Bacteriological Survey of Fresh Pork Sausage Produced at Establishments Under Federal Inspection

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At the time of manufacture, 75% of 67 sets of finished fresh pork sausage collected in 44 plants had aerobic plate counts in the range of 500,000 or fewer/g; 88% contained 100 or fewer E. coli/g; and 75% contained 100 or fewer S. aureus/g (geometric means of 10 samples). Salmonellae were isolated from 28% of 529 samples of pork trimmings used for sausage, and from 28% of 560 finished sausage samples. Semiquantitative analysis revealed that salmonellae were at low levels; more than 80% of the salmonellae-positive samples were positive only in 25-g portions (negative in 1.0- and 0.1-g portions).

A survey was conducted to determine the bacterial levels in fresh pork sausage during preparation and as packaged for shipment from representative establishments under Federal inspection in the United States.

To produce fresh pork sausage, chilled pork trimmings are first ground to permit easy mixing with spices. The ground pork is placed in a mixer with spices where water may be added. In some establishments, a chopper (cutter) is used for grinding-mixing. To maintain the chilled condition of the mixture for proper extrusion through stuffers, some operators add water in the form of wet ice and some operators add dry ice "snow." The total added water may not exceed 3%. The mixture is transferred to a sausage-stuffer through which it is extruded into casings (natural or artificial) held over the stuffing horn of the sausage-stuffer. The strands of stuffed casings are fed into a mechanical linker which twists the casing at regular intervals into links. Skinless links are produced by means of a dispenser attached to the outlet of the stuffer which forms and deposits six links automatically on paper.

Whole-hog sausage is processed similarly, using the warm meat and fat from sows conveyed directly from the slaughter-evacinator lines. Most whole-hog sausage is prepared as rolls, by stuffing into 2-inch-diameter polyethylene casing.

MATERIALS AND METHODS

Sampling. From September 1968 to June 1969, 67 sets of samples were collected from 44 federally inspected plants producing fresh pork sausage; some operations were sampled more than once. Eight of the plants were located in the Northeast, eight in mid-Atlantic states, nine, in the South and Southeast, 13 in the West and Midwest, and six on the West Coast.

Twenty-seven of the plants produced sausage from trimmings of chilled carcasses of market hogs slaughtered and eviscerated on the premises. Ten of the plants utilized pork trimmings which arrived chilled from local off-premises sources or frozen from more distant sources. Six of the plants produced whole-hog sausage, which consists of the meat and attached fat from eviscerated sow carcasses. One plant produced both whole-hog sausage and sausage from the trimmings of market hogs.

Production line samples totalling 1,152 and finished sausage samples totalling 710 were collected and analyzed. Sets of samples were collected aseptically at the following sites when possible: (i) skin from an eviscerated carcass, (ii) interior tissue from an eviscerated carcass, (iii) pork trimmings or cuts utilized for the sausage, (iv) meat at discharge of grinders, (v) meat at discharge of mixer (some plants used a chopper for grinding-mixing), (vi) meat at discharge of stuffer, (vii) sausage at discharge link-former, (viii) spices, (ix) natural casings (if used), and (x) finished product. In most cases a set of samples included 10 samples of pork trimmings or cuts and 10 samples of the finished product. Each set of

1 A preliminary account of this work was presented at the 1971 Annual Meeting of the American Society for Microbiology, Minneapolis, Minn., 2-7 May 1971.
samples was placed promptly into a freezer or under dry ice and shipped frozen to the laboratory for analysis. Analysis was begun 2 to 4 weeks from the dates of collection.

**Laboratory methods.** Methods used for aerobic plate count (APC), *Escherichia coli*, and *Staphylococcus aureus* have been fully described (9).

Most samples were examined semiquantitatively for salmonellae. From the blended 1:10 dilution prepared for the other determinations, 250 g (equivalent to 25 g of the sample) was weighed into a sterile jar containing 2.5 ml of sterile Tergitol and 26 ml of sterile 10× lactose broth. The jar and contents were shaken thoroughly, after which 11 ml (equivalent to 1.0 g of the sample) and 1.1 ml (equivalent to 0.1 g) were transferred to sterile tubes. The jar and tubes were incubated for 24 hr at 35 C (lactose pre-enrichment). After incubation, 0.5 ml from each portion was transferred to 10 ml of tetraphionate (TT) broth of Hajna and Damon (5) and incubated for 18 to 24 hours at 35 C. Loopfuls of the TT broth were streaked onto Brilliant Green sulfa agar (BGS) and xylose-lysine-deoxycholate-agar (XLD) plates and incubated for 24 hours at 35 C. Characteristic colonies from the selective agars were transferred onto triple-sugar-iron (TSI) and lysine-iron-agar (LIA) slants and incubated for a minimum of 24 hours at 35 C. Isolates with characteristic reactions on TSI and LIA slants that grouped with *Salmonella* somatic "O" antisera and demonstrated flagellar antigens with *Salmonella* polyvalent "H" antisera were recorded as *Salmonella* species. Isolates not meeting these criteria were examined further in accordance with the procedures of Edwards and Ewing (3) until either identified or eliminated as *Salmonella* species.

Commercially dehydrated media were used and were prepared in the manner suggested by the suppliers.

**RESULTS**

The bacterial content of the pork sausage is shown in Fig. 1, 2, and 3. The APC values, plotted in Fig. 1, show that the bacterial counts of the finished fresh pork sausage were primarily dependent on the bacteriological condition of the pork trimmings. Sausage made from trimmings with APC values of 100,000/g or below contained fewer than 200,000 75% of the time, and fewer than 500,000 96.4% of the time. Sausage made from trimmings with APC values over 100,000 exceeded 200,000 87% of the time and exceeded 500,000 49% of the time.

The processing of fresh pork sausage includes no step that will kill bacteria. If the APC values and *S. aureus* content of the sausage were equal to that of the trimmings, all points in Fig. 1 and 2 would fall on the solid diagonal line. Normal sample-to-sample variation would result in these points falling in a scattered pattern above and below the line. However, in Fig. 1 only 13 of the 67 points are below the line, and in Fig. 2 only 19 of the points are below the line. This indicates that there was some contamination during the processing of trimmings into sausage in about 60% of the sample sets. One would expect some contamination in even the very best operations.

Conversely, 44 of the 67 points in Fig. 3 are below the solid diagonal line, indicating a reduction of *E. coli* in the pork sausage as compared to the pork trimmings. The addition of spices, including about 2% NaCl and 1% sugar, to ground pork lowered the water activity to 0.97. The apparent loss of *E. coli* may have been due to a deleterious effect of the depressed water activity during the 2- to 4-week pre-examination frozen storage of the sausage. Some salmonellae and, of course, staphylococci are more resistant to depressions of water activity.

Most sample sets fell within 0.75 logarithm of the solid diagonal lines in Fig. 1, 2, and 3. Those sample sets above the broken diagonal lines represented unusually high contamination which, in most cases, appeared to result from inadequately cleaned and sanitized food contact surfaces. These conditions have since been corrected in the plants concerned.

However, the set marked "A" in Fig. 1 was high because the black pepper used in the spice mixture contained 40,000,000 bacteria per g. The incorporation of approximately 4% of high-count spice mixes to low-count pork also increased the APC significantly in four other sets of samples (sets "B", Fig. 1). Additional data from plant Y samples are shown in Table 1. In sets 2 and 3 of Table 1, the high count in the spice mix raised the count in the final packaged product because the bacterial level in the pork cuts was low. On the other hand, in set 1, high levels of bacteria in the trimmings masked the adverse effect of the high-count spice.

Most fresh pork sausage processors purchased premixed spices for the product. In most cases, the spices did not add appreciably to the bacterial count of sausage. Analysis of 59 premixed spice samples collected at the plants revealed that all were negative for salmonellae, *E. coli*, and *S. aureus*; and 35 had APC values below 100,000 per g. However, 10 had APC values greater than 1,000,000 per g. These would add measurably to the bacterial level of low-count meat.

Six firms prepared their own mixes from individual spices. Among 28 samples of these
individual spices, the APC values in 8 of them exceeded 1 million per g. All five of the black pepper samples exceeded 30 million per g.

The set marked "C" in Fig. 1 was high because of the poor bacteriological quality of the casings. This, and a companion set collected in the same plant on a different date, are shown in Table 2. The trimmings had very low APC values. If the plant had used trimmings with APC values greater than 100,000 per g, the effect of the bacterial load of the casings could not have been measured.

Figure 1 shows that there was no discernible difference in the range of APC values on pork trimmings from carcasses cut on premises and from those cut off premises. Initially, the APC values of pork trimmings and finished sausage were determined at both 35 C (2 days of incubation) and 25 C (4 days of incubation). The APC values at these temperatures were consistently similar, indicating that the bacteria were predominantly mesophiles and that the pork trimmings had not been in prolonged chill storage. It was noted during plant visits that pork sausage processors recognize freshness to be essential for an acceptable product with a reasonable shelf-life. APC values at 25 C were discontinued during the latter stages of this survey.

Figure 1 also shows that the range of bacterial counts of whole-hog sausage was similar to sausage processed from trimmings, though most whole-hog sausage was processed from freshly slaughtered, warm carcasses. Apparently the flushing of processing equipment by the surge of tissue, and prompt chilling of the finished product make whole-hog sausage neither more nor less susceptible to bacterial contamination and growth. Also, samples collected at intervals during the day in whole-hog sausage plants did not vary significantly in bacterial counts. Table 1 shows that in plant Y the samples of set 3 had counts similar to those of set 2, which had been collected 4 hr earlier.

Salmonellae were isolated from 150 (28%) of 529 pork trimming samples and from 158 (28%) of 560 sausage samples. Semiquantitative analysis revealed that salmonellae, when present, were at low levels. Of the 150 salmo-

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**Fig. 1.** Influence of bacterial content of pork trimmings on that of pork sausage (aerobic plate counts at 35 C).
nellae-positive trimming samples, 121 (81%) were positive only in 25-g portions, 23 (15%) were positive in 1.0-g portions, and 6 (4%) were positive in 0.1-g portions. Of the 158 salmonellae-positive sausage samples, 133 (84%) were positive only in 25-g portions, 24 (15%) were positive in 1.0-g portions, and 1 (0.6%) was positive in the 0.1-g portion. Thus, on the average, the processing of trimmings into sausage did not lead to increased salmonellae contamination.

Samples of skin from each of 36 eviscerated carcasses in 29 plants were examined. Thin strips of the skin were cut aseptically from the shoulder of carcasses on rails. In most cases, the animals had been slaughtered and eviscerated the previous day; in every case, the carcasses were to be cut and trimmed on the day of sampling. Salmonellae were recovered from 5 of the samples; low levels of E. coli and S. aureus were isolated from 11 and 15 samples, respectively. Three of the samples had APC values of more than 10⁴/g, but the geometric mean of the APC values of the 36 skin samples was 46,000/g. This figure is in close agreement with the bacterial levels found by Dockerty et al. (2) on pork carcasses at postevisceration, prechill, and postchill steps. Samples of tissue below the skin were collected from the same carcasses and, as expected, almost all were sterile by the test methods employed. Almost invariably, pork trimmings had much higher bacterial loads than eviscerated carcasses. Thus, the bacterial counts on pork for sausage increased during cutting, trimming, and boning of the carcasses.

At the time of manufacture, 75% of the sets of fresh pork sausage samples had APC values of less than 500,000/g; 88% contained 100 or fewer E. coli/g; and 75% contained 100 or
fewer S. aureus/g (geometric means of 10 samples). Such bacterial counts are not excessive for a raw, ground-meat product which is cooked thoroughly by the consumer.

Figure 1 shows that the APC (geometric mean of 10 samples) of only 20% of the sets of sausage samples was below 100,000/g. The plants consistently producing low-count sausage not only used low-count trimmings, but also maintained excellent control of sanitary conditions, particularly in that all equipment and contact surfaces were cleaned thoroughly and treated with a sanitizing agent daily. Brooks (M.S. thesis, Univ. of Tennessee, Knoxville, 1968) demonstrated that, in a fresh pork sausage plant, thorough cleaning and pro-

**TABLE 1.** Effect of high-count spice on bacteriological quality of whole-hog pork sausage in plant Y

| Sample                           | No. of samples per set | Aerobic plate count/g |
|----------------------------------|------------------------|-----------------------|
|                                  |                        | Set 1                 | Set 2                 | Set 3                 |
| Pork cuts                        | 10                     | 600,000*              | 33,000*               | 54,000*               |
| Spice mix                        | 1                      | 3,000,000             | 8,400,000             | 8,400,000             |
| Meat plus spices, discharge grinder | 1                      | 630,000               | 200,000               | 190,000               |
| Meat plus spices, discharge mixer | 1                      | 470,000               | 155,000               | 160,000               |
| Finished packaged product        | 10                     | 540,000*              | 150,000*              | 120,000*              |

* Geometric means.
per sanitization of all meat contact surfaces reduced the count of the product from $10^7$/g to $10^4$/g and doubled the shelf-life of the sausage.

**DISCUSSION**

After manufacture, chilled storage permits bacterial growth in fresh pork sausage during distribution and retailing. Elliott and Michener (4) described the factors affecting the growth of psychrophilic bacteria in chilled foods. Miller (8) found that 7 of 11 sets of pork sausage samples representing 10 brands collected at retail outlets had initial median counts of more than $10^6$/g and that some of the sausage had counts above $10^6$/g. Miller also noted that the sausage with higher counts developed abnormal odors after 3 to 7 days of additional storage at chill temperatures.

Freezing would, of course, prevent bacterial growth and extend shelf-life. Butler (1) and Hall, et al. (6) reported that seasoned pork sausage remained stable at frozen storage as long as unseasoned ground pork because the antioxidant properties of sage suppresses the pro-oxidant effect of sodium chloride. However, freezing cannot be a substitute for good sanitation in maintaining consumer protection or attaining a quality product. Hendrickson (7) reported that rapid chilling, proper management, and clean condiments were essential in retaining the quality of pork sausage during frozen storage; that large numbers of organisms were found to be conducive to off-flavors and rancidity development; and that palatability scores of the quality were found to correlate closely with the quantity of bacteria in the sausage.

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**TABLE 2. Adverse effect of high-count casings on bacteriological quality of fresh pork sausage in plant Z**

| Sample                        | No. of samples per set | Aerobic plate count/g |
|-------------------------------|------------------------|-----------------------|
| Pork trimmings                | 10                     | 17,000*               |
| Spice mix                     | 1                      | 11,300                |
| Meat plus spices, discharge   | 1                      | 22,000                |
| Meats plus spices, discharge  | 1                      | 30,000                |
| Natural casings               | 1                      | 130,000               |
| Sausage, discharge link-formers | 1                   | 350,000               |
| Finished packaged product     | 10                     | 150,000*              |

*Geometric means.