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FEED WITHDRAWAL PRIOR TO SLAUGHTER: EFFECTS ON PORK QUALITY & SAFETY

Introduction

Increasing muscle pH and improving fresh pork quality are objectives of the pork industry. Factors at all stages of production can contribute to fresh pork quality and sensory characteristics. Pre-slaughter handling is an area that has been targeted to improve pork quality. The effects of feed withdrawal prior to slaughter have been evaluated utilizing a wide range of approaches. Early research focused on economically important losses that occurred when pigs were marketed on a live weight basis and animals were off feed during extended transport or lairage. Feed withdrawal before slaughter has been evaluated recently because it can potentially improve pork quality by increasing ultimate pH, increasing water holding capacity, improving color and reducing the incidence of PSE pork. However, there are potential deleterious effects of feed withdrawal on live weight, carcass weight, liver characteristics, and stomach ulcers.

Weight Loss

Live animal weight loss is the most significant effect of fasting with percentage loss being greatest in the first 24 hr of fasting. The main source of live weight loss is gut fill, comprising 80% of the total loss in the first 24 hr of fasting (Jones et al., 1985). Fasting results in weight loss in the full and empty gastrointestinal tract, stomach, small intestine, and large intestine combined with lighter viscera and liver weights (Safle and Cole, 1960).

Carcass weight is typically not affected by short term feed withdrawal prior to slaughter. Davidson et al. (1968) found that carcass weight was lost with 68 and 70 hr of fasting. Jones et al. (1985) showed that 48 hr of feed and water removal decreased carcass weight. Water and fat mobilization are the most likely sources of carcass weight losses in these cases of extended fasting treatments. Recent studies that fasted pigs of commercial slaughter weights observed no difference in carcass weight (Bidner et al 1999a, Bidner et al 1999b).

Microbiological Impact

Feed withdrawal is potentially beneficial to food safety. Loss of gut fill on the farm results in a reduction in the volume of gut fill that must be removed from the slaughter facility. Additionally, feed withdrawal leads to increased ease of evisceration and reduces the incidence of intestinal tract rupture during evisceration (Miller et al., 1997). If rupture of the intestinal tract occurs, there is the potential of contamination of the carcass. Another benefit of feed withdrawal may be a reduction in the total volume of microorganisms in the gut. Izat et al. (1989) found that fasting broilers for (12 vs. 0 hr) reduced the number of many types of microorganisms. Recent research at the University of Illinois Department of Veterinary Medicine with pigs indicated that feed withdrawal prior to slaughter could also potentially reduce carcass contamination. Feed withdrawal for 24 h combined with transportation prior to slaughter reduced the incidence of Salmonella in ileo-cecal samples by approximately 50 % (Isaacson et al.

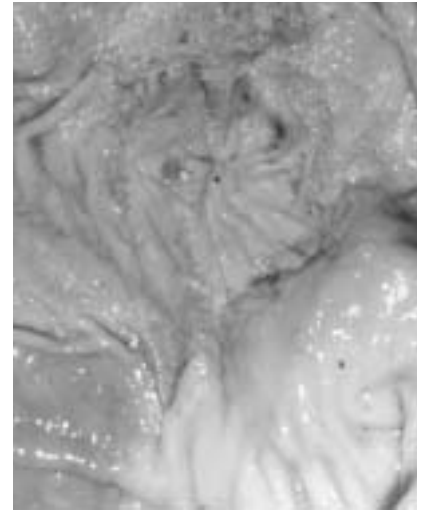
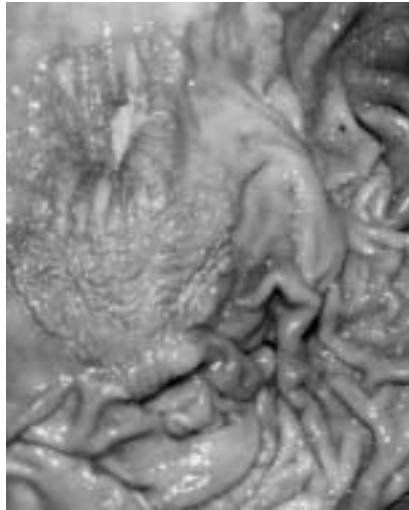
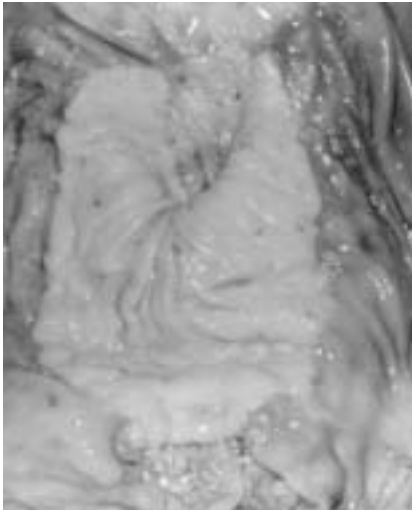
1999). These results indicate that feed should be withheld to reduce the shedding of microbial pathogens.

Stomach Ulceration

Animal welfare is a concern of many consumers. A period of feed withdrawal however is inevitable prior to harvest. Grandin (2000) recommended a fasting period of 12 h prior to harvest. A potential disadvantage of feed withdrawal is the possibility of the formation of stomach ulcers with long periods of feed withdrawal. Lawrence et al. (1998) fasted pigs for 24 h and reported increased ulcer score of the pars esophageal tissue of the stomach. Pocock et al. (1968) also reported that fasting pigs for 72 h increased keratinization and erosion of the stomach lining surrounding the entrance the esophagus, (called pars esophageal tissue). In an experiment conducted at the University of Illinois, the stomach was collected, opened and the pars esophageal region was scored for ulceration as described by Lawrence et al (1998) on a 4-point scale (0 = Normal, 1 = Keratinized, 2 = Eroded, 3

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Figure 1. Stomach ulceration score of the pars esophageal tissue of the stomach.



(0 = Normal, 1 = Keratinized, 2 = Eroded)

= Ulcerated) as shown in Figure 1. Feed withdrawal resulted in an increased stomach ulcer score with 79 % of stomachs from pigs fasted 36 h being scored as keratinized (Bidner 1999a). Of the pigs fasted 60 h, 57 % of stomachs were scored as keratinized and 43 % were scored as eroded (Bidner 1999a). Results of these studies indicate that stomach ulceration only occurs after extended fasting period.

Muscle and Liver Glycogen Depletion

Decreasing muscle and liver glycogen by feed withdrawal and stress, which occurs during feed withdrawal, is related to improvements in pork quality. *Semimembranosus* glycogen was decreased by 37 % with 48 vs. 0 hr of fasting (Warriss, 1982). Wittmann (1994) evaluated glycogen level in different muscles from pigs fasted for 0, 24, 48 or 72 hr and glycolytic potential was decreased by 19 % after 24 hr for the *longissimus* while glycolytic potential of the *Semispinalis* was decreased by 42 % after 24 hr (Wittmann, 1994). Fasting for any extended time period is a

source of significant psychological and physical stress in all animals. McVeigh et al. (1982) reported that muscle glycogen was decreased by 41 % when young bulls were stressed. Kelly et al. (1980) reported the aggression in pigs was highest after 24 hr of fasting. Warriss and Brown (1985) reported that pigs, which were observed fighting during transport/lairage, produced pork with higher *Semimembranosus* and *Adductor* pH. Reduction in muscle glycogen from stress associated with fasting is a likely cause of increases in ultimate pH, water holding capacity and color.

Liver weight and glycogen are also decreased with feed withdrawal. The liver has an extremely high moisture and glycogen content. Liver glycogen is decreased with fasting and is almost totally depleted after the first 24 hr (Warriss, 1982; Warriss and Brown, 1983; Warriss et al., 1987). Warriss and Brown (1983) found that greater than 50% of liver glycogen was depleted after 9 hr of fasting and most of the glycogen was mobilized by 18 hr. In a preliminary study conducted at the University of Illinois, 6 pigs were fasted 24 hr without com-

mingling and 6 pigs were slaughtered immediately after delivery and liver glycolytic potential was decreased by 67 % after 24 hr of fasting (294.7 vs. 96.0 mmole/g). Moisture (%) of the liver increased after 18 hr of fasting (Warriss and Brown, 1983). Warriss et al. (1987) found that fasting increased % moisture, fat and protein while liver weight, glycogen and lactate decreased with feed withdrawal. Fasting also produced livers with a higher pH and darker color (Warriss et al., 1987).

Pork Quality

Increasing ultimate pH, increasing water holding capacity, improving color and reducing the incidence of PSE pork are important objectives of the pork industry. Several studies have shown that feed withdrawal prior to slaughter increases ultimate pH, water holding capacity and color (Becker et al., 1989; Jones et al., 1985; Eikelenboom et al., 1991, Wittmann, 1994). One concern relative to feed withdrawal prior to slaughter is increasing the incidence of dark, firm, and dry (DFD) pork.

Eikelenboom et al. (1991) defined DFD as pork with an ultimate pH greater than 6.2 and fasting for 24 hr resulted in an increase in the incidence of DFD pork in 1 of 2 experiments. Fasting and mixing also resulted in an increase in DFD pork (Murray and Jones, 1994).

Feed withdrawal has been shown to improve quality of carriers and reactors of the halothane gene. Murray et al. (1989) compared the effect of 0, 24, or 48 h off feed on pork quality of pigs that were identified as non-carriers, carriers, or reactors for the halothane gene. Ultimate pH of halothane gene reactors was increased with fasting but there was no effect on non-carriers and carriers (Murray et al., 1989). Fasting for 48 h decreased drip loss in heterozygous (Nn) pigs while both 24 and 48 h of fasting reduced drip loss for homozygous reactors (nn). The percentage of soft, exudative pork for reactors (nn) was reduced from 87% to 48% after 48 h of fasting (Murray et al., 1989). A 48 h feed withdrawal period reduced the incidence of pale colored pork in the halothane reactors from 57% to 9% (Murray et al., 1989).

Feed withdrawal has not been successful at eliminating quality problems associated with the Rendement

Napole (RN) gene. The RN gene is associated with excess muscle glycogen and extremely low ultimate pH (~5.3-5.4). Fernandez et al. (1992) fasted Hampshire crossbred pigs that had high biopsy glycolytic potential values and found no difference in ultimate pH, drip loss or color. The effect of feed withdrawal on pigs that are carriers and non-carriers of the RN gene was evaluated by a series of studies at the University of Illinois (Bidner et al., 1999a and Bidner et al., 1999b) which discovered that feed withdrawal did not impact the quality of RN gene carriers. The interaction between feed withdrawal and the RN gene as shown in Table 1. The pork quality of normal pigs (rn+rn+) was improved by 36 and 60 hr of feed withdrawal prior to slaughter whereas there was no effect on RN gene carriers (Bidner et al., 1999a). In this study pigs were mixed during the feed withdrawal period. In another experiment there was no effect of feed withdrawal on normal or RN gene carrier pigs when feeders were removed 36 vs. 12 hours prior to slaughter (Bidner et al., 1999b). These studies suggest that genotype, level of stress and animal handling determine pork quality response to feed withdrawal.

Summary

Potential short-term disadvantages of feed withdrawal are the loss of live weight and after extended fasting the possibility of loss of carcass weight and formation of stomach ulcers. Feed withdrawal prior to slaughter is however beneficial to food safety and can improve ultimate pH, water-holding capacity and color. Muscle glycogen reduction during feed withdrawal is related to improvements in pork quality. Genotype, level of stress and animal handling can all interact to determine the pork quality response to feed withdrawal.

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Table 1. Effect of time of feed withdrawal and RN genotype on meat quality characteristics

Genotype ¹	rn+rn+			RN-rn+			SEM
Time of feed withdrawal (h)	12	36	60	12	36	60	
Ultimate pH	5.45 ^c	5.59 ^b	5.65	5.36 ^c	5.34 ^c	5.36 ^c	.02
Purge Loss %	4.10	2.46	2.37	4.48	4.66	4.05	.33
Drip Loss %	4.17	3.11	3.50	5.49	6.22	5.25	.30
Hunter L*	55.54 ^a	53.08 ^b	51.76 ^c	55.33 ^a	55.55 ^a	55.48 ^a	.45

Bidner et al. 1999a,

^{abc} Means within a row with different superscripts are different ($P < .05$)

¹ Animals with biopsy GP greater than 230 $\mu\text{mole/g}$ were classified as RNrn+ and those with GP less than 230 $\mu\text{mole/g}$ were classified as rn+rn+.



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