Economic coefficient} = \frac{\text{mg cell material formed} + \times 100}{\text{mg sugar utilized}}$$

Results and Discussion

The results are tabulated in Tables II, III and IV. The fat coefficient and economic coefficients of the 16 species of *Aspergillus* and *Penicillium*, 21 species of *Mucor* and 26 species other than Mucors of the order Mucorales which were found obviously good producers of fat are graphically represented in Figs. 1, 2 and 3 respectively.

On the basis of their capacity to synthesize fat (mg./100 mg dry felt), these species could be grouped into the following five groups:

Group I — Fat synthesis above 40 per cent.

8 species: *Mucor caninus*, 48,24%; *M. recurvus*, 46.25%; *M. peacockensis*, 42.72%; *Mucor circinelloides*, 42.48%; *Phycomyces blakesleeanus*, 41.48%; *Mucor oblongisporus*, 41.24%; *M. rouxii*, 40.25%; *M. subtilissimus*, 41.24%.

Group II — Fat synthesis, 30—40 percent.

19 species: *Rhizopus nigricans*, 38.25%; *R. oryzae*, 36.98%; *Mucor recurvus* var. *indica*, 36.26%; *Mortierella alpina*, 35.25%; *Mucor luteus*, 34.62%; *Mucor brunneus*, 34.60%; *M. lausannensis*, 34.24%; *Syncephalastrum racemosum*, 33.46%; *Mucor flavus*, 33.42%; *M. griseo ochraceus*, 33.40%; *M. albo-ater*, 33.62%; *Actinomucor elegans*, 30.78%; *Mortierella vesiculosa*, 30.25%; *Rhizopus arrhizus*, 30.25%; *Mucor hiemalis*, 30.25%; *M. mousanensis*, 30.25%; *Chaetocladium hesseltinii*, 30.25%; *Mucor indicus*, 30.20%; *Absidia lichtheimii*, 30.15%.

Group III — Fat synthesis, 20—30 percent.

9 species: *Penicillium oxalicum*, 26.25%; *P. variabile*, 23.25%; *Mucor ramannianus*, 21.24%; *Absidia repens*, 20.46%; *Rhizopus homothallicus*, 20.25%; *Mucor bacilliformis*, 20—25%; *M. silvaticus*, 20.24% *M. globosus*, 20.24%; *Penicillium notatum*, 20.12%.

Group IV — Fat synthesis, 10—20 percent.

41 species: *Mucor prayagensis*, 18.62%; *M. pertrinsularis*, 18.26%; *Aspergillus indicus*, 18.25%; *Absidia blakesleeana*, 18.25%; *Penicillium rugulosum*, 17.64%; *Mucor plumbeus*, 17.62%; *M. pusillus*, 16.24%; *Penicillium islandicum*, 16.20%; *Aspergillus allahabadii*, 16.0%; *Cunninghamella* species, 15.56%; *Mucor jansseni*, 14.68%; *Penicillium lanosum*, 14.58%; *Mucor lamprosporus*, 14.48%; *Cunninghamella bainieri*, 14.48%; *Helicostylum lucknowense*, 14.46%; *Aspergillus nidulans*, 14.24%; *Penicillium spinulosum*, 14.24%; *P. citreo-viridae*, 14.20%; *Mucor ramificus*, 13.76%; *M. aligarhensis*, 13.68%; *Penicillium frequentans*, 13.52%; *P. luteum*, 13.46%; *Mucor genevensis*, 13.42%; *Absidia coerulea*, 13.39%; *Penicillium chrysogenum*, 13.28%; *Mucor alternans*, 13.26%; *M. fragilis*, 12.40%; *Penicillium purpurogenum*, 13.25%; *Cunninghamella echinulata*, 13.25%; *Paecilomyces varioti*, 13.25%; *Aspergillus quercinus*, 1..25%; *Mucor racemosus*, 13.00%; *Circinella simplex*, 12.96%; *Absidia ramosa*, 12.85%; *Penicillium funiculosum*, 12.54%; *Mucor corticolus*, 12.45%; *Aspergillus ustus*, 12.24%; *Gongronella butleri*, 12.20%; *Mucor bainieri*, 11.20%; *Aspergillus flavus*, 10.25%.

Group V — Fat synthesis, 0—10.0%.

19 species: *Helicostylum cordense*, 9.82%; *Absidia heterospora*, 8.95%; *Helicostylum piriforme*, 8.75%; *Aspergillus niger*, 8.25%; *A. fischeri*, 8.20%; *A. flavipes*, 8.0%; *A. quadrilineatus*, 7.88%; *A. awamori*, 7.72%; *Absidia spinosa*, 7.75%; *Aspergillus oryzae*, 7.25%; *A. phoenicis*, 7.20%; *A. terreus*, 7.15%; *A. niveus*, 7.0%; *A. luchunensis*, 4.60%; *A. japonicus*, 4.65%; *A. fumigatus*, 4.20%; *A. versicolor*, 3.42%; *A. tamarii*, 3.25%; *A. carneus*, 3.20%.

It has been found that members of the order Mucorales in general are better synthesizers of fat than Aspergilli and Penicillia. The eight good species that yield more than 40 percent fat are all of the order Mucorales. Aspergilli and Penicillia grow faster and produce more of mycelial mat than the members of the order Mucorales but the accumulation of fat within the mycelium is less on dry weight basis than that of mucors. Similar have been the observations of earlier workers: Ward, Lockwood, May and Herrick (1935); Pruess, Eichinger and Peterson (1934); Kiabara (1948); Woodbine, Gregory and Walker (1951); and Murray, Woodbine and Walker (1953). Goupil (1914) has reported 60 percent of fat in the mycelium of *Mucor rouxianus*. Niethammer (1943 a, b) also found two species of *Zygorhynchus moelleri* (40 percent crude fat; F. C., 6.9) and *Absidia spinosa* (20 percent crude fat; F. C. 5.5) as good yielders

of fat. Blinc (1951) has also observed 51 percent of fat in *Mucor mucedo* and Bernhauer and Rauch (1948 a, b) even claim to have found a strain of *Mucor circinelloides* which could synthesize 65 percent fat with a fat coefficient of 13.6. *Phycomyces blackesleeanus* has also been found to be a good producer of fat (40 percent) by Bernhard and Albrecht (1948) while Garton, Goodwin, and Lijinsky (1950, 1951) have observed 44 percent of fat with the same organism.

Acknowledgements

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Aspergilli

1. *Aspergillus allahabadii* Meh. and Agni.
2. *A. awamori* Nakazawa
3. *A. flavipes* (Bain. et Sart.) Thom et Church
4. *A. flavus* Link
5. *A. fischeri* Wehmer
6. *A. fumigatus* Fresenius
7. *A. indicus* Meh. and Agni.
8. *A. japonicus* Saito
9. *A. luchunensis* Inui
10. *A. nidulans* Eidam
11. *A. niveus* Blochwitz
12. *A. niger* van Tieghem
13. *A. oryzae* (Ahlburg) Cohn
14. *A. phoenicis* (Corda) Thom
15. *A. quadrilineatus* Thom and Raper
16. *A. quercinus* (Bainier) Thom and Church
17. *A. sulphureus* (Fres.) Thom and Church
18. *A. terreus* Thom
19. *A. tamarii* Kita
20. *A. versicolor* (Vuillemin) Toraboschi
21. *A. ustus* (Bain.) Thom and Church

Penicillia

22. *Penicillium chrysogenum* Thom
23. *P. purpurogenum* Stoll
24. *P. spinulosum* Thom
25. *P. funiculosum* Thom
26. *P. variabile* Sopp
27. *P. notatum* Westling
28. *P. rugulosum* Thom
29. *P. oxalicum* Currey et Thom
30. *P. citrinum* Thom
31. *P. citreo-viridae* Biourge
32. *P. frequentans* Westling
33. *P. islandicum* Sopp
34. *P. lanosum* Westling
35. *P. luteum* Sopp

Paecilomyces

36. *Paecilomyces varioti* Bainier
37. *P. marquandii* (Massee) Hughes

Mucorales

Cunninghamella

38. *Cunninghamella bainieri* Naumov
39. *C. echinulata* Thaxter
40. *Cunninghamella* species

Actinomucor

41. *Actinomucor elegans* (Eidam) Benj. and Hesseltine

Mortierella

42. *Mortierella alpina* Peyronel
43. *Mortierella vesiculosa* Meh., Baijal and Meh.

Mucor

44. *Mucor lausannensis* Lend.
45. *M. fragilis* Bainier
46. *M. hiemalis* Wehmer

47. *M. corticolus* Hagem
48. *M. griseo-ochraceus* Naumov
49. *M. bainieri* Meh. and Baijal
50. *M. lamprosporus* Lendner
51. *M. alternans* v. Tiegh.
52. *M. racemosus* Fresenius
53. *M. luteus* Linnemann
54. *M. pusillus* Lindt
55. *M. recurvus* But. var. *indica* Baijal & Mehrotra
56. *M. indicus* Lendner
57. *M. genevensis* Lendner
58. *M. flavus* Bainier
59. *M. albo-ater* Naumov
60. *M. ramificus* Meh. and Nand
61. *M. ramannianus* Moller
62. *M. ramificus* Meh. and Nand
63. *M. oblongisporus* Naumov.
64. *M. mousanensis* Baijal and Mehrotra
65. *M. aligarhensis* Meh. and Meh.
66. *M. peacockensis* Meh. and Nand
67. *M. rouxii* Calmette
68. *M. silvaticus* Hagem
69. *M. petrinsularis* Naumov
70. *M. brunneus* Naumov
71. *M. plumbeus* Bonorden
72. *M. jansseni* Lendner
73. *M. globosus* Fischer
74. *M. subtilissimus* Oudemans
75. *M. bacilliformis* Hesseltine
76. *M. circinelloides* van Tiegh.
77. *M. recurvus* Butler
78. *M. caninus* Persoon

Helicostylum

79. *Helicostylum piriforme* Bain.
80. *H. cordense* Meh. and Meh.
81. *H. lucknowense* Rai, Tiwari, Mukerji

Rhizopus

82. *Rhizopus stolonifer* (Fries) Lind.
83. *R. oryzae* Went and Geerlings
84. *R. arrhizus* Fischer
85. *R. homothallicus* Hesseltine and Ellis

Syncephalastrum

86. *Syncephalastrum racemosum* (Cohn) Schroeter

Chaetocladium

87. *Chaetocladium hesseltinii* Meh. and Sarbhoy

Circinella

88. *Circinella simplex* van Tiegh.
89. *C. muscae* (Sorokine) Berl. et de Toni

Absidia

90. *Absidia coerulea* Bainier
91. *A. ramosa* Lendner
92. *A. repens* van Tiegh.
93. *A. heterospora* Ling-Young
94. *A. spinosa* Lendner
95. *A. lichtheimi* (Lucet et Cost.) -Lendner

Gongronella

96. *Gongronella butleri* (Lend.) Peyronel and Del-vesco

Table II. Accumulation of Fat in some Species of Fungi

Species	Synthetic Mucor culture medium (modified)					Pisano *et al.* (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coeffii cient	Fat coeffi-cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coeffi-cient	Fat coeffi-cient
1	2	3	3	5	6	7	8	9	10	10
Aspergillus niger	145.6	4.22	560.0	26.000	1.097	233.2	8.24	610.0	38.026	3.112
A. flavipes	140.0	2.12	580.0	24.138	5.116	198.8	8.00	600.0	33.133	2.650
A. nidulans	108.0	12.00	480.0	22.479	2.679	232.4	14.24	598.0	38.882	5.534
A. flavus	146.8	8.44	598.0	26.220	2.213	230.2	10.25	615.0	37.430	3.672
A. allahabadii	88.6	16.24	498.0	17.771	2.973	210.0	16.24	560.0	37.500	6.090
A. sulphureus	70.4	13.00	490.0	14.367	1.877	198.0	13.00	580.0	34.180	4.437
A. awamori	122.8	7.72	600.0	20.046	1.580	230.4	7.72	600.0	38.400	2.964
A. terreus	60.4	6.42	580.0	10.344/	0.668	210.0	7.42	610.0	34.426	2.554
A. oryzae	62.8	7.25	600.0	14.066	0.758	160.0	7.25	580.0	27.586	2.000
A. indicus	100.4	16.20	610.0	16.460	2.682	224.0	18.25	610.0	36.721	6.701
A. tamarii	88.8	3.00	610.0	14.557	4.367	112.0	3.42	590.0	18.983	0.649
A. carneus	60.0	3.00	580.0	10.034	3.131	110.0	3.00	580.0	18.965	0.569
A. niveus	40.6	7.00	560.0	7.250	0.507	100.0	7.00	560.0	17.857	1.250
A. phoenicis	88.6	6.00	600.0	14.766	0.886	198.0	7.26	540.0	36.666	2.661
A. quadrilineatus	88.0	6.82	600.0	14.662	1.002	110.0	7.88	540.0	20.370	1.789
A. fumigatus	90.0	4.00	618.0	14.563	0.582	154.8	4.26	540.0	25.518	1.226
A. japonicus	62.0	4.00	540.0	11.480	0.450	140.2	4.25	500.0	28.040	1.191
A. quercinus	35.4	12.20	500.0	7.000	0.863	126.0	13.22	500.0	25.200	3.330
A. fischeri	28.8	8.00	480.0	6.000	0.384	114.0	8.20	480.0	23.750	1.947
Penicillium luteum	52.4	13.00	560.0	11.142	1.448	140.2	13.25	550.0	25.490	3.377
P. chrysogenum	72.0	5.00	600.0	12.000	0.600	135.8	5.60	480.0	28.290	1.584
P. purpurogenum	40.6	6.25	500.0	8.120	0.507	101.8	8.75	426.0	23.986	2.090

Species	Synthetic Mucor culture medium (modified)					Pisano *et al.* (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coefficient	Fat coefficient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coefficient	Fat coefficient
1	2	3	4	5	6	7	8	9	10	11
P. spinulosum	68.4	8.40	610.0	11.213	0.941	141.2	10.12	400.0	35.300	3.572
P. funiculosum	58.4	11.00	600.0	9.733	1.706	140.8	12.54	408.0	34.509	4.328
P. variabile	60.0	12.00	580.0	10.344	1.241	108.0	22.00	360.0	33.000	6.600
P. notatum	78.0	12.00	600.0	13.000	1.560	135.8	13.25	500.0	28.529	4.498
P. rugulosum	80.6	4.26	600.0	13.433	0.572	140.2	8.75	430.0	32.604	2.852
P. oxalicum	78.6	14.20	600.0	13.100	1.860	128.0	26.25	400.0	32.000	8.400
P. citrinum	80.0	12.00	610.0	13.246	1.589	110.0	12.65	410.0	26.829	3.393
P. citreo-viridae	70.0	12.24	600.0	10.666	1.428	84.0	14.20	400.0	21.000	2.982
P. frequentans	80.0	10.24	610.0	13.246	1.356	120.8	13.52	446.0	27.085	3.661
P. islandicum	98.0	14.20	615.0	15.934	2.262	132.4	16.20	440.0	25.050	3.652
P. lanosum	60.4	12.24	580.0	10.413	1.274	100.2	14.58	400.0	25.050	3.652
Paecilomyces varioti	50.2	10.00	500.0	10.400	0.502	82.4	13.82	380.0	21.736	2.961
P. marquandii	40.8	10.00	500.0	8.160	0.800	80.0	12.82	398.0	20.301	2.603

Table III. Accumulation of Fat in some Species of Fungi

Species	Synthetic Mucor culture medium (modified)					Pisano *et al.* (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coeffii cient	Fat coeffi-cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coeffi-cient	Fat coeffi-cient
1	2	3	3	5	6	7	8	9	10	10
Mucor lausannensis	88.4	34.24	540.0	16.370	5.605	14.8	30.42	110.2	13.454	4.092
M. oblongisporus	94.8	41.24	502.0	18.888	7.787	18.6	28.62	200.0	9.300	2.661
M. recurvus	92.6	46.25	500.0	18.520	8.565	14.0	21.42	180.0	7.777	1.665
M. indicus	72.6	30.20	512.0	14.179	4.282	10.0	18.24	140.0	7.143	1.302
M. circinelloides	98.2	42.86	510.0	19.254	8.252	18.0	28.29	201.0	8.950	2.533
M. bacilliformis	36.2	30.25	420.0	8.619	1.745	8.4	13.68	100.0	8.400	1.148
M. subtilissimus	82.4	40.24	590.0	13.966	5.619	10.2	24.42	140.0	7.285	1.778
M. globosus	54.4	20.24	530.0	10.264	2.077	12.4	10.82	150.0	8.266	0.894
M. janssenii	68.4	14.68	540.0	12.703	1.864	8.4	10.40	140.0	6.000	0.624
M. brunneus	94.6	34.60	520.0	18.192	6.294	10.2	13.42	180.0	5.999	0.760
M. pusillus	32.4	15.24	426.0	7.605	1.235	15.2	11.46	220.0	6.909	0.791
M. luteus	94.6	34.60	522.0	18.122	3.049	20.4	24.32	225.0	9.066	1.204
M. caninus	87.6	48.24	618.0	14.174	6.837	12.8	24.80	200.0	6.040	1.587
M. racemosus	82.4	13.00	500.0	16.58	2.142	16.2	8.00	140.0	6.750	0.540
M. alternans	62.8	13.26	410.0	20.310	2.031	10.8	12.42	200.0	5.400	0.670
M. lamprosporus	78.2	14.48	426.0	18.356	2.657	14.8	7.62	250.0	5.920	0.451
M. bainieri	32.2	11.20	312.0	16.474	1.068	15.4	8.45	260.0	5.923	0.501
M. griseo-ochraceus	99.8	33.40	600.0	16.633	1.068	20.8	20.80	300.0	6.903	1.442
M. corticolus	51.6	12.45	424.0	12.167	1.515	16.4	10.46	280.0	5.354	0.612
M. hiemalis	42.4	24.65	500.0	8.480	2.070	10.2	20.00	200.0	5.100	1.020
M. fragilis	62.8	13.25	525.0	11.961	1.524	8.6	12.00	150.0	5.733	0.688
M. recurvus var. *indica*	84.8	36.26	536.0	15.820	5.773	12.8	22.80	150.0	8.533	1.944

Species	Synthetic Mucor culture medium (modified)					Pisano *et al.* (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coefficient	Fat coefficient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coefficient	Fat coefficient
1	2	3	4	5	6	7	8	9	10	11
Mucor rouxii	62.84	41.24	520.0	12.076	4.980	13.20	18.24	150.0	8.133	1.483
M. silvaticus	62.2	20.24	462.0	13.463	2.724	10.8	12.90	156.0	6.923	0.836
M. petrinsularis	42.6	18.46	562.0	7.580	1.399	8.4	10.24	120.0	7.000	0.771
M. genevensis	48.8	13.42	400.0	10.700	1.435	10.2	8.20	150.0	6.800	0.557
M. flavus	51.2	33.42	510.0	10.039	3.555	11.2	11.25	160.0	7.000	0.552
M. albo-ater	92.4	32.82	540.0	17.037	5.616	8.2	27.00	150.0	5.466	1.469
M. ramannianus	21.2	21.42	362.0	5.828	1.254	13.2	30.24	180.0	7.333	2.717
M. aligarhensis	82.4	13.68	498.0	16.546	2.273	7.6	13.00	100.0	7.600	0.988
M. peacockensis	123.4	42.72	510.0	24.196	10.336	8.2	30.00	150.0	4.466	1.640
M. ramificus	84.4	13.76	490.0	17.224	2.370	7.6	8.42	100.0	7.600	0.639
M. prayagensis	86.2	18.62	610.0	14.131	2.631	4.2	7.62	120.0	3.500	0.266
M. plumbeus	92.4	17.62	600.0	15.400	2.713	8.7	10.60	150.0	5.800	0.515
M. mousanensis	82.4	30.25	492.0	16.749	5.069	10.4	18.42	140.0	7.428	1.368

Table IV. Accumulation of Fat in some Species of Fungi

Species	Synthetic Mucor culture medium (modified)					Pisano *et al.* (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coeffii cient	Fat coeffi-cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Economic coeffi-cient	Fat coeffi-cient
1	2	3	3	5	6	7	8	9	10	10
Absidia coerulea	62.4	13.39	520.0	12.000	1.668	10.2	13.00	112.0	9.108	1.179
A. ramosa	76.2	12.85	586.0	13.003	1.670	18.2	8.24	290.0	6.275	0.517
A. repens	62.8	20.46	500.0	12.560	2.569	10.2	10.64	300.0	3.617	0.381
A. heterospora	46.2	8.95	498.0	17.792	0.830	8.2	4.62	115.0	7.043	0.329
A. spinosa	62.4	7.65	480.0	13.812	0.994	10.2	4.00	130.0	7.846	0.313
A. blakesleeana	46.2	18.25	420.0	11.000	2.075	20.6	12.62	320.0	6.437	0.812
A. lichtheimi	80.4	30.15	490.0	16.408	4.947	22.0	10.62	330.0	6.566	0.708
Gongronella butleri	82.4	12.20	470.0	17.531	2.138	8.2	4.52	220.0	3.727	0.172
Rhizopus stolinifer	82.6	38.25	540.0	15.296	5.850	20.8	12.40	360.0	5.694	0.716
R. oryzae	68.6	36.98	540.0	12.703	4.697	18.6	20.20	355.0	5.239	1.058
R. arrhizus	82.6	30.25	490.0	16.857	5.098	12.4	18.24	263.0	4.626	0.843
R. homothallicus	60.6	20.25	510.0	11.882	2.406	14.6	12.60	200.0	7.300	0.919
Helicostylum cordense	28.6	9.82	414.0	6.908	0.678	7.6	4.62	100.0	7.000	0.351
H. lucknowense	62.6	14.46	300.0	20.866	3.017	6.2	8.20	120.0	5.166	0.423
H. piriforme	42.8	8.75	345.0	12.405	1.085	8.2	4.00	100.0	8.200	0.328
Mortierella alpina	38.2	35.25	448.0	8.256	2.057	0.0	0.00	0.0	0.000	0.000
M. vesiculosa	42.6	30.25	464.0	9.180	2.777	0.0	0.00	0.0	0.000	0.000
Actinomucor elegans	62.6	30.78	525.0	11.923	3.670	6.8	15.40	210.0	3.238	0.479
Phycomyces blakesleeanus	99.4	41.48	525.0	18.933	7.767	10.4	30.20	330.0	3.141	0.951
Chaetocladium hesseltinii	66.4	30.25	520.0	12.764	3.718	12.8	20.00	220.0	5.818	1.163
Syncephalastrum racemosum	46.4	33.46	598.0	7.767	2.613	8.6	12.60	200.0	4.300	0.541
Cunninghamella bainieri	52.4	14.46	510.0	9.732	1.485	8.6	8.60	120.0	7.166	0.616
C. echinulata	48.2	13.25	498.0	9.707	1.282	12.6	10.20	200.0	6.300	0.642
Cunninghamella species	32.4	15.56	440.0	7.363	1.145	24.6	12.40	280.0	8.785	0.420
Circinella muscae	21.2	10.78	440.0	4.818	0.519	8.2	8.20	160.0	5.125	0.420
C. simplex	16.2	12.96	450.0	3.600	0.466	8.0	10.00	100.0	8.000	0.800

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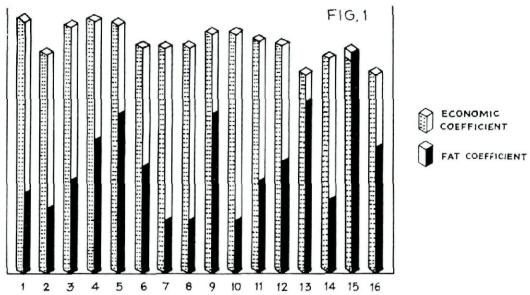
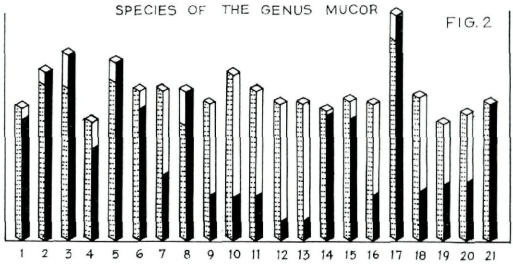
SPECIES OF THE GENUS ASPERGILLUS

FIG. 1



SPECIES OF THE GENUS MUCOR

FIG. 2



OTHER SPECIES OF THE ORDER MUCORALES

FIG. 3

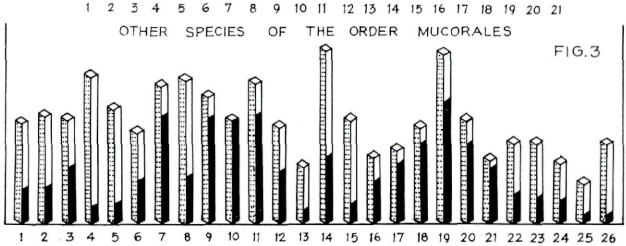


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Plate V. Mould Species examined for Fat Synthesis

Fat production by some species of *Aspergillus, Penicillium, Paecilomyces* and order Mucorales.

Fig. **1**. Analytical comparison of 16 species of *Aspergillus* and *Penicillium* in terms of economic and fat coefficients. 1 = *Aspergillus niger*, 2 = *A. flavipes*, 3 = *A. flavus*, 4 = *A. nidulans*, 5 = *A. allahabadii*, 6 = *A. sulphureus*, 7 = *A. awamori*, 8 = *A. terreus*, 9 = *A. indicus*, 10 = *A. phoenicis*, 11 = *Penicillium spinulosum*, 12 = *P. funiculosum*, 13 = *P. variabile*, 14 = *P. rugulosum*, 15 = *P. oxalicum*, 16 = *P. islandicum*.

Fig. **2**. Analytical comparison of 21 species of *Mucor* in terms of economic and fat coefficients. 1 = *Mucor lausannensis*, 2 = *M. oblongisporus*, 3 = *M. recurvus*, 4 = *M. indicus*, 5 = *M. circinelloides*, 6 = *M. brunneus*, 7 = *M. luteus*, 8 = *M. caninus*, 9 = *M. racemosus*, 10 = *M. alternans*, 11 = *M. lamprosporus*, 12 = *M. bainieri*, 13 = *M. griseo-ochraceus* var. *indica*, 14 = *M. recurvus* var. *indica*, 15 = *M. albo-ater*, 16 = *M. aligarhensis*, 17 = *M. peacockensis*, 18 = *M. ramificus*, 19 = *M. prayagensis*, 20 = *M. plumbeus*, 21 = *M. mousanensis*.

Fig. **3**. Analytical comparison of 26 species of Order Mucorales in terms of economic and fat coefficients. 1 = *Absidia coerulea*, 2 = *A. ramosa*, 3 = *A. repens*, 4 = *A. heterospora*, 5 = *A. spinosa*, 6 = *A. blakesleeana*, 7 = *A. lichtheimi*, 8 = *Gongronella butleri*, 9 = *Rhizopus stolonifer*, 10 = *R. oryzae*, 11 = *R. arrhizus*, 12 = *R. homothallicus*, 13 = *Helicostylum cordense*, 14 = *H. lucknowense*, 15 = *H. piriforme*, 16 = *Mortierella alpina*, 17 = *M. vesiculosa*, 18 = *Actinomucor elegans*, 19 = *Phycomyces blakesleeanus*, 20 = *Chaetocladium hesseltinii*, 21 = *Syncephalastrum racemosum*, 22 = *Cunninghamella bainieri*, 23 = *C. echinulata*, 24 = *Cunninghamella species*, 25 = *Circinella simplex*, 26 = *C. muscae*.