RESEARCH REPORT
PORK SAFETY

NATIONAL PORK RETAIL MICROBIOLOGICAL BASELINE

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Introduction

Several studies have either been completed or are currently in progress to determine the presence of indicator and/or pathogenic microorganisms on pork carcasses. These investigations have increased understanding of the numbers and species of microorganisms that may be found on the carcass due to cross-contamination or poor handling/processing practices. Most studies have concentrated on the carcass; however, pork can subsequently be re-contaminated with bacteria during fabrication, packaging, distribution and retail preparation and, therefore, more information on contamination levels and pathogen incidence must be gathered. This information can be helpful in the development and revision of HACCP plans in order to improve process control.

The data obtained from this study will be used as part of a microbial baseline to facilitate risk assessment and decision-making at various levels of the food safety chain. By sampling the final, finished goods, which are the products closest to the consumer and are affected by the sum of all processes and handling before the actual purchase of pork by consumers, the hazards associated with pork products can be evaluated and the potential to prevent, reduce and possibly eliminate biological hazards in the food chain can be determined. Pathogens such as *Salmonella* spp., *Campylobacter* spp. and *Escherichia coli* O157:H7, while not increasing in overall incidence, have become greater public health concerns. The beef industry has had to endure a negative "label" associated with ground beef due to *E. coli* O157:H7 foodborne outbreaks and, recently, the pork industry has encountered similar media attention due to *L. monocytogenes* outbreaks in ready-to-eat products. In 1998, there was an increased number of reported cases of illness due *Listeria monocytogenes* which CDC, as well as state and local health departments, attributed to the consumption of cooked hot dogs and deli meats (FSIS, 1999). The pork industry needs to take steps to prevent the occurrence of such unfortunate and potentially devastating events.

Objectives

Phase I of this study was designed to determine the microbiological counts and relevant pathogen incidence in freshly-ground pork and /or freshly-ground pork sausage products generated from three different types of U.S. pork processing plants. Phase II of the study compared microbiological counts and pathogen incidence in (a) freshly-ground pork and/or pork sausage, (b) fresh, store-packaged whole-muscle cuts, (c) pre-packaged ground pork and/or pork sausage and (d) whole-muscle, enhanced (injected) pork cuts in a retail environment. The project objectives were as follows:

(I) To determine Aerobic Plate Counts, Total Coliform Counts, *Escherichia coli* Counts and the incidence (presence/absence) of *Salmonella* spp., *Listeria* spp., *Listeria monocytogenes*, *Yersinia* spp., *Yersinia enterocolitica* and *Campylobacter jejuni/coli* on (a) whole-muscle store-packaged pork retail cuts, (b) fresh , store-ground pork and pork sausage, (c) pre-packaged (at the processing plant) ground pork and/or pork sausage, and (d) whole-muscle, enhanced (injected) pork cuts. Samples were collected in six continental U.S. cities (Los Angeles, Denver, Dallas, Sioux Falls, Memphis and Baltimore).

(II) To compare Aerobic Plate Counts, Total Coliform Counts, *E. coli* Counts and the incidence (presence/absence) of *Salmonella* spp., *Listeria* spp*., L. monocytogenes, Yersinia spp., Yersinia enterocolitica and C. jejuni/coli* in pre-packaged ground pork and/or pork sausage with those in store-packaged ground pork and/or pork sausage.

(III) To determine Aerobic Plate Counts, Total Coliform Counts, *E. coli* Counts and the incidence (presence/absence) of *Salmonella* spp., *Listeria* spp., *L. monocytogenes*, *Yersinia* spp., *Y. enterocolitica* and *C. jejuni/coli* in freshly ground pork and/or fresh pork sausage products processed in three types of processing plants (hot-boned sow/boar sausage plants, slaughter/fabrication plants and further processing plants).

(IV) To characterize and detect *E. coli* non-O157 VTEC (verotoxigenic) bacteria in retail pork products to ascertain if a potential foodborne illness problem exists. Verocytotoxin-producing *E. coli* (VTEC) of serotype O157:H7 have been implicated in several foodborne outbreaks; however, it is becoming more evident that other serotypes of VTEC also can be associated with human foodborne illness (Johnson et al., 1996).

Materials and Methods

Phase I: Sample Collection

In Phase I of this study, six processing facilities located in six different cities of the continental United States allowed Colorado State University scientists to collect twenty samples of freshly-ground pork and/or freshly-ground pork sausage from each facility during a two-day period in each plant. The pork processing facilities included two hot-boning sow/boar sausage plants, two fed pig slaughter/fabrication plants and two further- processing plants. From the slaughter/fabrication plants and the further-processing plants, samples of approximately 300g of ground pork and/or pork sausage were collected (aseptically after final grinding) with sterile gloves and placed into sterile bags (Whirl-Pak ®, Nasco, Ft Atkinson, WI). Samples from the hot-boned sow/boar sausage plants consisted of 454g chubs. It was not possible to sample directly after final grinding in the sow/boar plants due to the direct automated transport of product into the packaging system. Sausage samples contained pork, water and spices. Samples did not contain "anti-microbial" ingredients other than added salt. All samples were placed immediately into pre-chilled containers containing commercial ice substitutes and a temperature-recording device and were transported to IDEXX Food Safety Net Laboratory (San Antonio, TX) for microbiological testing. Figure 1 illustrates the experimental design of Phase I.

Phase II: Sample Collection

In Phase II of the study, 384 samples of retail pork products, wrapped for sale and displayed in the retail merchandising case, were collected from four retail stores in each of six continental U.S. cities (Los Angeles, Denver, Dallas, Memphis, Sioux Falls and Baltimore; 24 stores total). Pork products that were sampled included (a) whole-muscle, store-packaged (tray and polyvinyl chloride overwrap) pork retail cuts, (b) fresh, store-ground pork and/or pork sausage (paper-wrapped or tray and polyvinyl chloride overwrap), (c) pre-packaged (at the processing plant) ground pork and/or pork sausage and (d) whole-muscle, enhanced (injected with a brine solution; pre-packaged under vacuum or store-packaged in trays wrapped with polyvinyl chloride overwrap) pork cuts. No samples were cured or had any added anti-microbial ingredients other than salt. Sixteen samples of the retail pork products listed above (four samples of each type of product) were collected from the four stores in each city over a two-day period. Immediately following purchase, retail pork samples were placed in a container containing commercial ice substitutes. Purchased retail pork samples were transported, within five hours of purchase, in their intact retail packaging and in pre-chilled containers containing commercial ice substitutes and a temperature-recording device, by overnight delivery to IDEXX Food Safety Net Laboratory (San Antonio, TX) for microbiological testing. Figure 2 illustrates the experimental design of Phase II.

Laboratory Procedures

Upon arrival at IDEXX Food Safety Net Laboratory, (San Antonio, TX), samples were monitored for temperature abuse (>5.6°C). Temperature-abused samples would not have been used for analyses; however, in this study, none of the samples suffered from temperature abuse.

Both plant and retail samples were analyzed for the presence of *Salmonella* spp., *Listeria* spp*., L. monocytogenes, Campylobacter jejuni/coli*, *Yersinia* spp. and *Y. enterocolitica*. Presence of

Salmonella spp., *Listeria* spp., *L. monocytogenes* and *C. jejuni/coli* was determined using procedures recommended in the USDA-FSIS Microbiology Laboratory Guidebook, Volume 1 and 2 (USDA-FSIS, 1998) and the presence of *Yersinia* spp. and *Y. enterocolitica* was determined using procedures recommended in the Compendium of Methods for the Microbiological Examination of Foods (Sheimann et al., 1992). Additionally, Aerobic Plate Counts (APC), Total Coliform Counts (TCC) and *E. coli* Counts (ECC) were determined using Petrifilm™ (3M™ Microbiology Products, St. Paul, MN) and Butterfield's phosphate buffer (Difco Laboratories, Detroit, MI) to make serial dilutions before plating. Petrifilm™ Aerobic Count Plates for quantifying APC were incubated for 48 h at 35°C, and colonies were counted manually. Following incubation for 48 h at 35°C, coliform colonies both non-*E. coli* and *E. coli* (red and blue colonies associated with a gas bubble) growing on Petrifilm™ *E. coli* Count Plates were counted manually as well as *E. coli* colonies (dark blue colonies associated with a gas bubble).

Fifty *E. coli* isolates (including both sorbitol negative and sorbitol positive isolates) obtained from fifty different pork samples, including both retail and plant samples across all cities and plant types, were tested for the production of verotoxins (VTs) – also known as Shiga-like toxins (SLTs) – using an in vitro microwell enzyme immunoassay. Isolates that were positive for verotoxins were then identified by biochemical characterization and serotyping. Verotoxin testing was completed using the Premier Enterohemorrhagic *E. coli* test (Meridian Diagnostics, Inc., Cincinnati, OH). Methodology for this test is presented in Appendix I.

Microbiological plate count data were transformed into logarithms before computing means and performing statistical analyses. All microbiological counts were reported as log CFU/g. Data were analyzed using analysis of variance (ANOVA) and the general linear model procedures of SAS® (SAS®, 1995). Least square means were separated using a pairwise t-test of SAS® (SAS®, 1995). All statistically significant differences were reported at the $P < 0.05$ level of Type I error.

Results

Microbiological Plate Counts for Ground Pork Samples Collected in Three Types of Processing Facilities

Mean APC, TCC and ECC (log CFU/g) in freshly ground pork and/or pork sausage samples produced in three types of plants (hot-boned sow/boar sausage plants, slaughter/fabrication plants, further processing plants) are provided in Table 1. Differences in mean APC among the three types of plants were less than 0.5 log CFU/g but mean APC and TCC were higher ($P < 0.05$) for samples collected from the slaughter/fabrication plants than for samples collected from the other types of plants (which did not differ from each other). Mean ECC were lower ($P < .05$) for samples obtained from the further processing plants compared to ECC for the other two types of plants. It appears that, overall, further processing plants generated product containing less fecal contamination than did the other types of plants and that, overall, products from slaughter/fabrication plants contained the greatest amounts of contamination even though these differences were not large.

Fresh, ground pork was sampled at only two of the six plants. The remainder of the freshly-ground samples collected in the plant consisted of freshly-ground pork sausage. Only three of the six plants produced a ground pork product. The third plant that ordinarily produced ground pork was not processing this product at the time of sampling. At each of the plants producing ground pork, equal samples of freshly ground pork ($n = 10$) and freshly ground pork sausage were obtained ($n = 10$) over the two days of sample collection. Freshly-ground pork sausage contained pork, water, spices and salt. Ten of the sausage samples also contained sodium lactate. Some of these sausage ingredients, such as salt and sodium lactate, can be anti-microbial. Mean values (log CFU/g) for APC, TCC and ECC are presented in Table 2. Freshly ground pork had higher mean APC (log CFU/g) than did pork sausage, but the two types of product did not differ in TCC and ECC (log CFU/g). Clearly, some sausage ingredients had an anti-microbial effect on the product because of the impact that they had on APC.

Microbiological Plate Counts for Retail Pork

Mean values (log CFU/g) for APC, TCC and ECC across all six cities and for each of the four types of retail pork products are presented in Table 1. For pork samples collected at retail supermarket stores, mean APC and TCC (log CFU/g) were highest ($P < .05$) for ground pork that was processed and packaged in the store, followed by the APC and TCC for whole-muscle product packaged in the store. Whole-muscle enhanced (injected/marinated) products and pre-packaged (at the processing plant, before distribution to the retail store) ground pork and/or pork sausage had the lowest ($P < .05$) APC, but did not differ from each other. In addition to having the highest mean APC and TCC of the samples collected from retail stores, store-ground pork and/or pork sausage also generated mean ECC (log CFU/g) values that were higher than mean ECC for the other samples collected from retail stores. Other types of retail pork products did not differ ($P > .05$) in ECC from each other.

Differences reported in this study between the four pork retail products may have resulted from a combination of causative factors. Store-ground pork and/or pork sausage and whole muscle pork products cut and packaged in the stores had higher levels of microbial contamination in comparison to products packaged before distribution to the store. Store-packaged pork samples were possibly exposed to greater amounts of handling and to more equipment, thus contributing to increased exposure to environmental contamination and cross-contamination. Of the whole-muscle enhanced pork samples, 60 percent were store-packaged and 40 percent were pre-packaged at the processing plant of origin. In contrast, the non-injected whole muscle cuts were all store-packaged and, thus were exposed to more handling and contamination. Lower mean APC, TCC and ECC for whole-muscle enhanced products compared to counts for the non-enhanced products also may have been due to possible anti-microbial effects of the enhancing (injection) solutions. Some studies have indicated that pumping solutions containing sodium lactate can be effective in reducing total bacterial counts in food products (Scannell et al., 1997).

Significant differences in APC, TCC and ECC were apparent between store-ground pork and/or pork sausage and pre-packaged ground pork and/or pork sausage. The mean values for store-ground pork APC exceeded the mean values for pre-packaged product by over 2 log CFU/g. In addition, there was greater than one log CFU/g difference in TCC mean values between these products. Clearly, high levels of contamination occurred in the retail stores involved in this study. Some possible explanations for these high levels of contamination included improper cleaning and sanitizing of equipment and poor employee hygiene within the store. It appeared that many stores lacked appropriate good manufacturing practices (e.g., keeping the walls, floors and work areas clean during processing).

Pathogen Incidence for Ground Pork Samples Collected in Three Types of Processing Facilities

Incidence (presence or absence) of pathogens in samples of ground pork and/or pork sausage obtained from three different types of plants is presented in Table 3. The most common pathogen detected in samples collected from plants was *Listeria monocytogenes*, with an overall incidence of 26.7 percent. The overall incidence of *Yersinia enterocolitica* in plant samples (3.3%) was much lower than that detected in whole-muscle and ground products prepared and packaged in retail grocery stores (incidences of 19.8% and 11.5 %, respectively; Table 4). Contamination with *Yersinia enterocolitica* appeared to occur after the product left the plant, during further processing and in retail stores.

The incidence of pathogens in the samples of freshly-ground pork and freshly-ground pork sausage, across two plants, are shown in Table 5. Only non-pathogenic species were detected. There was a lower incidence (5%) of *Listeria* spp. and *Yersinia* spp. in the fresh ground pork samples than in the freshly-ground pork sausage samples (20%).

Pathogen Incidence for Retail Pork

Incidence (presence or absence) of pathogens contained in pork retail samples are presented in Table 4. Only minimal differences existed in the low incidence of *Salmonella* spp. and *C. jejuni/coli*

between product types. Overall, *C. jejuni/coli,* with an incidence of 1.3 percent across all types of retail products sampled, was the least frequent pathogen found on retail pork samples.

As shown in Table 4, there was a high incidence of *Listeria* spp. (pathogenic and non-pathogenic species) in retail pork samples with an overall incidence of 41.9 percent across all retail products sampled. *Listeria monocytogenes* was the most prevalent pathogen found in retail pork samples (19.8%) and was present more frequently in ground product (store-ground and pre-packaged ground pork) than in whole-muscle products (whole muscle, store-packaged and whole muscle enhanced). *Listeria monocytogenes* is known to have the ability to attach to different surfaces, such as stainless steel, glass and rubber (Herald and Zottola, 1988). Furthermore, *Listeria monocytogenes* can form a biofilm on these surfaces that can be resistant to various sanitizers (Frank et al., 1990). The ground pork product samples in this study may have been contaminated from improperly cleaned grinding and processing equipment. Proper efforts need to be made to ensure that grinding and mixing equipment used in the production of ground pork or sausage is cleaned correctly before each use.

Yersina spp. (non-pathogenic plus pathogenic) were detected more often in products that had been handled and further processed in the retail store. *Yersinia enterocolitica* was detected most often in whole-muscle, store-packaged cuts (19.8%) and second most often in store ground product (11.5%) in comparison to whole-muscle enhanced products (5.2%) or pre-packaged ground product (1.0%). In each case, whole or ground, the products that were pre-packaged at the processing facility before distribution had a lower incidence of *Yersinia* spp. and *Y. enterocolitica*. Appropriate and effective sanitation standard operating procedures need to be implemented in the retail processing facilities to reduce this contamination.

Verotoxin Production

None of the fifty *E. coli* isolates, collected from all regions and from each of the products, tested positive for verotoxins. These results were not surprising due to the low prevalence of VTEC

(verocytotoxin-producing *E. coli*) in pigs. In a survey completed in Germany, VTEC were isolated from 7.5% of pigs as compared to 66.6% of sheep and 21.1% of cattle (Beutin et al., 1993). The source of VTEC contamination on meat is from the soiling of the carcass and the plant environment with fecal material during processing (Johnson et al., 1996). Ruminants have a higher incidence of VTEC in their feces; so, meat from ruminants are more likely to be contaminated with VTEC than is meat from non-ruminants. Even though VTEC was not detected in the samples obtained in this study, continuing efforts need to be made to detect and characterize non-0157:H7 *E. coli* in order to prevent potential outbreaks of foodborne illness.

Summary

Pork products exposed to more extensive handling and processing (e.g., products processed at the retail store or products that are ground) appeared in this study to have lower microbiological quality. The microbiological plate counts and pathogen incidences were higher for more extensively handled/processed products. *Listeria monocytogenes*, the most common pathogen found in retail pork samples, was present more frequently in ground product and *Y. enterocolitica* was detected more often in store-handled product (whole muscle, store-packaged and store-ground pork product). There were only minimal differences in the incidence of *Salmonella* spp. and *C. jejuni/coli* between pork retail products which were low overall across all retail products.

Contamination of freshly-ground pork and/or pork sausage samples collected at the plants appeared generally to be lower in further processing plants, while the samples collected from slaughter/fabrication plants had more contamination. *L. monocytogenes* was the most common pathogen detected in samples collected from plants. *Y. enterocolitica* was detected much less frequently in these plant samples than in store ground products.

Good Manufacturing Practices and Sanitation Standard Operating Procedures are keys to reducing microbiological contamination in pork products. Most retail stores do not have quality assurance programs, as evident in the higher microbiological contamination in store processed and packaged products. It is likely that development of retail HACCP plans would be beneficial to ensure the safety of pork products. Furthermore, supermarket operations should take a closer look at how completely they are cleaning and sanitizing grinding equipment. Further studies would be warranted to identify means for more completely removing bacterial contamination from equipment in both processing plants and retail stores.

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APPENDIX I

Premier Enterohemmorhagic *E. coli* Test Procedures

Meridian Diagnostics, Inc., 1995

(Cincinatti, OH)

MATERIALS PROVIDED

1. **Antibody Coated Microwells (96) – Plastic wells coated with monoclonal antibody specific for *E. coli* Shiga-like toxin I and II.**
2. **Positive Control (3.4ml) – Inactivated Shiga-like toxin in a buffered protein solution with preservative.**
3. Negative Control (3.4ml) – Buffered solution with a preservative
4. Sample Diluent (18.8ml) – Buffered Protein solution with a preservative
5. 20X Wash Buffer (100ml) – Concentrated wash buffer with a preservative
6. Detection Antibody (10.0ml) – Rabbit antibodies specific for Shiga-like toxins in buffered protein solution containing preservative.
7. Enzyme Conjugate (10.0ml) – Goat anti-rabbit antibody conjugated to horseradish peroxidase in buffered protein solution containing preservative.
8. Substrate (10.0ml) – Buffered solution containing urea peroxide.
9. Stop Solution (10.0ml) – 2N Sulfuric Acid.
10. Transfer pipets (96)
11. Microwell strip holder
12. Microwell strip sealer

MATERIALS NOT PROVIDED

1. Wooden applicator sticks
2. Pipet capable of delivering 200µl
3. Test tubes (12 x 75mm) for dilution of sample
4. Distilled or deionized water
5. Squirt bottle
6. Graduated cylinder for making 1X wash buffer
7. EIA plate reader capable of reading absorbance of 450 or 450/630nm.

REAGENT PREPARATION

1. Bring the entire kit, including microwell pouch, to room temperature before use.
2. Prepare 1X wash buffer as needed.
   For example: 4.0ml of 20X Wash Buffer + 76.0ml of distilled or deionized water is sufficient to wash one strip. Place in a clean squirt bottle. The 1X wash buffer can be stored at room temperature for up to three months.

PROCEDURE

1. After the pouch has reached temperature, break off the required number of microwells (one well for each specimen plus one positive and negative control well per batch). Place the microwells in the microwell strip holder and record the location of all wells.
2. Add 100µl of diluted specimen (second mark from the tip of the pipet) to the appropriate well (place pipet tip halfway into well and let sample slowly run down the side of well).
3. Add two free-falling drops of Positive and Negative Control to the appropriate wells. Mix wells by firmly shaking/swirling the plate for 30 seconds.
4. Cut plate sealer to size and press firmly onto top of microwells to seal. Incubate the plate for 1 hour at room temperature (22^{o}-27^{o}C).
5. Carefully, remove the plate sealer and wash wells
   a. Dump plate contents firmly into a biohazard receptacle.
   b. Bang the inverted plate on a clean stack of paper towels.
   c. Fill all wells with 1X Wash Buffer.
   d. Repeat washing cycle (dump, bang on fresh towells, fill) four additional times. After the last fill, dump and bang plates on fresh towels hard enough to remove as much excess Wash Buffer as possible but do not allow wells to completely dry at any time.
6. Add two free-falling drops of Detection Antibody to each well. Firmly shake/swirl the plate for 30 seconds.
7. Press plate sealer firmly onto top of microwells to seal. Incubate the plate for 30 minutes at room temperature (22^{o}-27^{o}C).
8. Repeat wash procedure (Step #5)
9. Add two free-falling drops of Enzyme Conjugate to each well. Firmly shake/swirl the plate for 30 seconds.
10. Press plate sealer firmly onto top of microwells to seal. Incubate the plate for 30 min at room temperature (22^{o}-27^{o}C).
11. Repeat wash procedure (Step #5).
12. Clean the underside of all wells with a lint free tissue.
13. Add two free-falling drops of Substrate Solution to each well. Firmly shake/swirl the plate for 30 seconds. Incubate for 10 minutes at room temperature.
14. Add two free-falling drops of Stop Solution to each well. Firmly shake/swirl the plate for 30 sec.
15. Observe Reactions:
    a. Visual Determination – Read within 15 minutes after adding Stop Solution
    b. Spectrophotometric Determination – Zero EIA reader on air. Wipe underside of wells with a lint free tissue. Read absorbance at 450nm or 450/630nm within 30 minutes of adding Stop Solution.

INTERPRETATION OF RESULTS

1. Visual Reading
   Negative = colorless
   Positive = definite yellow color
   A faint yellow color must be evaluated spectrophotometrically

2. Spectrophotometric Single Wavelength (450nm)
   Negative = $OD_{450} < 0.180$

Positive = $OD_{450} \geq 0.180$

3. Spectrophotometric Dual Wavelength (450/630nm)
   Negative = $OD_{450/630} < 0.150$
   Positive = $OD_{450/630} \geq 0.150$

Figure 1. Experimental Design of Phase I -- 120 samples of freshly-ground pork and/or pork sausage were collected over 2 days from 6 processing facilities of three different types.

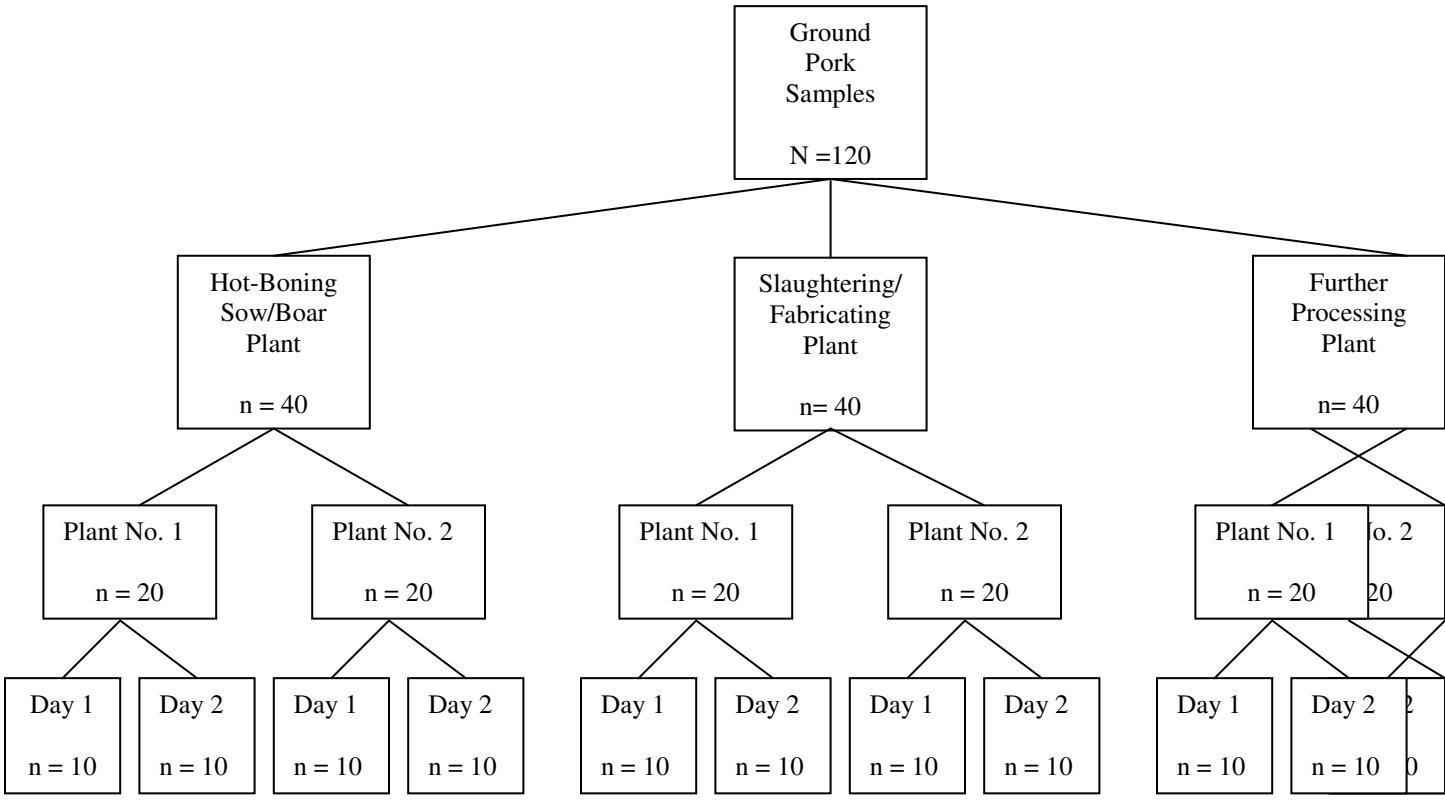

Figure 2. Experimental Design of Phase II -- 384 samples of retail pork products (4 types) were collected from 4 retail stores over 2 days in each of six continental U.S. cities.

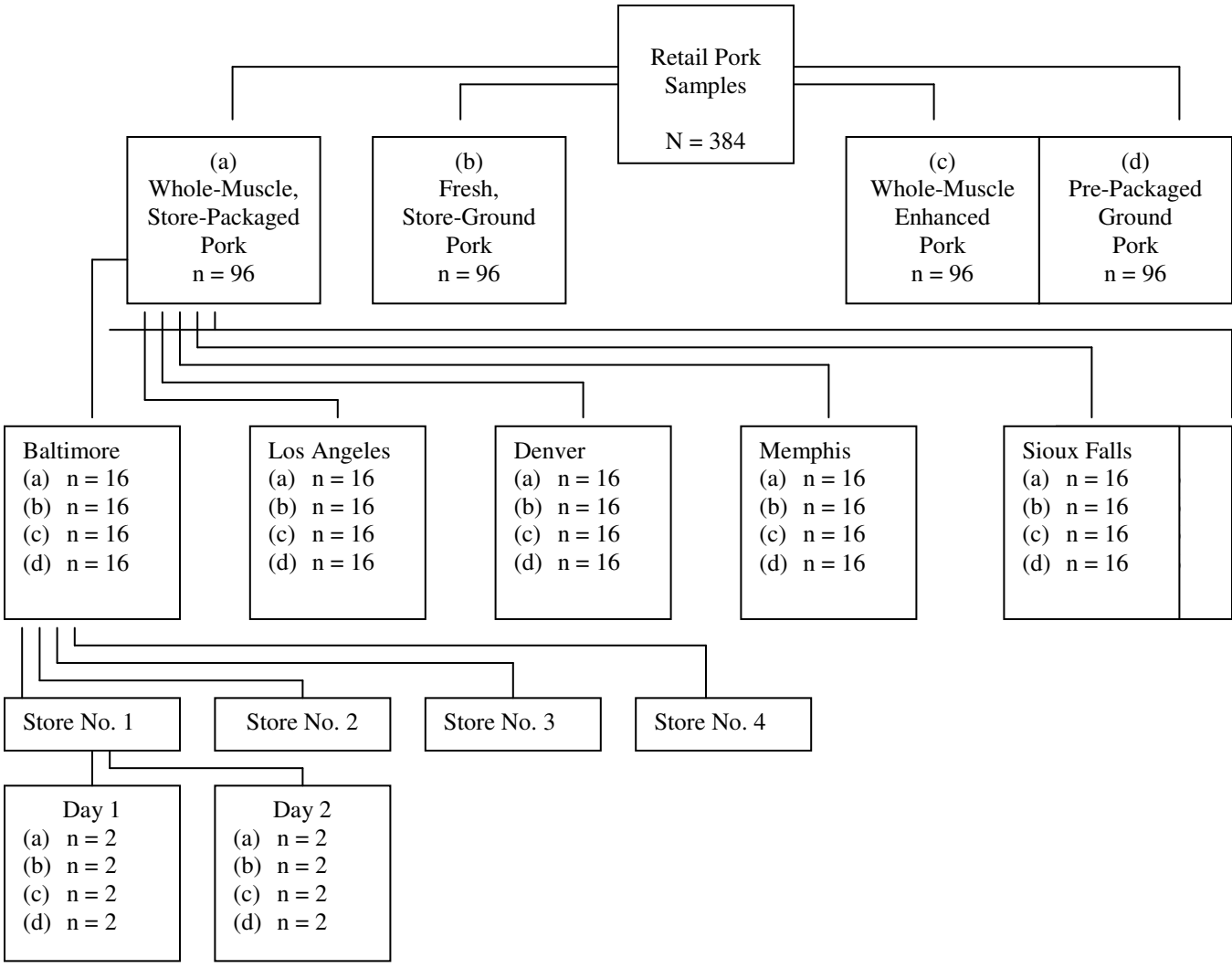

Table 1. Bacteria counts (log CFU/g) for pork samples collected from 24 retail supermarket stores and three types of pork production plants

		APC[d]			TCC[e]			ECC[f]		
Product	n	Mean	Min	Max	Mean	Min	Max	Mean	Min	M
Plant Samples:										
Hot-Boning Sow/Boar Sausage Plants (454g chubs)	40	2.92[b]	2.26	3.83	1.32[b]	<1	2.08	1.09[a]	<1	1
Slaughtering and Fabricating Plants (300g samples)	40	3.29[a]	2.30	3.96	1.52[a]	<1	2.96	1.04[a]	<1	1
Further Processing Plants (300g samples)	40	2.98[b]	2.08	4.81	1.15[b]	<1	1.95	0.96[b]	<1	1
Retail Samples:										
Whole-Muscle, Store-Packaged (tray and polyvinyl chloride overwrap)	96	4.36[b]	2.00	7.28	1.54[b]	<1	3.04	0.97[b]	<1	2
Whole-Muscle, Enhanced (60% store-packaged with tray and polyvinyl chloride overwrap, 40% vacuum, pre-packaged before distribution to retailer)	96	3.80[c]	1.30	6.88	1.31[c]	<1	3.52	0.97[b]	<1	2
Store-Ground Fresh Pork and/or Sausage (paper-wrapped or tray and polyvinyl chloride overwrap)	96	5.61[a]	2.90	6.85	2.19[a]	<1	4.15	1.22[a]	<1	3
Pre-Packaged Ground Pork and/or Sausage (chub packaged, tray and polyvinyl chloride overwrap, or paper boxes for links and patties)	96	3.77[c]	2.00	6.87	1.28[c]	<1	5.20	0.98[b]	<1	1

[abc]Means in a column, within a type of plate count and type of sample collected (retail or plant), bearing a different superscript letter differ (P<.05).
[d]Aerobic Plate Count
[e]Total Coliform Count
[f]*E. coli* Coliform Count

Table 2. Bacteria counts (log CFU/g) in freshly-ground pork and freshly-ground pork sausage in two plants (slaughtering/fabricating plant and further processing plant)

		APC[c]			TCC[d]			ECC[e]		
Product	n	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Freshly-Ground Pork (50% 454g chub packaged samples and 50% 300g samples obtained with sterile glove)	20	3.19[a]	2.54	4.81	1.17[a]	<1	2.34	1.08[a]	<1	1.70
Freshly-Ground Pork Sausage (50% 454g chub packaged samples and 50% 300g samples obtained with sterile glove)	20	2.80[b]	2.20	3.54	1.20[a]	<1	2.96	1.01[a]	<1	1.70

[ab]Means in a column, within a type of plate count and between the type of sample collected, bearing a different superscript letter differ ($P < .05$).

[c]Aerobic Plate Count

[d]Total Coliform Count

[e]*E. coli* Coliform Count

Table 3. Incidence of pathogens in ground pork and/or pork sausage produced in three types of plants

Plant-Type	n	*Salmonella* spp.		*Listeria spp.*[a]		*Listeria monocytogenes*		*Yersinia* spp.[a]		*ent*
		Positive Samples	Percent Positive	Positive Samples	Percent Positive	Positive Samples	Percent Positive	Positive Samples	Percent Positive	Posi Sam
Hot-Boning, Sow/Boar Plant	40	4	10.0	16	40.0	5	12.5	4	10.0	0
Slaughtering/Fabricating Plant	40	3	7.5	23	57.5	13	32.5	4	10.0	3
Further Processing Plant	40	0	0.0	18	45.0	14	35.0	1	2.5	1
Total	120	7	5.8	57	47.5	32	26.7	9	7.5	4

[a] Includes all positive samples for both pathogenic and non-pathogenic species

Table 4. Incidence of pathogens in four different types of pork retail product collected from stores located in six U.S. cities (n=384).

Product	n	*Salmonella* spp.		*Listeria spp.*[a]		*Listeria monocytogenes*		*Yersinia* spp.[a]		*ent*
		Positive Samples	Percent Positive	Positive Samples	Percent Positive	Positive Samples	Percent Positive	Positive Samples	Percent Positive	Posi Sam
Whole-Muscle, Store-Packaged (tray and polyvinyl chloride overwrap	96	8	8.3	27	28.1	14	14.6	47	49.0	1
Whole-Muscle, Enhanced (60% store-packaged with tray and polyvinyl chloride overwrap, 40% pre-packaged, vacuum prior to distribution to retailer)	96	10	10.4	24	25.0	14	14.6	19	19.8	5
Store-Ground Fresh Pork and/or Sausage (paper-wrapped or tray and polyvinyl chloride overwrap)	96	7	7.3	59	61.5	22	22.9	22	22.9	1
Pre-Packaged Ground Pork and/or Sausage (chub package, tray and polyvinyl chloride overwrap, or paper box (links and patties)	96	12	12.5	51	53.1	26	27.1	11	11.5	1
Total	384	37	9.6	161	41.9	76	19.8	99	25.8	3

[a] Includes all positive samples for both pathogenic and non-pathogenic species

Table 5. Incidence of pathogens in freshly-ground pork and freshly-ground pork sausage obtained from two plants.

Product Description	n	*Salmonella* spp.		*Listeria* spp.[a]		*Listeria monocytogenes*		*Yersinia* spp.[a]		*en*
		Positive Samples	Percent Positive	Positive Samples	Percent Positive	Positive Samples	Percent Positive	Positive Samples	Percent Positive	Posi Sam
Fresh Ground Pork (50% 454g chub packaged samples and 50% 300g samples obtained with sterile glove)	20	0	0.0	1	5.0	0	0.0	1	5.0	0
Fresh Ground Pork Sausage (50% 454g chub packaged samples and 50% 300g samples obtained with sterile glove)	20	0	0.0	4	20.0	0	0.0	4	2.0	0
Total	40	0	0.0	5	12.5	0	0.0	5	12.5	0

[a] Includes all positive samples for both pathogenic and non-pathogenic species