Fat Hardness in Swine Products, Dietary Challenges and Opportunities

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▪ Take Home Messages

Fat hardness in swine products is an important issue for the swine industry. Modern production systems present some challenges that can be mitigated through dietary approaches.

Challenges include:

- Genetic improvement of pigs has reduced fat content of pork carcasses such that fat composition is influenced to a great degree by the type of fat consumed.
- Use of unsaturated fats in swine diets will likely increase, which will exacerbate the challenges created by soft fat.

Dietary approaches to improve fat hardness include:

- Formulate diets according to Iodine Value Product specifications.
- Withdraw or significantly reduce unsaturated fats in finishing diets at least 3 weeks before pigs are harvested.
- Feed conjugated linoleic acid to increase fat hardness.
- Evaluate the potential for dietary glycerol to increase fat hardness.

▪ Introduction

The effects of diet on hardness of pork fat have been known for years. In 1926, researchers at the United States Department of Agriculture demonstrated that feeding peanuts or soybeans dramatically decreased hardness of carcass fat compared with corn-based diets (Ellis and Isbell, 1926). Until recently, this relationship between diet and fat firmness has not been a topic of great interest to the swine industry. However, the rapid growth of the bio-fuels industry in North America has made the feeding of fermentation co-products from ethanol production commonplace. Economic considerations have driven pork producers to feed high levels of dried distillers grains with solubles (DDGS), which precipitates occurrence of soft fat. Currently, the influence of diet composition on pork fat quality is the subject of much discussion and research.

Hardness of pork fat plays an important role in pork quality. Fat hardness is directly controlled by the fatty acid composition of the fat and fatty acid composition heavily influences shelf life and flavor of pork (Wood et al., 2003). In addition to pork quality, fatty acid composition of pork fat influences the processing characteristics of pork. Soft fat does not possess the rigidity necessary for high-speed slicing of bacon and slows other processes. Consequently, pork processors prefer firm fat in pork products, which typically means that the fat is relatively high in saturated fatty acids. In contrast, consumers seek to reduce their consumption of saturated fats so they generally prefer fat with elevated unsaturated fatty acids which makes the fat softer. So, conflicting demands are being placed on the pork industry.

The main focus of this paper is to highlight some of the challenges associated with firmness of fat in pork carcasses and suggest possible solutions that address the problem. While fat firmness and composition are closely related to overall pork quality, this paper will not address the wide array of pork quality measures used to determine overall acceptability of pork products to the consumer.

▪ Background

Physiology of Fat Hardness

Hardness of pork fat is directly related to the ratio of saturated (SFA) and polyunsaturated fatty acids (PUFA) that compose the fat (Wood et al., 2003). Fats containing a high proportion of saturated fatty acids (fatty acids containing no double bonds) are solid at room temperature. As the degree of unsaturation (presence of double bonds) in fatty acids increases, the melting point declines such that fats containing a relatively high proportion of unsaturated fatty acids are liquid at room temperature. As this ratio of polyunsaturated to saturated fatty acids increases, pork fat becomes increasingly softer. In pork fat, this ratio and the resulting fat hardness is heavily influenced by the ratio of linoleic acid to stearic acid (Wood et al., 2003; Nishioka and Irie, 2006). Hugo and Roodt (2007) reviewed the work of several researchers and suggested that fat of acceptable firmness should contain 12 to 15% linoleic acid and more than 41% saturated fatty acids.

The fatty acid composition of pork fat results from dietary fat and endogenous fatty acid synthesis. Dietary fat is deposited in the pig's body with no alterations while endogenous synthesis is primarily saturated fatty acids. So, body fat of pigs will reflect the fatty acid profile of dietary fat (Ellis and Isbell, 1926; Averette Gatlin et al., 2002; Jackson et al., 2009) as modified by endogenous fatty acid synthesis. Genetically lean pigs fed vegetable-based diets will tend to possess softer fat than similarly-fed pigs with a higher propensity for fat deposition because lean pigs have lower endogenous fat synthesis. Increasing dietary fat concentration depresses de novo fat synthesis in pigs (Azain et al., 2004), which further exacerbates the effects of dietary fat on composition of pork fat.

Methods to Measure Fat Hardness

Several methods have been used to quantify fat hardness. Physical measures of fat hardness such as the Instron compression tests, Durometer, Hardness meter, and Penetrometer have been attempted with mixed results (Apple et al., 2010). The belly flop or belly flex test has been used widely to measure the degree of flex demonstrated by a pork belly that is suspended over an elevated stick (Thiel-Cooper et al., 2001; Rentfrow et al., 2003; Whitney et al., 2006). A belly that demonstrates minimal flex is indicative of firmer fat. However, other factors such as belly thickness, temperature of the belly, orientation of the belly on the stick (skin side up or skin side down), and moisture content of the belly can all influence results (Apple et al., 2010).

Iodine Value (IV) is a measure of the degree of unsaturation in fatty acids and is one of the most common measures of fat hardness. Iodine value can be measured directly in the laboratory but most commonly it is calculated from the fatty acid composition of a fat sample using a prediction equation (AOCS, 1998). Typical IV's range from 55 to 95 with higher values indicating softer fat. Recently, Apple (2010) questioned the accuracy of IV in quantifying fat firmness because longer chain fatty acids are not included in the equation developed by AOCS. Meadus et al. (2010) included seven additional long-chained fatty acids when calculating IV. Presumably, this equation provides a better prediction of fat firmness but this awaits confirmation.

Where Should Fat Hardness Be Measured?

Pigs deposit fat in several locations in their bodies. It seems reasonable to theorize that there may be differences among these depots which could influence the assessment of fat firmness if only one depot is sampled. Cromwell et al. (2011) demonstrated that the inner layer of backfat of pigs contains a higher percentage of saturated fatty acids and a lower concentration of polyunsaturated fatty acids compared with the outer layer of backfat. Wiegand et al. (2011) found weak and inconsistent correlations of IV among four fat depots of pigs fed diets with varying energy concentrations with and without ractopamine. They argued that jowl fat IV is not a good predictor of belly fat IV because pigs were harvested at similar bodyweights but differing physiological maturities. However, others have reported more consistency in IV among fat depots. If the outer and inner layers of backfat are collected as one sample and not segregated, IV of backfat is very similar to IV of belly fat (Averette Gatlin et al., 2003; Jacela et al., 2011). In contrast, Xu et al. (2010b) found that IV of backfat is lower than IV of belly fat but these two estimates become more similar as IV of the carcass increases. Leick et al. (2010) reported the IV, total monounsaturated fatty acids (MUFA), total PUFA, and MUFA:PUFA ratio of jowl fat was significantly correlated to that of belly fat. In their study, jowl fat underestimated IV of belly fat by about 5% but Jacela et al. (2011) found the jowl fat IV was essentially the same as IV of belly fat. Because belly fat is difficult to sample directly without damaging a valuable pork cut, it seems that both backfat and jowl fat will provide reasonable estimates of belly fat hardness realizing that jowl fat may slightly underestimate belly fat IV.

▪ Challenges That Reduce Fat Hardness

Genetic Improvement of Pigs

Pigs harvested today are significantly leaner than pigs harvested 10 or 15 years ago. Increased leanness of pigs decreases de novo synthesis of fat which is primarily saturated fat. This decline in de novo fat synthesis due to genetic selection for leanness results in a carcass with fat composition that more nearly reflects the composition of dietary fat. If dietary fat is increasingly supplied by vegetable sources that are higher in polyunsaturated fatty acids than animal fats, carcass fat will get softer. It is not likely that the pork industry will reverse directions and begin selecting for fatter pigs so soft fat will continue to be a challenge. It will be interesting to see if widespread adoption of immuno-castration occurs in the North American swine industry and how this might affect fat hardness.

Availability of Traditional Fat Sources

Historically, caloric density of diets for livestock has been increased by fat supplementation.

Supplemental fats were of animal (tallow, choice white grease, yellow grease) or vegetable (corn oil, soybean oil, canola oil) origin. This practice continues currently. However, the availability of animal fats, which tend to be more saturated, may be reduced in the future due to competition from other users and increased price. The drive for "green" energy and energy independence has encouraged increased production of biodiesel from fats (animal and vegetable). Biodiesel production in the U.S. and Europe combined has increased from less than 1 million metric tonnes in 2001 to over 10 million metric tonnes in 2009 (National Renderers Assoc., 2011). If this huge appetite for fat, especially animal fat, is sustained, competition for saturated animal fats to use in swine diets will be fierce and may limit availability. This demand for animal fats is reflected in a 120% increase in the price of inedible fats from 2001 through 2009 (National Renderers Assoc., 2011). There are numerous other uses for animal fats that also contribute to this competition.

The increased competition for animal fats will, by default, encourage greater use of vegetable fats in swine diets. These vegetable fats will not likely be added separately as supplemental fats but rather will enter swine diets as components of other feedstuffs such as grains and ethanol co-products, specifically DDGS. In the foreseeable future, DDGS will remain an important component of swine diets due to its competitive price compared with other available feed ingredients.

In summary, the two primary factors challenging our ability to maintain hard fat in pork carcasses are:

- The high lean content of modern pigs and the drive to maintain or increase leanness; and
- The increasing use of vegetable fats that are relatively high in polyunsaturated fatty acids.

▪ Dietary Opportunities to Improve Fat Hardness

Formulate Diets Based On IVP

Iodine value product (IVP) is a tool that nutritionists can use to formulate swine diets with an eye toward controlling the increase in IV of pork fat when feeding diets containing high levels of unsaturated fatty acids. Madsen et al. (1992) proposed the concept of IVP, which they defined as (IV of dietary fats x % of dietary fats) x 0.10. Essentially, this concept estimates the degree of unsaturation in dietary fats which can be used to predict the degree of unsaturation or IV of pork carcass fat. Benz et al. (2011a) tested this concept by feeding pigs diets with low, medium, or high IVP. Within the medium and high categories, diets had similar IVP but were derived from differing fat sources. After 83 days on feed, there was no significant relationship between IVP of the diet and IV of backfat or jowl fat. These researchers relied on the commonly-used equation proposed by AOCS (1998) to calculate IV of dietary fat and carcass fat. Perhaps, a different outcome would have resulted if they used the more extensive equation proposed by Meadus et al. (2010).

Cast (2010) stated that IVP is not an absolute number but can be used to guide improvement in IV of carcass fat. He suggested that one must know the IVP of current diets being fed and the resulting IV of the target fat depot. With this information, one can re-formulate diets to achieve a lower IV then monitor effects on IV of carcass fat. This approach will be farm-specific but can be useful.

Withdraw Fat in the Late Finishing Period

Time period of response

Adipose tissue in pigs is a dynamic tissue because fats are continually being deposited and mobilized depending on the physiological state of the pig. This high degree of activity allows rather rapid changes to be manifested in composition of fat in adipose tissue. Wood et al. (1994) suggested that the bulk of change in fatty acid composition of adipose tissue occurs within 25 days of a dietary change. Similarly, IV of belly fat declined 5% in just 21 days after DDGS was removed from diets of finishing pigs (Xu et al., 2010a). Even faster changes have been reported by Warnants et al. (1999) when they noticed that about 50% of the change in linoleic acid incorporation into backfat occurred 14 days following a dietary switch from 2.5% tallow to 15% full-fat soybeans. Within 6 weeks of the diet switch, a plateau in fatty acid composition was achieved. Similarly, Averette Gatlin et al. (2002) concluded that significant changes in fatty acid composition and IV of pork fat could be elicited in as little as 6 weeks.

So, dietary changes in fat composition 3 to 6 weeks before harvest will have significant influences on composition and firmness of fat in pork carcasses. Complete removal of supplemental dietary fat or high-fat ingredients will have the most profound effects. Switching from a diet with a relatively high concentration of unsaturated fat to a diet containing a more saturated fat or reducing the dietary concentration of unsaturated fat will change composition of carcass fat but it may not achieve the degree of hardness in carcass fat that is desired.

Dried distillers grains with solubles

Dried distillers grains with solubles requires special mention because this ingredient is used extensively in the swine industry and it is so widely blamed for problems with soft fat in pork carcasses. The DDGS used in swine feeds is derived primarily from fermentation of corn for ethanol production; so most data available are based on corn DDGS. Inclusion of DDGS in diets for growing-finishing swine clearly decreases fat hardness and increases flex or softness of pork bellies (Stein and Shurson, 2009). This response is likely due to the elevated linoleic acid content of fat in DDGS. Increasing concentrations of DDGS in finishing pig diets up to 30% (Xu et al., 2010b) or 45% (Cromwell et al., 2011) results in linear increases in IV of carcass fat and linoleic acid content of carcass fat coincident with a linear decrease in belly firmness. Similarly, Widmer et al. (2008) found decreased belly firmness when diets contained 20% but not 10% DDGS.

An obvious solution to this problem of DDGS-induced soft fat is to remove or significantly reduce dietary concentrations of DDGS in the late finishing phase. As mentioned above, this dietary change must occur at least 3 weeks before pigs are harvested to ensure a significant decline in IV and PUFA content of belly fat as demonstrated by Xu et al. (2010a). A total withdrawal of dietary DDGS can be made abruptly as there appears to be no detrimental effects of this sudden dietary change on pig performance (Hilbrands et al., 2009; 2011). Feeding a modified DDGS product with lower fat content than traditional DDGS can decrease PUFA content of belly fat and increase firmness of bellies harvested from finishing pigs (Dahlen et al., 2011). Jacela et al. (2011) did not observe similar decreases in PUFA content of belly fat when feeding de-oiled DDGS but they supplemented diets with choice white grease to standardize energy density of the diets which likely influenced fatty acid composition of the carcass.

Feeding Conjugated Linoleic Acid (CLA)

Conjugated linoleic acid can influence the quantity and composition of fat deposited by pigs. Dietary CLA at concentrations between 0.12 and 0.6% significantly decreased tenth rib backfat depth of pigs at harvest (Thiel-Cooper et al., 2001; Weber et al., 2006). As mentioned above, decreased accumulation of carcass fat would suggest decreased de novo fat synthesis, decreased saturation and increased softness because carcass fat would be more reflective of dietary fat. However, dietary CLA increases the saturated:unsaturated fatty acid ratio and decreases IV of pork fat (Thiel-Cooper et al., 2001; Dugan et al, 2004; Weber et al., 2006; White et al., 2009). These changes in fatty acid composition of pork fat occur because CLA suppresses activity of desaturase enzymes that play a role in synthesizing unsaturated fatty acids (Smith et al., 2002). The end result of changes in enzyme activity and fatty acid composition is that CLA increases fat hardness of pork bellies when contained in the diet at 0.50 to 1.0% (Thiel-Cooper et al., 2001; Weber et al., 2006: Larsen et al., 2009).

The consistent improvement in fat hardness elicited by feeding CLA suggests a unique application for CLA in diets containing high levels of DDGS. White et al. (2009) fed pigs 0, 20, or 40% DDGS with or without 0.6% dietary CLA. They found no interaction between dietary DDGS and CLA for measures of fat firmness suggesting that CLA has the same effects on fat firmness regardless of dietary DDGS content. These researchers found that CLA could partially reverse the negative effects of dietary DDGS on fat hardness. More recently, Ochoa et al. (2010) fed barrows 0 or 30% DDGS in diets with 0, 0.5 or 1.0% dietary CLA. They too found no interaction between DDGS and CLA. Dietary CLA increased carcass lean content and improved belly firmness at 1.0% dietary CLA but IV of backfat was not affected. It appears that dietary CLA has utility in correcting problems with soft fat caused by diets high in unsaturated fatty acids.

Feeding Crude Glycerol

Crude glycerol is the three-carbon backbone of triglycerides that remains after production of biodiesel. Crude glycerol is available for feeding pigs as an energy source. Diets containing 5% glycerol can decrease the concentration of PUFA's, linoleic and linolenic acids in backfat while increasing the concentration of the monounsaturated oleic acid (Mourot et al., 1994). Lammers et al. (2008) reported that linoleic acid concentration of fat in pork loin chops decreased as dietary glycerol increased to 10%. These slight changes in fatty acid composition of carcass fats toward a higher degree of saturation may signal increased fat hardness. Schieck et al. (2010) fed growing-finishing pigs diets containing 8% crude glycerol for 8 or 14 weeks before harvest. They found a 40% improvement in belly firmness for pigs receiving glycerol for 8 weeks compared to pigs receiving no dietary glycerol. Belly firmness was measured by the belly flex test. Unfortunately, they did not measure fatty acid composition of bellies. These limited data suggest that dietary glycerol may have some utility in improving fat hardness of pork carcasses.

Grain Source for Finishing Diets

Choice of cereal grain used in finishing diets can influence fat hardness but the magnitude of effect is small. Lampe et al. (2006) compared various types of corn to barley for finishing pigs and found that barley significantly reduced PUFA content and increased SFA content of subcutaneous fat. This reduced IV of subcutaneous fat about 4 points. Similarly, Benz et al.

(2011b) found that a finishing diet based on sorghum reduced IV of jowl and back fat about 2 points compared with a diet based on corn. In contrast, no differences in fatty acid composition or IV of carcass fat were observed when Carr et al. (2005) compared corn, wheat, and barley in swine diets. Han et al. (2005) also reported no differential effects of corn or wheat on fatty acid composition of back fat. It appears there may be beneficial effects on fat hardness when corn is replaced in the diet by other cereal grains with lower linoleic acid content but the magnitude of those effects are small.

In summary, given that the challenges with soft fat are here to stay for the foreseeable future, nutritionists and pork producers need to find ways to manage the challenge. Currently, the approaches that seem most effective include: 1. Formulating diets to an IVP specification and monitoring effects on carcass fat; 2. Reduce unsaturated fat content of diets in the last 3 to 6 weeks of the finishing period; and 3. Include CLA in diets to increase fat hardness. Inclusion of glycerol in the diet may have some utility in improving fat hardness, but additional research is needed to confirm early observations.

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