MICROBIOLOGY AND MICROBIAL STANDARDS OF PORK AND PORK PRODUCTS

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Introduction

Pork has been used as human food for centuries. Evidence indicates hogs were domesticated for food in the Middle East about 7000 BC and arrived in the region that became the U.S. with Hernando de Soto in 1539. During the nineteenth century, the addition of salt as a preservative resulted in the popular product salt pork. The tradition of "salt pork" remains today in the form of cured products such as ham and lunchmeat, which account for about 60% of pork consumption at lunch.

Fresh pork products, however, particularly in the form of chops, are more popular at dinner, accounting for about 35% of pork consumption at that meal. An increase in consumer knowledge about food safety has been attributed to greater media coverage of food-borne illness outbreaks.

Forty percent of respondents, however, either thought food could not be made safe to eat or could not cite a way to make food safe. One-third of the respondents in a survey reported unsafe food preparation practices, including not washing their hands and cross-contaminating raw meat and other foods. Improper food handling has frequently been reported to be a leading cause of food-borne illness worldwide.

The concerns about consumer food handling point to the continuing need to produce meat products that meet high standards for microbiological as well as sensory quality.

General microbial types and loads in Pork


A variety of microorganisms, including pathogens such as Salmonella, Campylobacter, Escherichia coli, Yersinia and Listeria, and spoilage organisms such as Lactobacillus and Pseudomonas, are commonly detected on pork and other meats. Trichinella spiralis, a parasitic roundworm, has also been associated with pork products.
Rates of contamination vary widely and depend on a number of factors including area of the carcass evaluated, method of evaluation, and where in the process the evaluation is made. Hides, intestinal contents, personnel, and equipment are only a few of the numerous potential sources of contamination during pork processing.

**Common Pathogens in Pork**

*Trichinella spiralis* is a parasitic roundworm that invades the tissues of both carnivorous and omnivorous animals. Humans become infected with the organism through consumption of inadequately cooked meat containing *Trichinella* larval cysts. Once in the gastrointestinal tract, the larvae invade the bowel wall, producing symptoms such as abdominal pain, vomiting, diarrhea or constipation, and fever. As the larvae migrate into muscle tissue, symptoms such as edema, headaches, rashes, and coughing may develop.

*Trichinella* has historically been associated with pork as a result of hogs fed garbage containing animal waste materials. Rates of trichinellosis have declined substantially over time due to laws, which prohibits the use of potentially contaminated garbage as swine feed.

Despite such laws, pork was reported to be the source of trichinellosis in several incidences. Although *Salmonella* is more often associated with poultry products, the pathogen is a hazard in all meats. Provisions in the PR-HACCP rule require all meat processing plants to meet a standard for *Salmonella* rates. For pork that performance standard is 8.7% or no more than 6 *Salmonella*-positive samples in a 55-sample set (USDA-FSIS 2000). Analysis of samples collected from swine carcasses at large processing plants indicated a *Salmonella*-positive rate of 6.5%. Data generally indicate *Salmonella* is most often isolated prior to fabrication and/or refrigerated storage and decreases in *Salmonella* levels are frequently noted as carcasses proceed through processing.

*Yersinia* is a gram negative, psychrotrophic, facultative anaerobe. Although one species, *Yersinia pestis*, is responsible for plague, the most common species associated with food-borne illness is *Yersinia enterocolitica*. Yersiniosis results in acute gastroenteritis, fever, bloody diarrhea, and vomiting and has been associated with pseudoappendicitis, reactive arthritis, and other severe conditions.

*Yersinia enterocolitica* was from 6% of vacuum packaged pork samples, including both frozen and refrigerated samples. Researchers reported *Yersinia enterocolitica* in 19.8% of whole muscle, store-packaged pork samples and in 11.5% of store ground pork samples. Outbreaks of yersiniosis due to chitterlings (pork intestines) have also been reported.

*Campylobacter* is another pathogen frequently isolated from meats. Although *Campylobacter jejuni* is the most commonly isolated species in meats such as beef, the presence of *Campylobacter coli* is more frequently reported in pork. Reports says a 12.5% isolation rate of the organism in freshly slaughtered pork carcasses. *Campylobacter coli* was isolated from 5% of pork chop samples and 4.2% of pork sausage samples in a cooperative study by nine U.S. laboratorios. Although *Campylobacter* has been detected in pork products, many of the processing steps in pork production, including singeing, scalding, and chilling, are detrimental to *Campylobacter* survival.
Increased handling is often associated with increases in microbial loads in pork and other meats. Among retail pork samples from stores in cities, including store packaged whole muscle and ground products, prepackaged ground pork, and marinated whole muscle products, the highest aerobic plate and coliform counts were found in store ground samples. Pork samples from slaughter and fabrication plants, however, had higher aerobic plate and total coliform counts compared to pork from hot-boning and further processing plants.

**Controlling microorganisms on pork products and the effect on sensory properties**

1. **Temperature:**

   Although the effect of both hot and cold temperatures on microbial levels in pork products has been investigated, cold temperatures are by far the most frequent method of controlling microbial loads in meats. Chilling has been cited as a critical control point in pork processing although microbial loads have been reported to both increase and decrease during chilling. The effect of methods of chilling as well as temperature of storage on microbial loads and sensory properties of pork have been investigated. Freezing can be an effective means of reducing microbial loads/infectivity on foods.

   The thermal death time of *Trichinella spiralis* in pork to be 8 minutes at -20°C with an upper confidence level of 48 minutes. Bacterial generation time was not different between fresh and frozen/thawed samples. Although freezing was associated with only a slight darkening and loss of brightness, an interaction between muscle quality and freezing/thawing on appearance case-life of the pork was noted. While freezing thawing significantly reduced the appearance case-life of the pork regardless of muscle quality, odour was not affected by freezing/thawing treatments.

   Cryogenic chilling is another method of cooling that can affect both microbial loads and quality attributes of pork. Neither chilling in liquid nitrogen for 1 or 3 minutes nor chilling at 1°C for 24 hours were effective in reducing mesophilic bacterial loads in pork. Liquid nitrogen was most effective at reducing *Pseudomonas* spp.; reductions in *Brochothrix thermosphacta*, *Escherichia coli*, and *Salmonella typhimurium* due to liquid nitrogen treatments were also noted.

   Although color of liquid nitrogen-treated muscle was slightly darker and muscle shear values were higher for carcasses treated with liquid nitrogen for 1 minute, few significant differences in objective pork quality characteristics were found. Subjective evaluation of palatability characteristics such as initial tenderness, juiciness, and flavor desirability sensory panel indicated little difference in all characteristics except sour off flavors that were higher in liquid nitrogen-treated carcasses from pigs with high glycolytic rates. Lower storage temperatures are typically associated with lower microbial growth.

   Pork samples stored above 0°C had shelf life of 14 to 28 days while those stored at -4°C had minimal changes in microbial and quality characteristics through 49 days. Pork stored at 7°C was consistently rated lower for overall appearance and had increased exudates, green discoloration, and off odors compared to samples stored at -4, 0, or 3°C.

2. **Washing and Sanitizing**

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Washing and sanitizing are some of the most commonly used methods for reducing microbial loads on pork and other meats. Water was compared to several combination treatments as a decontamination method on lean and fat-covered pork tissue.

Reductions in coliform levels of $1.46 \log_{10} \text{cfu/ cm}^2$ (15 seconds) to $2.52 \log_{10} \text{cfu/ cm}^2$ (180 seconds) were noted when $15^\circ C$ water was used to wash lean tissue contaminated with feces. Water plus lactic acid and three treatments using combinations of water, hot water, hot air, and lactic acid were more effective than water alone at reducing levels of aerobic bacteria, coliforms, *Escherichia coli*, lactic acid bacteria, and psychrotrophic bacteria.

Combination treatments were associated with a decrease in redness and an increase in yellowness. Ground pork samples treated with water plus lactic acid were reported to be dark red with a mushy appearance. The use of acids as decontaminating agents has also been investigated. Spraying 1% lactic acid at $55^\circ C$ onto pork carcasses immediately after dehairing, after evisceration, and at both points in the processing lower the mean total aerobic counts. Overall appearance, lean color, fat color, surface discoloration, and off odor did not differ between treated and untreated samples. Hot ($55^\circ C$) lactic acid solutions were more consistently effective in reducing *Salmonella typhimurium* contamination on pork carcasses than were cold solutions.

Pork chops were dipped into 1% acetic acid, 1% acetic acid/1% lactic acid, 1.5% acetic acid/l.5% sodium acetate, 3% acetic acid/3% sodium ascorbate, 3% acetic acid/2% sodium chloride (NaCl) or sterile, distilled water and subsequently vacuum packaged and stored at 2 to $4^\circ C$ for 6 weeks. All samples except those containing 3% acetic acid had microbial loads of $10^7$ to $10^9$ cfu/cm$^2$ after 3 weeks storage and were considered spoiled. Samples treated with solutions containing 3% acetic acid had lower mesophilic and psychrotrophic counts than all other samples throughout the evaluation period. Acetic acid, however, were effective at reducing *Enterobacteriaceae* levels.

Acetic and citric acids were associated with a decrease in total aerobic plate and coliform counts during the first 14 days of storage at 2 to $4^\circ C$ and all acid-treated samples had lower total aerobic plate counts compared to controls at 42 days storage. Off odors were detected at day 5 for citric acid, day 7 for acetic acid, and day 14 for lactic acid, and all samples exhibited undesirable off odors by day 35. Surface color of chops changed from red 1 day after cutting to gray-pink 8 to 12 days after cutting. Color, however, as well as other sensory characteristics were not different between treatments.

3. Added Substances

Pork longissimus muscle marinated with a combination of citric acid and sodium pyrophosphate had lower total aerobic plate counts at 14 and 21 days when stored at $4^\circ C$ compared to those marinated with either sodium tripolyphosphate or sodium acid pyrophosphate. The lower pH in pork from the citric acid treatment, however, was associated with lower juiciness, tenderness, and palatability compared with muscle from the higher pH treatments. Another phosphate compound, trisodium phosphate (TSP), has been reported to be an effective antimicrobial agent in beef and poultry, but results have been less consistent in pork.
No improvements in mean aerobic plate counts were found when pork carcasses and loins were dipped in, sprayed with, or scalded with TSP solutions. The addition of 2 to 3% sodium or potassium lactate has been reported to reduce total aerobic plate counts and extend refrigerated shelf life of pork products by 12 to 14 days. The delay in microbial deterioration was associated with a delay in sour and off-flavor development.

Protection of red colors and enhancement of juiciness and pork flavor has been consistently reported. Protection of fat color (white) during chub storage and fat stability with the addition of lactates have also been reported. Enhanced salty flavors was found in fresh pork sausage containing sodium lactate, but the salty flavor of sodium was less intense from sodium lactate than from sodium chloride.

**Irradiation**

Irradiation treatment of pork and other meats as a means of microbial reduction was found safe by the USDA in 1997 (USDA-FSIS 1999). The final rule approving irradiation of meats was issued in 2000. The PR-HACCP rules require irradiation be done in accordance with an established HACCP plan with irradiation being designated as a critical control point.

An absorbed dose of 1.9 1KGY or higher was necessary to reduce microbial loads in vacuum-packaged fresh pork to undetectable levels. The levels of mesophiles, psychrotrophs, and anaerobes/facultative anaerobes were reduced by a 1-Kgy irradiation treatment. An irradiation dose of 1.75 KGY reduced microbial loads of 10^6 cell/g by 1 to 5 logs depending on the microbial species. Of the pathogens studied, *Clostridium perfringens* was the most resistant and *Yersinia enterocolitica* the least resistant to irradiation. Microflora in irradiated samples was primarily gram positive immediately after treatment. *Lactobacillus* and coryneforms predominated after 9 and 12 days of storage at 5°C. *Staphylococcus*, *Micrococcus*, and yeasts were also detected in fresh pork irradiated with 0.57 KGY. In contrast to studies with poultry, only limited effects on sensory properties of pork due to irradiation have been reported. Short-term irradiation affects on pork sensory properties 24 hours after treatment, a distinct “irradiation odor” in pork chops.

**4. High Pressure Processing**

High-pressure processing has received increased attention in recent years as a food preservation method. The application of high pressure causes volume changes in the food or its constituent parts, resulting in protein denaturation, textural alterations, gelation, greater flavor and color retention, and enzyme modifications. High-pressure processing can also effectively reduce microbial loads, but the results depend on many factors including amount of pressure applied, type of microorganism, presence of spores, temperature, and water activity. Although hydrodynamic pressure was associated with a decrease in numbers of *Trichinella spiralis* recovered from pork, infectivity of the larvae was not eliminated by the treatment. *Psychrotrophs* reached 5.71 log_{10} cfu/g after 33 days storage at 4°C in pork loin treated with pressure at 25°C compared to 7.0 log_{10} cfu/g in untreated loins.

Mesophiles exceeded 6.0 log_{10} cfu/g in both untreated and pressure-treated samples after 3 days when stored aerobically at 25°C and all samples were considered spoiled after 5 days storage at 25°C. A 10 log_{10} reduction was noticed in a resistant strain of *Listeria monocytogenes*.
in ground pork patties treated with 414 MPa at 50°C for 6 minutes. The addition of the mild heat to the pressure treatment reduced the D value ranges from 1.89 to 4.17 minutes to 0.37 to 0.63 minutes. Treated samples had a shelf life of 28 days compared to 5 days for control patties when stored at 4°C.

The use of high-pressure processing to reduce microbial loads may also result in changes in pork quality characteristics. Sensory panelists, however, could not distinguish between high-pressure plus heat treated pork patties and controls after grilling. No differences in flavor, juiciness, firmness, color, texture, water-holding capacity, and moisture between pressure treated (25°C) and control samples when the pork loins were cooked.

5. Packaging Material and Environments

Packaging materials and environments can have significant affects on both microbiological and sensory qualities of pork products. Comparison on the effects of parchment wrapping versus vacuum packaging on quality characteristics of fresh pork loins that had been either hot or conventionally processed. Few differences in processing/packaging treatments were noted during storage at 2°C until day 14 when vacuum-packaged loins exhibited both lower total plate counts and lower off odor scores.

Vacuum-packaged pork loins had less surface discoloration than parchment wrapped loins at days 7 and 14. Higher surface discoloration was also associated with parchment wrapping. Fresh pork loins were first stored unwrapped, wrapped in parchment, or vacuum packaged. Chops cut from each type of stored loin were then displayed wrapped in either oxygen-permeable or high oxygen barrier film. Lean color scores differed little, but overall appearance was lower in chops from parchment-wrapped and vacuum-packaged loins compared to unwrapped loins. Chops from unwrapped loins also had less off odors and cooked off odors. Microflora of chops displayed in high-oxygen barrier wrap was primarily Lactobacillus and Micrococcus spp. while Pseudomonas spp. predominated in chops displayed in oxygen permeable wrap.

Although microbial loads for chops from unwrapped loins were also 10^7 to 10^8 cfu/cm^2 at 6 to 10 days storage, lower off odor scores were apparently due to a shorter exposure time to high microbial loads. Modification of the atmosphere within packaged pork products has also been investigated. One of the most common gases used in such modifications is CO₂. Lactic acid bacteria were only detected in pork loin stored under CO₂ at -1.5°C through 24 weeks, with a maximum of 10^7 cfu/cm^2 at 9 weeks. Lactic acid bacteria and pseudomonads were the primary spoilage organisms detected during retail display of the loins. Although lactic acid bacteria dominated the microflora of both vacuum-packaged pork and pork stored under CO₂ at 3°C, spoilage was attributed to a substantial increase by Brochothrix thermosphacta.

On comparison of laboratory and commercial bulk packaging systems for pork using a 100% CO₂ atmosphere followed by aerobic retail display, the initial total microbial loads at day 0 of retail display were about 4 log₁₀ cfu/cm² for all CO₂ bulk storage times.
Counts increased as display time increased, reaching an unacceptable level of greater than 7 \( \log_{10} \text{ cfu/cm}^2 \) after 5 days of retail display. Anaerobic, lactic acid bacteria, and pseudomonad counts followed similar trends. Color of all samples are evaluated as pale to normal throughout bulk storage and retail display. The fresh meat odor was observed in all samples after 14 days storage under CO\(_2\). Odor became increasingly unacceptable, however, as retail display progressed. The presence of environmental oxygen can have significant effects on both microbiological and quality characteristics of pork.

Presence of residual oxygen in the packaging atmosphere has generally been associated with lighter, less red, and more yellow pork compared to oxygen-free atmospheres. Increased discoloration was also detected as the oxygen level increased in the storage atmosphere.

Although strong off odors were associated with the presence of oxygen immediately after treatment, those odors weakened during storage. Microflora after modified atmosphere storage is often lactic acid bacteria, and few differences are generally reported regardless of whether or not oxygen is present. Controlled atmospheres using combinations of CO\(_2\), O\(_2\) and N\(_2\) have also been studied. The presence of O\(_2\) has been associated with a greater increase in psychrotrophs compared to environments containing CO\(_2\) or CO\(_2\) and N\(_2\) at storage temperatures of both 2 and 5\(^\circ\)C. Pseudomonas accounted for as much as 60\% of microbial loads in the samples. Although the 100\% CO\(_2\) environment resulted in the greatest extension based on sensory results, combinations containing mixtures of CO, and N\(_2\) were reported to be best for extending overall shelf life of the pork chops.

**Conclusion:**

Reducing the microbial contamination of pork and other meats continues to be a challenge for the food industry. The presence of pathogens on pork can be a significant safety risk, particularly in light of the many reports of improper handling of meat by consumers. Growth of both pathogens and spoilage organisms on meat can also have a significant impact on organoleptic properties of pork and other meats and contribute to food waste. Methods used to reduce microbial loads on meats can also have significant impacts on texture, juiciness, appearance, odor, and other sensory properties. Research into newer technologies such as high-pressure processing may provide improved ways to produce pork products that are microbiologically stable and organoleptically acceptable.
### General Microbiological Standards as prescribed by Bureau of Indian Standards (BIS, 1995)

<table>
<thead>
<tr>
<th>Organisms</th>
<th>Fresh Meat</th>
<th></th>
<th>Chilled Meat</th>
<th></th>
<th>Frozen Meat</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
<td>M</td>
<td>c</td>
<td>n</td>
<td>M</td>
</tr>
<tr>
<td>Aerobic plate count/g</td>
<td>5</td>
<td>1x10⁶</td>
<td>5x10⁶</td>
<td>3</td>
<td>1x10⁵</td>
<td>5x10⁵</td>
</tr>
<tr>
<td>E. coli/g</td>
<td>5</td>
<td>5x10¹</td>
<td>5x10²</td>
<td>2</td>
<td>1x10¹</td>
<td>1x10²</td>
</tr>
<tr>
<td>Salmonella in 50g</td>
<td>5</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S. aureus/g</td>
<td>5</td>
<td>1x10⁷</td>
<td>1x10²</td>
<td>2</td>
<td>1x10²</td>
<td>1x10³</td>
</tr>
<tr>
<td>Yeast &amp; mould/g</td>
<td>5</td>
<td>1x10⁴</td>
<td>5x10⁴</td>
<td>2</td>
<td>1x10¹</td>
<td>1x10²</td>
</tr>
</tbody>
</table>

Where,

- $n$ = number of samples to be tested
- $m$ = maximum permissible number of relevant bacteria. The values above this are marginally acceptable or unacceptable
- $c$ = maximum allowable number of sample units having microbiological counts between $m$ and $M$.
- $M$ = level at or above which the lot has to be rejected.