

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; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 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; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 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 , 3.0 g; KCl, 0.2 g; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.2 g; Na_2SO_4 , 0.1 g; NaH_2PO_4 , 0.2 g; $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 4.5 mg; $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 5.0 mg; $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, 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 room 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:

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

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 blakesleeanae*, 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%; *Pacilomyces 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. tamaris*, 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 Herriek (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 blackesleeuanus* 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* (Masse) 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. rouzii* Calmette
 68. *M. silvaticus* Hagem
 69. *M. petriularis* Naumov
 70. *M. brunneus* Naumov
 71. *M. plumbeus* Bonorden
 72. *M. jansseni* Lendner
 73. *M. globosus* Fischer
 74. *M. subtilissimus* Oudemans
 75. *M. bacilliformis* Hesselstine
 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* Hesselstine and Ellis
- Syncephalastrum*
86. *Syncephalastrum racemosum* (Cohn) Schroeter
- Chaetocladium*
87. *Chaetocladium hesselstini* 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 <i>et al.</i> (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient
1	2	3	3	5	6	7	8	9	10	10
<i>Aspergillus niger</i>	145.6	4.22	560.0	26.000	1.097	233.2	8.24	610.0	38.026	3.112
<i>A. flavipes</i>	140.0	2.12	580.0	24.138	5.116	198.8	8.00	600.0	33.133	2.650
<i>A. nidulans</i>	108.0	12.00	480.0	22.479	2.679	232.4	14.24	598.0	38.882	5.534
<i>A. flavus</i>	146.8	8.44	598.0	26.220	2.213	230.2	10.25	615.0	37.430	3.672
<i>A. allahabadii</i>	88.6	16.24	498.0	17.771	2.973	210.0	16.24	560.0	37.500	6.090
<i>A. sulphureus</i>	70.4	13.00	490.0	14.367	1.877	198.0	13.00	580.0	34.180	4.437
<i>A. awamori</i>	122.8	7.72	600.0	20.046	1.580	230.4	7.72	600.0	38.400	2.964
<i>A. terreus</i>	60.4	6.42	580.0	10.344/	0.668	210.0	7.42	610.0	34.426	2.554
<i>A. oryzae</i>	62.8	7.25	600.0	14.066	0.758	160.0	7.25	580.0	27.586	2.000
<i>A. indicus</i>	100.4	16.20	610.0	16.460	2.682	224.0	18.25	610.0	36.721	6.701
<i>A. tamarii</i>	88.8	3.00	610.0	14.557	4.367	112.0	3.42	590.0	18.983	0.649
<i>A. carneus</i>	60.0	3.00	580.0	10.034	3.131	110.0	3.00	580.0	18.965	0.569
<i>A. niveus</i>	40.6	7.00	560.0	7.250	0.507	100.0	7.00	560.0	17.857	1.250
<i>A. phoenicis</i>	88.6	6.00	600.0	14.766	0.886	198.0	7.26	540.0	36.666	2.661
<i>A. quadrilineatus</i>	88.0	6.82	600.0	14.662	1.002	110.0	7.88	540.0	20.370	1.789
<i>A. fumigatus</i>	90.0	4.00	618.0	14.563	0.582	154.8	4.26	540.0	25.518	1.226
<i>A. japonicus</i>	62.0	4.00	540.0	11.480	0.450	140.2	4.25	500.0	28.040	1.191
<i>A. quercinus</i>	35.4	12.20	500.0	7.000	0.863	126.0	13.22	500.0	25.200	3.330
<i>A. fischeri</i>	28.8	8.00	480.0	6.000	0.384	114.0	8.20	480.0	23.750	1.947
<i>Penicillium luteum</i>	52.4	13.00	560.0	11.142	1.448	140.2	13.25	550.0	25.490	3.377
<i>P. chrysogenum</i>	72.0	5.00	600.0	12.000	0.600	135.8	5.60	480.0	28.290	1.584
<i>P. purpurogenum</i>	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 <i>et al.</i> (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient
I	2	3	4	5	6	7	8	9	10	11
<i>P. spinulosum</i>	68.4	8.40	610.0	11.213	0.941	141.2	10.12	400.0	35.300	3.572
<i>P. funiculosum</i>	58.4	11.00	600.0	9.733	1.706	140.8	12.54	408.0	34.509	4.328
<i>P. variabile</i>	60.0	12.00	580.0	10.344	1.241	108.0	22.00	360.0	33.000	6.600
<i>P. notatum</i>	78.0	12.00	600.0	13.000	1.560	135.8	13.25	500.0	28.529	4.498
<i>P. rugulosum</i>	80.6	4.26	600.0	13.433	0.572	140.2	8.75	430.0	32.604	2.852
<i>P. oxalicum</i>	78.6	14.20	600.0	13.100	1.860	128.0	26.25	400.0	32.000	8.400
<i>P. citrinum</i>	80.0	12.00	610.0	13.246	1.589	110.0	12.65	410.0	26.829	3.393
<i>P. citreo-viridae</i>	70.0	12.24	600.0	10.666	1.428	84.0	14.20	400.0	21.000	2.982
<i>P. frequentans</i>	80.0	10.24	610.0	13.246	1.356	120.8	13.52	446.0	27.085	3.661
<i>P. islandicum</i>	98.0	14.20	615.0	15.934	2.262	132.4	16.20	440.0	25.050	3.652
<i>P. lanosum</i>	60.4	12.24	580.0	10.413	1.274	100.2	14.58	400.0	25.050	3.652
<i>Paecilomyces varioti</i>	50.2	10.00	500.0	10.400	0.502	82.4	13.82	380.0	21.736	2.961
<i>P. marquandii</i>	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 <i>et al.</i> (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient
1	2	3	3	5	6	7	8	9	10	10
<i>Mucor lausannensis</i>	88.4	34.24	540.0	16.370	5.605	14.8	30.42	110.2	13.454	4.092
<i>M. oblongisporus</i>	94.8	41.24	502.0	18.888	7.787	18.6	28.62	200.0	9.300	2.661
<i>M. recurvus</i>	92.6	46.25	500.0	18.520	8.565	14.0	21.42	180.0	7.777	1.665
<i>M. indicus</i>	72.6	30.20	512.0	14.179	4.282	10.0	18.24	140.0	7.143	1.302
<i>M. circinelloides</i>	98.2	42.86	510.0	19.254	8.252	18.0	28.29	201.0	8.950	2.533
<i>M. bacilliformis</i>	36.2	30.25	420.0	8.619	1.745	8.4	13.68	100.0	8.400	1.148
<i>M. subtilissimus</i>	82.4	40.24	590.0	13.966	5.619	10.2	24.42	140.0	7.285	1.778
<i>M. globosus</i>	54.4	20.24	530.0	10.264	2.077	12.4	10.82	150.0	8.266	0.894
<i>M. jansseni</i>	68.4	14.68	540.0	12.703	1.864	8.4	10.40	140.0	6.000	0.624
<i>M. brunneus</i>	94.6	34.60	520.0	18.192	6.294	10.2	13.42	180.0	5.999	0.760
<i>M. pusillus</i>	32.4	15.24	426.0	7.605	1.235	15.2	11.46	220.0	6.909	0.791
<i>M. luteus</i>	94.6	34.60	522.0	18.122	3.049	20.4	24.32	225.0	9.066	1.204
<i>M. caninus</i>	87.6	48.24	618.0	14.174	6.837	12.8	24.80	200.0	6.040	1.587
<i>M. racemosus</i>	82.4	13.00	500.0	16.58	2.142	16.2	8.00	140.0	6.750	0.540
<i>M. alternans</i>	62.8	13.26	410.0	20.310	2.031	10.8	12.42	200.0	5.400	0.670
<i>M. lamprosporus</i>	78.2	14.48	426.0	18.356	2.657	14.8	7.62	250.0	5.920	0.451
<i>M. bainieri</i>	32.2	11.20	312.0	16.474	1.068	15.4	8.45	260.0	5.923	0.501
<i>M. griseo-ochraceus</i>	99.8	33.40	600.0	16.633	1.068	20.8	20.80	300.0	6.903	1.442
<i>M. corticolus</i>	51.6	12.45	424.0	12.167	1.515	16.4	10.46	280.0	5.354	0.612
<i>M. hiemalis</i>	42.4	24.65	500.0	8.480	2.070	10.2	20.00	200.0	5.100	1.020
<i>M. fragilis</i>	62.8	13.25	525.0	11.961	1.524	8.6	12.00	150.0	5.733	0.688
<i>M. recurvus</i> var. <i>indica</i>	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 <i>et al.</i> (1964) medium (modified)					
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient	
	1	2	3	4	5	6	7	8	9	10	11
<i>Mucor rouxii</i>	62.84	41.24	520.0	12.076	4.980	13.20	18.24	150.0	8.133	1.483	
<i>M. silvaticus</i>	62.2	20.24	462.0	13.463	2.724	10.8	12.90	156.0	6.923	0.836	
<i>M. petrinsularis</i>	42.6	18.46	562.0	7.580	1.399	8.4	10.24	120.0	7.000	0.771	
<i>M. genevensis</i>	48.8	13.42	400.0	10.700	1.435	10.2	8.20	150.0	6.800	0.557	
<i>M. flavus</i>	51.2	33.42	510.0	10.039	3.555	11.2	11.25	160.0	7.000	0.552	
<i>M. albo-ater</i>	92.4	32.82	540.0	17.037	5.616	8.2	27.00	150.0	5.466	1.469	
<i>M. ramannianus</i>	21.2	21.42	362.0	5.828	1.254	13.2	30.24	180.0	7.333	2.717	
<i>M. aligarhensis</i>	82.4	13.68	498.0	16.546	2.273	7.6	13.00	100.0	7.600	0.988	
<i>M. peacockensis</i>	123.4	42.72	510.0	24.196	10.336	8.2	30.00	150.0	4.466	1.640	
<i>M. ramificus</i>	84.4	13.76	490.0	17.224	2.370	7.6	8.42	100.0	7.600	0.639	
<i>M. prayagensis</i>	86.2	18.62	610.0	14.131	2.631	4.2	7.62	120.0	3.500	0.266	
<i>M. plumbeus</i>	92.4	17.62	600.0	15.400	2.713	8.7	10.60	150.0	5.800	0.515	
<i>M. mousanensis</i>	82.4	30.25	492.0	16.749	5.069	10.4	18.42	140.0	7.428	1.368	

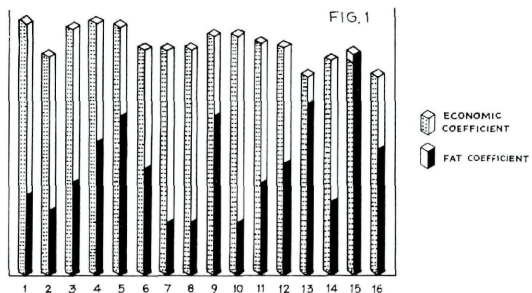
Table IV. Accumulation of Fat in some Species of Fungi

Species	Synthetic Mucor culture medium (modified)					Pisano <i>et al.</i> (1964) medium (modified)				
	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient	Dry wt of felt (mg./ per flask)	Fat (mg./ 100 mg. dry felt)	Sugar used (mg./ per flask)	Econo- mic coeffi- cient	Fat coeffi- cient
1	2	3	3	5	6	7	8	9	10	10
<i>Absidia coerulea</i>	62.4	13.39	520.0	12.000	1.668	10.2	13.00	112.0	9.108	1.179
<i>A. ramosa</i>	76.2	12.85	586.0	13.003	1.670	18.2	8.24	290.0	6.275	0.571
<i>A. repens</i>	62.8	20.46	500.0	12.560	2.569	10.2	10.64	300.0	3.617	0.381
<i>A. heterospora</i>	46.2	8.95	498.0	17.792	0.830	8.2	4.62	115.0	7.043	0.329
<i>A. spinosa</i>	62.4	7.65	480.0	13.812	0.994	10.2	4.00	130.0	7.846	0.313
<i>A. blakesleeana</i>	46.2	18.25	420.0	11.000	2.075	20.6	12.62	320.0	6.437	0.812
<i>A. lichtheimi</i>	80.4	30.15	490.0	16.408	4.947	22.0	10.62	330.0	6.566	0.708
<i>Gongronella butleri</i>	82.4	12.20	470.0	17.531	2.138	8.2	4.52	220.0	3.727	0.172
<i>Rhizopus stolonifer</i>	82.6	38.25	540.0	15.296	5.850	20.8	12.40	360.0	5.694	0.716
<i>R. oryzae</i>	68.6	36.98	540.0	12.703	4.697	18.6	20.20	355.0	5.239	1.058
<i>R. arrhizus</i>	82.6	30.25	490.0	16.857	5.098	12.4	18.24	263.0	4.626	0.843
<i>R. homothallicus</i>	60.6	20.25	510.0	11.882	2.406	14.6	12.60	200.0	7.300	0.919
<i>Helicostylum cordense</i>	28.6	9.82	414.0	6.908	0.678	7.6	4.62	100.0	7.000	0.351
<i>H. lucknowense</i>	62.6	14.46	300.0	20.866	3.017	6.2	8.20	120.0	5.166	0.423
<i>H. piriforme</i>	42.8	8.75	345.0	12.405	1.085	8.2	4.00	100.0	8.200	0.328
<i>Mortierella alpina</i>	38.2	35.25	448.0	8.256	2.057	0.0	0.00	0.0	0.000	0.000
<i>M. vesiculosa</i>	42.6	30.25	464.0	9.180	2.777	0.0	0.00	0.0	0.000	0.000
<i>Actinomucor elegans</i>	62.6	30.78	525.0	11.923	3.670	6.8	15.40	210.0	3.238	0.479
<i>Phycomyces blakesleeanus</i>	99.4	41.48	525.0	18.933	7.767	10.4	30.20	330.0	3.141	0.951
<i>Chaetocladium hesseltinii</i>	66.4	30.25	520.0	12.764	3.718	12.8	20.00	220.0	5.818	1.163
<i>Syncephalastrum racemosum</i>	46.4	33.46	598.0	7.767	2.613	8.6	12.60	200.0	4.300	0.541
<i>Cunninghamella bainieri</i>	52.4	14.46	510.0	9.732	1.485	8.6	8.60	120.0	7.166	0.616
<i>C. echinulata</i>	48.2	13.25	498.0	9.707	1.282	12.6	10.20	200.0	6.300	0.642
<i>Cunninghamella species</i>	32.4	15.56	440.0	7.363	1.145	24.6	12.40	280.0	8.785	0.420
<i>Circinella muscae</i>	21.2	10.78	440.0	4.818	0.519	8.2	8.20	160.0	5.125	0.420
<i>C. simplex</i>	16.2	12.96	450.0	3.600	0.466	8.0	10.00	100.0	8.000	0.800

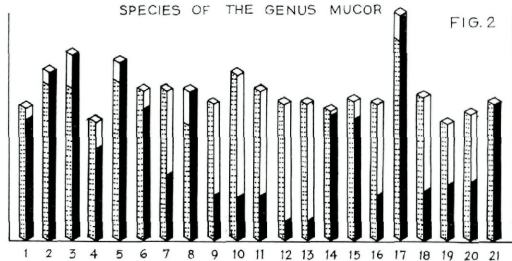
References

- Bernhard, K. and H. Albrecht: Die lipide von *Phycomyces blakesleeanus*. Helvet. Chim. Acta, 31: 377—988 (1948).
- Bernhauer, K., A. Niethammer and J. Rauch: Beiträge zur mikrobiologischen Eiweiss- und Fettsynthese. II. Mitt. vergleichende Untersuchungen über die Eiweiss- und Fettbildung durch verschiedene Mycelpilze in der Submerskultur. Biochem. Z., 319: 94—101 (1948).
- Bernhauer, K. and J. Rauch: Beiträge zur mikrobiologischen Eiweiss- und Fettsynthese I. Mitt. Die grundlegenden Bedingungen für die Eiweiss- und Fettproduktion durch Mycelpilze in der Submerskultur. Biochem. Z., 391: 77—93 (1948a).
- Bernhauer, K. and J. Rauch: Beiträge zur mikrobiologischen Eiweiss- und Fettsynthese III. Mitt. Zur Methodik der Submersen Mycelzucht in der, Ruhrkultur und deren Anwendung zur Erzeugung von Fettmycel. Biochem. Z., 319: 102—119 (1948b).
- Fink, H., G. Haeseler and M. Schmidt: Zur Frage der Fettgewinnung mit Hilfe von Mikroorganismen, Über das Fettbildungsvermögen verschiedener Stämme von *Oidium lactis* (*Oospora lactis*). Z. Spiritus-industr., 60: 74—77 (1937).
- Foster, J. W.: Chemical Activities of Fungi. New York. Academic Press, pp. 648 (1949).
- Garton, G. A., Goodwin, T., and Lijinsky, W.: The biogenesis of B-carotene in the fungus *Phycomyces blakesleeanus*. Biochem. J. 46, XXXV, (1950).
- Garton, G. A., Goodwin, T., and Lijinsky, W.: Studies in cartogenesis I. General conditions governing B-carotene synthesis by the fungus *Phycomyces blakesleeanus*. Biochem. J. 48: 154 (1951).
- Goupil, R.: Recherches sur les matières grasses, formées par l'*Amylomomyces rouxi*, C. r. Acad.-Sci. Paris, 158, 522—525 (1914).
- Kiabara, T. T.: Die Fettproduktion von Schimmelpilzen J. agricul. Ch. Soc. Japan. 22: 89 (1948).
- Kordes, H.: Biologische Untersuchungen über das in Dauerzellen und Hyphen verschiedener Pilze auftretende Fett. Bot. Arch., 3: 282—311 (1923).
- Lockwood, L. B., Ward, G. E., May, O. E., Herrick, H. T., and O'Neill, H. T.: The production of fat by *Penicillium javanicum* van Beijma. Zentbl. j. Bakt. etc. (II) 90: 411—425 (1934).
- Murray, S., M. Woodbine, and Walker, T. K.: Microbiological synthesis of fat. The formation of fat from sucrose. J. exptl. Bot. 4: 251—266.
- Niethammer, A.: Hefen, sowie mikroskopische Pilze aus Blüten, ferner von Samen und Früchten. Arch. Mikrobiol. 13: 42—59 (1942a).
- Ernährungsphysiologische Untersuchungen Fusarien, unter Hervorhebung der Ölspeicherung. Arch. Mikrobiol. 13: 140—149 (1942b).
- Pruess, L. M., E. C. Eichinger, and W. H. Peterson: The chemistry of mold tissue. III. Composition of certain moulds with special reference to the lipid content. Centr. Bakt. Parasitenk., Abt. II. 89: 370—377 (1934).
- Rippel, A.: Energetische Betrachtungen zur Ökonomie der Fettbildung bei Mikroorganismen. Arch. Mikrobiol., 11: 271 (1940).
- Schnell, E.: Zbl. Bakt (Abt. 2), 35: 1 (1912).
- Somogyi, M.: A new reagent for the determination of sugars. Jour. biol. Chem., 169: 61 (1945).
- Ward, G. E., L. B. Lockwood, O. E. May and H. T. Herrick: Production of fat from glucose by moulds. Cultivation of *Penicillium javanicum* van Beijma in large-scale laboratory apparatus. Ind. Eng. Chem., 27: 318 (1935).

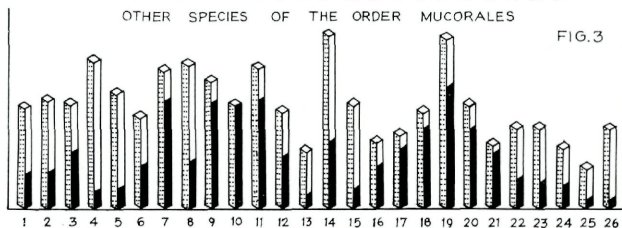
SPECIES OF THE GENUS ASPERGILLUS



SPECIES OF THE GENUS MUCOR



OTHER SPECIES OF THE ORDER MUCORALES



Woodbine, M., Gregory, M. E., and Walker, T. K.: Microbiological synthesis of fats. Preliminary survey of fat producing moulds. *J. expt. Bot.*, 2: 204 (1951).

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*.

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