Prevention of Surface Mold Growth on Italian Dry Sausage by Natamycin and Potassium Sorbate†

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Inhibition of uncontrolled mold growth on three types of raw cured Italian dry salami was studied under commercial production conditions. Salami were dipped or sprayed with natamycin (pimaricin) or were given a combined organic acid-plus-potassium sorbate treatment. Acetic and citric acids potentiated the inhibitory effects of potassium sorbate significantly, but lactic and succinic acids showed little or no effect. Treatment of salami by dipping in 2.5% (wt/vol) potassium sorbate or 2,000 ppm (mg/liter) of pimaricin did not successfully prevent the growth of surface molds. At 10% potassium sorbate on all types of salami and at 2.5% sorbate on Casalingo salami, visual inhibition of mold growth was observed, but numbers of viable fungi on all salami types treated with 2.5% sorbate were not significantly (95% confidence) different from numbers found in the untreated controls. Pimaricin spray (2 × 1,000 ppm) was as good as or slightly better than 2.5% potassium sorbate, but greater concentrations of each were required to satisfactorily inhibit surface mold growth during the 25- to 50-day ripening period.

Dried sausages with various degrees of surface mold growth are preferred by ethnic groups from many countries. Unfortunately, overgrowth of the surface by undesirable molds is not uncommon and has attracted the interest of scientists in Italy, Hungary, Germany, and the United States. Dragoni et al. (10) and Cattaneo et al. (7) concluded that molds were not a part of the normal microflora of Italian dry sausage. Ayres et al. (2) noted that mold growth on genuine Italian salami was somewhat scanty, whereas similar products produced in the United States were heavily covered with mold.

In North America there is generally consumer reluctance to purchase moldy food items, and dried sausages do not appear to be an exception. Although sausages evenly covered with dense white mycelium are considered desirable by some groups, the uncontrolled mold growth seen on most dry cured meat products is usually pigmented green, gray, or yellow and thus has little appeal.

Mold growth on cured meat products can take place not only during curing but also during wholesale distribution and in the retail showcase. At each stage in the distribution chain, pigmented mold is removed by washing to improve product appearance. Vacuum packaging of the fully mature cured product is also used; however, washing is usually necessary before packaging, and the product becomes more costly. The danger inherent in the practice of mold removal by washing is that the procedure does nothing to remove toxic and allergenic mold metabolites which may have diffused into the meat as a result of the original mold growth. Although Ayres et al. (1) observed mycotoxin formation in dry sausages under controlled conditions, it is felt that if storage temperatures below 15°C are maintained, mycotoxin production will not occur (1, 5, 6).

Surface molding of dry sausages and cured meats generally was a problem in three of four meat processing plants recently viewed. Of these, products manufactured in the Italian plants were most affected. This was probably because, unlike German-type sausages, Italian salami are not smoked, and smoking is known to inhibit mold development on the surface of the sausages (9, 17, 20).

Italian dry salami has a water activity which ranges between 0.671 to 0.920, a moisture content of 24.3 to 43.4%, and a pH of approximately 4.3 to 7.1 (12, 16, 21, 24, 25). Thus, under conditions of relative humidity (RH) greater than 70%, mold will readily form on the salami surface.

Both potassium sorbate (3, 15, 17, 26) and pimaricin, also known as natamycin (7, 14, 19), have been found effective as antifungal treatments on cured meat products under specific conditions. It was therefore considered important to evaluate the ability of these compounds to reduce or eliminate the surface molding problem on several types of raw cured pork-type Italian sausages in a single plant under normal production conditions which were conducive to mold growth.

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MATERIALS AND METHODS

Salami. Three types of Italian dry fermented sausage, which contained from 21 to 25% fat, 53 to 58% moisture, and about 16% protein immediately after formulation, were studied during and after their commercial manufacture. The salami contained pork, salt, nonfat dry milk powder, dextrose, glucono-delta lactone, spice, monosodium glutamate, sodium erythorbate, garlic, potassium nitrate, and sodium nitrite. No commercial starter cultures were used.

Minor differences in spice formulation were noted between the Genoa (each weighed about 5 lb, or about 2.3 kg) and Casalingo (about 3 lb, or 1.4 kg) salami. These coarse-ground sausages differed from Abruzzese salami (about 1 lb, or 0.45 kg) in that the latter were finely ground and contained 1-2 cm² pieces of pork fat similar to that in mortadella formulations. Casings used for Genoa and Casalingo salami were of a multi-layered seamless regenerated collagen type. A natural hog casing (porcine bung) was used for the Abruzzese salami.

The complete meat, spice, and curing ingredients formulation was stuffed into casings at 2°C and transferred to the curing (green) room, where the sausages were held at 20 to 24°C and 95% RH for 2 to 3 days. During this period, major bacterial growth and fermentation took place. Alterations in temperature to 20°C and RH to 60% according to the size of the commercial amount of salami in the chamber and their individual sizes. On the 4th and 5th days, the temperature and RH were gradually changed to 11°C and 77%, respectively. Salami were then transferred to a drying room for an additional 20- to 45-day ripening period at 11°C and 77% RH. Since these salami were manufactured in the traditional Italian manner, they were neither cooked nor smoked during processing. Experiments carried out to determine the effect of surface mold inhibitors during salami maturation were conducted under commercial ripening conditions at Santa Maria Foods Ltd., Belvédère, Ontario, Canada.

Pimaricin treatments. Immediately after stuffing, six samples each of Casalingo and Genoa salami were sprayed with 1,000 ppm (mg/liter) of pimaricin (Delvocid; Gist-Brocades Inc., Montreal) or dipped for 30 s in 2,000 ppm of pimaricin. These samples had not been pretreated with organic acids. The pimaricin had been formulated to contain 5% (wt/vol) NaCl, and since the Delvocid powder is 50% active pimaricin, 2 g/liter was used to give a 1,000-ppm solution and 4 g/liter was used to yield a 2,000-ppm solution. Spraying was carried out with a plastic, pistol-type, hand-operated atomizer. Spray was applied until the salami was generously covered and liquid dripped from the samples. These pimaricin-treated samples were placed in the green room for 5 days as previously described. At the end of this period, samples sprayed with 1,000 ppm of pimaricin were sprayed again as before and returned to the drying room until mature.

Only a single pimaricin treatment (1,000-ppm spray) was given to the Abruzzese salami, but casings were given the normal 5-min soak in 2% acetic acid before stuffing. Six Abruzzese salami were removed from the green room on day 2 of fermentation. These were sprayed until dripping with 1,000 ppm of pimaricin as previously described and then returned to the green room and treated in the normal manner.

Acid pretreatments. Casalingo, Genoa, and Abruzzese salami were treated with organic acids before being treated with potassium sorbate. All Abruzzese casings were soaked for 3 min in 2% (vol/vol) acetic acid before stuffing since this was normal plant practice for natural casings. Other casings were moistened in tap water and stuffed, and then the salami was given an organic acid pretreatment. Casalingo and Genoa salami were assembled in 4 groups of 18 salami each. Each group was dipped for 30 s in one of the following acids: 2% (wt/vol) citric, 2% (wt/vol) succinic, and 2% (vol/vol) lactic acid. The fourth group of Casalingo salami was dipped in commercial vinegar (5% [vol/vol] acetic acid), whereas the fourth group of Genoa salami was dipped in vinegar diluted to contain 2% (vol/vol) acetic acid. An untreated control group of each type of salami was also used. After treatments, Abruzzese and Genoa salami were placed in the green room at 20 to 24°C and 95% RH as described earlier. Casalingo samples were treated in the same manner but were stored at 4°C overnight before being placed in the green room.

Potassium sorbate treatments. At the end of 5 days of normal incubation in the green room, six Genoa and Casalingo salami from each acid pretreatment (acetic, citric, lactic, and succinic) were dipped for 60 s in aqueous 2.5, 10, or 20% (wt/vol) solutions of potassium sorbate (Sorbiskat-K; Pfizer Canada Ltd., Montreal) and were placed in the curing room at 11°C and 77% RH. At the end of 2 days of incubation in the green room, six Abruzzese salami were dipped for 60 s in 2.5, 10, or 20% (wt/vol) solutions of potassium sorbate and were returned to the green room to continue the normal maturation schedule.

Sampling pimaricin- and sorbate-treated salami. Whole Genoa salami were sampled on days 0, 5, 9, 16, 24, 34, and 50. These samples were frozen and stored at -20°C. At each sampling, a sterile bag containing 250 ml of 0.1% (wt/vol) pimaricin was used. Each bag was then allowed to remain at room temperature for 60 min, and then 3 ml of 0.1% (wt/vol) pimaricin solution was added, mixed, and stored at -20°C until needed. Similarly, Abruzzese samples were taken on days 3, 7, 9, 11, 15, and 25 and frozen for later study at the laboratory. Identical sampling patterns were followed for untreated control groups, which were carried for all experiments. Genoa, Casalingo, and Abruzzese salami were allowed to mature for 50, 26, and 25 days, respectively.

Measurement of salami surface mold growth. A cross-sectional center piece of salami measuring 5 to 7.5 cm long was cut from each type of salami tested. The salami was slit longitudinally and peeled aseptically from the meat. The casing was placed in a sterile 24-oz (ca. 720 ml) Whirl-Pak bag (Nasco Educational Materials Ltd., Guelph, Ontario), and the area of the sample was determined. The casing was transferred to a sterile Stomacher bag, 100 ml of 0.1% (wt/vol) peptone was added, and the mixture was stomached for 1 min. The casing was removed and the peptone was further diluted as necessary to obtain viable counts of fungi, using potato dextrose agar (PDA) and the pour plate technique. Plates were incubated at 22°C for 3 days. Results were expressed as colonies per square centimeter of casing surface area.

Visual estimates of surface growth by fungi were
made on a scale of 0 to 5 after examination of salami samples during maturation. A photographic record of the maturation process was kept.

Statistical evaluation. Viable surface mold counts per square centimeter were transformed to logarithms (base 10). These data were subjected to one-way analysis of variance and were further subjected to the Neuman-Keuls test for equality of means (27).

RESULTS

Pimaricin treatment. The 2,000-ppm pimaricin dip was found to be ineffective in preventing surface mold growth on either Genoa or Casalingo salami aged 50 or 26 days, respectively (Table 1). Pimaricin spray (2 × 1,000 ppm) was effective on both salami types, but mold growth was replaced by a dusting of yeast colonies that covered the surface to a degree that varied directly with the length of ripening. Photographs of pimaricin-treated fully ripened Casalingo (26 days) and Genoa (50 days) salami are shown in Fig. 1A and 2A.

Abruzzese salami sprayed with pimaricin showed no mold growth for a week after stuffing, and then a light dusting of mold became visible. This growth continued until the end of the ripening period, when there was only a slight improvement of pimaricin-treated salami over the untreated control samples. Abruzzese salami are shown, after 26 days of ripening, in Fig. 1C.

Acid pretreatments. Genoa salami treated with the four organic acids at day 0 appeared to be equally susceptible to surface mold growth when examined before being dipped in potassium sorbate at day 5 (Table 1).

Casalingo salami, pretreated with citric acid, showed no visible surface mold growth 5 days after treatment. Very slight mold growth was apparent on samples treated with acetic acid, but greater growth was present on lactic acid- and succinic acid-treated salami. Succinic acid did not significantly prevent surface mold growth on either the Casalingo or Genoa salami (Table 1). Casings of Abruzzese salami, which had been dipped in 2% (vol/vol) acetic acid, showed no mold growth at day 2, when they were given pimaricin or sorbate treatment. The natural casings were more resistant to mold growth.

Potassium sorbate treatment. From visual examination of Genoa salami, it became apparent that the 2.5% potassium sorbate treatment was only marginally better than no treatment (Table 1). A marked improvement was noted with 10% sorbate, and very little mold growth was visible with 20% potassium sorbate (Fig. 2B-D).

Treatment with 2.5% potassium sorbate significantly reduced the degree of visible mold growth.

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<th>Table 1. Extent of salami surface mold growth assessed by visual inspection</th>
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a Salami were given a 30-s acid pretreatment on day 0 followed on day 5 by a 60-s dip in 2.5, 10, or 20% potassium sorbate.

b Surface growth by fungi assigned numerical values: no growth, 0; very slight, 1; slight, 2; moderate, 3; marked, 4; confluent, 5.

c Days of ripening.

d Salami were either dipped for 30 s in 2,000 ppm or sprayed with 1,000 ppm of pimaricin on day 0. On day 5 the sprayed samples were sprayed again with 1,000 ppm of pimaricin.
growth on Casalingo salami compared with untreated controls (Fig. 1A, B), but the best suppression of mold growth on Casalingo was evident upon examination of salami treated with 20% potassium sorbate. Under these conditions, there was slightly less mold growth on the samples which received the acetic acid pretreatment (Table 1). In fact, acetic acid alone had some visible effect on mold growth even after 26 days of ripening (Fig. 1B). As seen with Genoa salami (Fig. 2C), individual centers of mold growth became enlarged where treatments had a visible inhibitory effect (Fig. 1B).

Abruzzese salami did not appear to be significantly affected by surface mold growth when fully ripened (Fig. 1C). There was very slight mold growth with 2.5% sorbate, somewhat less with 10%, and essentially none with 20% potassium sorbate. A single treatment with 1,000 ppm of pimaricin spray was as effective as 10% sorbate on Abruzzese salami.

**Viable surface mold growth.** Mold growth on the surface of Genoa salami did not appear to be retarded by a 1-min 2.5% potassium sorbate dip (Table 2). After one-way analysis of variance and application of the Newman-Keuls test for equality of means (27), the acetate-sorbate data were separable into two significantly different groups at the 95% confidence level. The first group contained Genoa salami treated with 20%
potassium sorbate. The second group was made up of the remaining treated Genoa salami, which were not significantly different from the untreated control salami. There was no statistical difference between viable surface growth at day 50 on salami pretreated with acetate or citrate.

Casalingo salami casingspretreated with acetic acid were examined similarly, and it was evident that treatment means could be arranged in several groups (Table 3). Viable numbers were lowest (95% confidence level) after treatment with 20% sorbate, a trend which was seen throughout ripening. The Neuman-Keuls test also showed that the 10 and 2.5% sorbate treatment means were equivalent. This test also grouped the 2.5% sorbate and untreated salami together, but the 10% sorbate results were different from results for the control salami. Pimaricin data were similar to those obtained for 10 and 2.5% sorbate treatments.

Abruzzese salami casings sprayed once with 1,000 ppm of pimaricin or dipped in the various potassium sorbate solutions were also examined for viable fungi (Table 4). There was no differ-

| Treatment | Yeast and mold count/cm² (
| Pretreatment | 3.322 | 4.742 | 6.787 | 7.144 | 7.462 | 5.996 |
| 10% | 4.885 | 3.642 | 3.626 | 3.494 | 3.238 | 4.728 |
| 20% | 0.899 | 1.996 | 2.681 | 2.973 | 2.703 | 4.610 |
| Pimaricin | 1.740 | 2.217 | 2.503 | 4.673 | 5.444 |

*Surface area of salami sampled (mean ± standard deviation) = 144.4 ± 10.5 cm².
*Results expressed as the logarithm (base 10).
*Days of ripening.
*Samples in this column received a 2% citric acid pretreatment. With the exception of pimaricin treatments, all other samples were given a pretreatment with 2% acetic acid.
*Pimaricin sprayed on day 0 and day 5 at 1,000 ppm, no pretreatment.

| Treatment | Yeast and mold count/cm² | 5  | 11  | 17  | 25  |
| Control | 3.371 | 4.375 | 3.857 | 3.158 |
| Sorbate | 1.987 | 5.508 | 2.672 | 3.522 |
| 10% | 2.303 | 1.556 | 1.944 | 1.748 |
| 20% | 2.068 | 1.799 | 1.301 | 1.591 |
| Pimaricin | 3.330 | 3.130 | 4.244 |

*Mean ± standard deviation of casing area per salami sampled = 111.9 ± 14.2 cm².
*See Table 2.
*1,000 ppm of spray, 2% acetic acid casing dip before being stuffed.

**DISCUSSION**

Pimaricin treatments. In view of the success reported by others in using pimaricin to prevent mold growth on salami (7, 14, 19), it was disappointing to find that dipping the salami in 2,000 ppm of pimaricin had essentially no effect (Fig. 1A and 2A). This was not too surprising since it had been shown (19) that immersion treatment with pimaricin was not very satisfactory unless salami were stuffed in natural casings. When sprayed, a 1,000-ppm pimaricin treatment protected smoked Dutch salami stuffed in protein fiber casings and stored for 5 weeks at 18°C and 65 to 85% RH (19). When Genoa and Casalino salami were sprayed twice (days 0 and 5) with 1,000 ppm of pimaricin, there was an improvement which was slightly better than that obtained after treatment with acetic acid plus 2.5% potassium sorbate (Table 1, Fig. 1A and 2A). However, there was a noticeable increase in small yeast colonies on the surface of pimaricin-sprayed samples of Genoa and Casalino which gave them a slight grayish hue. In the case of a pimaricin-sprayed sample visible in Fig. 2A, mold growth appeared significant, but this patch of growth was probably due to the two salami touching when hung. This can cause a local increase in water activity, thus permitting easier growth (19). In addition to the better result reported here for sprayed salami, Hechelman and Leistner (14) also had better antimold results when pimaricin (0.25%) was sprayed on freshly stuffed salami. It is difficult to explain why yeast growth was prominent on pimaricin-
treated salami. Perhaps the yeast simply replaced the inhibited mycelial forms. These yeasts either had a high tolerance for pimaricin or developed resistance to inhibition by pimaricin. The latter possibility seems unlikely in view of the study conducted by deBoer et al. (8). They surveyed 16 meat plants in Germany to determine whether resistance to pimaricin was developing in populations of yeasts and molds present in the plants. Comparisons were made of the minimal inhibitory concentrations obtained in plants where pimaricin had been in use for as long as 5 to 9 years with those obtained in plants where pimaricin had never been used. No difference in the susceptibility of organisms was found among the plants.

Mold growth on pimaricin-sprayed (1,000 ppm) Abruzzese salami was not visually extensive; however, neither was growth on the untreated control sample. Comparison of viable colony-forming units on the surface of these salami (Table 4) with those of the Genoa and Casalingo types (Tables 2 and 3) support this observation. The less extensive mold growth on the surface of Abruzzese salami was probably due to the barrier action of the natural casing to mold invasion. The porcine bungs used were significantly thicker than the artificial collagen casings and contained many fatty deposits which did not appear to support surface growth.

**Acid pretreatments.** To prevent the formation of off-flavor or discoloration of the salami, potassium sorbate was applied after green room processing (17). This necessitated the use of an interim inhibitor at the time the salami were stuffed so that the surface fungi would not achieve significant growth before sorbate application. Many processors apply a short smoke cycle during this period which effectively retards mold growth; however, Italian processors of raw cured pork meat products do not traditionally use smoke (24). Leistner et al. (17) suggested that a lactic acid dip of casings before salami ripening might prevent mold growth on non-smoked products. On the basis of previous work, it was felt that other organic acids might also be effective (11, 18, 22).

Acid pretreatments used during the present study appeared to cause only very slight inhibition of mold growth on Genoa salami, and there was no visible difference among acid treatments (Table 1). On Casalingo salami differences were noted (Table 1), and at day 5 the order of efficacy from the best to worst inhibitor was citric > acetic > lactic > succinic acid. The result is in general agreement with the findings of Levine and Fellers (18), who reported that the order of inhibitory activity against mold was acetic > hydrochloric > lactic acid; however, the result disagrees with the findings of Erickson and Fabian (11), who found acetic acid best but also found citric acid less effective than lactic acid against molds in laboratory media. In contrast to the results obtained in these mold studies, Raccach and Baker (22) found succinic acid to be better than lactic, acetic, or citric acid at equivalent pH (4.7) for the inhibition of *Staphylococcus aureus* in fermentable poultry meat. Snijders et al. (23) found that 0.75% lactic acid was effective against bacteria on beef carcasses, but Levine and Fellers (18) suspected that *Aspergillus niger* used lactic acid as a carbon source during their inhibition study. Citric acid appeared useful during the present investigation. Although its inhibitory effects on molds were not discussed, it has been reported that at Kulmbach, a spray of 11.7% citric acid and 21.6% sodium chloride was used successfully to reduce microbial growth on the surface of animal carcasses (Anon, Meat Industry 26:28–29, 1980).

The improved performance of acetic acid (5%) on Casalingo salami over that obtained with 2% acetic acid on Genoa salami cannot be explained totally by the difference in concentration. Citric acid was also more inhibitory on Casalingo salami, and the same concentration was used throughout these experiments. It may be that storage of the Casalingo salami at 4°C overnight after acid pretreatments or the smaller diameter of the Casalingo salami enhanced the antimicrobial action of pretreatments. The inadequacy of acid treatment alone, applied when salami were stuffed for prevention of mold growth, was shown by the failure of the 5% acetic acid dip (Fig. 1B).

The concentration of acetic acid used on the salami (2 to 5%, vol/vol) was greater than that reported to be effective in laboratory media (4, 11, 18) and the 1.0 to 1.2% found effective against mold in food (13); however, the effectiveness of 2% (wt/vol) citric acid was better than had been expected. Concentrations of lactic and succinic acids greater than those used here would be necessary to yield acceptable control of mold growth.

**Potassium sorbate treatment.** Treatment of the Genoa, Casalingo, and Abruzzese salami with 20% (wt/vol) potassium sorbate caused the most complete inhibition of surface mold growth. There were statistically (95% confidence level) fewer viable colony-forming units on salami treated with 20% sorbate (Tables 2–4, Fig. 3). For Genoa and Casalingo salami, this conclusion held regardless of the type of acid pretreatment used; however, the best combination was 20% sorbate with an acetic acid pretreatment. At 10% sorbate there was still significant visual mold inhibition and fewer viable fungi. This
Fig. 3. Inhibition of yeast and mold development on the surface of Genoa and Casalingo dry Italian salami during ripening. Casing samples of known size were peeled from the salami, and viable yeasts and molds were counted on potato dextrose agar after incubation at 22°C for 3 days. Casalingo and Genoa casing data from days 5 and 9 were combined and averaged. Additional Genoa samples were taken on days 16, 34, and 50. The remaining data are from analysis of Casalingo casings. The first pimaricin spray (1,000 ppm) was given immediately after stuffing; the second spray (1,000 ppm) was given at day 5 of curing. Other samples were dipped once in potassium sorbate for 60 s on day 5 and had been pre-treated immediately after stuffing with acetic acid. Symbols: ○, untreated control; ●, 2.5% (wt/vol) potassium sorbate; □, 10% potassium sorbate; ■, 20% potassium sorbate; Δ, 2 × 1,000 ppm of pimaricin spray.

difference was statistically significant on the surface of Casalingo but not Genoa salami. At 2.5 and 10% sorbate, many yeasts and molds were present on the surface which grew only when washed from the casing and placed on growth medium containing no sorbate. At these sorbate concentrations, inhibitory but nonlethal effects of sorbate were apparent.

Although 2.5% (wt/vol) potassium sorbate is used in the United States for the prevention of surface mold growth on dry cured salami (24), under the conditions of its use here on Genoa salami, 2.5% potassium sorbate was ineffective. In fact, higher viable numbers of fungi were present on 2.5% potassium sorbate-treated (fully ripened) salami than on the untreated control casings (Table 2). Genoa, Casalingo, and Abruzzese types have diameters of about 8.8, 5.6, and 5.6 to 7.5 cm, respectively. Since it is known that sorbate penetrates from the surface (17), it can be speculated that as sorbate penetrated the larger diameter salami it was diluted to a greater degree, which caused a more rapid loss of inhibitory ability at the surface.

In contrast to the results found here, Kemp et al. (15) found that a 2.5% potassium sorbate dip at the time of deboning was satisfactory for control of surface mold growth on boneless dry-cured ham. But although those hams were held longer (84 days) and part of the time at a higher temperature (24°C for 4 weeks) than used here, the hams were smoked. Elastic netting appeared to retard mold development on inside surfaces because the meat pieces were held together better. Again in contrast, the string on the surface of Casalingo salami appeared to elevate the local water activity and permitted fungal growth underneath, particularly yeast growth on pimaricin treatments.

Kemp et al. (15) found that there was a beneficial effect of sorbate treatment on ham acceptability. No off-flavors or off-colors were noted on any of the experimental salami used in this study, although the string on salami dipped in 10% or greater concentrations of sorbate was stained yellow. Leistner et al. (17) did not find off-colors, off-flavors, or odor when salami were treated with 20% sorbate after curing in the green room.

Ballock et al. (3) studied the mold-inhibiting properties of 2.5, 5.0, and 10% potassium sorbate solutions on fully ripened country cured hams. The sorbate was applied as a 1-min spray and was believed to be partly effective because of the removal of mold spores by the rinsing action of the spray. This action was seen during pimaricin spraying of Genoa and Casalingo salami and may also explain the success of the pimaricin spray over the dip. Ballock et al. (3) found that a spray of 5% sorbate was the lowest effective concentration which prevented mold development over the 30-day storage period. A 10% solution was more effective, but inhibition was lost somewhere between 30 and 60 days at 21°C and 70% RH.

To improve statistical evaluation, viable mold count data for acetate-pretreated Genoa and Casalingo salami were pooled and subjected to the Neuman-Keuls test. Three statistically different (95% confidence level) groups then became evident (Fig. 3). The most efficacious treatment was 20% potassium sorbate. The second best treatment was either a 10% sorbate dip or double 1,000-ppm pimaricin spray, although visually 10% sorbate performed better on both types of salami. The 2.5% potassium sorbate dip and the untreated control were placed in the last group as not being significantly different. It should be noted that there was visible inhibition of surface mold by 2.5% sorbate but only on Casalingo salami, and this was not supported by viable count data.

Abruzzese (natural casing) samples were less affected by mold growth, but viable count data showed that 10% sorbate treatments gave results
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equivalent to those obtained after 20% sorbate treatment. This probably reflects the difficulty surface fungi face when attempting to grow on natural casings.

An examination of seven isolates from the surface of these salami samples revealed that the organisms present, which were mainly *Penicillium* species plus a strain each of *Aspergillus* and *Saccharomyces*, were typical of the fungi found on the surface of dry-cured salami (2).

In cases where original mold growth was moderate, Leistner et al. (17) found that treating sausage by dipping in 10% potassium sorbate was sufficient to protect the meat from surface mold growth for about 14 days. This concentration of sorbate with an acetate pretreatment appeared adequate for protection during the maturation of the three types of salami used in this study.

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LITERATURE CITED


