RESEARCH REPORT
PORK SAFETY

Title: The effect of feed withdrawal on pork quality and the prevalence of Salmonella and gastric ulcers at slaughter – **NPB 97-2001**

Investigator: Morgan Morrow

Institution: North Carolina State University

Co-Investigators: Todd See
Joan Eisemann
Peter Davies
Kelly Zering

Abstract:

To help producers decide whether they should withdraw feed prior to slaughter, we designed a study that examined the effect of feed withdrawal on the proportion of gastrointestinal tract lacerations, prevalence of *Salmonella spp.* in cecal contents at slaughter, prevalence and severity of gastric ulcers, and meat quality as measured by ultimate pH, color, and water holding capacity. Finally, we analyzed the economic impact of the treatments. We assigned treatments to a finishing floor of 1133 National Pig Development barrows that were sent to slaughter in 3 groups. Each marketing group (feed withdrawn once, first group; twice, second group; or three times, third group) had an equal number of pigs that had feed withdrawn for 0 (control) 12, or 24 hours.

Withdrawing feed for 12 or 24 hours improved ultimate pH, Japanese color score, water holding capacity, and color as measured by Minolta L* but reduced carcass weight to 76.4 kg, and 74.5 kg respectively compared to no feed withdrawal (77.4 kg). Repeated feed withdrawal over the three week period reduced ultimate pH, water holding capacity, Minolta L* measure and Minolta b*. Pigs in the first group marketed (feed withdrawn once) had nearly twice the water holding capacity of the second and third marketing groups. These results suggest that on-farm withdrawal of feed for 24 hours prior to slaughter enhances ultimate pork quality. However, because pigs in the third marketing group have lighter carcasses and reduced carcass quality producers will receive less for the hogs if they are paid on a carcass-merit program. Yet, most of the discount may be unrelated to the feed withdrawal immediately prior to slaughter. It might be more associated with the poor performing pigs and decreased growth associated with the severe ulcers seen in pigs in the third marketing group.

Overall, prevalence of severe ulcers in this study was 13.7%. Damage from ulcers increased from the first of the three groups marketed to the third. Overall, prevalence of

chronic damage was 19.3% with 57.9% of chronic damage in stomachs from animals in the third marketing group (3 times treatment). Prevalence of esophageal constrictions was 10.4% with 66.7% of esophageal constrictions in stomachs from animals in the third marketing group (3 times treatment). Severity of damage, chronic damage, and esophageal constrictions all increased as carcass weight decreased, most notably for carcasses in the lowest weight quartile. These data show that withdrawal of feed prior to slaughter, for up to 24 hours, did not lead to an increase in stomach damage when compared to the appropriate control group. The relation of severity of damage, chronic damage, and esophageal constrictions to carcass weight suggests that the impact of chronic ulcers on growth of pigs may be greater than is widely appreciated.

Overall, 62% of cecal samples were positive for *Salmonella* but isolation was not associated with hours of feed withdrawal. The percentage of *Salmonella* positive ceca decreased from the first marketing group (73%) to the second (64%), and the third (52%). This indicates that feed withdrawal prior to slaughter did not increase the prevalence of Salmonella as reported in previous experimental studies and in this study the prevalence actually decreased over time.

Overall, 15.7% of gastrointestinal tracts were lacerated in one or more sections including the stomach (8.4%), colon (5.7%), small intestine (2.1%), and ceca (0.9%). The withdrawal of feed before slaughter decreased the weight of the gastrointestinal tract. Neither marketing group (feed withdrawn once, twice, or three times) nor the hours feed was withdrawn (0, 12, or 24) affected lacerations. Gastrointestinal tract lacerations were highest (14.4%) in the lightest quartile of carcass weight suggesting that the eviscerator was not able to adjust his work rhythm to account for the lighter, and presumably shorter carcasses. Most (94.1%) gastrointestinal tracts were lacerated in 1 section but 5.9% were lacerated in 2 sections. The proportion of lacerations in this study (15.5%) is higher than previously reported (4.5%). The difference may be due to the higher rate of evisceration (18 pigs per minute), or our more detailed examination of the gastrointestinal tracts.

Excluding meat quality differences, one time feed withdrawal had slightly positive but statistically insignificant effects on net returns from hogs in the first marketing group. Repeated feed withdrawal (twice and three times) reduced net returns from hogs in the second and third marketing groups. It appears that the animals that had feed withdrawn repeatedly had significantly lower carcass weights than controls in the same marketing groups. A question for further research is how much longer would the hogs that had feed withdrawn twice or three times have to remain on feed to attain the same carcass weight as the control hogs in their marketing group. It may be that negative effects of repeated feed withdrawal on net returns could be reduced by leaving the hogs on feed for several more days.

Introduction:

To compete in today's global markets the USA pork industry is rapidly changing from treating pork as a commodity product to one focused on quality. The outbreak of *E. coli* O157:H7 in 1993 increased government and industry focus on enhancing the safety of meat and lead to the adoption of HACCP principles to improve pork quality. Pork retailers have indicated that their top four quality concerns are: excessive color variation, too much purge, short shelf life, and lack of uniformity or consistency (NPPC,

Pork Chain Quality Audit). Unfortunately, a recent survey indicated that 26% of the pork evaluated at 14 major plants had unacceptable muscle quality (Kauffman 1992). Many of these quality problems are related to Porcine Stress Syndrome (PSS).

To decrease the proportion of PSE pork, producers are recommended (Eikelenboom 1991) to withdraw feed from hogs 12-24 hours prior to slaughter. Because producers are penalized for selling hogs outside a narrow weight range, most who have all-in/all-out facilities will send their hogs to slaughter over 3-4 weeks. In most cases, they withdraw feed from the last load but earlier loads are usually on full feed until they are shipped. The benefits of feed withdrawal are not without risks including a possible rise in the proportion of pigs with gastric ulcers or an increase in the proportion of pigs excreting *Salmonella spp.*

Salmonellosis currently costs the USA between $0.6 billion and $3.5 billion annually making it the most costly bacterial foodborne disease. From an estimated 696,000 to 3,840,000 cases, 690 to 3,800 people die each year in the United States (Buzby, AER, #741). Since 1970, there has been a steady increase in non-typhoid salmonellosis in humans caused by non-host adapted serotypes, particularly *S. typhimurium*, with the majority of outbreaks traced to foods of animal origin (Tauxe 1991)

Pork is a major cause of foodborne salmonellosis throughout the world. Studies of pork in retail stores found 15-22% of samples were contaminated. In Denmark in 1993, pork was the most important source of foodborne salmonellosis when meat contaminated with *S.infantis* accounted for an outbreak of 20 cases per 100,000 inhabitants. Although slaughter equipment is often the immediate source of contamination, the initial source is the carrier pig and transmission is thought to occur by pig-to-pig contact or from exposure to the contaminated environment. The handling and transport of pigs prior to slaughter has long been recognized as increasing the prevalence of *Salmonella spp.* To counteract these inherent risks researchers have been investigating techniques that may decrease the risk of contaminating carcasses. Withholding feed from pigs before slaughter decreases gastrointestinal contents and appears to decrease the risk of gastrointestinal spillage and consequent carcass contamination. However, feed withdrawal may be stressful and may increase the proportion of pigs excreting *Salmonella spp*.

In addition to the effects of feed withdrawal on carcass quality the possibility that it will also increase the proportion of pigs with gastric ulcers must be considered. The mechanisms by which gastric ulcers develop are not understood, however, if acid is a major factor and the pH of proximal stomach contents declines as time post-feeding progresses, then it is possible that feed withdrawal will initiate damage to healthy mucosa or accentuate damage where it exists already. The impact of feed withdrawal would likely be magnified if repeated several times. The result could be decreased growth rate due to severe lesions or death.

For the pork industry to remain competitive in domestic and international markets it must continue to focus on the needs of the customer. Withdrawing feed from hogs before they are slaughtered has the following potential benefits: decreased weight and contents of the gastrointestinal tract resulting in fewer lacerations and consequently decreased risk of carcass contamination, less feed wastage, increased yield, fewer carcasses with PSE, and decreased cost of manure treatment at the abattoir. The potential disadvantages include a possible reduction in live weight, possible reduction in

tenderness and juiciness (Ellis 1996), a possible increase in the proportion of pigs excreting *Salmonella spp.* and consequently an increased risk of carcass contamination, and the possibility of an increased prevalence of gastric ulcers. To effectively implement feed withdrawal as a standard production practice these benefits and disadvantages should be evaluated as a system.

Objectives:

To determine the effect of withdrawing feed from pigs at 0, 12, or 24 hours before they are shipped to slaughter and the effect of sorting by weight and withdrawing feed once, twice, or three times in a carcass-merit situation on:

- Proportion of gastrointestinal tract lacerations
- Prevalence of *Salmonella spp.* in cecal contents at slaughter
- Prevalence and severity of gastric ulcers
- Meat quality as measured by ultimate pH, color, and water holding capacity
- The economic impact of the treatments

Procedures:

Subjects: In March 1998, 1133 National Pig Development (NPD) barrows from a nursery site were weighed, individually identified and assigned, blocked by weight, to 36 pens. The barn had 40 pens and the other 4 pens were used to hold the cull pigs and the extreme lightest and heaviest pigs that were excluded from the study. Each pen of 29-32 pigs had pigs of similar minimum and maximum weight with similar variation between pens. Maximum variation within a pen, rather than minimum, allowed us to progressively select the heaviest third of pigs for slaughter from each pen and simulate the slaughter close-out of a barn of pigs where on about three occasions the heaviest third in the barn are taken to slaughter. By design, however, this procedure confounds the effects of repeated feed withdrawal with pig weight because the lighter weight (presumably slower growing) pigs are exclude from the first marketing group. Pigs were presumed homozygous stress negative because they came from lines that had been DNA tested and found negative for the HAL 1843 gene. In June, the 6 pens that had the fewest pigs (attrition from death and culling) were deleted from the study because they exceeded our needs.

Salmonella status: In February, 1998, we selected a nursery site that we had previously screened to ensure the pigs were Salmonella positive. After placement at the finishing site, we collected fecal samples on May 18-19, 1998 from about 2/3 individual pigs in all 36 pens and tested them for salmonella. On June 8-9, 1998 we collected fecal samples from the 30 pens remaining in the study.

Experimental design: A 3 by 3 factorial.

Treatments: Treatments included feed withdrawal of 0, 12, and 24 hours and marketing group (1, 2, and 3) selected on weight and having feed withdrawn once, twice, or three times prior to shipment. Treatments were allocated at random, blocked on pen prevalence of *Salmonella spp.* as determined from the fecal sampling in May and June. Feeders to the pens containing hogs for slaughter were shut off and any feed in the feeding troughs was returned to the pens' feeders.

Shipments: For the first and second marketing groups, the 10 heaviest pigs in each pen were visually identified and shipped (feed withdrawn once or twice). The third marketing group closed out the barn and consisted of all pigs remaining in all the test pens. In the second marketing group, an accident at the packing plant resulted in the loss of all data on all the pigs (60) for that day (Table 1). Pigs were individually tattooed with a unique 4 digit identifying number coded to describe the day and treatment. Time in transport and lairage were recorded by the person accompanying the pigs. In lairage, pigs had free access to water but not feed.

Table 1. Number of pigs shipped by day, marketing group, and treatments.

		Number of times feed withdrawn from the 12 and 24 hour pigs								
		Once			Twice			Three times		
		Feed withheld, hours			Feed withheld, hours			Feed withheld, hours		
		0	12	24	0	12	24	0	12	24
Marketing Group 1	June 22	20	20	20						
	June 23	20	20	20						
	June 24	20	20	20						
	June 25	20	20	20						
	June 26	20	20	20						
Marketing Group 2	June 29				20	20	20			
	June 30				20	20	20			
	July 1				20	20	20			
	July 2				20[a]	20[a]	20[a]			
	July 6				20	20	20			
Marketing Group 3	July 8							18	24	25
	July 9							19	19	21
	July 10							21	20	20
	July 13							22	23	18
	July 14							19	22	16
Total	907	100	100	100	100	100	100	99	108	100

[a]Data from all July 2 pigs were lost because of an industrial accident in the plant.

Gastrointestinal tracts (GIT): Standard evisceration procedure at the plant was as follows: the head was removed, the brisket cut open, the abdominal cavity opened, the anus (bung) dropped, then the gastrointestinal tract and thoracic cavity contents (pluck) were cut from the carcass and placed on a tray. On the tray, the esophagus was cut from the stomach and the pluck removed and placed on a hook for further processing.

Immediately the abdomens were opened we tagged the gastrointestinal tracts with temporary paper numbered tags which we could correlate to the carcass tattoos. The gastrointestinal tracts were then removed from the viscera trays, placed in plastic bags and taken off-line for us to examine. Tracts were trimmed to remove viscera and muscle and then weighed. Each tract was examined in detail, section by section, and noted which sections (stomach, small intestine, cecum, and colon) were lacerated. Then, the stomach was opened and rinsed. The pars esophageal region was scored from 1 (normal) to 7 (completely ulcerated) and evaluated for presence of chronic ulcers and constrictions of the esophagus.

Cecal samples: Each cecum was opened and 10 gm samples of cecal contents were collected and transported to the laboratory in Raleigh. To detect *Salmonella* organisms, all samples were treated by the standard techniques previously reported (Davies et al., JAVMA, 210:386-389).

Composition and Ultimate Muscle quality: Data on 657 pigs were collected on 11 days (no Saturday data). Hot carcass weight was collected and fat and muscle depth were determined by the Fat-O-Meter optical probe (SFK Technology, Denmark) at 30 minutes post stunning. One chop was collected from each carcass at the tenth rib location at 24 h. post-mortem and after a minimum 20 minute bloom time was evluated for color, water holding capacity, ultimate pH, and temperature (^{o}C). The loin was

measured in triplicate (medial, middle, lateral) and mean values calculated for color lightness (L*), redness (a*) and yellowness (b*) using a Minolta Chromameter 200 (set to D65 illuminant, a 2 degree standard observer, using an 8 mm optical port with glass insert, and calibrated with Minolta white standard color plate). A visual color score was also determined on a scale from 1 to 6 (1 = pale, 6 = very dark) using plastic Japanese color standards. On the same sample ultimate pH was measured using an Engold electrode and an Omega pH-50 meter. Water-holding capacity was evaluated by using filter paper (4.5 cm circles; S&S Filter Paper; Keene, NH) absorption of excess fluids on the cut surface as determined by weight increase (Kauffman et al. 1986).

Statistical Analyses: All data were analyzed in SAS. Categorical data were examined initially in the PROC FREQ and then GENMOD procedure. The following tests were adopted: where cell frequency was less than 5 for one or more cells, Fisher's Exact test; where data were ordinal, Mantel-Haenzel Chi-Squared; otherwise, Pearson's Chi-Squared. Continuous dependent variables were analyzed in PROC GLM using a variety of models.

For meat quality measures the statistical model included the fixed effects of feed withdrawal (0, 12, and 24), marketing group (1, 2, and 3), and withdrawal by market group interactions. The random cold temperature was fit as a covariate for ultimate pH, water holding capacity and Japanese color score. Contrasts among feed withdrawal treatments were also tested for linear and quadratic effects.

Economic analyses: Differences in revenues and costs were calculated for pigs in each of the 9 subgroups (0, 12, and 24 hour feed withdrawal combined with the three marketing groups that had feed withdrawal once, twice or three times prior to slaughter). Standard base values were assigned for price per pound of carcass weight ($0.60 per pound), feed cost per additional pound of gut weight ($0.025 per pound gut weight), non-feed cost of additional days on feed ($0.05 per day), and value of feed saved during feed withdrawal for animals that were returned to feed ($0.1312 per hog per 12 hour feed withdrawal and $0.2625 per hog per 24 hour feed withdrawal). Carcass merit value differences were calculated separately using the same carcass base price ($0.60 per pound) with the addition of a backfat adjustment (0.25% per mm. of backfat) and a muscle adjustment (0.20% per mm. of loin muscle depth). Carcass merit prices also included discounts of 30% for carcasses weighing less than 125 pounds, 20% for carcasses weighing 125 to 145 pounds, 3% for carcasses weighing 146 to 166 pounds, 2% for carcasses weighing 195 to 215, and 6% for carcasses weighing above 215 pounds. Values were calculated for each pig slaughtered and analyzed for effects of treatment and the marketing group.

Results:

Pigs were loaded and left the farm between 2-5am, traveled for 1hr 15 min (range: 1 hr 45 min to 48 min) and held in lairage for 3hr 50 min (range: 4 hr 47 min to 1 hr 58 min).

Meat Quality:

Tables 2 and 3 present least squares means for the effects of feed withdrawal and marketing group, respectively. Withdrawal of feed for 0, 12, and 24 h prior to slaughter resulted in linear reduction in hot carcass weight ($P < .01$) but did not have a significant effect ($P > .5$) on fat or muscle depth. Both linear and quadratic responses ($P < .01$) were observed for hot carcass weight over marketing groups that experienced repeated feed withdrawal. While a linear response ($P < .01$) was observed for fat and muscle depth indicating that later marketing groups were both leaner and heavier muscled. At slaughter carcasses were evaluated by collecting a loin chop from the 10^{th} rib location. Withdrawal of feed for 0, 12, and 24 h prior to slaughter resulted in linear improvements in ultimate pH, Japanese color score, water holding capacity, and color lightness as measured by Minolta L*. However, repeated feed withdrawal and graded marketing over the three week period resulted in linear ($P < .01$) and quadratic ($P < .01$) reductions in muscle quality as measured by ultimate pH, water holding capacity, Minolta L* measure and Minolta b* measure. No significant effect ($P > .05$) for feed withdrawal or marketing group was observed for color redness as determined by Minolta a*.

Table 2. Effect of feed withdrawal on carcass composition and ultimate muscle quality.

Measure	Feed withdrawal (h) 0	12	24	Pooled standard error
Hot carcass weight (kg)[a]	77.4	76.4	74.5	.5
Fat depth (mm)	21.0	21.3	20.8	.3
Loin depth (mm)	47.1	47.2	46.6	.4
Ultimate pH [b]	5.63	5.65	5.66	.01
Water holding capacity (mg) [c]	894.6	915.8	819.2	30.3
Minolta L* [b]	53.1	52.9	52.3	.1
Minolta a*	5.44	5.44	5.21	.09
Minolta b*	4.74	4.72	4.68	.09
Japanese color score [c]	2.99	3.17	3.14	.06

[a] Linear effect of feed withdrawal, $P < .01$
[b] Linear effect of feed withdrawal, $P < .05$
[c] Linear effect of feed withdrawal, $P < .1$

Table 3. Effect of marketing group on carcass composition and ultimate muscle quality.

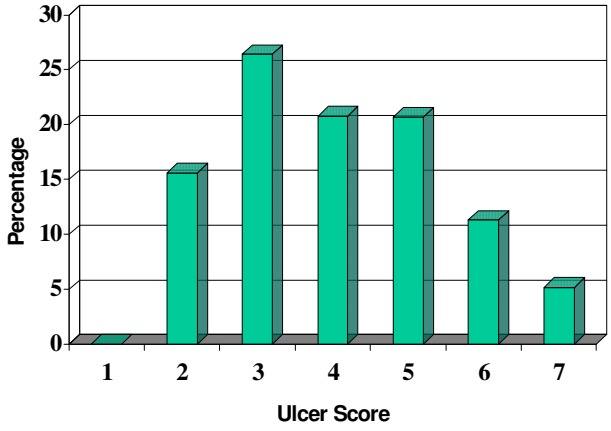
Measure	Marketing group 1	2	3	Pooled standard error
Hot carcass weight (kg) [a,b]	77.4	79.0	71.9	.5
Fat depth (mm) [a]	21.8	21.7	19.6	.3
Loin depth (mm) [a]	46.0	46.3	48.7	.4
Ultimate pH [a,b]	5.71	5.61	5.62	.01
Water holding capacity (mg)[a,b]	604.2	1085.9	939.5	32.9
Minolta L* [a,b]	50.5	54.3	53.5	.3
Minolta a*	5.18	5.44	5.47	.10
Minolta b* [a,b]	4.33	5.01	4.80	.10
Japanese color score	3.07	3.12	3.12	.06

[a] Linear effect of feed withdrawal, P < .01
[b] Quadratic effect of feed withdrawal, P < .01

Gastric Ulcers:

A total of 752 stomachs were evaluated for damage. The esophageal region of the stomach was scored, and signs of chronic damage to stomach tissue and constriction of the esophagus were noted. The scoring system ranged from 1 (normal, healthy tissue) to 7 (ulcerated completely). No stomach was given a score of 1. Almost every stomach evaluated showed bile staining. The percentage of pigs with each ulcer score across all treatments is shown in Figure 1. Scores of 3-4 reflect tissue that was roughened, often with elongated projections and breaks in the tissue. Scores of 5 and above indicate presence of increasingly severe ulcerations.

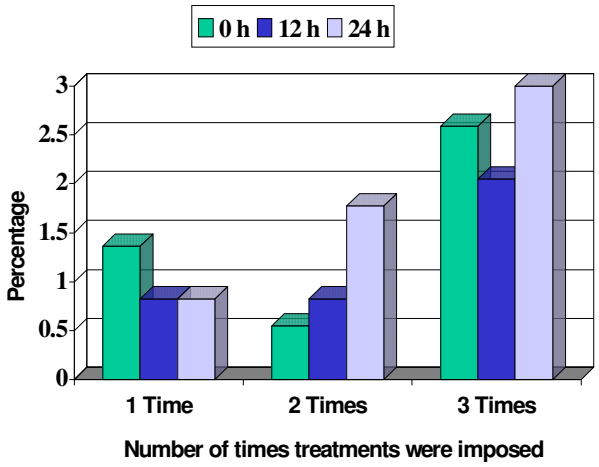
Figure 1. Percentage of pigs with each ulcer score (across treatments).



The average ulcer scores differed (P <.005) for 0, 12 and 24 h withdrawal and were 3.8, 3.6 and 4.1, respectively; however, there was no difference between stomachs from pigs on 0 vs 12 and 24 h withdrawal. The average scores for marketing groups differed also (P <.001) and were 3.6, 3.8 and 4.1, respectively, showing that damage increased in the pigs that were marketed later and as the number of times treatments were imposed increased. Ulcer scores were grouped as mild (1-3.5), moderate (4-5.5)

and severe (6-7). Overall, prevalence of severe ulcers in this population was 13.7%. The percentage of pigs with severe ulcers in each treatment is shown in Figure 2.

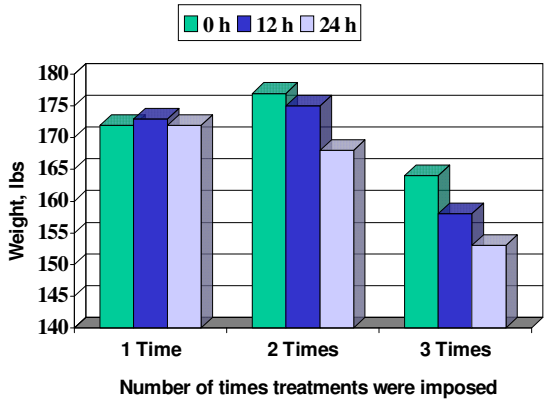
Figure 2. Percentage of pigs with severe damage for 0, 12, or 24 h feed withdrawal.



Overall, prevalence of chronic damage was 19.3% with 57.9% of chronic damage in stomachs from animals in the third marketing group (3 times treatment). Overall, prevalence of esophageal constrictions was 10.4% with 66.7% of esophageal constrictions in stomachs from animals in the third marketing group (3 times treatment). Prevalence of chronic damage and esophageal constrictions were not affected by the length of feed withdrawal.

Because stomach damage was highest in pigs in the third marketing group (3 times treatment) with no relation to time of feed withdrawal, carcass weight was considered as a variable that might explain the greater prevalence of damage in the 3 times treatments. There was an interaction ($P < .01$) between the effect of length of feed withdrawal and marketing group for carcass weight such that carcasses were lighter as length of feed withdrawal increased and they were also lighter as the number of times that feed was withdrawn increased. The lightest carcasses were from the pigs that had feed withdrawn for 24 hours and were in the third marketing group (Figure 3).

Figure 3. Carcass weight of pigs for 0, 12, or 24 h feed withdrawal



Carcass weight was separated into quartiles to examine the relationship between carcass weight and severity of damage, chronic damage, and esophageal constrictions. Severity of damage (Figure 4; P <.01), chronic damage (P <.05), and esophageal constrictions (Figure 5; P <.001) all increased as carcass weight decreased, most notably for the lowest quartile.

Figure 4. Percentage of pigs with mild, moderate, or severe damage in each carcass weight class.

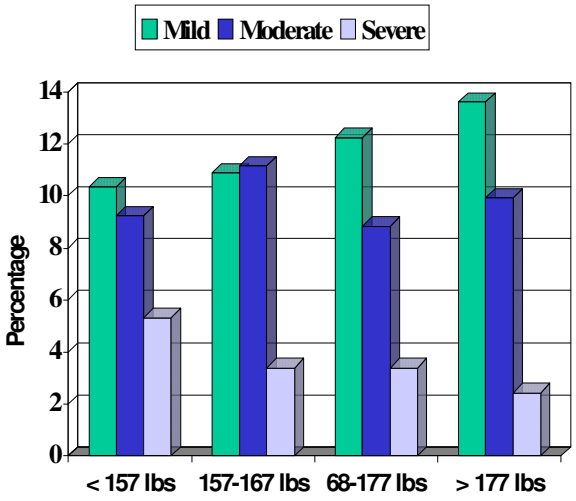
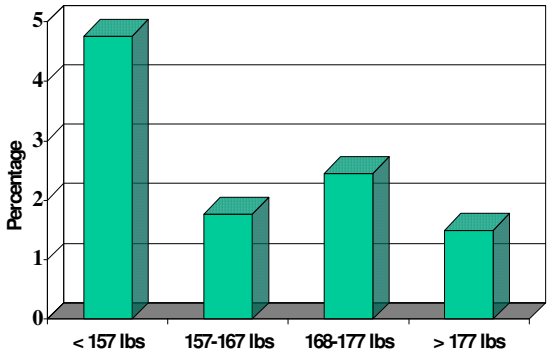


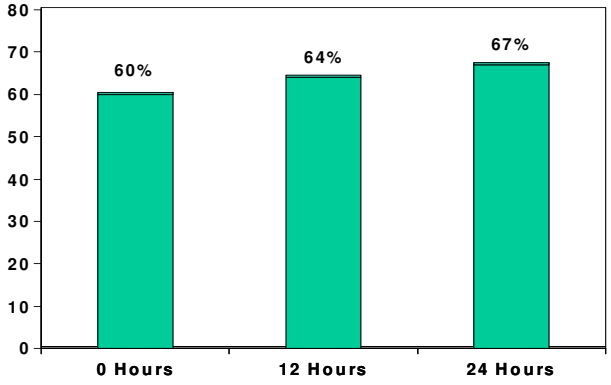
Figure 5. Percentage of pigs with esophageal constriction in each carcass weight class.



Salmonella:

Overall, 62% of cecal samples were positive for Salmonella. Isolation of Salmonella was not associated (P =0.1) with hours of feed withdrawal (Figure 6) but was highly related (P =0.0001) to the marketing group (number of times feed was withdrawn)(Table 4).

Figure 6. Percentage of cecal samples positive for *Salmonella* by hours of feed withdrawal.



The percentage of positive salmonella cecal samples decreased (P = 0.001) from the first to the last marketing groups 73%, 64%, and 52% respectively (Table 4).

There were no differences in the percentage of positive salmonella cecal samples between pigs who had their feed withdrawn once (73%) and their controls (72%); feed withdrawn twice (68%) and their controls (56%) or feed withdrawn three times (53%) and their controls (49%)(Table 4). Control pigs were in the same marketing group but did not have feed withdrawn.

Table 4. Percentage of positive Salmonella cecal samples by marketing group.

	Feed withdrawn		
	12 and 24 hours	0 hours, controls	Overall
First marketing group	73%	72%	73%
Second marketing group	68%	56%	64%
Third marketing group	53%	49%	52%

The prevalence of Salmonella in fecal samples in May was much greater than prevalence in June (Table 5).

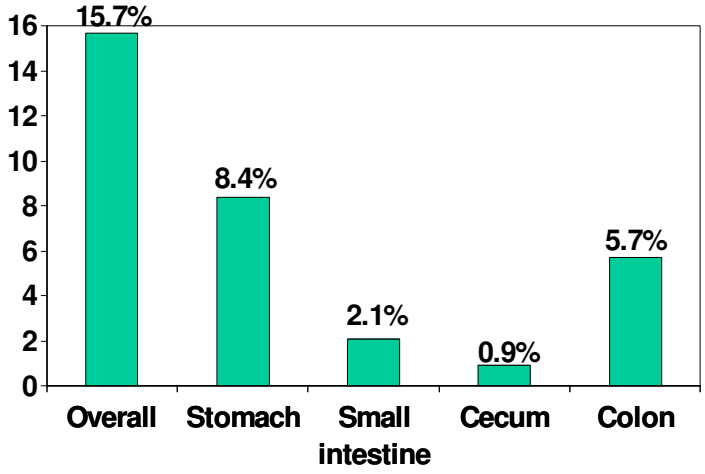
Table 5. The pen prevalence of Salmonella in fecal samples in May and June 1998.

	Pen prevalence of Salmonella											
	0%	4.8%	5.8%	9.5%	14.3%	19%	23.8%	28.6%	38.1%	42.9%	57.1%	66.7%
May, 1998	1	6	1	2	5	2	6	3	1	1	1	1
June, 1998	17	6	0	4	0	1	1	1				

Lacerations:

Overall, 15.7% of the 773 gastrointestinal tracts examined were lacerated in one or more sections (Table 6).

Table 6. Percentage of lacerations overall and by section.



Withdrawal of feed before slaughter decreased the weight of the gastrointestinal tract. The weights of the gastrointestinal tracts of pigs with no feed withdrawal (7.7kg ±1.04) were greater (P = 0.0001) than the pigs with 12 hr feed withdrawal (6.6kg ±0.87) and they were greater (P = 0.06) than the pigs with 24 hr feed withdrawal (6.3kg ±0.91). The proportion of gastrointestinal tract lacerations ranged by day from 8.3% to 23.9%, but the differences were not significant (P = 0.32)

Overall, the feed withdrawal treatments, or marketing group, had no effect on lacerations. However, 11.4% of stomachs were lacerated on 0 hr feed withdrawal compared with 6.9% for the 12 and 24 hour feed withdrawal (P = .03). The likelihood of laceration of the gastrointestinal tracts (excluding lacerations to the stomach because they may have been cut by plant staff removing the esophagus) was highest (14.4%) in the lightest quartile (table 7) of carcass weight and there was a tendency (though not statistically significant) for more lacerations (16%) in the heaviest gastrointestinal tracts (greater than 9 kg)(table l9).

Table 7. Prevalence of lacerations by carcass weight.

	Carcass weight, kg			
	81 or more	80-76.5	76-71	70 or less
Sample size, n	178	170	191	174
Percent with lacerations	5.1%	7.6%	5.8%	**14.4%**

Table l9. Prevalence of Lacerations by Gastrointestinal tract weight.

	Gastrointestinal tract weight, kg					
	≤5	>5 to ≤6	>6 to ≤7	>7 to ≤ 8	>8 to ≤ 9	>9
Sample size, n	20	124	260	188	75	25
Percent with lacerations	10.0%	8.9%	8.1%	6.9%	9.3%	**16%**

There was a tendency for lacerations of the small intestine to be associated (P = 0.14) with carcass weight, 4.8% of small intestine in the lightest quartile were lacerated compared with 1.24% of the others. Lacerations to the cecum were not associated with either treatment or carcass weight. Lacerations to the colon were not associated with carcass weight but there was a tendency (P = 0.09) for more lacerations in 0 h feed withdrawal, 7.2%, compared with 12 h and 24 h, 5%. Most (94.1%) gastrointestinal tracts were lacerated in 1 section but 5.9% were lacerated in 2 sections.

Economics:

Excluding carcass merit or meat quality effects, the hogs that had feed withdrawn only once or were in the corresponding control group (the first marketing group) demonstrated no significant effect of feed withdrawal on the selected revenues and costs. Net revenue differences for the 12 hour feed withdrawal and 24 hour withdrawal were +$0.99 (P = .52) per hog and +$0.19 (P = .90), respectively versus no feed withdrawal. The hogs in the second marketing group (feed withdrawn twice) and their corresponding control group demonstrated a statistically insignificant effect from those withdrawn from feed for 12 hours (-$0.96, P =.54) and significant effect from those off feed for 24 hours (-$5.51, P = .0004) versus the control group. The hogs in the third marketing group (feed withdrawn three times) also demonstrated a statistically significant effect from both those withdrawn from feed for 12 hours (-$3.71, P =.0047) or 24 hours (-$6.29, P =.0001) versus the control group. Effects of feed withdrawal on carcass price through backfat and loin muscle premiums and carcass weight discounts were not statistically significant (12 hour feed withdrawal: +$0.14 per cwt. (P = .80); 24 hours: -$0.34 per cwt. (P =.54) versus the control group) for the first marketing group. Hogs in the second marketing group (feed withdrawn twice) also did not demonstrate

significantly different carcass merit adjustments to carcass price (12 hours: -$0.07 per cwt. (P =.92); 24 hours: -$1.12 per cwt. (P =.0863) versus the control group). The hogs in the third marketing group (feed withdrawn 3 times) demonstrated statistically mixed effects on carcass merit adjustments to carcass price (12 hours: -$0.86 per cwt. (P =.1331); 24 hours: -$2.20 per cwt. (P =.0002) versus the control group).

Discussion:

Meat Quality:

These results suggest that on-farm withdrawal of feed for 24 h prior to slaughter enhances ultimate pork quality. However, in a carcass-merit situation ultimate muscle quality was reduced over time. This reduction may be caused by any one, or the combination, of smaller, slower growing pigs that may have had increased health challenges, increased incidence of gastric ulcers, and repeated withdrawal of feed over time.

Gastric Ulcers:

These data show that withdrawal of feed prior to slaughter, for up to 24 hours, did not lead to an increase in stomach damage when compared to the appropriate control group. The relation of severity of damage, chronic damage, and esophageal constrictions to carcass weight suggests that the impact of chronic ulcers on growth of pigs may be greater than is widely appreciated. However, the causes of chronic stomach damage in this population of pigs is not known.

Lacerations:

The proportion of lacerations in this study (15.5%) was higher than previously reported (4-5%) (Miller et al, 1997). The difference may be due in our study to the high processing speed for evisceration (18 pigs per minute) and/or a more detailed examination of the gastrointestinal tracts in this study which may have decreased under-reporting. As expected, the weight of the gastrointestinal tracts decreased with increasing duration of feed withdrawal. However, unexpectedly, the increase in lacerations was not associated with the heavier gastrointestinal tracts but with the lightest carcass weights. It may be that, in this plant, the rhythm of the evisceration process was disrupted by the lighter and presumably smaller carcasses resulting in an increase in lacerations.

If the reduced weight of the gastrointestinal tract is due to reduced feed content in the gastrointestinal tracts of pigs withheld from feed, and not an increase in water content for the control pigs, then the slaughter enterprise could have substantial benefit by having a reduced amount of feed waste to process.

From the perspective of bacterial contamination, an important finding is the low prevalence of cecal lacerations and lack of association of cecal lacerations to treatment or carcass weight.

This is important because most contamination occurs after singing (Gerats, 1990) and the ceca is the second highest site for recovery of Salmonella (71%) after the palatine tonsils (93.5%) (Wood et al, 1989). In addition, the cecum usually has a very fluid content which could readily spill and potentially grossly contaminate of the carcass. The association of lacerations to particular sections of the gastrointestinal tract may arise because of the effect of feed withdrawal (stomach and colon) and carcass weight (small intestine), on the rhythm of the evisceration process.

Salmonella:

Our results indicate that feed withdrawal 12 or 24 hours prior to loading does not increase the percentage of cecal samples positive for Salmonella post-slaughter.

These findings support the hypothesis that the prevalence of Salmonella in pens of pigs in finishing barns is a poor predictor of prevalence of Salmonella at slaughter. Transport (Williams and Newell, 1970) and lairage (Morgan et al., 1987) along with close contact with other pigs are likely more important determinants of Salmonella prevalence at slaughter.

The pattern of *Salmonella* isolations over time in the finishing barn indicate that many pigs that were excreting *Salmonella* in May had stopped by June. This trend is in accordance with Oosterom and others, 1981, who reported that when pigs become infected with *Salmonella* they gradually stop excreting over 9 weeks. If this trend of decreased excretion continued from June until when all pigs were slaughtered, it could explain the decrease in percentage of *Salmonella* positive cecal samples from the first group slaughtered (73%) to the last group (52%). Our results concur with findings from experimental *Salmonella* infections of pigs which indicate that fecal shedding declines over time.

A limitation of our study is that we may have overestimating the true prevalence among treatments of cecal Salmonella at slaughter because pigs of all feed withdrawal treatments (0, 12, and 24 hour) were daily transported to slaughter on the same truck and shared the same lairage.
The increased stocking density combined with the stress involved may have led to cross-infection with *Salmonella* among the treatments. During transport and lairage an initial *Salmonella* infection of the tonsils may reach the colon and rectum in 2 hours (Edel et al., 1974; Oosterom et al., 1981) which is less than the 5 hours our pigs were in transport and lairage.

Economics:

A consistent economic result emerged from the analysis. Feed withdrawal had no statistically significant effects on net revenue from the hogs that had feed withdrawn only once excluding meat quality benefits. However, marketing groups did show statistically significant reductions in net income for animals that had feed withdrawn. The effect was most significant for the 24 hour withdrawal in the second and third marketing group. Reduced carcass weight in pigs that had feed withdrawn twice or three times as compared to their control groups appears to be a primary factor in net revenue effects. This "within marketing group" reduction in net revenue was in addition to the lower revenue earned by the third marketing group consisting of "tail-enders". While it is difficult to attach a dollar value to meat quality attributes, the economic results are consistent with the meat quality results: feed withdrawal may be a net benefit as long as feed is not withdrawn more than once.

Research questions this study raises:

Meat Quality:

Our results indicate that 24 hour feed withdrawal improves meat quality but quality was progressively reduced from the first marketing group. These findings need to be

tested in other finishing sites to determine if our results can be generalized across farms. A remarkable finding for meat quality from this study is that those animals sent to slaughter in the first marketing group have twice the water holding capacity of the later groups. This needs to be tested in other finishing sites and the biological reasons investigated.

Gastric Ulcers:

We found a high prevalence of severe ulcers that probably were established before we started the feed withdrawal treatment. We suspect that these ulcers were primarily responsible for the lighter carcass weight in the third marketing group. If so, then gastric ulcers are contributing to a major decrease in growth efficiency and meat quality. This hypothesis needs to be investigated at other finishing sites and the underlying cause further explored.

Salmonella:

The decrease in Salmonalla isolates with later marketing groups in our study suggests that the tendency for pigs to decrease shedding of Salmonella over time is more important than the stress of successive feed withdrawal. This hypothesis needs to be investigated at other finishing sites and the underlying cause further explored.

Lacerations:

Our study indicates a much higher prevalence of gastrointestinal lacerations than previously reported. This finding need to be investigated at other finishing sites servicing other packing plants and the underlying and contributing factors, such as carcass weight, further explored.

Economics:

A question for further research is how much longer would the hogs that had feed withdrawn twice or three times have to remain on feed to attain the same carcass weight as the control hogs in their marketing group. It may be that negative effects of repeated feed withdrawal on net returns could be reduced by leaving the hogs on feed for several more days. If one or more of the carcass characteristics (weight, meat quality, salmonella prevalence, etc.) is affected by repeated feed withdrawal and/or by marketing group, then economic analysis is required to compare alternative sorting strategies in combination with alternative feed withdrawal strategies for each marketing group.

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