RESEARCH REPORT
INTERNATIONAL TRADE

Title: Survey of Microbiological Status of Offal Products from Pork Processing Facilities in the United States **– NPB #16-162**

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Industry Summary: In the United States, approximately five million metric tons of pork variety meats and other byproducts are generated each year with a large amount of this material being rendered to generate low value products like pet food, meat/bone meal, fat, and grease. An alternative use of the US variety meats would be to market and sell them to consumers in countries like China that prefer strong tasting pork products like the variety meats. The desirability of these products in foreign markets makes them higher value products, which could help increase the value of live hogs for US producers. To be able to market and sell these variety meats in global markets, it is important to understand the microbiological status of these products. Therefore, the objective of the current study was to: **Determine the microbiological profile of commonly consumed offal products (liver, heart, kidney, brain and intestine) as currently handled in pork production facilities in the United States. This microbiological profile will include tests for: mesophilic aerobic plate counts (APC), *Salmonella*, *Yersinia enterocolitica*, and *Toxoplasma gondii*.** To address this objective, samples of heart, kidney, liver, brain and intestine were obtained from 15 pork processing plants in 10 states found across the Midwestern and Southeastern pork-producing region of the US. Of the 370 offal samples tested in this study, 9 (2.4%) tested positive for *Yersinia enterocolitica*, 81 (21.8%) tested positive for *Salmonella*, 11 (3.2%) had APC >10^7 CFU/g, and 0 (0%) tested positive for *Toxoplasma gondii*. Eight of the nine *Yersinia*-positive samples came from one processing plant indicating that *Yersinia* is not a common contaminant of US offal products. The 81 *Salmonella*-positive samples included 37 (46%) intestinal samples, 25 (31%) brain samples, 9 (11%) heart samples, 8 (9%) liver samples, and 2 (2%) kidney samples. High levels of *Salmonella* contamination of intestinal samples is not a surprising result, since it is a commonly found in the intestine of healthy pigs. The high rate of *Salmonella* positives in the brain samples can likely be attributed to the non-standardized harvesting methods for brain. If we focus on the higher value variety meats including liver, heart and kidney, 10 out of the 15 plants did not have any positive *Salmonella* tests for these variety meats. In fact, two

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processing plants accounted for 15 of the 19 (79%) *Salmonella*-positive tests in liver, heart and kidney. Consistent with the observation that microbiological contamination of heart, liver and kidney is relatively low, we found 14 out of the 15 plants did not have any positive *Yersinia* tests. These results indicate that most of pork processing plants are doing well at minimizing microbiological contamination of liver, heart and kidney. In summary, the primary benefits of this research study to pork producers include: 1)This survey of the microbiological status of pork variety meats establishes a baseline for future improvements in the production of offal products for export, 2)The result of this study demonstrate that the heart, liver and kidney as currently harvested by a large majority of processing plants are relatively clear of potentially dangerous microbiological contamination, 3)*Salmonella* is by far the biggest microbiological problem for variety meat production; therefore, efforts to reduce *Salmonella* at all stages in pork production would be beneficial to the marketing of variety meats to export markets, and 4)Harvesting intestine and brain as edible offal will require additional work to reduce *Salmonella* contamination. Overall, the results of this study show that while there is room for improvement in the handling of variety meats and offal products, the US pork processing industry is poised to continue to be a world leader in the provision of safe, high quality pork products including variety meats and edible offal.

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Keywords: Offal, Variety meats, *Salmonella*, *Yersinia, Toxoplasma*, Processing plants

Scientific Abstract: In the United States, five million metric tons of pork variety meats and other byproducts are generated each year with a large amount of this material being rendered to generate low value products like pet food, meat/bone meal, fat, and grease. An alternative use of the US variety meats would be to market and sell them to consumers in countries like China that prefer strong tasting pork products like the variety meats. The desirability of these products in foreign markets makes them higher value products, which could help increase the value of live hogs for US producers. To be able to market and sell these variety meats in global markets, it is important to understand the microbiological status of these products. Therefore, the objective of the current study was to: **Determine the microbiological profile of commonly consumed offal products (liver, heart, kidney, brain and intestine) as currently handled in pork production facilities in the United States. This microbiological profile will include tests for: mesophilic aerobic plate counts (APC), *Salmonella*, *Yersinia enterocolitica*, and *Toxoplasma gondii*.** To address this objective, samples of heart, kidney, liver, brain and intestine were obtained from 15 pork processing plants in 10 states found across the Midwestern and Southeastern pork-producing region of the US. Of the 370 offal samples tested in this study, 9 (2.4%) tested positive for *Yersinia enterocolitica*, 81 (21.8%) tested positive for *Salmonella*, 11 (3.2%) had APC $>10^7$ CFU/g, and 0 (0%) tested positive for *Toxoplasma gondii*. Eight of the nine *Yersinia*-positive samples came from one processing plant indicating that *Yersinia* is not a common contaminant of US offal products. The 81 *Salmonella*-positive samples included 37 (46%) intestinal samples, 25 (31%) brain samples, 9 (11%) heart samples, 8 (9%) liver samples, and 2 (2%) kidney samples. High levels of *Salmonella* contamination of intestinal samples is not a surprising result, since it is a common component of normal intestinal microflora. In fact, *Salmonella's* presence in the intestine likely acts as a source for contaminating other tissues in the processing plant environment. The high rate of *Salmonella* positives in the brain samples can likely be

attributed to the non-standardized harvesting methods for brain. If we focus on the higher value variety meats including liver, heart and kidney, 10 out of the 15 plants did not have any positive *Salmonella* tests for these variety meats. In fact, two processing plants accounted for 15 of the 19 (79%) *Salmonella*-positive tests in liver, heart and kidney. Consistent with the observation that microbiological contamination of heart, liver and kidney is relatively low, we found 14 out of the 15 plants did not have any positive *Yersinia* tests and 15 out of 15 plants did not have APC>10^7. These results indicate that most of pork processing plants are doing well at minimizing microbiological contamination of liver, heart and kidney. In summary, the primary benefits of this research study to pork producers include: 1)This survey of the microbiological status of pork variety meats establishes a baseline for future improvements in the production of offal products for export, 2)The result of this study demonstrate that the heart, liver and kidney as currently harvested by a large majority of processing plants are relatively clear of microbiological contamination, 3)*Salmonella* is by far the biggest microbiological problem for variety meat production; therefore, efforts to reduce *Salmonella* at all stages in pork production would be beneficial to the marketing of variety meats to export markets, and 4)Harvesting intestine and brain as edible offal will require additional work to reduce *Salmonella* contamination.

Introduction:

Edible offal products from slaughtered hogs represent about 14% of the animal's live weight (Marti, Johnson, & Mathews, 2011). These offal products include the variety meats, which are the edible organs and glands including brain, liver, kidney, thymus gland, heart, and tongue. Variety meats are usually sold fresh to consumers with minimal processing. In the US, it is estimated that five million metric tons of pork variety meats and other byproducts are generated each year with a large amount of this material being rendered to generate low value products like pet food, blood meal, meat/bone meal, fat, and grease (Masker, 2015). An alternative use of the variety meats produced in the US would be to market and sell these variety meats to consumers in countries like China that prefer strong tasting pork products like the variety meats (Oh & See, 2012). The desirability of these products in foreign markets makes them higher value products, which could help increase the value of live hogs for US producers. To be able to market and sell these variety meat products in the global markets, it is important to understand the microbiological status of these products as currently produced in US pork processing plants.

Variety meats are particularly susceptible to deterioration or spoilage after processing and may contain potential human pathogens like *Salmonella, Yersinia* and *Toxoplasma*. Determining the microbiological status of a variety meat sample should include tests for general contamination, spoilage potential, and the presence of specific pathogenic microorganisms that are commonly found in pork products and have the potential to cause human disease (ICMSF, 2002). To evaluate general contamination and potential for spoilage, mesophilic aerobic plate counts can be performed (Ryser & Schuman, 2015). The specific human pathogens that have been commonly been detected in pork products include *Salmonella, Yersinia* and *Toxoplasma*. *Salmonella* are Gram-negative bacteria that are one of the most common causes of food-borne illness transmitted from pork (Scallan, Hoekstra, Mahon, Jones, & Griffin, 2015). The disease caused by *Salmonella* involves an intestinal infection leading to diarrhea, abdominal cramps, and fever that lasts from 3 to 7 days. Severe *Salmonella* infections, which occur more commonly in young and elderly persons, can lead to bloody diarrhea, vomiting, and rarely death. *Yersinia enterocolitica* are Gram-negative bacteria that are commonly found in pork products and are known to cause intestinal infections resulting in diarrhea, mostly in children under 5 years of age. *Toxoplasma gondii* is a protozoan parasite that has been found in variety of porcine tissues including brain, heart, lung and muscle of infected pigs (Jurankova et al., 2013). *Toxoplasma gondii* causes mild

influenza-like symptoms in most infected individuals, but it can cause life-threatening infections in fetuses and immunocompromised individuals (Wang et al., 2012). Since these three human pathogens are commonly found in pork products, it is important to determine the prevalence of these pathogens in variety meats produced by US pork-processing plants. This information will allow us to understand the current level of microbiological contamination of variety meats.

Goals and Objectives:

The overall goal of this project is to gain an understanding the microbiological profile of commonly consumed swine offal products (liver, kidney, heart, brain and intestine) as currently produced in US pork-processing plants in order to determine the acceptability of these offal products as protein foods for worldwide populations. To meet this overall goal, we propose studies to address the following objective:

- ***Objective #1:*** Determine the microbiological profile of commonly consumed offal products (liver, heart, kidney, brain and intestine) as currently handled in pork production facilities in the United States. This microbiological profile will include tests for: mesophilic aerobic plate counts (APC), *Salmonella*, *Yersinia enterocolitica*, and *Toxoplasma gondii*.

Materials and methods.

Survey Design. To perform a survey of the microbiological status of offal products that is representative of pork processing plants throughout the US, 15 pork-processing facilities from 10 different states within the major pork-producing regions of the United States were chosen to obtain offal samples from. The sampling protocol for this study was designed to determine if the offal products coming from a processing plant are acceptable for marketing as a human food product. The Microbiological Testing in Food Safety Management manual suggests the use of the following two criteria for developing sampling protocols: 1)Level of concern relative to health hazards of each potential pathogen (e.g. low, moderate, serious, severe) and 2)Condition of use of the food product (e.g. if the food has a preparation step, like heating, that would reduce microorganism populations). We determined appropriate levels of risk for each of our target organisms: *Salmonella*, *Yersinia enterocolitica*, *Toxoplasma gondii*, and aerobic plate counts (APC). Based on this information, we determined that the sampling protocol should include at least five samples of each offal product from each plant (Table 1).

Table #1 – Sampling protocol for determining acceptability of offal for human consumption.

Organism	*Degree of Concern*	*# of samples in sampling batch N=*	*Expected performance*	*Maximum number of sample units yielding unsatisfactory results*
APC	Indicator	5	Counts < $1x10^7$ cfu/g	3
Salmonella	Serious	5	Negative	0
Yersinia enterocolitica	Serious	5	Negative	0
Toxoplasma gondii	Serious	5	Negative	0

Each set of five offal samples collected from each plant represents a sampling batch; thus, each sample collection from a plant has one sampling batch of each type of offal to evaluate as acceptable or unacceptable for human consumption. Overall from the 15 plants, 75 samples of each of the five offal products for a total of

375 samples in the study were collected and analyzed. Five microbiological analyses was performed on each sample for a total of 1875 microbiological tests.

Sample Procurement and Plant Surveys. Samples of heart, kidney, liver, brain and intestine were obtained from 15 pork-processing plants in 10 states found across the Midwestern and Southeastern region of the United States. Pork variety meat samples were obtained from the carcass prior to evisceration, or from the offal trays or at packaging, depending upon plant operation. Five samples (>400 g) of each variety meat product (heart, liver, kidney, brain and intestines) were collected and placed in a Whirl-Pak bag with as little cross contamination as possible. Immediately upon collection, samples were placed on ice. Samples were obtained every 5 to 10 minutes to ensure there are multiple farms represented in each sample set. Samples were not be identified by farm number or name. Samples were then shipped overnight or hand-delivered to the ADRDL Food Safety Microbiology (FSM) laboratory for microbiological analysis. All samples were kept stored at 4°C until analysis. Tests to detect bacterial targets were initiated within 96 hours of sample collection. Tests for *Yersinia*, *Salmonella* and APC were performed on 100 g of fresh offal that was cut into small pieces using sterile scalpels and scissors. Prior to mincing the intestine, the ingesta within the lumen of the intestinal samples, which had been harvested from the ileum just prior to the ileocecal valve, was aseptically removed from the lumen by squeezing the contents out of the end of the harvested segment of ileum. In addition to the analysis of the fresh samples, a portion (100 g) of each tissue sample was frozen and stored at -20°C for later analysis to detect *Toxoplasma gondii*.

A processing plant survey (Table 4) was conducted by visual observation and conversations with plant personnel. This plant survey information includes generic observations and plant input (minus any that could be considered proprietary) to help possibly formulate a best management practices for processing pork offal products destined for export. The general focus was on variety meat harvest, sanitation efforts directed toward this operation, and hurdle approaches applied to minimize microbial contamination and growth.

Mesophilic Aerobic Plate Counts (APC). Mesophilic aerobic plate counts (APC) are a common food analysis technique used to assess the sanitary quality, organoleptic acceptability, and, to a limited extent, spoilage potential of food products. The method selected for quantitation of APC was the 3M Aerobic Count Petrifilm ™ Plate method. After a brief stomaching of the offal sample in a neutral buffer, the tissue homogenate was appropriately diluted and pipetted onto the Petrifilm plate and allowed to incubate at 37°C for 48 hours. After this time elapses, analysts counted any colonies present, which are visualized with the aid of tetrazolium dye incorporated into the plate material. The Association of Analytical Chemists (AOAC) designated this method as an "Official Method Status – 990.12" for all foods, which is a very high level of validation for a food microbiology method.

Salmonella Detection. Methods of pathogen detection were selected based upon laboratory familiarity and validation levels. Many methods exist for detection of *Salmonella;* however, the SD ADRDL FSM Lab has extensive experience with the Microbiology Laboratory Guidebook (MLG) *Salmonella* method. The MLG, published by the USDA's Food Safety Inspection Service (FSIS), acts as the reference manual for most laboratories performing testing on meat-based matrices for common food pathogens. *Salmonella* detection was achieved using a combination of PCR screening and cultural confirmation. Small pieces of the tissue were homogenized using a stomacher in Buffered Peptone Water and incubated overnight at 37°C. A commercial real-time PCR, DuPont Qualicon BAX™, allows the analyst to screen the overnight enrichments for the presence of *Salmonella* DNA. The samples that screen positive via BAX PCR were cultured to a pair of selective

secondary liquid media enrichments, Hajna Tetrathionate and Rappaport-Vassiliadis Broth, which were incubated overnight at 42°C. Analysts streaked 10µl of each of the broths to a set of selective agar plates, XLT4, Hektoen Enteric Agar, and Brilliant Green Agar, incubating them overnight at 37°C and examining them the next day for typical colonies (USDA Food Safety and Inspection Service, 2014). Biotyping using a Bruker Matrix Assisted Laser Desorption Ionization – Time of Flight Mass Spectrometer (MALDI-TOF MS) was used to verify that cultured isolates are *Salmonella.*

Yersina Detection. Detection of *Yersinia enterocolitica* within the SD ADRDL utilizes traditional culture along with MALDI-TOF MS. The offal were cut into small pieces and homogenized using a stomacher in a specialized broth containing peptone, sorbitol, and bile and then spread onto MacConkey and Cefsulodin-Irgasan-Novobiocin (CIN) Agar and allowed to incubate at 30°C for 48 hours. *Y. enterocolitica* fail to produce H_2S on Lysine Arginine Iron Agar (LAIA) and hydrolyze esculin on bile esculin agar, so these simple biochemical tests were used to screen out many isolates (Ceylan, 2015). Biotyping using a Bruker MALDI-TOF MS was used to verify that cultured isolates are *Y. enterocolitica* (Stephan et al., 2011).

Toxoplasma Detection. The method that we used for detecting *Toxoplasma* in offal samples was based on the sample preparation and RT-PCR method previously described for analyzing meat samples (Opsteegh et al., 2010). A portion of the fresh offal tissue samples (100 g) was frozen and stored at -20°C when they arrive at the ADRDL. While it is known that *Toxoplasma* oocysts are partially inactivated by freezing, the DNA-based assay used in this study is still be able to detect the presence of *Toxoplasma* DNA in the sample. For analysis, the samples were thawed and cut into small pieces. The offal pieces (10 g) were placed into a stomacher bag with a filter and 25 mL of cell lysis buffer containing 100 mM Tris-HCl, pH 8.0, 5 mM EDTA, 0.2% SDS, 200 mM NaCl, 40 mg/L proteinase K (30mAnson-U/mg) was added. The sample was stomached on high for 2 minutes. The resulting suspension was incubated in a water bath at 55°C for 16 hours to digest the tissue and release any oocysts present. The sample was homogenized for 1 additional minute. A 20 mL aliquot of the sample was centrifuged for 45 min at 3500 x g. Five milliliters of the supernatant was transferred to a clean tube and heated at 100°C for 10 minutes to deactivate the proteinase K. An aliquot was removed and stored at 4°C until PCR testing. The *Toxoplasma* DNA in the samples was amplified and detected using the primers and real-time quantitative PCR methods previously described (Opsteegh et al., 2010). A positive control sample of sheep placenta that had been naturally infected with *Toxoplasma* was used to verify that the sample preparation and RT-PCR methods were capable of detecting the presence of *Toxoplasma* DNA.

Results:

During this project, 370 offal samples were obtained from 15 pork-processing plants. All of these samples were analyzed for the presence of *Salmonella, Yersinia enterocolitica* and *Toxoplasma gondii*, and evaluated using an APC. A summary of the results of these analyses is shown in Table 2.

Table #2 – Percentage of each type of offal that tested positive

Type of offal	*Percentage of samples that tested positive*			
	Yersinia enterocolitica	***Salmonella***	***APC > 10^7/g***	***Toxoplasma***
Intestine	1/75; 1.3%	37/75; 49.3%	11/75; 14.7%	0/75; 0%
Heart	1/75; 1.3%	9/75; 12%	0/75; 0%	0/75; 0%
Kidney	2/75; 2.7%	2/75; 2.7%	0/75; 0%	0/75; 0%
*Brain**	3/70; 4.3%	25/70;35.7%	0/70; 0%	0/70; 0%

Liver	2/75; 2.7%	8/75; 10.7%	0/75%; 0%	0/75; 0%
Total	***9/370; 2.4%***	***81/370; 21.8%***	***11/370; 3.2%***	**0/370; 0%**
***One plant did not allow the collection of brain samples.**				

The results of the microbiological analyses of offal samples from the individual pork processing plants are shown in Table #3. Our analysis detected *Salmonella* in at least one sample from all 15 plants. *Salmonella* was detected in at least one of the samples (thus unacceptable for human consumption) of intestine in 13 of 15 plants, brain in 10 of 15 plants, heart and liver in 3 of 15 plants, and kidney in 1 of 15 plants. *Yersinia* was only detected in samples from two of the 15 plants tested with one plant having 8 positives out of 25 samples, including all 5 types of offal. The other *Yersinia*-positive plant only had one positive sample, which was a brain sample. *Toxoplasma gondii* was not detected in any samples from the 15 plants.

Table #3 – *Individual plant results.*		**Number of negative samples/number of samples tested.**			
Plant	Tissue	*Yersinia enterocolitica*	*Salmonella*	APC	*Toxoplasma*
A	Intestine	5/5	**4/5**	5/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**4/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
B	Intestine	5/5	**1/5**	4/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	5/5	5/5	5/5
	Liver	5/5	**3/5**	5/5	5/5
C	Intestine	5/5	**2/5**	5/5	5/5
	Heart	5/5	**2/5**	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**4/5**	5/5	5/5
	Liver	5/5	**4/5**	5/5	5/5
D	Intestine	5/5	**1/5**	5/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**4/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
E	Intestine	**4/5**	**4/5**	3/5	5/5
	Heart	**4/5**	5/5	5/5	5/5
	Kidney	**3/5**	5/5	5/5	5/5
	Brain	**3/5**	**3/5**	5/5	5/5
	Liver	**3/5**	5/5	5/5	5/5
F	Intestine	5/5	**1/5**	5/5	5/5
	Heart	5/5	**1/5**	5/5	5/5
	Kidney	5/5	**4/5**	5/5	5/5
	Brain	5/5	**3/5**	5/5	5/5

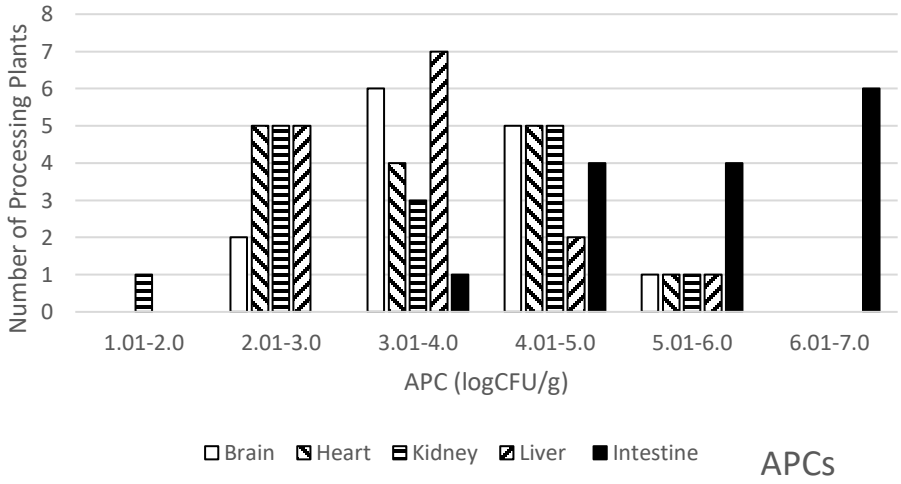
	Liver	5/5	**0/5**	5/5	5/5
G	Intestine	5/5	**4/5**	5/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	5/5	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
H and I combined	Intestine	10/10	**5/10**	6/10	10/10
Samples from these two plants were shipped together and no indication of plant origin was given	Heart	10/10	10/10	10/10	10/10
	Kidney	10/10	**9/10**	10/10	10/10
	Brain	5/5	5/5	5/5	5/5
	Liver	10/10	10/10	10/10	10/10
J	Intestine	5/5	**1/5**	3/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**1/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
K	Intestine	5/5	**0/5**	5/5	5/5
	Heart	5/5	**3/5**	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	**4/5**	**3/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
L	Intestine	5/5	**0/5**	5/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**1/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
M	Intestine	5/5	5/5	5/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**0/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
N	Intestine	5/5	5/5	3/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**3/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5
O	Intestine	5/5	5/5	5/5	5/5
	Heart	5/5	5/5	5/5	5/5
	Kidney	5/5	5/5	5/5	5/5
	Brain	5/5	**4/5**	5/5	5/5
	Liver	5/5	5/5	5/5	5/5

- Results highlighted in **boldface type** represent sampling batches that would be considered unacceptable according to criteria discussed earlier in report.

When the 5 samples of each type of offal from an individual processing plant are considered a sampling batch and the criteria outlined in Table 1 of the Materials and Methods is used to determine the acceptability of the offal for human consumption, we found that 6 of 74 sampling batches were unacceptable based on *Yersinia* testing, and 30 of 74 were unacceptable based on *Salmonella* testing. All sampling batches were acceptable for human consumption based APC and *Toxoplasma* testing. Interestingly, 5 of the 6 unacceptable *Yersina* batches came from one plant and included all 5 types of offal tested. The other unacceptable *Yersinia* batch was a single brain sample from a second processing plant. On a positive note, 13 of the 15 processing plants produced offal that was acceptable for human consumption based on *Yersinia* testing. Obviously, *Salmonella* prevalence was much higher than *Yersinia* with 30 of 74 batches judged unacceptable. Among the 30 sampling batches that were unacceptable based on *Salmonella* testing, there were 11 intestine batches, 11 brain batches, 3 heart batches, 3 liver batches, and 2 kidney batches. All 15 plants produced as least one offal-sampling batch that was judged unacceptable based on the presence of *Salmonella*. In other words, *Salmonella* was present in at least some offal samples collected from all 15 processing plants. On a positive note, all of the batches of heart, liver and kidney from 10 of the 15 plants were judged acceptable, indicating that these relatively high value offal products are currently being harvested at these plants in a manner that minimizes microbiological contamination.

Mesophilic aerobic plate counts (APC) are a common food analysis technique used to assess the sanitary quality, organoleptic acceptability, and, to a limited extent, spoilage potential of food products. Since the APC test involves actual counting and quantitation of the concentration of aerobic bacteria in a sample, we were able to do a quantitative evaluation of the offal collected from the processing plants (Figure 1). In this analysis, we found that brain, heart, kidney and liver had similar patterns with 14 for the 15 plant having APCs that averaged less than 5.0 log CFU/g, which is considered low for meat samples and indicates that overall contamination of these samples is relatively low. Not surprisingly, average APCs from intestine were much higher with 10 processing plants having average APC counts over 5.0 logCFU/g and 6 of those processing plants having average APC counts over 6.0 logCFU/g. This result is not surprising since the lumen of the ileum naturally contains high concentrations of bacteria.

Figure #1 – Summary of APC results from 15 pork-processing plants.



In general, all pork-processing facilities in this study did an adequate job of following sanitation standard operating procedures (SSOPs), Good Manufacturing Practices (GMPs) and properly harvesting the animals and related variety meat and offal items (Table 4). While all were at least adequate in appearance, 7 of the 15 plants rated excellent/ very good based on visual observations. In addition, another three plants

rated good with only two plants rating as only adequate. While visible differences were observed between all plants, there appeared to be no differences between hot-boned sow and traditional market hog plants. Observations of the process and procedures was clean in sow plants but a higher percentage of hearts (70%) and livers (55%) were positive. Overall, 41% of all positives came from hot bone sow plants (4) with 16% coming from one hot bone sow plant rated as very good. Overall, 52% of positives came from plants rated excellent or very good with 58% of all positives coming from only 5 plants (3 rated excellent/ very good). These inconsistencies indicate that current SSOPs, GMPs and proper harvest techniques are not necessarily correlated with variety meat contamination. However, considering that only 24% of the positive tests were on normally collected offal (hearts, livers and kidneys), it appears that most plants are doing a very good job in minimizing contamination throughout the harvest process, even though some improvements can still be made.

Table 4: Survey of plant operations	**Number of plants acceptable**	**Comments**	**Sow Plants Only**
Sanitation SOP includes pre-op responsibilities, monitoring, record keeping, and corrective action procedures	**15/15**		**4/4**
Sanitation SOP includes operational responsibilities, monitoring, record keeping, and corrective action procedures	**15/15**		**4/4**
Specific area cleaning procedures available	**15/15**		**4/4**
Specific equipment cleaning procedures available	**15/15**		**4/4**
Offal Pans cleaned and Sterilized	**15/15**	**3 steam/ 12 hot water**	**4/4**
Utensils/ knives/ etc regularly cleaned and santitized	**12/15**	**3 not santitized always between each animal**	**3/4**
Cross contamination minimized between items	**13/15**	**2 less frequently**	**3/4**
Finished Product temperatures monitored & acceptable	**12**	**3 not noted**	**2/4**
Scald temperatures and pH monitored regularly	**11**	**4 not applicable**	**NA**
`Scalder water turnover reguarly monitored	**11**	**4 not applicable**	**NA**
ATP testing conducted regularly	**11**	**4 unknown**	**1/4**
Environmental testing for TPC conducted weekly	**11**	**4 unknown**	**4/4**
Manufacturing equipment cleanable, sanitary design, and properly maintained	**15/15**		**4/4**
No rough welds on equipment	**15/15**		**4/4**
No water pockets at shaft connections	**15/15**		**4/4**
No string, tape, or cardboard use for temporary repair	**14**	**One had plastic separating a portion of the eviceration line**	**3/4**
Hand washing sinks adequately available	**15/15**		**4/4**
Sinks hand ___, foot ___, or knee ___ operated	**15/15**		**4/4**
Hot water sufficiently available at hand wash sinks	**15/15**		**4/4**
Soap and towels sufficiently available at hand wash	**15/15**		**4/4**
Product wash sinks adequately available	**15/15**		**4/4**

Air control and exhaust fans controlled properly	**15/15**		**4/4**
Product Reconditioning available	**13**	**2 not noted**	**4/4**
Employee Hygiene GMP available	**13**	**2 not noted**	**4/4**
Product temperatures acceptable during processing	**15/15**		**4/4**
Condensation removal procedure adequate	**11**	**4 not noted**	**4/4**
Utensil use and protection adequate	**15/15**		**4/4**
Finished product labeling meets all requirements	**14**	**1 not noted**	**4/4**
Carcass venting contamination	**14**	**1 had minimal contamination**	**3/4**
Occurrence of intestinal contamination	**12**	**3 had minimal contamination**	**4/4**
Organ contamination	**12**	**3 had minimal contamination**	**4/4**
Product handling practices	**12**	**3 good to acceptable**	**4/4**
Cross contamination by inspection practices	**12**	**3 had minimal contamination**	**3/4**
Sanitation practices during operation	**12**	**3 good to acceptable**	**4/4**
Contamination cleanup	**13**	**2 not noted**	**4/4**
Overall process effectiveness	• **7 excellent/ very good** • **3 good** • **3 ok** • **2 adequate**		• **2 very good** • **1 good** • **1 ok**

Discussion:

Of the 370 offal samples tested in this study, 9 (2.4%) tested positive for *Yersinia enterocolitica*, 81 (21.8%) tested positive for *Salmonella*, 11 (3.2%) had APC >10^7 CFU/g, and 0 (0%) tested positive for *Toxoplasma gondii*. Eight of the nine *Yersinia*-positive samples were from one processing plant with all five types of offal found to be contaminated in that plant's samples. Overall, these results indicate that *Yersinia* is not a common contaminant of offal products from US pork-processing plants; however, its detection in two processing plants means it still has to be considered as a possible microbiological contaminant in pork products. The 81 *Salmonella*-positive samples included 37 (46%) intestinal samples, 25 (31%) brain samples, 9 (11%) heart samples, 8 (9%) liver samples, and 2 (2%) kidney samples. The low level of *Salmonella* contamination of kidneys is likely due to its encapsulation within the body cavity reducing contamination during processing.

As anticipated, the intestines were the type of offal that was most commonly contaminated with *Salmonella*. This is not a surprising result, since *Salmonella* is a common bacteria found in the small intestine. In fact, *Salmonella's* presence in the intestine likely acts as source for contaminating other tissues in the processing plant environment. The intestinal samples in the current study were collected in the plants without any type of rinsing or removal of the luminal contents. When the intestinal samples were analyzed in the SDSU FSM lab, the intestinal contents were aseptically removed by squeezing the contents out with no wash step included. Thus, these intestinal samples still contained the bacteria that were in that intestinal segment at collection. So these intestinal samples are a reflection of the percentage of pigs whose intestines (distal ileum) contained *Salmonella* at slaughter, which was found to be 49% of the pigs in this study. This result is consistent with other studies that have looked at *Salmonella* levels in pigs at various steps in the slaughter process. Obviously, it would be wise for pork processing plants that market intestine as edible offal

to incorporate some type of wash step, possibly including an antimicrobial, to decrease levels of *Salmonella* in intestinal samples.

The high rate of *Salmonella* positives in the brain samples could likely be attributed to the non-standard harvesting methods used to collect brains in the processing plants. While other offal samples in this study were obtained at normal steps in the processing plant (like from an offal tray), the brain samples were harvested from skulls by collectors participating in this study. There was not much consistency in the collection methods since the collector had to use whatever means were available to them to collect the brain samples. Consequently, the level of *Salmonella* contamination among brain samples likely reflects a combination of contamination that occurs in normal processing plant activities and during sample collection. To market brains as a food products, a standard harvesting method for brain would have to be incorporated to avoid contamination of the brains during processing and collection.

If we eliminate intestine and brain from this survey and focus on the higher value variety meats including liver, heart and kidney, 10 out of the 15 plants did not have any positive *Salmonella* tests for these variety meats. A closer examination of the results shows that two plants accounted for 15 of the 19 (79%) *Salmonella*-positive tests in liver, heart and kidney. In addition for heart, liver and kidney, 14 out of the 15 plants did not have any positive *Yersinia* tests and 15 out of 15 plants did not have APC>10^7. Overall, most of the pork processing plants are doing well at minimizing microbiological contamination of these three types of edible offal.

From the results of the current survey, it looks like the biggest microbiological challenge for the US pork processing plants that want to market variety meats to export markets is to reduce *Salmonella* in offal products. Since *Salmonella* is commonly found in the intestinal lumen of most pigs, reducing the number of intestinal samples with *Salmonella* contamination would likely have to be accomplished prior to slaughter (pre-harvest) or by using a harvesting method that kills or removes the bacteria. The *Salmonella* found in other offal products is likely the result of contamination of these products with intestinal *Salmonella*. So, *Salmonella* in these products could be decreased within processing plants by implementing more stringent offal harvesting practices that reduce cross contamination by intestinal bacteria. A combination of reducing intestinal *Salmonella* load at the pre-harvest level and reducing cross contamination within the processing plants would likely be the most effective method of decreasing *Salmonella* contamination of variety meats.

In summary, the results of this project indicate that while there is room for improvement in the handling of variety meats and offal products, the pork processing industry in the United States is poised to continue to be a world leader in the provision of safe, high quality pork products, including variety meats and offal items. With pork exports increasing, this opportunity offers much potential to add value throughout the pork value chain. While the overall evaluation of the plants themselves for food safety and sanitation practices was good, efforts need to be made to enhance the effectiveness of certain plants. Continued diligence is needed to further limit the amount of cross contamination within specific facilities. In addition, the use of antimicrobials on products to further minimize contamination levels should be explored in plant level operations. Also, intestinal products should be re-evaluated after a cleaning process to get a more realistic evaluation of their contamination in the industrial process. Finally, unless brains become an economically viable product, their use as food products will be limited without a more uniform harvest method that limits contamination.

Summary of the immediate and future benefits of this research study to pork producers.

1. This survey of the microbiological status of pork variety meats establishes a baseline for future improvements in the production of offal products for export.

2. The result of this study demonstrate that the heart, liver and kidney as currently harvested by a large majority of processing plants are relatively clear of microbiological contamination.
3. Out of the microbes tested, *Salmonella* is by far the biggest problem for variety meat production. An effort to reduce *Salmonella* at all stages in pork production would be beneficial to the marketing of variety meats to export markets.
4. Harvesting intestine as edible offal will require some additional work. A luminal wash step, possibly including an antimicrobial, would likely significantly lower microbiological contamination levels.
5. Marketing brains as a variety meat to export markets would require processing plants to develop a consistent harvesting method that reduces microbiological contamination to a minimum.

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