Chapter 23

Managing Pork Fat Quality When Feeding High Amounts of DDGS to Growing-Finishing Pigs

Introduction

The effects of diet on pork fat firmness have been known for many years. In 1926, researchers at the U.S. Department of Agriculture demonstrated that feeding diets containing peanuts or soybeans dramatically decreased the firmness of carcass fat of pigs compared with feeding corn-based diets (Ellis and Isbell, 1926). However, until recently, the relationship between diet and fat firmness has not been a significant concern in the pork industry, but with the substantial reductions in feed costs resulting from feeding high dietary levels (> 30%) of DDGS to growing-finishing pigs, soft carcass fat has become a significant issue in many countries and markets.

The firmness of pork fat is an important characteristic of overall pork quality and is directly controlled by the fatty acid composition of the fat, which significantly affects shelf life and flavor of pork (Wood et al., 2003). In addition to pork quality, fatty acid composition of pork fat also influences the processing characteristics of pork. Soft fat may not have the necessary rigidity for efficient high-speed slicing of bacon and may slow other pork processing activities. Consequently, pork processors prefer firm fat in pork products which means that the fat must be relatively high in saturated fatty acids. In contrast, many consumers want to reduce their consumption of saturated fats and therefore, they generally prefer fat with elevated unsaturated fatty acids which makes the fat softer. As a result, managing pork fat quality is a challenge because of conflicting demands that are being placed on the pork industry.

The biology of pork fat firmness

Pork fat firmness is directly related to the ratio of saturated (SFA) and polyunsaturated fatty acids (PUFA) that are comprised in the fat (Wood et al., 2003). The PUFA to SFA ratio is commonly referred to as the iodine value (IV), which is based on the laboratory procedure using iodine to measure the number of double bonds (degree of unsaturation) in fats and oils. Fats containing a high proportion of SFA (fatty acids containing no double bonds) are solid at room temperature and have a relatively low IV. As the degree of unsaturation (presence of double bonds) in fatty acids increases, the melting point declines, IV increases, and fats are liquid at room temperature. Therefore, as IV increases, pork fat becomes increasingly softer. In pork fat, IV and the resulting fat firmness 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 scientific studies from several researchers and suggested that acceptable firmness of pork fat is achieved when it contains 12 to 15% linoleic acid and more than 41% saturated fatty acids.

The fatty acid composition of pork fat results from the amount and composition of dietary fat as well as endogenous fatty acid synthesis. Fatty acids obtained from the diet are deposited in the pig's body with no alterations, while endogenous synthesis is comprised primarily of saturated fatty acids. Therefore, carcass 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 with low amounts of carcass fat and fed diets containing a high proportion of PUFA will tend to possess softer fat than pigs with a higher propensity for fat deposition fed similar diets because lean pigs have lower endogenous fatty acid synthesis. Increasing dietary fat concentration depresses de novo fat synthesis in pigs (Azain et al., 2004) which causes a greater influence of dietary fat on composition of carcass pork fat.

How is pork fat firmness measured?

Several physical measures have been evaluated for quantifying pork fat firmness including Instron compression tests, Durometer, Hardness meter, and Penetrometer, but their accuracy has produced mixed results (Apple et al., 2010). The belly flop or belly flex test has been widely used 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 chemical measure of the ratio of unsaturated fatty acids to saturated fatty acids and is one of the most common measures of pork fat firmness. 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 of pork fat can 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 (1998). Meadus et al. (2010) included seven additional long-chained fatty acids when calculating IV, and it appears that this equation provides a better prediction of fat firmness, but needs to be validated.

Currently, there are no accurate, inexpensive, and fast methods of determining pork fat firmness in commercial pork processing facilities. Consequently, it is difficult to quantitatively differentiate pork carcasses based on pork fat firmness.

Where should fat firmness be measured?

Pigs deposit fat in several locations in their bodies and there are differences in fatty acid composition 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 SFA and a lower concentration of PUFA 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 indicated 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 consistent 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 to 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 belly fat IV. Because belly fat is difficult to sample directly without damaging it, it seems that both backfat and jowl fat provide reasonable estimates of belly fat firmness realizing that jowl fat may slightly underestimate belly fat IV.

Genetic and management factors that affect pork fat firmness

Genetic improvement of pigs

Carcass fat of modern genetic lines today is significantly less than from pigs harvested 10 or 15 years ago. High lean genotypes have decreased de novo fatty acid synthesis, which is primarily saturated fat, and results in a carcass with fat composition that more nearly reflects the composition of dietary fat. If the dietary fat is supplied by vegetable oil sources that are higher in polyunsaturated fatty acids, rather than animal fats, carcass fat will become softer.

Gender

Gilts have carcasses with more lean and less fat than barrow carcasses of the same weight and physiological maturity. As a result, gilts fed diets containing high concentrations of PUFA generally have a higher IV than barrow carcasses.

Management factors

In general, housing conditions that reduce feed intake such as reduced space allowance, limited feeding, and high environmental temperatures often reduce carcass fat. As carcass fat is reduced, the impact of diet fatty acid composition on IV of pork fat increases.

Effects of DDGS on pork quality

Adding DDGS to grower-finisher diets does not affect muscle quality, eating characteristics, and shelf life of pork, but can negatively affect belly and pork fat quality, especially at high (> 20%) dietary inclusion rates (Xu et al., 2010a). Inclusion of DDGS in diets for growing-finishing swine clearly decreases fat firmness and increases flex or softness of pork bellies (Stein and Shurson, 2009). This response is primarily due to the high concentration (58%) of linoleic acid (C18:2) in the corn oil present 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.

Feeding and formulation strategies to minimize DDGS effects on pork fat quality

Withdrawal or reducing dietary DDGS level in late finishing period

In order to minimize the negative effects of feeding high dietary levels of DDGS on pork fat firmness, the most practical strategy is to remove or significantly reduce the amount of DDGS in the diet during the late finishing phase. Xu et al. (2010b) showed that feeding 30% DDGS diets up to 3 weeks before harvest and then withdrawing it from the diet, resulted in backfat and belly fat having an IV less than 70, which is considered acceptable by current U.S. pork industry standards. Hill et al. (2008) showed similar results. A total withdrawal of dietary DDGS can also be made abruptly because there appears to be no detrimental effects of this sudden dietary change on pig performance (Hilbrands et al., 2009; 2011).

Adipose tissue in pigs is dynamic because fats are continually being deposited and mobilized depending on the physiological state of the pig. This high degree of adipose tissue activity allows rather rapid changes to occur in the composition of fat in adipose tissue. Wood et al. (1994) suggested that the majority 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 backfat 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 achieved in as little as 6 weeks.

Therefore, 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 significant 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.

Feeding reduced-oil DDGS

With a significant number of U.S. ethanol plants extracting oil from DDGS, feeding a lower fat DDGS source (3 to 9% crude fat) compared to traditional DDGS sources (10 to 12 % crude fat) can decrease PUFA content of belly fat and increase firmness of bellies harvested from finishing pigs (Dahlen et al., 2011). However, the metabolizable energy (ME) content of DDGS is also reduced when a portion of the oil is removed from DDGS, making it a less valuable energy source in the diet. In another study, Jacela et al. (2011) did not observe similar decreases in PUFA content of belly fat when feeding reduced-oil DDGS (3.5% crude fat), but they supplemented diets with choice white grease to standardize energy density of the diets which likely influenced fatty acid composition of the carcass.

Formulate diets on an Iodine Value Product (IVP) basis

The iodine value product (IVP) concept is a feed formulation strategy that is being used with some success to manage pork fat quality. It was developed by Madsen et al. (1992) and is based on the concept that if the diet and carcass IV's are known, diet formulation adjustments can be made to get closer to the target IV for pork fat in the carcass. Iodine product value involves a calculation including the amount of fat and the IV of the fat in each ingredient in the diet to meet a desired final diet IV specification. This formulation method was later revised by Boyd et al. (1997), where the IV of backfat = 0.32(IVP) + 52.4 and IVP = IV of the diet oil x % diet oil x .1. Using IVP does not always result in desired final carcass IV because there are several confounding factors such as growth rate, genetics, and health that likely underestimate the impact of linoleic acid on pork fat firmness. The IVP of corn DDGS is quite high (112) compared to corn (47), barley (23), wheat (23), and soybean meal (18). Therefore, use of IVP in diet formulation is another tool that can help manage pork fat quality concerns when feeding DDGS diets to growing-finishing pigs. Cast (2010) indicated 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 and then monitor effects on IV of carcass fat. This approach will be farm-specific but can be useful.

Use alternative cereal grains in finishing diets

Choice of cereal grain used in finishing diets can influence pork fat firmness. Lampe et al. (2006) compared corn and barley diets for finishing pigs and found that barley diets significantly reduced PUFA, and increased SFA content of subcutaneous fat, resulting in a reduction of IV by about 4 units. Feeding growing-finishing pigs wheat and barley-based diets results in lower IV in pork fat than when feeding corn-soybean meal diets. Beltranena et al. (2009) showed that IV of pork fat in western Canada diets (wheat, barley, and canola meal) is lower compared to U.S. corn-soybean meal based diets, and withdrawing corn DDGS from wheat and barley based diets is a good strategy for reducing pork fat IV, compared to feeding 30% DDGS continuously. Benz et al. (2011) found that a sorghum-based finishing diet reduced IV of jowl and back fat by approximately 2 units compared with a corn-based diet. 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 differences in fatty acid composition of backfat when feeding corn or wheat-based diets. It appears that there may be beneficial effects on fat firmness when corn is replaced in the diet by other cereal grains with lower linoleic acid content, but this response is not always observed.

Addition of saturated fats to DDGS diets

Adding more saturated animal fat sources to DDGS diets have resulted in inconsistent responses on pork fat quality. Stevens et al. (2009) showed that feeding corn-soybean meal-DDGS diets, with or without 5% choice white grease (pork fat), during a 26-day DDGS withdrawal program resulted in a partial recovery of some of the adverse effects on pork fat quality caused by the increase in linoleic acid contributed from DDGS. However, they indicated that a longer DDGS withdrawal period is required for complete recovery of pork fat quality. The addition of a dry animal fat source (4% of the diet) high in saturated fatty acids (70%) did not alleviate the increase in IV resulting from the addition of 30% DDGS to the diet (Freitas et al., 2009). This was most likely due to the low digestibility of the saturated fat used in the study. Recently, research at the University of Minnesota (Pomerenke et al., 2011) showed that adding 5% tallow to 30% DDGS diets did not improve belly firmness. Based on the results of these studies, we need to learn more about fatty acid digestibility among various fat sources in order to understand how they may or may not impact pork fat quality in pigs fed DDGS diets.

Feeding conjugated linoleic acid (CLA)

Conjugated linoleic acid is approved for use in swine growing-finishing diets in the U.S. and 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). In addition, dietary CLA decreases the 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 are involved in synthesizing unsaturated fatty acids (Smith et al., 2002). As a result of changes in enzyme activity and fatty acid composition, CLA increases firmness 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 firmness from feeding CLA suggests a unique application for its use 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 and found no interaction between dietary DDGS and CLA for measures of fat firmness which indicates that CLA has the same effects on fat firmness regardless of dietary DDGS content. Furthermore, 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 also found no interaction between DDGS and CLA, but observed an increase in carcass lean content and improved belly firmness when 1.0% CLA was added to the diet. However, backfat IV was not affected. Therefore, it appears that the addition of CLA to the diet during the late finishing phase may be used to reduce IV of carcass fat, but it is not currently used in the U.S. because of cost, and is not available or approved for use in other countries.

Feeding crude glycerol

Glycerol is the three-carbon component of triglycerides that remains after production of biodiesel. Crude glycerol can be used as an energy source for pigs if it is economical and available. Diets containing 5% glycerol can decrease the concentration of PUFA, linoleic, and linolenic acid in backfat while increasing the concentration of the monounsaturated fatty acid, 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 fat may result in increased pork fat firmness. 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 (measured by the belly flex test) for pigs receiving glycerol for 8 weeks compared to pigs receiving no dietary glycerol. Unfortunately, these researchers did not measure the fatty acid composition of bellies, but these limited data suggest that dietary glycerol may have some utility in improving fat hardness of pork carcasses.

Conclusions

Pork fat firmness decreases linearly with increasing levels of DDGS in the diet for growing-finishing pigs, and the effects are greater in lean pigs compared to fat pigs. Iodine value of pork fat varies among carcass location and should be considered when measuring pork fat to meet desired pork fat IV standards. Currently, the most effective and practical approaches to minimize the negative effects of feeding diets containing high levels of DDGS include: 1) Reduce or withdraw typical DDGS (10 to 12% crude fat) from the diet during the last 3 to 6 weeks prior to harvest; 2) Feed reduced-oil DDGS; 3) Formulate diets to an IVP specification and monitor the effects on carcass fat; and 4) Substitute wheat, barley, or sorghum for corn in grower-finisher diets.

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