Dietary Modifications to Improve Pork Quality

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Introduction

The definition of pork quality can vary somewhat across different sectors of the pork chain. Some of the attributes of pork quality can include muscle color, muscle firmness, marbling, water holding capacity as well as palatability. Recently, pork quality has also encompassed the firmness and color of fat often referred to as fat quality. Fat quality affects both the ability of pork to meet export qualifications as well as further processing characteristics. Traditionally, nutritionists have formulated diets for finishing swine on the basis of balancing the energy and amino acid requirements for maximum growth performance and carcass leanness. Vitamins and minerals were added to the diet to prevent deficiency symptoms. Supplementary dietary fat source (if added) was dictated by economics as to what source to use. With the pork industry evolving and consolidating in recent years, there has been an increased interest in improving pork quality by dietary modifications. Numerous studies have been conducted to investigate what modifications can be made to the diet to ultimately improve the quality of pork and pork products being produced. The objective of this paper is to discuss some potential dietary modifications and their ultimate impact on pork quality.

Feed Withdrawal

Researchers have studied the effects of withholding access to feed for a period of time before the slaughter process. Results from this work show there can be some possible potential advantages. One possible advantage resulting from feed withdrawal would be that the glycogen concentrations in the muscle of the pig at slaughter would be decreased. By having less glycogen to fuel glycolysis, this would lead to a reduction in the production of lactic acid leading to a higher ultimate pH and possibly more desirable meat quality. Another advantage would be a reduction in gut fill on the harvest floor. This reduction would potentially lower the incidence of stomach and gut punctures during the evisceration process leading to carcass contamination.

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.*, 1999[a] and Bidner *et al.*, 1999[b]), which discovered that feed withdrawal did not impact the quality of RN gene carriers. The pork quality of normal pigs (rn^+rn^+) was improved by 36 or 60 hours of feed withdrawal prior to slaughter, whereas there was no effect on RN gene carriers (Bidner *et al.*, 1999[a]). 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.*, 1999[b]). These studies suggest that genotype, level of stress, and animal handling factors all interact to establish the pork quality response to feed withdrawal. However, there can also be negative effects from too long of feed withdrawal which can include live weight and carcass weight reductions, negative liver characteristics, and an increase in visual stomach ulcerations. (Bidner, 1999[a])

Conjugated linoleic acid (CLA)

Conjugated linoleic acid (CLA) is a series of positional and geometric isomers of linoleic acid that have several effects in the pig. The anticarcinogenic properties of CLA have prompted an increased interest in producing pork with increased CLA levels. One possible effect is the improvement in carcass leanness when CLA is fed to pigs. The data are somewhat conflicting with some studies showing improvement (Weigand *et al.*, 2001) and others showing no response (Ramsay *et al.*, 2001). Variation in response may well reflect, in part at least, the specific isomer composition of the CLA product. Modified tall oil, a by-product of the wood pulp industry, is a source of CLA that has been used in previous studies. However, now there are some manufactured sources available. Interestingly, although CLA reduces carcass fat it has been shown in a number of studies to increase intramuscular fat or marbling. CLA has also been found to increase fat and belly firmness via a shift in the fatty acid profile of body fat from unsaturated to saturated. Conjugated linoleic acid may, therefore, be used to counteract the negative effect of dietary unsaturated fats on fat firmness. Joo *et al.*, (2002) reported a decrease in lipid oxidation of pork with increased levels of CLA in the meat with CLA levels in the diets ranging from 0 to 5% CLA. There are reports of improvements in pork color and water-holding

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capacity in CLA fed pigs (Joo *et al.*, 2002). Dose levels for CLA used in studies, with the exception of Joo *et al.* (2002), have generally been in the range of 0 to 1% of the diet and at the highest dose level the concentration of CLA has been up to around 2% in subcutaneous fat and 0.3 to 0.4% in lean tissue. With these levels for CLA, no effect on the oxidative stability of the fat was observed.

Fat Quality

Fat quality is generally defined in terms of physical characteristics, mainly firmness, which is directly related to the fatty acid composition of the body fat, particularly the level of unsaturated fatty acids. High levels of unsaturated fatty acids, primarily linoleic (C18:2), in subcutaneous fat are associated with soft fat and consequent carcass handling and meat processing problems. Carcasses with soft fat are difficult to process and result in both reduced slicing yields in bacon and also smearing of fat in grinding operations resulting in a product that is often deemed unattractive to the consumer. In addition, tissue separation, where the fat separates from the lean, is a problem in carcasses with soft fat. Also, as the degree of unsaturated fat increases, its oxidative stability is reduced. This can result in potential problems with oxidative rancidity and reduced shelf life of the product.

The issue of soft fat has become a major concern in the United States and is becoming of increasing concern to the meat-processing sector. The soft fat issue has emerged as a result of changes in the swine industry over the last decade. These changes include the feed ingredients used in swine rations and the genotype of the pig. The substantial improvements in percent lean in the carcass and at heavier weights that have been achieved over recent years have been accompanied by reductions in intramuscular fat (IMF) or marbling. The average percent IMF in pigs in the United States is 2% or less. There are approaches to increasing IMF content that can be used by producers. These include feeding a low lysine or protein diet (Cisneros *et al.*, 1996; Witte *et al.*, 2000; Bidner, 2003) in late finishing; however, these approaches can also increase production costs significantly.

From the perspective of manipulations of fatty acid composition by dietary alterations, lean pigs have the advantage or disadvantage that a greater amount of their fat is derived from dietary fat sources, with a smaller proportion of their deposited fat coming from *de novo* synthesis. Because of this, leaner pigs are more responsive to dietary manipulation of fat composition than fatter animals. In lean animals, the fatty acid profile of body fat is more closely related to the profile of the diet the pig consumed. With today s production costs, some producers are implementing least-cost ration formulation strategies. With this strategy, a diet is formulated on the basis of cost first and then nutritive value of the ingredient. Growth and efficiencies of the live pig are not affected by this strategy as all nutritive requirements are being satisfied. However, it can negatively affect fat quality and belly firmness if the least cost ingredient has a high level of unsaturated fatty acids. In addition, there has been an increased use of fats and oils in diets for growing-finishing swine to increase energy density of the diet. Some oil and fat sources, particularly from poultry and plant sources including soybeans and corn, have relatively high concentrations of unsaturated fatty acids. When pigs are fed diets containing these highly unsaturated energy sources at too high of levels, the firmness of the fat is reduced significantly. One of the metrics to measure saturation level of pork fat is the Iodine Value (IV). This number represents the grams of Iodine bound to 100 grams of fat. The higher the IV, the more unsaturated (softer) the fat. High quality pork fat has been characterized by the NPPC (1999) as having less than 15% polyunsaturated fatty acids, more than 15% steric acid (C18:0), and an iodine value lower than 70 mg iodine/100 g of fat (Lea *et al.* 1970).

The debate relating to fat composition and quality also has implications for pork palatability. Most research investigating the relationship between fatty acid concentrations in pork and palatability traits have addressed potential problems with off-flavors and odors associated with long chain unsaturated fatty acids, particularly those found in oils and fishmeals (Overland *et al.*, 1996). However, there is evidence of a positive association between the concentration of certain fatty acids and pork palatability. In particular, Cameron and Enser (1990) found favorable correlations between the concentration of oleic acid (C18:1) in the intramuscular fat and pork tenderness, juiciness and flavor.

Another issue is the relative effects of dietary fat composition on the fatty acid profile of the different fat depots. Most research has focused on subcutaneous fat and there is a good understanding of the relationship between dietary fatty acid profile and that in the subcutaneous fat. However, the relationship between the fatty acid profile of the diet and the composition of the IMF and intermuscular fat (seam fat) is not as well established at this time.

Magnesium

Feeding magnesium salts for a short period prior to slaughter has recently been investigated in a number of studies. A range of magnesium salts have been evaluated including chloride, sulfate, proteinate, mica, and aspartate and all have shown efficacy for improving water-holding capacity and color. Responses have been somewhat variable; early Australian research showed a consistent reduction in the incidence of PSE from pre-slaughter magnesium administration (D Souza *et al.*, 1998; D Souza *et al.*, 1999a; D Souza *et al.*, 1999b; D Souza *et al.*, 1999c). However, a number of studies carried out in the US and Canada (Schaefer *et al.*, 1993; Caine *et al.*, 2000; Apple *et al.*, 2005) have shown a much smaller, less consistent effect. Studies have shown a benefit of magnesium supplementation although the results have been somewhat inconsistent with respect to the optimum dose level and time of administration (Hamilton *et al.*, 2002). The most common dosage level tested has been 3.2g of elemental magnesium per pig per day and a

feeding period of 5 days. However, in some studies lower levels (1.6g magnesium/pig/day) and shorter feeding period (l to 2 days) have produced a response. Frederick *et al.* (2004) showed that supplemental magnesium in the water (0.12% Mg daily) for as short as 2 days may improve pork quality characteristics; however, results were inconsistent across supplemental durations and muscles.

Lipid Oxidation in Pork

Lipid oxidation is potentially a major cause of detrimental changes in pork during storage that has been associated with deterioration in muscle color, increased oxidative rancidity, and associated increase in off flavors in the meat, and reduced shelf life. This reduction in shelf life is of critical importance in products that are exported because of the extended time from slaughter to consumption of the meat. In addition, it has been suggested that oxidation of the lipids within the cell membranes can reduce membrane integrity and increase drip loss from the muscle.

As the degree of unsaturation of pork fat increases its oxidative stability is reduced. This results in potential problems with oxidative rancidity and reduced shelf life of the product (Larrick *et al.*, 1992; Wood *et al.*, 1999). Oxidative rancidity is a major cause of deterioration of meat. This deterioration of the meat product in associated with oxidation of unsaturated fatty acids in particular the polyunsaturated fatty acids, fats with 3 or more double bonds. These polyunsaturated fatty acids are associated with the phospholipids, which are critical to the development of off-flavors in meat or muscle foods (Allen and Foegeding, 1981). The oxidation process of these fatty acids proceeds as follows:

1. Free-radical chain mechanism
   a. Initiation

   $RH + O_2 \rightarrow R^{\bullet} + {}^{\bullet}OH$

   b. Propagation

   $R^{\bullet} + O_2 \rightarrow ROO^{\bullet} \rightarrow$ initial product of fatty acid oxidation

   $ROO^{\bullet} + RH \rightarrow ROOH + R^{\bullet}$

   c. Termination

      1. $R^{\bullet} + R^{\bullet} \rightarrow RR$
      2. $ROO^{\bullet} + ROO^{\bullet} \rightarrow ROOR + O_2$
      3. $RO^{\bullet} + R^{\bullet} \rightarrow ROR$
      4. $ROO^{\bullet} + R^{\bullet} \rightarrow ROOR$
      5. $2RO^{\bullet} + 2ROO^{\bullet} \rightarrow 2ROOR + O_2$

The primary product is the formation of hydroperoxides or peroxides (ROOH). Peroxides can also continue to break down to carbonyls, form polymers, or react with vitamins, protein or pigments of the product.

Vitamin E

The most widely researched antioxidant in livestock production is vitamin E. There are numerous peer reviewed studies relating to the effects of feeding high levels of α-tocopherol to pigs prior to slaughter and its effects on lipid oxidative changes in pork and pork products. Recommendations for dietary requirements for α -tocopherol are around 11 mg/kg (NRC, 1998). Ullrey, (1981) recommended higher levels (30 mg/kg or above) in scenarios where increased levels of unsaturated fats are being included in the diet. Pettigrew and Esnaolo (2000) reviewed the impact of feeding high vitamin E levels on pork quality. Feeding durations have ranged from 42 days to 6 months with inclusions ranging from 100 to 800 mg/kg of feed of DL- α -tocopherol. The majority of studies showed a dose-dependent increase in muscle vitamin E levels and a reduction in lipid oxidation during storage. Variable responses in muscle color and water-holding have been observed. As a result of vitamin E supplementation in the diet, several studies have shown that high levels of vitamin E in the diet can preserve muscle redness (a* values on colorimeters) and a few studies have shown a reduction in drip loss. Various recommendations are to feed 200 mg/kg of α -tocopherol for at least 6 weeks prior to slaughter, although these are based as much on economics as on efficacy.

Cereal Grains

Recently, there has been a growing interest in manipulating the fat quality and color of pork by feeding pigs different varieties of corn. There are several varieties of corn on the market designed to fulfill the needs of the livestock industry. Some of these varieties would include high oil corn, high lysine corn and nutrient dense corn. Another corn variety on the market is a white corn that is normally marketed as a human food grade corn for the tortilla market. This white corn does not have the carotenoid content observed in conventional yellow corn. These carotenoids are a group of pigments including β-carotene that are associated with the yellow color of conventional corn.

A study was conducted that compared the fat quality and fat color of pigs fed conventional yellow corn compared to a white food grade corn from 25 kg to slaughter (Fent *et al.*, 2003). No differences were found in any carcass quality or belly thickness measurements. Only minor differences were observed in the backfat and bellyfat depots of the pigs. Fat quality traits that were measured included objective color, firmness and fatty acid profile of both the bellyfat and the subcutaneous backfat depots of the tested pigs.

Another strategy in manipulating the fat quality and color of pork is to use barley or wheat in place of corn in the diet. Barley and wheat contain lower levels of cartenoids and

xanthophylls, and also have lower levels of C18:2 (NRC, 1998) than of corn. Barley feeding, in particular, has been hypothesized to produce a fat that is whiter, firmer and more desirable for the Japanese export market. Lampe *et al.*, (2003) investigated different cereal grain sources (barley, white corn, and yellow corn) and their effects on meat and eating quality traits when fed to swine from 27.6 kg to 130.2 kg. Results from this study suggested that different cereal grain sources have little effect on eating quality of pork that had been aged for 25-27 days post harvest. Another study was conducted by Carr *et al.*, (2005) looking at the effects of different cereal grains (corn, wheat, and barley) and ractopamine hydrochloride on performance, carcass characteristics and fat quality in late-finishing pigs. Results from this trial indicated that feeding corn, wheat or barley with or without ractopamine had little to no effect on muscle or fat quality attributes.

Other Compounds

A range of other dietary compounds have been evaluated for their effectiveness in improving muscle color and water-holding capacity. These include betaine, carnitine, chromium, electrolytes, reduced starch levels, selenium, sodium oxalate, tryptophan, vitamin C, vitamin D3, and creatine monohydrate.

Conclusions

There are numerous possibilities for nutrition to alter pork quality both advantageous and deleterious and many more possibilities that this paper has not covered. There is no easy answer as in most cases an improvement in pork quality via nutritional modification will result in an increase in productions costs. Systems that are vertically integrated could possibly be more successful in capturing the added value on the carcass side that could potentially offset the extra production costs on the live side and make the improvements that the market place is requesting today.

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