factsheet
Pork Information Gateway

Variation in Pork Lean Quality

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Introduction

The pork industry has made significant progress in recent years in altering the composition of carcasses, resulting fresh cuts and processed products to provide consumer products containing increased lean and less trimmable fat. This strong positive progress in product composition has allowed the industry to shift more attention to another important feature of pork, the quality of the lean. "Lean quality" in fresh pork could refer to a wide range of factors, but in this fact sheet, lean quality will focus on muscle color, texture, marbling and functionality (such as water-holding ability). These factors affect product attractiveness to potential customers, processing characteristics for value-added product manufacture and the ultimate palatability and satisfaction of pork products to consumers.

Descriptors of Pork Lean Quality

Desirable lean quality in fresh pork is described as reddish-pink in color, firm in texture and free of surface wateriness (non-exudative). Such high quality lean is identified as RFN. Quality variations from this ideal result in the less desirable quality extremes of pale, soft and exudative (PSE) lean, and dark, firm and dry (DFD) lean (Figures 1, 2 and 3.) During the 1990's a fourth quality designation was recognized in lean which had desirable reddish-pink color, but was soft and exudative (RSE). It is not unusual to find varying degrees of the RFN, PSE, RSE and DFD conditions in pork cuts displayed in a retail meat case, and in primals destined for further processing.

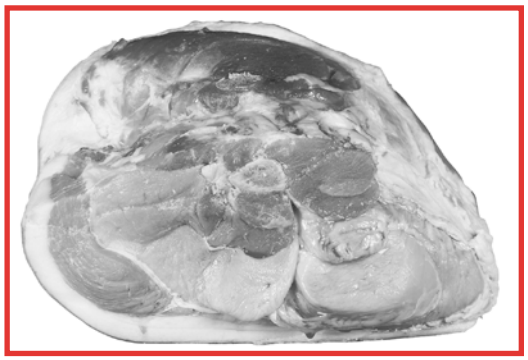

Figure 1. PSE.

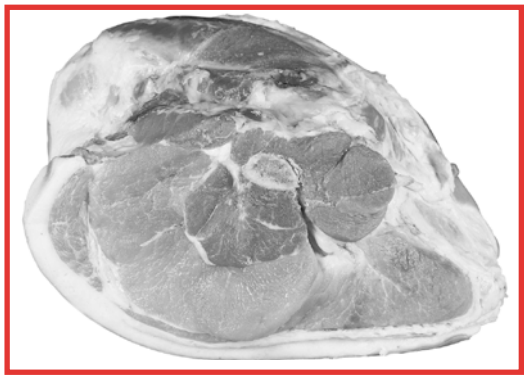

Figure 2. RFN.

Why are PSE, RSE and DFD Conditions Less Desirable?

Color and appearance are an important factor in consumers' meat purchase decisions. Unusual and variable lean color and excessive fluid accumulation (purge) in retail packages influence some shoppers to avoid these products.

PSE lean is not only abnormally pale in color, but is more susceptible to developing gray or greenish-gray discoloration during display. The pale condition primarily affects the loin and outer ham muscles, resulting in a two-toned

appearance in some cuts. PSE muscle's soft texture gives a "mushy," less attractive appearance, and affected muscle usually contains little marbling. PSE and RSE muscles readily give up moisture due to reduced water-holding ability of muscle proteins. In fresh PSE or RSE pork this pink fluid accumulates within retail packages, and leads to less juicy pork after cooking. Hams produced from PSE and RSE muscles may have 5% to 10% lower processing yields, and may lack a uniform cured color.

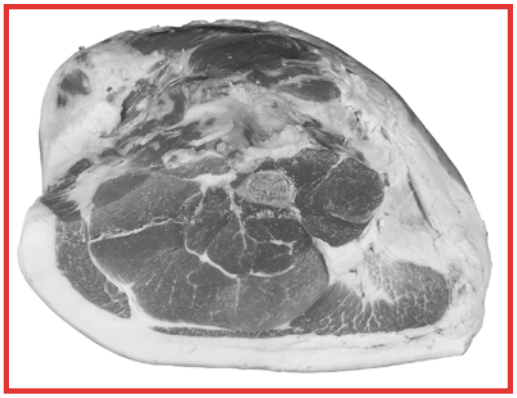

Figure 3. DFD.

Although DFD muscle has exceptional water-holding ability and excels in tenderness, its dark color is less appealing to consumers, who often interpret it as an indication of meat from older animals, or lacking in freshness. DFD lean is more susceptible to microbial spoilage because of its higher pH (less acidity) which favors bacteria growth. All muscles of the pork carcass are subject to the DFD condition.

The Incidence of PSE and DFD Lean

The most recent significant survey of pork lean quality was a 1991 National Pork Producers Council funded survey of the lean quality of hams from 10,753 carcasses slaughtered at 14 major packing plants across the U.S. It found 16% of the carcasses to have PSE muscle, while 10% were DFD, suggesting that as much as 25% of the pork supply had undesirable lean properties. The remaining carcasses had either desirable red, firm, normal (RFN) lean quality, or exhibited attractive pink lean color, but had some degree of muscle softness and exudation (RSE).

What Causes PSE and DFD Pork?

The causes of these conditions in pork muscle are linked to chemical and physical changes in muscle before, during and after harvest of the animal. An important reaction in postmortem muscle is the conversion of stored muscle sugar (glycogen) to lactic acid. Since blood flow has ceased, this acid accumulates in muscle, causing it to become slightly acidic, and dropping its pH from 7.0 to about 5.5 to 5.7 (Figure 4) in "normal" muscle. In muscles that develop desirable lean quality, acid production occurs at a moderate rate over a prolonged time period as muscle temperature drops in response to carcass chilling. Under these "normal" conditions pork lean exhibits typical red color, and muscle proteins retain acceptable water-holding ability.

However in PSE muscle, lactic acid is produced at a greatly accelerated rate after slaughter (Figure 4), creating an acidic muscle environment while carcass temperature is still quite high. The combination of rapidly increasing acidity (falling pH) and high muscle temperature denatures muscle proteins, reducing their ability to bind water. Causes of the soft texture in PSE muscle are not well understood, but are probably linked to changes in muscle proteins and their orientation within the muscle cells. Denaturation of the pigmented protein myoglobin, as well as accumulation of free water on the cut muscle surface which increases light reflectance, produces a pale appearance in the lean. The cause of the accelerated reactions in PSE muscle immediately after death can be due to the genetics of the pig, and/or improper handling of the animal (excess stress and excitement) prior to slaughter.

The DFD condition is also related to acid production in pork muscle after slaughter, but the nature of the chemical change is different. PSE develops because of an accelerated rate of acid production while muscle temperature is still high. Conversely, DFD results from a lack of acid production in the muscle. Muscles destined for DFD pork have low levels of glycogen at the time of slaughter that restricts the amount of acid that can be produced, and limits pH fall. While both normal and PSE muscle end up with similar "ultimate" (final) pH values of about 5.5, DFD muscle usually has an ultimate pH above 6.0 (Figure 2). This reduced acidity provides increased water-holding ability in the lean, tightly binding water to muscle proteins, and contributing to a firm texture. Muscle cells swollen with retained water and tightly packed together absorb more light (darker color), and also restrict how deeply oxygen can penetrate into the tissue to "brighten" muscle pigment. A period of extended stress on the pig, caused by factors such as severe weather, long transport or unfavorable holding conditions, can deplete muscle glycogen and cause the DFD condition in pork muscle.

Lean Quality and Pig Genetics

Pig genetics can pre-dispose some animals to exhibit a higher frequency of the PSE condition, and also contribute to development of DFD muscle. PSE is associated with the heritable condition of porcine stress syndrome (PSS), first described in the late 1960s. This is inherited through a single recessive gene, often called the "stress gene." PSS pigs show intolerance to stress, and exhibit accelerated muscle metabolism and increased heat production in muscles, causing muscle twitching and red skin blotches in the pigs. In extreme cases PSS pigs my die on the farm, during transport, or during holding at the slaughter plant.

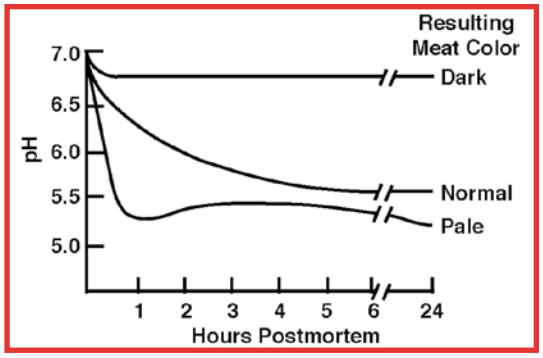

Figure 4. Conversion of muscle to meat and development of Meat Quality

The chemical conditions PSS produces in muscles (rapid lactic acid production and elevated temperature) strongly favors the development of PSE lean. Likewise, since these pigs do not cope well with stress, longer-term exposure to unfavorable conditions can deplete their muscle glycogen, leading to the DFD condition. Unfortunately, PSE-prone pigs carrying the stress gene are usually very lean and muscular. This negative association creates conflict between the goals of increasing carcass lean yield, and maintaining acceptable muscle quality.

Figure 5. 1.0 Marbling Standard

PSS pigs homozygous for the stress gene exhibit extreme muscle rigidity when exposed to the anesthesia halothane (therefore also termed the *halothane* or *hal* gene). However, the halothane challenge does not detect heterozygous carriers of this gene. A more recently developed gene marker test using a DNA probe allows identification of non-PSS pigs carrying this gene, and there possible elimination from the animal population. This is important because 30 to 50% of stress gene carriers can produce carcasses with inferior lean quality. These genetic screening tools have produced moderate improvements in lean pork quality in recent years.

Figure 5. 2.0 Marbling Standard

A second genetic factor affecting pork lean quality is the Napole (RN) gene first reported in 1990. The effect of this dominant gene is to reduce the ultimate pH of muscle, particularly in loin and ham muscles. Meat with such lower pH values generally has inferior processing characteristics.

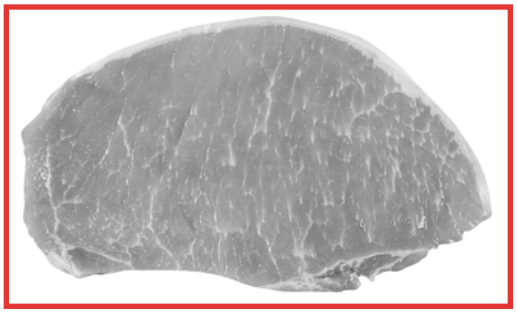

Figure 5. 3.0 Marbling Standard

Marbling and Pork Lean Quality

While color, firmness and exudation are important considerations in evaluating lean pork quality, marbling or intramuscular fat content of the lean also is an important factor. Marbling contributes to the juiciness and flavor of the product. While marbling levels vary widely in fresh pork (Figure 5), selection for leaner pigs has generally reduced the marbling content of the lean, increasing the potential for less desirable eating satisfaction by consumers. In selecting pigs for desirable lean quality, marbling should be considered. Some genetic lines capable of producing higher levels of marbling in the lean have been used to niche market branded products valued for their increased marbling content (such as Berkshire Gold).

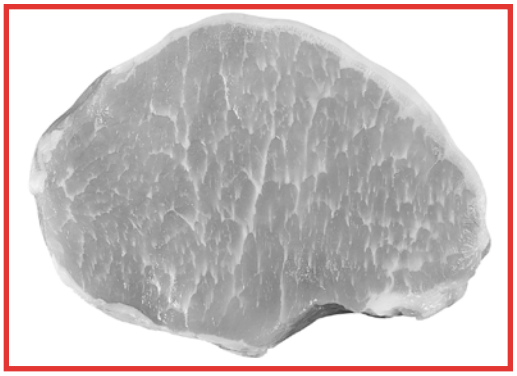

Figure 5. 4.0 Marbling Standard

What Can be Done to Improve Pork Lean Quality?

The PSE, RSE and DFD conditions result from both heredity and animal handling practices, and can be influenced by slaughter plant procedures. Use of available genetic screening techniques to identify and reduce or eliminate the recessive PSS gene from breeding stock can lead to further improvement in lean pork quality. Some PSE and most DFD are caused by handling practices applied to pigs. Stress or excitement of animals on the farm, during transport or at the slaughter plant may result in some degree of these conditions. This includes lack of access to feed for long periods of time, commingling of unfamiliar animals, and holding and moving of pigs. Greater attention to these management factors from farm to plant can improve pork muscle quality.

Figure 5. 5.0 Marbling Standard

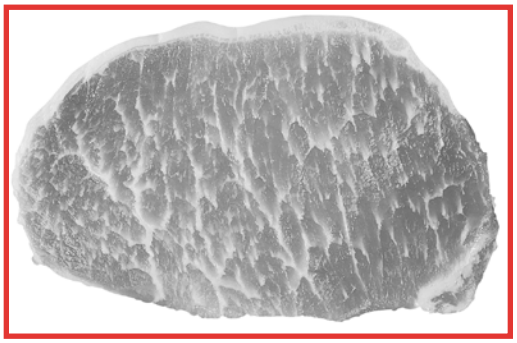

Figure 5. 6.0 Marbling Standard

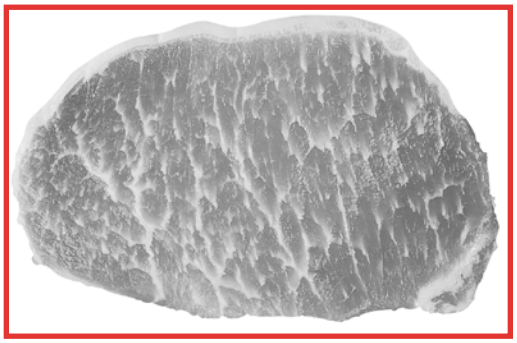

Figure 5. 10.0 Marbling Standard

To guide and encourage improvement in pork lean quality, carcasses should be evaluated for muscle quality at slaughter. Methods to allow lean quality determinations to take place easily, accurately and at high slaughter-line speeds are under development (such as measurements of muscle pH, electrical conductivity, and light scattering and reflectance as determined by fiber optic probe). With this information producers can have the opportunity to make breeding decisions which include a lean quality component, and to be financially rewarded for producing pigs with both acceptable lean quality and high carcass lean yields.

In addition to proper holding and moving of pigs at the slaughter plant, stunning method, processing times, and carcass chilling procedure can influence lean quality. Head-only electrical stunning reduces the potential for PSE over head-to-back stunning. Since the PSE condition is caused by rapid acid accumulation in muscle while muscle temperature is still high, accelerated chilling of carcasses has been shown to improve lean color. However, research suggests that although rapid chilling can reduce muscle paleness, it has a variable effect on muscle water-holding capacity, and it does not always reduce drip loss from the lean.

In recent years the pork industry has developed processing techniques to help address fresh pork lean quality variation. *Enhanced* or *pumped* pork is injected up to 10% of its weight with solutions containing ingredients such as salt, phosphates, or flavor enhancers. The solutions are effective in improving juiciness and tenderness of today's lower-fat fresh pork. While this technique can bring increased uniformity and eating satisfaction to the pork supply, it should not be regarded as a substitute for genetic selection for desirable lean quality traits in breeding stock, or proper animal handling practices during the marketing of animals for slaughter.

Summary

Considerable variation exits in the color, texture, water-holding ability and marbling of pork lean. The primary defects in lean quality are varying degrees of the pale, soft and exudative (PSE) and dark, firm and dry (DFD) conditions. While both are unattractive to consumers, PSE (as well as intermediate RSE—red, soft and exudative) muscles exhibit excessive moisture loss in retail handling and during cooking and processing, and DFD product has a shorter shelf life. The basic cause of these defects is linked to the conversion of muscle sugar (glycogen) to lactic acid soon after slaughter, and the nature of this chemical change is affected by pig genetics, animal handling practices and slaughter plant procedures.

Pork lean quality can be improved by using available genetic screening tests to eliminate the porcine stress syndrome (PSS) gene from breeding stock populations, by careful handling of pigs from farm to

packing plant, and by utilizing slaughter procedures which minimize the potential for adversely affecting lean quality. Identifying lean quality and providing financial incentive at the packer level for producers to improve lean quality, will also contribute significantly to reduction of this problem.

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Note: The Official Color and Marbling Standards can be ordered from the National Pork Board by calling (515-223-2600) or by referring to the email site porkscience.org.

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