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Molds and Meats

L. Leistner and J. C. Ayres

Institut für Bakteriologie und Histologie der Bundesanstalt für Fleischforschung, Kulmbach, Bundesrepublik Deutschland
and
Food Processing Laboratory, Iowa State University, Ames, U.S.A.

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L. Leistner* and J. C. Ayres**

This report is focusing on molds in relation to cured meats, in particular "fermented" sausages and "country cured" hams. Our investigation was supported by contract 12-14-100-6886(73) from the U.S. Department of Agriculture, and most of the experimental work has been carried out in the Food Processing Laboratory, at Iowa State University in Ames, U.S.A.

Initially, the only objective was to study the beneficial influence molds might have on the flavor, appearance, and preservation of cured meats; with the ambition in mind to select cultures for the use as starters in the processing of sausages and hams. These starters should improve the products, and lead to better controlled and streamlined processes. This in turn could foster the utilization of pork in the U.S.

However, in the light of the recent discovery or rediscovery that some molds produce most powerful toxins, the objective of the study had to be broadened. The questions were included whether potentially toxinogenic mold species are commonly associated with meats, and whether toxin production occurs if cured meats are the substrate for these molds. Furthermore, the occurrence of pathogenic molds on cured meats was given some attention, since these organisms could be hazardous for the producer as well as the consumer of meats.

Materials and Methods

As Table 1 indicates, 67 samples of cured and aged meats - representing 32 different brands - have been investigated. Most of these samples were high-quality, gourmand-type products for which fungi are believed to be desirable. Forty "country cured" hams were obtained from 5 different states of the U.S. So-called "country cured" hams are unskinned, unboned, dry-cured hams, with a curing and ripening time of 6 to 12 months. On the surface of "country cured" hams heavy mold

* Institut für Bakteriologie und Histologie der Bundesanstalt für Fleischforschung, Kulmbach, Bundesrepublik Deutschland

** Food Processing Laboratory, Iowa State University, Ames, Iowa, U.S.A.

growth often occurs and is sometimes regarded as an indication of good quality. The 27 "fermented" sausages examined originated from the U.S. and Europe. Plentiful mold growth was present on the casings of many of these products.

From the 67 samples investigated 307 mold strains were isolated. The surface, as well as the interior of all samples was plated. Depending on the size of the samples, 3 - 10 regions from the surface and 2 - 12 regions from the interior were investigated. The recovery of molds was greatly improved by using a variety of media. The material from each region was plated on APT agar (Difco), potato dextrose agar (Difco), trypticase soy agar (BBL), Czapek Dox agar (Difco), Czapek Dox agar (Difco) + 17 % sucrose, and Czapek Dox agar (Difco) + 16 % sodium chloride. The inoculated plates were incubated for one to three weeks at room temperature. The shorter incubation time was suitable for the recovery of relatively fast growing molds, while on the media with low water activity (i. e. Czapek Dox agar with the addition of sucrose or sodium chloride) slow growing, xerophilic molds were recovered only after several weeks of incubation.

Of the 307 mold isolates, 299 were identified to the genus level and 233 to the species level. Molds of the genera Aspergillus, Penicillium, Scopulariopsis, and Paecilomyces were identified using Raper, Fenell, and Austwick (31) and Raper, Thom, and Fennel (30) as references. For the identification of molds of the Mucorales and Dematiaceae, the classification schema adopted was that of Gilman (13). Difficulties were encountered in the identification of the penicillia, and careful observation of these isolates was needed in repeated transfers on Czapek Dox agar (Difco), Czapek Dox agar (Difco) + 1 % concentrated corn steep liquor, and malt extract agar (adjusted to pH 4,7). In addition, inoculations of apples (Grimes Golden and Golden Delicious varieties) were carried out to support the identification of penicillia, particularly of the series Penicillium expansum. Each of the 121 Penicillium isolates were inoculated into 4 different apples in successive runs.

Results

Molds were recovered from the surface of all sausages and hams examined, but were detected in significant amounts in the interior of only three hams which were organoleptically spoiled. These latter hams showed deep cracks in their surface, through which the mold - in every instance Aspergillus ruber - had penetrated into the interior. The amount of mold growth on the surface of the "country cured" hams examined varied considerably and was apparently influenced by the relative humidity at which the hams were held during the ripening period. In general, hams kept wrapped in paper during the curing and ripening process and held at ambient humidity exhibited abundant mold growth on their surface, especially on the meat portion, less on the skin and fat portions. On the other hand, hams which were not wrapped in paper and were held at a low relative humidity (about 65 %) during ripening developed only little mold growth. The fat on the surface of the latter hams appeared strongly oxidized after several months of ripening; and this rancidity may have contributed to the inhibition of mold growth. The amount of mold growth on the surface of "fermented" sausages was dependent on the type of product. The investigated samples of genuine Hungarian salami, and "Hungarian type salami" produced in Holland, as well as "Italian type salami", collected from several plants in the San Francisco area of the U.S., showed heavy mold growth on the casings. On genuine Italian salami, and the sausage samples obtained from Spain, Germany, and Switzerland mold growth was scanty.

The identified molds, isolated from the 67 samples studied, represented 6 families and 13 genera (Table 2). Molds of the order Mucorales and belonging to the genera Rhizopus, Mucor, Mortierella, and Syncephalastrum were present on 19 % of the sausages and 15 % of the hams examined, but generally only in small amounts. The low a_w of cured and aged meats probably is responsible for poor growth of these cosmopolitan fungi. Molds of the genera Paecilomyces Oospora, Cladosporium, Alternaria, Epicoccum, and Fusarium were recovered

exclusively from hams, but were never present in large amounts. Apparently, only the occurrence of Cladosporium (Hormodendrum) deserves some attention, since this mold was present on 30 % of the hams investigated and caused undesirable "black spots" which were not merely a superficial covering but were deep-seated and could not be washed away. The very strong proteolytic activity of Cladosporium together with the dematiaceous character of this mold could explain this phenomenon. Whereas the above mentioned mold genera are apparently only of minor importance for cured and aged meats, the genera Penicillium, Aspergillus, and Scopulariopsis are significant for these products. The genera Aspergillus and Penicillium are predominant on "country cured" hams, while the genera Penicillium and Scopulariopsis are predominant on "fermented" sausages.

Molds of the genus Scopulariopsis were isolated from 5 % of the hams and 33 % of the sausages examined; these organisms were recovered regularly and often in large amounts from genuine Hungarian salami, and "Hungarian type" sausages. Most of the Scopulariopsis isolates tested were proteolytic and lipolytic. The strong proteolytic action of some of the isolates was indicated by "white spots" which were observed under Scopulariopsis colonies on the skin surface of "country cured" hams. Cured and aged meats are suitable substrates for Scopulariopsis, because the isolates investigated were xerotolerant; some proved to be xerophilic. Most strains of Scopulariopsis isolated from sausages or hams produced black, abortive perithecia on Czapek Dox agar (Difco) after three to four weeks incubation at 22 °C, which is characteristic for S. alboflavescens Zach. and the probably synonymous S. cinereus Weill and Gaudin. A few isolates, which failed to produce this abortive perithecia, had to be classified as S. brevicaulis, var. alba, or S. brevicaulis var. glabra.

Molds of the genus Penicillium were recovered from 89 % of the sausages and from 83 % pf the hams investigated. On sausages, penicillia prevail during the entire ripening process, or share predominance with Scopulariopsis species, which proliferate on quite matured products only. On hams penicillia are predominant early in the ripening process, but after longer aging are succeeded by aspergilli. This difference in pattern between sausages and hams is probably due to the

water activity of the substrates. To-date, of the 121 isolates of penicillia recovered from the samples studied, 113 isolates have been identified to the series level and 97 isolates to the species level. In Table 3, the represented series are listed; every series includes one or several species. As this table indicates, a variety of penicillia was present on the surface of the sausages and hams examined. Only those of the series Penicillium expansum, P. janthinellum, P. chrysogenum, P. commune, and P. viridicatum were found on many samples. Considering the fact that most of the isolated of the series P. commune and P. viridicatum were obtained from several hams originating from only one producer, it may be assumed that penicillia of these two series are more likely a part of the resident flora of this particular plant than frequent inhabitants of cured and aged meats. Thus, the prevailing penicillia of the habitat studied are probably found in only three series, i. e. P. expansum, P. janthinellum, and P. chrysogenum. The series P. expansum includes two species, i. e., P. expansum and P. crustosum. As determined by their microscopic and colony characteristics, all isolates of the series P. expansum represented the species P. expansum. This species has been isolated from 60 % of the hams and 40 % of the sausages examined; on many of these products P. expansum was predominant. Cured and aged meats apparently provide a very suitable substrate for this species, and this is probably due to the xerotolerance of the mold. Penicillia of the P. janthinellum series are of particular interest for "fermented" sausages, since these organisms were recovered from 70 % of the sausages examined and were present in large amounts on most sausages with heavy mold growth on the casings. Two closely related species - P. simplicissimus and P. miczynskii - of the series P. janthinellum were represented. P. simplicissimum was found regularly and in large amounts on genuine Hungarian salami On the other hand, P. miczynskii was the predominant mold on the casings of five brands of "Italian type salami" collected in the San Francisco area of the U.S.A. Furthermore, also on two out of three sausages obtained from a plant in Nebraska, U.S.A., P. miczynskii was detected in small amounts. On genuine Italian and Spanish sausages, P. simplicissimum and P. miczynskii were present in slight to moderate amounts. To-date molds of the P. janthinellum

series have not been detected on hams, and this could indicate that the water activity of "country cured" hams is too low for these organisms. Penicillia of the P. chrysogenum series, which includes the species P. chrysogenum and P. notatum, were recovered from 30 % of the hams and 19 % of the sausages examined, and were often present in large amounts on the surface of these samples. The species P. chrysogenum was isolated from eight hams and two sausages; the species P. notatum was isolated from four hams and three sausages. Therefore, P. chrysogenum was found more frequently than P. notatum, and both species were recovered less frequently from sausages than from hams. The tested isolates of the series P. chrysogenum proved to be xerotolerant.

Molds of the genus Aspergillus were recovered from 90 % of the hams but from only 33 % of the sausages examined. Apparently the low water activity of "country cured" hams is favorable for certain aspergilli whereas at higher a_w of "fermented" sausages, competitive penicillia are often dominant. Molds of the A. glaucus group - which thrive at a relatively low a_w - were generally detected on sausages only if little or no growth of penicillia was present, but they were recovered from almost all "country cured" hams after the a_w during the ripening process had decreased to a level which is more favorable for these aspergilli than for penicillia. In addition to the decrease of a_w an increase in temperature, which is applied after 3 to 4 months in ham ripening, could favor more the aspergilli in the later stages of the ripening process. Of the species belonging to the A. glaucus group, A. ruber and A. repens were predominant (Table 4). Also A. amstelodami was quite frequently found. A. ruber, which is more xerophilic than A. repens and A. amstelodami, is apparantly the most important mold species of fully matured "country cured" hams, since this species was not only recovered from every ham examined with a ripening time of longer than 4 months, but was also present in very large amounts on many of these products. In fact, it seems difficult to produce a typical "country cured" ham on which A. ruber cannot be found, however, the quantity of the growth of this mold species is substantially influenced by the relative humidity during ripening. For instance, on hams not

wrapped in paper and held at 65 % relative humidity A. ruber was detected only in small amounts, while on hams held wrapped in paper during curing and ripening this organism was present in abundant amounts on the fully matured product. Besides the A. glaucus group, molds of the groups A. restrictus and A. versicolor apparently find a suitable substrate on cured and aged meats. Most species included in the A. restrictus group are strongly xerophilic. This is particularly true for A. penicilloides, a species recovered from six hams with a curing and aging time of half a year or longer. A. penicilloides was especially prevalent on the skin surface of these hams, where the a_w is even lower than on the meat surface. Molds of the A. versicolor group also were recovered exclusively from hams, on which they were present quite frequently but only in small amounts. Aspergilli of groups other than A. glaucus, A. restrictus, and A. versicolor were detected only sporadically; this was probably due to competitive penicillia on sausages and the low water activity of "country cured" hams.

Discussion

The presence and activity of molds on cured meats could be desirable as well as undesirable. Desirable changes brought about by molds could improve the flavor, appearance, and preservation of hams and sausages. Undesirable molds could cause spoilage of the product or could be pathogenic or toxinogenic for man, and thus hazardous for the processor or consumer of cured meats. All molds of significance for cured meats must find a suitable nutrient source on this substrate, and have in common a tolerance of a relatively low water activity.

Desirable flavor changes might be produced by xerotolerant and proteolytic or lipolytic molds growing on "fermented" sausages or on "country cured" hams. Hungarian workers often expressed the opinion that molds are important for the ripening of genuine Hungarian salami(38, 39, 40, 9, 26, 14, 15, 19, 21, 33, 36). According to Vas and Pulay (40) the "mold of choice" might only prevent

the growth of undesirable molds and bacteria on Hungarian type sausage, thus indirectly improve the flavor. Jirkovsky and Galgóczy confirmed earlier reports (39, 29, 23, 24) that Penicillium and Scopulariopsis species prevail on genuine Hungarian salami; and identified the predominant mold species of high-quality salami as Scopulariopsis brevicaulis var. alba, Penicillium camemberti, and P. commune (17). However, on the 4 samples of genuine Hungarian salami (3 produced in Budapest and 1 in Szeged) examined in our study Penicillium simplicissimum, and Scopulariopsis albo-flavescens were the predominant molds. According to Polish workers Mucedinaceae (Halobyssus Zukal) are the typical mold of Hungarian salami (3). Sausages which were inoculated with Halobyssus after smoking, and were held during the subsequent ripening for 6 - 8 weeks at 10 - 12 °C, and a relative humidity of 75 - 85 % developed, in comparison with uninoculated controls, an improved flavor (3). Some producers of "country cured" hams are of the opinion that high-quality hams exhibit a "dark green" mold on the surface. The organism involved probably is Aspergillus ruber, however, growth of this mold is perhaps simply an indicator of a low water activity, i. e. a long ripening time which might be the real cause of the desired and characteristic "country cured" ham flavor. For work still in progress in our laboratories, selected mold strains are used as inocula for hams and sausages, which are cured and aged under controlled conditions in the pilot plant. The resulting flavor, in comparison with that of uninoculated controls, is evaluated by taste panels and gas chromatography.

A musty flavor is undesirable; it develops in sausages and hams which are held at too high a relative humidity and temperature, and show excessive mold growth. Jirkovsky and Galgóczy recovered from musty Hungarian sausages Penicillium biforme, a species not encountered on high-quality salami; furthermore, on the casings of musty samples Aspergillaceae and Mucoraceae were present in relatively large amounts (17).

The appearance of cured meats is easily judged by the consumer, and in most instances the occurrence of molds on hams or sausages is considered an indication of spoilage. In fact, for the processor

it is often quite troublesome to prevent any mold growth on cured meats (16). The application of smoke during curing and ripening, and vacuum-packaging of the finished product are the measures most often taken to suppress mold growth on hams or sausages. More recently, also the use of antibiotics is considered for the inhibition of molds.

Only on "country cured" hams and "fermented" sausages of the Hungarian or Italian type mold growth is tolerated or even desired by the consumer. The mold on Hungarian salami should be greyish- or yellowish-white and uniform in color, dry, not too thick, and adhering closely to the entire surface (39, 40, 28, 29). Molds of the genera Penicillium, Scopulariopsis, and Aspergillus, if growing on the casing of Hungarian sausage, may cause the desired appearance of this product. The Scopulariopsis and Aspergillus species employed are of a white or whitish color. Aspergillus candidus produces a snow-white cover which, however, does not adhere satisfactorily to the casing (40). According to Polish workers, penicillia should be kept in the mycelium stage by low temperature (5 to 10 °C), and a relative humidity of 75 % during the ripening process (29). Hungarian salami is smoked for 192 - 240 hours at 8 - 14 °C, and a relative humidity of 80 - 85 %; the ripening thereafter takes up 14 - 16 weeks at 9 - 14 °C, and 95 - 75 % relative humidity (19). However, even on "country cured" hams and "fermented" sausages only the appearance of certain molds is welcome. Molds of the genus Cladosporium (Hormodendrum) produce undesirable "black spots" on meats (1, 24) and molds of the genus Scopulariopsis cause "white spots" on the skin of "country cured" hams, which also are undesirable (24). "Wiskers" on sausages and hams are due to the mycelium growth of Mucorales, such as Rhizopus. It is an old practice in Hungarian plants to remove this "wiskers" from salami (17). Finally, it could be mentioned that cellulase-producing molds bring about defects in cellulose casings of sausages, which render the product unsightly (22).

The preservation of cured meats might be favored by molds. Mold-

covered sausages dry more uniformly and slowly (28, 40, 29, 3), and this results not only in an improved quality, but also a reduction of weight loss by about 7 % (40). The fat on the surface of mold-covered "country cured" hams becomes slightly oxidised only, even after a ripening period of 9 - 12 months, while the fat of hams without molds develops strong rancidity (24). Also the mold growth on Hungarian salami apparently suppresses in the sausage the oxydation of fat, at least during a part of the ripening process (25). Common penicillia on hams and sausages, such as Penicillium chrysogenum, P. notatum, and P. expansum, inhibit Staphylococcus aureus by antibiotic action, and thus may reduce a health hazard (24).

Several mold inocula have been proposed or are already used as starters for sausages, e. g., molds of the family Mucedinaceae (2, 3), or the genus Penicillium (27). Molds which are considered to be used as inocula for hams or sausages must be effective in bringing about desirable changes, and must neither be pathogenic nor toxinogenic. Information on the pathogenicity of molds is plentiful (8, 37, 34, 30, 7, 35, 31), but not always conclusive. The information available should be applied to the evaluation of the pathogenicity of the molds recovered in this study: Molds of the genus Aspergillus are predominantly saprophytic, but certain species are quite regularly pathogenic. The organ most commonly attacked is the lung where symptoms clinically resembling those of pulmonary tuberculosis are produced by aspergilli, especially A. fumigatus, and A. flavus. Other aspergilli, such as A. penicilloides, A. niger, A. ruber, A. repens, A. amstelodami, A. sydowi, A. versicolor, and A. nidulans occasionally infect the ear, nails, feet, and cornea of human beings. However, these species do not appear in any consistent manner as pathogens (8, 37, 34, 7). Occupational, repeated exposure may be of importance (34, 7). The latter could occur in plants where hams or sausages with mold growth are processed and the environment is saturated with mold spores. Molds of the genus Cladosporium (Hormodendrum) sometimes cause dermatomycoses in man, especially of the feet; but again these molds are not consistently pathogenic (8, 7). Molds of the genus Penicillium are frequently

mentioned in medical literature, but there are only a few references in which the organisms involved have been sufficiently described to ensure that they belong in this genus (8, 30). P. citrinum has been isolated from lung and respiratory infections of humans, but actual pathogenicity has not been proved (30). While there is little real evidence that penicillia are ever pathogenic, there is adequate information that several species of Scopulariopsis are invasive (8). Probably much of the animal pathogenicity attributed to penicillia is, in reality, due to different species of Scopulariopsis which have erroneously been referred to the penicillia (30). Molds of the genus Scopulariopsis represent a fairly common cause of onchymycosis of the hands and feet, with the nails becoming whitish, thickened, and brittle. They have been isolated in several instances from the tongue and oral cavity, and from fatal cases of so-called "American blastomycosis". Furthermore, these molds are not an uncommon cause of dermatomycoses of different parts of the body. There is also ample evidence that isolates of Scopulariopsis are pathogenic for laboratory animals, such as guinea pigs, rats, pigeons, mice, and rabbits (8). In medical literature, the species of Scopulariopsis usually reported in connection with lesions in man is S. brevicaulis (Sacc.) Bainier. Jirkovsky and Galgóczy isolated S. brevicaulis var. alba from about 80 %, and S. brevicaulis from about 20 % of the 59 samples of genuine Hungarian salami investigated (17). In our study, most isolates of Scopulariopsis from sausages represented S. alboflavescens or the probably synonymous S. cinereus. Perhaps the isolates of Jirkovsky and Galgóczy were not thoroughly examined for black, abortive perithecia, which are typical for S. alboflavescens, and thus have been erroneosly characterized as S. brevicaulis. However, with the evidence on hand, all Scopulariopsis species should be considered as potential pathogens, and could only be employed as inocula for cured meats after thorough testing for pathogenicity.

Recently, there is much concern regarding toxinogenic molds. Even at unusually low levels, toxins such as aflatoxin B1, produced by molds, have been proven to cause severe damage to vital

tissues, such as the liver and kidneys, of a wide variety of laboratory animals, including monkey (42). In addition to Aspergillus flavus, a number of other mold species are now known to be toxinogenic and probably more will be discovered. For this reason, it has been suggested that all mold growth in foods should be prevented (32). On the other hand, there is little objection to traditional processes in which fungi are used, as long as it has not been demonstrated that the organisms involved are toxinogenic. Of the mold genera, from which certain strains have been reported to be toxinogenic (10, 18, 20, 4, 6, 5, 12, 32, 41), the genera Aspergillus, Penicillium, Cladosporium, Rhizopus, Alternaria, Paecilomyces, Mucor and Fusarium were present on the samples studied. Of the potentially toxinogenic species of these genera, Aspergillus ruber, A. amstelodami, A. chevalieri, A. sydowi, A. niger, A. wentii, A. candidus, A. fumigatus, A. flavus, A. mangini, Penicillium notatum, P. cyclopium, P. citrinum, P. frequentans, P. urticae, P. variabile, and Paecilomyces varicti were detected on the samples investigated. Of particular interest are A. ruber, A. amstelodami, P. notatum, and P. cyclopium, since these potentially toxinogenic species have been found frequently on "country cured" hams, i. e. on 78 %, 23 %, 18 %, and 13 % of the samples respectively. Should A. ruber, for example, produce mycotoxins during the curing the curing and ripening of "country cured" hams, a dramatic change of the traditional process for this product would be essential. Further attention must also be devoted to the identification of the P. cyclopium series, since these penicillia bear a close resemblance to the P. expansum series, and separation from the latter is often difficult. According to Raper, Thom, and Fennel (30) members of the P. cyclopium series produce no rot in inoculated apples within two weeks, whereas P. expansum produces a distinct rot, commonly referred to as "blue mold rot" of apples. However, it seems doubtful whether the separation of the P. cyclopium series from the P. expansum series can be based on this rather uncertain test. In general, every mold species or strain suggested as inoculum for cured meats has to be thoroughly investigated for mycotoxin production. It should be borne in mind the interplay of different organisms in mixed culture, since one mold might enhance or inhibit the toxin production of others. For instance, according to Forgacs

(11) there is a strong possibility that Scopulariopsis brevicaulis inhibits toxin production by other molds.

Conclusions

Molds to be considered as inocula for cured and aged meats should grow readily on these products, i. e. should find a suitable nutrient source, and should tolerate a reduced water activity. Certain species of the genera Penicillium, Aspergillus, and Scopulariopsis fulfill these requirements.

Molds to be considered as inocula for cured and aged meats must be neither pathogenic nor toxinogenic. The genus Scopulariopsis includes several pathogenic, and the genus Aspergillus numerous toxinogenic species. Therefore, the interest is focused on the genus Penicillium.

On "country cured" hams molds of the genus Penicillium prevail in the earlier stages of the ripening process, while aspergilli predominate on the fully matured product. If "country cured" hams are held under environmental conditions which favor mold growth, probably both potentially desirable and undesirable molds could be encountered, i. e. penicillia which prevail earlier in the ripening process will be succeeded by potentially toxinogenic aspergilli. whether molds are essential for the typical, desired flavor of "country cured" hams is doubtful. Perhaps the frequent occurrence of molds of the Aspergillus glaucus group on full matured hams is simply an indicator of a low water activity of the product, i. e. a long ripening time during which the flavor developed.

Mold growth on "fermented" sausages possibly contributes to the flavor, appearance, and preservation of these products. From Hungarian and Italian type salami molds of the genus Penicillium are recovered frequently and in large amounts; the prevailing penicillia represent the species P. simplicissimum, P. miczynskii, and P. expansum. Most isolates tested of P. simplicissimum and P. expansum were strongly lipolytic and weakly proteolytic, while most isolates of P. miczynskii were strongly proteolytic but moderately lipolytic. Thus, from a mixed culture of two or three of these penicillia action on the proteins as well as on the lipids of sausages could be expected. It should be tested whether these species are toxinogenic or pathogenic.

Table 1. Number and origin of samples studied

	"Fermented" Sausages		"Country Cured" Hams	
Number	27		40	
Origin	U.S.A.	(14)	Missouri	(13)
	Hungary	(4)	Kentucky	(11)
	Italy	(3)	Iowa	(11)
	Spain	(2)	Virginia	(3)
	Holland	(2)	Tennessee	(2)
	Germany	(1)		
	Switzerland	(1)		
Brands	19		13	

Table 2. Molds recovered from the 67 samples studied

Family	No. and % of Samples	Genus	No. of Samples		
			Hams	Sausages	Total
Mucoraceae	9 (13 %)	Rhizopus	5	3	8
		Mucor	0	1	1
Mortierellaceae	2 (3 %)	Mortierella	1	1	2
Cephalidaceae	1 (1 %)	Syncephalastrum	1	0	1
Moniliaceae	66 (99 %)	Penicillium	33	24	57
		Aspergillus	36	9	45
		Scopulariopsis	3	11	14
		Paecilomyces	3	0	3
		Oospora	3	0	3
Dematiaceae	14 (21 %)	Cladosporium	12	0	12
		Alternaria	5	0	5
Tuberculariaceae	3 (4 %)	Epicoccum	3	0	3
		Fusarium	1	0	1
Unidentified	4 (6 %)				

Table 3. Penicillia recovered from the 67 samples studied

Series	No. and % of Samples	No. and % of Sausages	No. and % of Hams
expansum	34 (51 %)	10 (40 %)	24 (60 %)
janthinellum	18 (27 %)	18 (70 %)	0
chrysogenum	17 (25 %)	5 (19 %)	12 (30 %)
commune	9 (13 %)	2 (7 %)	7 (18 %)
viridicatum	6 (9 %)	0	6 (15 %)
cyclopium	5 (7 %)	0	5 (13 %)
roqueforti	4	1	3
citrinum	4	3	1
frequentans	3	0	3
brevi-compactum	3	1	2
urticae	3	3	0
javanicum	1	0	1
purpurogenum	1	0	1
Ramigena	1	0	1
unidentified	9 (13 %)	1 (4 %)	8 (20 %)

Table 4. Aspergilli recovered from the 67 samples studied

Aspergillus Group	No. and % of Samples	Aspergillus Species	No. of Samples Hams	Sausages	Total
glaucus	42 (63 %)	A. ruber	31	3	34
		A. repens	27	2	29
		A. amstelodami	9	1	10
		A. chevalieri	4	1	5
		A. pseudoglaucus	1	0	1
		A. mangini	1	0	1
restrictus	6 (9 %)	A. penicilloides	6	0	6
versicolor	7 (10 %)		7	0	7
niger	5 (7 %)		3	2	5
wentii	2 (3 %)		2	0	2
candidus	1 (2 %)		0	1	1
fumigatus	1 (2 %)		1	0	1
flavus	1 (2 %)		0	1	1

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Summary

This report is concerned with molds in relation to cured meats. The investigated material includes 40 "country cured" hams and 27 "fermented" sausages; these samples were obtained from 32 different producers in the U.S.A. and Europe. Most samples represented high-quality, gourmand-type products for which molds are believed to be desirable. From the 67 samples investigated 307 mold strains were isolated; most of the isolates have been identified to the genus or species level.

The results indicate that the genera Aspergillus and Penicillium are predominant on "country cured" hams, while the genera Penicillium and Scopulariopsis are predominant on "fermented" sausages. Furthermore, molds of the genera Rhizopus, Mucor, Mortierella, Syncephalastrum, Paecilomyces, Oospora, Cladosporium, Alternaria, Epicoccum, and Fusarium were recovered.

The presence and activity of molds on cured meats could be desirable as well as undesirable. Desirable changes brought about by molds could improve the flavor, appearance, and preservation of hams and sausages. Undesirable molds could cause spoilage of the product or could be pathogenic or toxinogenic, and thus hazardous for the processor or consumer of cured meats.

Molds which are considered to be used as inocula for hams or sausages must be effective in bringing about desirable changes, and must neither be pathogenic nor toxinogenic. The genus Scopulariopsis includes several pathogenic, and the genus Aspergillus numerous toxinogenic species. Therefore, the interest is focused on the genus Penicillium, in particular the species P. simplicissimum, P. miczynskii, and P. expansum which were recovered frequently and in large amounts from cured meats such as Hungarian and Italian type salami.