Incorporation of meat quality and use of ultrasound technology for swine genetic improvement programs

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Abstract: Real-time ultrasound has been, and will continue to be, one of the most important tools in enhancing genetic improvement in the U. S. Recent advancements in the technology have allowed ultrasound to be used in evaluating intramuscular fat in live animals. Together with other genetic improvement tools, ultrasound technology will offer seedstock producers the opportunity to select for improved IMF in potential breeding stock replacements and hence speed genetic progress for the improvement of this trait. After three generations of selection for IMF using real-time ultrasound in an Iowa State University study, the average EBV for select line pigs is 0.83% greater than for control line pigs. Selection for IMF has, however, resulted in slightly more backfat and less loin muscle area, and a trend toward more days to 114 kg in the select line compared to the control line. Carcass evaluation of a sample of pigs from each litter indicated a similar increase in IMF, increase in backfat, and reduction in loin muscle area for select line pigs. No differences were found for Hunter L^* color, Minolta reflectance, and ultimate pH.

Key words: swine; meat quality; intramuscular fat; ultrasound technology
CLC number: S813 **Document code**: A **Article ID**: 1001-411X(2005)S0-0088-016

The goal of any swine genetic improvement program is rapid genetic progress in economically important traits. Two keys for significant genetic improvement are identification of which traits are the most important and accurate records of performance for those traits. Tremendous progress has been made in the swine industry in the reducing backfat and increasing lean meat percentage over the past decade. In recent years, meat quality traits have received more attention and have become more important in breeding programs.

This paper will describe real-time ultrasound technology and how it is used in swine genetic improvement programs. It will also describe the important characteristics of meat quality in pigs and their relevance to the industry. Finally, the paper will address how real-time ultrasound can be used to measure meat quality on live pigs and how this technology can be applied to the swine industry.

1 Ultrasound and its principles

Ultrasound has been used extensively in the swine industry to assess composition traits in live pigs and carcasses and more recently, to estimate intramuscular fat content of the pork loin. Applications of the technology include genetic selection, lean-growth modeling, body condition scoring, and carcass merit buying systems. The ability of ultrasound technicians to accurately measure composition traits has allowed the swine industry to make significant progress in changing the composition of breeding and market swine. The observed changes in composition are the result of high-quality ultrasound instrumentation and the technician training and certification processes now available through the National

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Swine Improvement Federation

Ultrasound technology for biological applications was first introduced in the 1950's. Early machines utilized a single ultrasound transducer (A-mode ultrasound) emitting and receiving a single sound wave passed through animal tissue. The A-mode devices reported a single location estimate of fat and/or muscle depth at the designated anatomical location. Technological advances expanded the capabilities of ultrasound machines. Multiple transducers were arranged in linear arrays allowing two-dimensional images of the internal anatomy to be viewed on a video monitor. With two-dimensional ultrasound images, fat depth, muscle depth, muscle area, and muscle circumference are able to be measured with accuracy and repeatability. The enhanced machines are described as B-mode or "real-time" ultrasound machines and are capable of providing well-defined images of animal tissue. Since the first commercial application of real-time ultrasound in the 1980s, accuracy of live animal estimates of backfat and loin muscle area have been made and have enhanced genetic improvement in these traits.

Ultrasound machines emit high frequency sound waves that are above the human auditory range (16 000 Hz). The standard range of sound transmission for imaging biological tissue is from 2 to 20 megahertz (MHz). At lower MHz, the degree of resolution is much less defined when compared with higher values, but the depth of penetration is increased. At higher MHz, an increasing level of absorption by the tissue allows for more precise resolution but limited penetration into the biological tissue. Frequencies between 1 and 5 MHz are generally used for live animal evaluation with 3.0 to 3.5 MHz most commonly used [1].

Pulses of ultrasound are produced in a transducer by the vibrations of piezoelectric (pressure-electric) quartz crystals. These pulses are transmitted through a tissue until they reach a tissue interface, such as between fat and lean tissue. Because different tissues have different acoustical properties, a portion of the sound wave continues to penetrate the tissue while some of the wave is reflected back to the transducer. At this point, the transducer acts as a receiver and the reflected waves produce mechanical energy as they strike and deform the piezoelectric crystals. This energy is converted to electrical energy, processed, and displayed in different formats [1].

While there are many different types of ultrasonic instruments on the market, they all operate on the principle of sound waves creating an echo when they hit a dense surface. In livestock, the dense surfaces include the skin, the membrane between fat layers, the membrane between fat and muscle, and the muscle and bone [2].

With real-time ultrasound, a linear array of several transducers is fired in succession, sending sound waves into the tissue. These sound waves interact, both constructively and destructively, to form patterns of energy within the tissue. By varying phases of the oscillation of the crystals across the transducer, their energy is steered into a described pattern. This technique is used to focus the linear array transducers to optimize depth resolution on reception of the ultrasound signals. With an effective instrument design, the B-mode system can be used to accurately image cross-sectional views of a medium. The display format for B-mode is a two-dimensional array of dots (pixels). The position of each pixel on the screen is determined by the time it takes for an echo to return to the transducer. The brightness of each dot is proportional to the amplitude (or strength) of the returning echo [1].

Real-time ultrasound is a version of B-mode ultrasound. With real-time, the display on the screen is updated instantaneously and sequentially to create a live image of the tissue of interest (Fig. 1). The screen image displays the signals that are returned to the transducer after encountering tissues with different acoustical properties. Therefore, the ultrasound technician's knowledge of anatomy, proper placement of the transducer and scanning of the animal, and a thorough understanding of how the image is created contribute to a technician's ability to accurately interpret an ultrasonic image.

Fig. 1 Cross-sectional real-time ultrasound image taken between the 10^{th} and 11^{th} ribs of the live pig

Linear distance can be determined if the velocity of sound in the medium is known (distance = time × velocity ÷ 2). The velocity of sound will vary with the type and temperature of tissue. Most real-time ultrasound scanners are calibrated based on the velocity of water at body temperature. It can be seen that this represents an average value (Tab. 1)[1].

Tab. 1 Speed of sound through biological tissues

tissue	velocity /($m \cdot s^{-1}$)
water	1 500
skin	1 700
fat	1 430
muscle	1 620

2 Measuring backfat and loin Muscle

Carcass and live animal ultrasonic measurements of fat thickness and loin muscle area are typically measured between the 10^{th} and 11^{th} ribs. When combined in a prediction equation with carcass or live weight, both measurement systems are accurate predictors of weight and (or) percentage of lean in the pig. However, proficiency in gathering the measurements has a dramatic impact on accuracy of lean prediction, particularly for ultrasonic measurements. To become a qualified ultrasound technician, knowledge of proper transducer location relative to anatomical landmarks on and within the pig and the ability to interpret ultrasonic images are essential. To assess accuracy, live ultrasound estimates of fat thickness and loin muscle area are compared with a measurement taken on the carcass.

Fat thickness, measured between the 10^{th} and 11^{th} ribs, is the standard for technician certification by the National Swine Improvement Federation (NSIF, 97). The NISF Guidelines prescribe that subcutaneous fat depth, including skin, is to be measured to the nearest 1.27 mm and the measurement is to be taken at a point one-half the distance along the longest axis of the loin muscle and perpendicular to the skin surface (Fig. 2). Ultrasound technicians should note that typical carcass measurements of tenth rib backfat are taken at the 3/4 distance away from the medial edge of the loin muscle (Fig. 3). The NSIF recommendation for measurement at the one-half distance is two-fold: 1) The ability to determine the one-half location is easier and more consistently measured on the ultrasound image and carcass; 2) The one-half distance corresponds to approximately 5 cm off of the dorsal midline which is the target location for fat measurements taken when using single transducer, A-mode ultrasound devices. While slight variation in the measurement of backfat thickness may occur between 1/2 and 3/4 point locations, the rank of animals within a group will not change if measurements are taken at a consistent location across all animals evaluated. All comparisons of ultrasound with carcass measurements should be taken at the corresponding anatomical location (Fig 3).

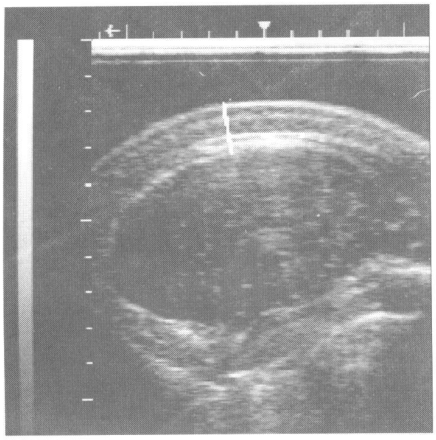

Fig 2 Measurement of fat thickness on a real-time ultrasonic image obtained between the 10^{th} and 11^{th} ribs of the live pig. Fat depth is measured near the middle of the long axis of the loin muscle and includes the skin depth.

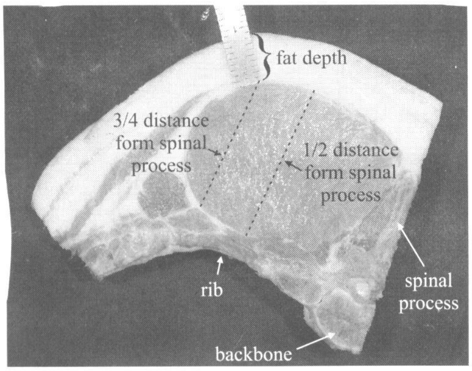

Fig 3 Illustration of a cross-sectional view of the loin muscle separated between the 10^{th} and 11^{th} ribs and locations corresponding to 1/2 and 3/4 point measurement locations for fat thickness (The Ohio State University, 2003)

Accuracy of ultrasonic measurements of loin muscle area is more difficult than fat thickness measurements and is very technician dependent. Appropriate training and experience are necessary to overcome the challenges represented in measurement of ultrasonic loin muscle area.

Cross-sectional area of the loin muscle (longissimus) is recorded in square inches (in^2) or square centimeters (cm^2) on the exposed loin surface between the 10^{th} and 11^{th} ribs. An ultrasound image with the loin muscle traced is shown in Fig 4 (untraced image in Fig 2). The cross-sectional area is calculated using built-in software or an external computer with measurement capabilities. Fig 5 indicates the outline of the cross-section of loin muscle on the carcass. Loin muscle area on the carcass may be either measured directly, using the plastic grid, or indirectly by tracing the outline of the loin muscle on acetate paper and using a planimeter or plastic grid to determine area.

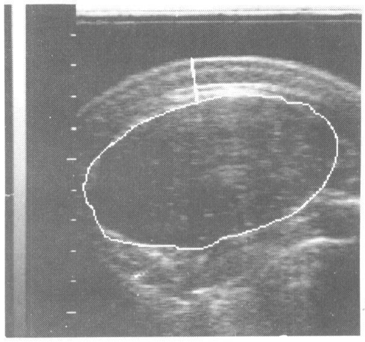

Fig 4 Tracing of the loin muscle and location of the fat measurement on a real-time ultrasound image taken between the 10^{th} and 11^{th} rib (The Ohio State University, 1999)

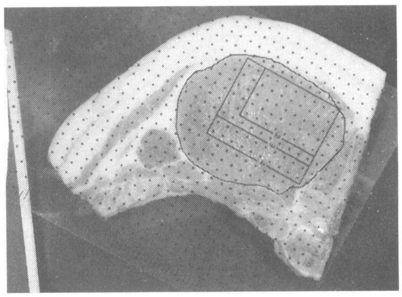

Fig 5 Tracing and grid placement for measuring loin muscle area on the carcass between the 10^{th} and 11^{th} ribs (The Ohio State University, 2003)

3 Meat quality

3.1 Importance of meat quality

Ideal quality in fresh pork can be defined as a combination of traits that include appearance, taste, nutritional value, and wholesomeness. Because of differences in the various markets along the pork chain, the perception of "ideal" quality in pork products by the various segments of the pork industry is not necessarily the same. Producers strive to produce lean, high yielding pork carcasses in a package that is profitable to produce. Packers and retailers want a product with high yields that is stable in cold storage and attractive in appearance. Tenderness ranks high with pork loin consumers while water-holding capacity is important to ham processors. Consistency and uniformity in quality of the product received rank high for all segments of the pork chain. The word quality can mean many things, but most importantly, it means customer satisfaction with pork products.

Inferior muscle quality continues to be a serious pork industry problem. The increased participation in merit buying programs by producers has increased the emphasis given to leanness and muscling in selection programs of the seedstock industry. Unfortunately, this emphasis on leanness has resulted in a reduction in meat quality and eating quality traits of pork. Breeders in Denmark have been very successful in increasing carcass lean, but now face the problem of reduced eating quality. British breeders have increased carcass lean percent for over fifteen years, but have also reduced intramuscular fat, a measure of meat quality, below acceptable levels.

Pork quality is influenced by numerous factors including, but not limited to, genetics, nutrition, preslaughter handling, slaughter techniques, meat handling, and cooking methods. Research shows between 10%–70% of the variation in meat quality can be attributed to genetics.

Objective measures of muscle quality traits in the packing plant at line speed are being evaluated and, if found reliable, will lead to pricing based on quality traits in addition to lean composition. Because of these potential price incentives/discounts, packers, processors, and producers are scrambling to evaluate technology to determine reliable and inexpensive methods to assess quality differences.

3.2 Selection for quality

Long-term progress or improvement in muscle quality traits is ultimately the responsibility of the seedstock supplier. If selection progress is to be made and emphasis on the trait is to be worthwhile, the following criteria must be met:

· Trait must be measurable (accurately).

· Trait must be under genetic control (heritability).

· Trait must not have a significant negative relationship to other important production and quality traits.

· Trait must be economically important to the producer.

The following traits are important quality traits.

(1) Color: Ideal color in fresh pork is described as reddish pink. Consumers object to pork that is either too pale or too dark. Abnormally pale muscles quickly turn gray in the retail display case and often undergo considerable shrink, resulting in economic losses during processing and dry tasting products after cooking. Extremely dark pork will generally have a shorter shelf life because it is less acidic and therefore supports bacterial growth.

Color can be measured objectively using a Minolta Chromameter on the cut surface of the loin muscle or other available muscle of the carcass after the surface has been allowed to bloom. Color may be expressed as Minolta (normal range from 17–33) or Hunter L^* values (normal range from 30–60). Lower values are darker and higher numbers are paler, lighter colored meat. Consumers prefer medium to darker colored meat.

Visual color scores based on the NPPC scale of 1 – 6 may also be used to estimate color. NPPC values are:

- 1=Pale, pinkish gray to white;
- 2=Grayish pink;
- 3=Reddish pink;
- 4=Dark reddish pink;
- 5=Purplish red;
- 6=Dark purplish red.

These visual color scores correspond to Hunter L^* values (1=61; 2=55; 3=49; 4=43; 5=37; 6=31).

(2) Water holding capacity or drip loss: Water holding capacity is the ability of meat to retain its water during cutting, heating, grinding, and pressing. This trait is of great concern to the entire industry since pork with poor water holding capacity or high drip loss does not hold a cure and results in reduced processing or cooking yields. In addition, it is objectionable to consumers who are concerned about excessive purge, and the product dries excessively during cooking. Water holding capacity is the amount of exudate or moisture on the cut loin surface and can be estimated using the Kaufmann filter paper method. A pre-weighed piece of filter paper is placed on the cut surface of the loin and allowed to absorb surface moisture. The filter paper is then reweighed and the difference is the amount of moisture taken up by the filter paper. Lower numbers indicate less moisture loss and are more desirable due to their association with higher value for all segments of the industry.

A visual firmness score based on a simple three-point scale may also be used to evaluate pork (S=soft; F=firm; VF=very firm). Ratings of firm and very firm are most desirable.

(3) Ultimate pH: A measurement that is highly correlated to water holding capacity or drip loss is pH or the acidity of the meat. Ultimate pH is measured in the cooler 24 hours after slaughter by inserting a pH probe into the pork muscle. Lower pH values are related to greater drip losses during further meat processing. Higher pH values are more desirable because they are associated with less drip loss, darker color, more firmness, and increased tenderness of the loin chop-all positive attributes. A loin pH value of 5.80 – 5.85 or higher is generally set as a desirable goal while numbers less than 5.60 – 5.65 are generally considered to be undesirable. Since variation in day to day plant pH values may exist, values should be compared to a plant standard or average for the day of evaluation.

(4) Intramuscular fat (IMF): This trait may also be called marbling or lipid content. It is estimated using laboratory analysis of total lipid content of a loin muscle sample. Some marbling is necessary for a juicy and flavorful cooked product. Cooked pork without marbling is usually dry and less flavorful. On the other hand, pork with large amounts of marbling supplies excess calories and is visually objectionable to consumers. Research results indicate a minimum of 2.5% – 3.5% IMF is needed for desirable eating quality.

Visual marbling scores based on new NPPC standards are also available. Marbling scores range from 1 – 10 and correspond to percent intramuscular lipid content. Scores of 2 – 4 are considered desirable in most situations.

(5) Instron tenderness: Tenderness is measured in the laboratory by a Universal Testing Machine using the star probe. It is expressed in kg of pressure needed to compress a cooked loin sample. Less pressure (lower kg) means more

tender cooked loin. Consumer preference studies indicate consumers are willing to pay more for pork with lower instron tenderness values.

(6) Sensory panel scores: Trained sensory panels are used to evaluate palatability, often expressed as tenderness, juiciness, chewiness, and flavor. While these traits are generally low in heritability, they do give an indication of the traits that are important to consumers. Sensory panel scores for tenderness and chewiness have a strong correlation with instron tenderness values and juiciness scores have a strong relationship with intramuscular fat percentage.

4 Intramuscular fat

4.1 Selection for intramuscular fat

As mentioned previously, emphasis placed on lean, fast growing pigs over the past decade has contributed to a general decline in pork quality. Inferior quality problems cost the industry an estimated $90 million annually[3], and the incidence of pale, soft and exudative (PSE) pork has risen from 10.0% to 15.5% between 1996 and 2003[3,4]. Fresh pork quality has become important and has received more attention as producers and processors try to meet consumer demand for high quality, nutritious products. Many different traits have been identified as indicators of consumer acceptance of fresh pork. These include color, firmness, pH, intramuscular fat percentage (marbling), water-holding capacity, tenderness, juiciness and flavor. Each of these has been shown to be low to moderately heritable[5,6] and to impact consumer acceptance of fresh pork products. However, measuring these traits in the live animal has been difficult.

Intramuscular fat percentage is one of the meat quality traits which has the potential to be measured on the live animal[7-9], and has favorable genetic correlations with many other meat quality traits. Greater amounts of IMF have been shown to positively impact sensory panel traits such as tenderness, juiciness, and flavor, along with mechanical measures of tenderness[10-14].

4.2 Prediction of intramuscular fat (IMF)

Purebred Durocs ($n = 207$) were used to develop a model to predict loin intramuscular fat percentage (PIMF) of the longissimus muscle in live pigs[9]. Purebred Durocs were utilized in this study because they are known to offer the unique combination of positive attributes for not only growth and performance, but IMF as well. Additionally, it has been shown that variation exists in IMF measures within the Duroc breed. A minimum of four longitudinal, real-time ultrasound images were collected 7 cm off-midline across the 10th - 13th ribs on the live animal using an Aloka 500V SSD ultrasound machine fitted with a 3.5 MHz, 12.5 cm linear-array transducer (Corometrics Medical Systems, Inc., Wallingford, CT). A trained technician used texture analysis software to interpret the images and produce 10 image parameters. Backfat and loin muscle area were measured from a cross-sectional image at the 10th rib. After harvest, a slice from the 10th - 11th rib loin interface was used to determine carcass loin intramuscular fat percentage (CIMF) using the method of Bligh and Dyer[15].

The model to predict loin intramuscular fat percentage was developed using linear regression analysis with CIMF as the dependent variable. Initial independent variables were off-test weight, live animal ultrasonic 10th rib backfat and loin muscle area, and the 10 image parameters. Independent variables were removed individually until all variables remaining were significant ($P < 0.05$). The final prediction model included live animal ultrasound backfat and five image parameters.

Multiple coefficient of determination (R^2) and root mean square error (RMSE) for the prediction model were 0.32 and 1.02%, respectively. An independent data set of Duroc ($n=331$) and Yorkshire ($n=288$) pigs from two replications of the National Pork Board's Genetics of Lean Efficiency Project were used for model validation. The product moment correlation and rank correlation coefficients between PIMF and CIMF were 0.60 and 0.56, respectively, in the Duroc population. Duroc pigs provided the best validation of the model. This demonstrates that real-time ultrasound image analysis can be used to predict intramuscular fat percentage in live swine.

4.3 Selection for increased IMF

A selection project to increase intramuscular fat percentage using real-time ultrasound was initiated at the Bilsland Memorial Swine Breeding Farm at Iowa State University in 1998. The project was started by purchasing 40 Duroc gilts from Midwest breeders. Two generations of random mating using Duroc boars available at regional boar studs were used to expand the population, and to ensure that the population represented the genetic variability that was currently available in the Duroc breed. A base population of 56 litters was produced in 2000. At weaning, two boars in each litter were randomly selected to remain boars and all other boars in the litter were castrated. At an average weight of approximately 114 kg, pigs were ultrasonically evaluated with an Aloka 500V SSD ultrasound machine for measurement of 10th rib off midline backfat depth and loin muscle area. A minimum of four longitudinal images were collected 7 cm off midline across the 10th – 13th ribs. Predicted IMF was determined by the method described in Newcom et al[9].

All barrows within each litter meeting the minimum weight requirement (> 98 kg) were harvested 5 days after scanning. If no barrows were available, a randomly chosen gilt was harvested. After harvest, a slice of the longissimus muscle from the 10th – 11th rib interface was analyzed for carcass IMF as previously described [15]. In total, 379 pigs were scanned and 141 pigs harvested in the base population.

From the litters produced, littermate pairs of gilts were randomly chosen to produce the next generation. One gilt in each littermate pair was assigned to the select line and the remaining littermate was assigned to the control line. Littermate gilts across both lines were mated to the same boar (*via* natural mating or artificial insemination) to maintain genetic ties between the lines for production of generation 1. A total of 24 sires from 14 sire families were used to produce 50 control and 45 select line litters. At weaning, two boars in each litter were randomly selected to remain boars and all other boars in the litter were castrated. When generation 1 animals reached an average of 114 kg, pigs were scanned and harvested according to the protocol previously described. In total, 324 and 283 pigs from the control and select lines, respectively, were scanned. A total of 148 pigs (87 control and 61 select) from Generation 1 were harvested.

Breeding values were estimated for predicted and carcass IMF by fitting a two-trait animal model and the full relationship matrix in MATVEC [16]. Genetic and environmental variances were estimated using predicted and carcass IMF values from the 289 pigs harvested using the following model: $\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Za} + \boldsymbol{Hd} + \beta + \boldsymbol{e}$, where $\boldsymbol{y}$ = the vector of observations; $\boldsymbol{b}$ = the vector of fixed effects (scan contemporary group, harvest contemporary group, and sex), $\boldsymbol{a}$ = the vector of random additive genetic effect, which includes the numerator relationship matrix among animals; $\boldsymbol{d}$ = the vector of common litter effects, which is assumed to be uncorrelated with the random animal effects; β = covariate of off test weight, and $\boldsymbol{e}$ = the vector of residuals. The incidence matrices relating observations to fixed, random animal, and common litter effects are $\boldsymbol{X}$, $\boldsymbol{Z}$, and $\boldsymbol{H}$, respectively.

Selection was based on EBV for carcass IMF. In the select line, the 10 boars and 75 gilts with the highest EBV were selected. To minimize inbreeding, no more than two boars per sire family were selected, selection of full-sib boars was not permitted, and no more than four gilts per litter were selected. In the control line, one boar from each of the 14 sire families and 50 gilts representing all 14 sire families were randomly selected. Animals within each line were randomly mated to produce generation 2, but matings were designed to control inbreeding and ensure several litters from each selected boar.

In generation 2, 56 select and 36 control line litters were produced. At weaning, three boars in each select litter and two boars in each control litter were randomly selected to remain boars and all other boars in the litter were castrated. When generation 2 animals reached an average of 114 kg, pigs were scanned and harvested according to the protocol previously described. A total of 614 pigs were scanned and 103 pigs from generation 2 were harvested. The genetic evaluation described above was performed to make selections.

In generation 3, 54 select and 38 control line litters were produced. At weaning, three boars in each select litter and a minimum of six boars in each control sire group were randomly selected to remain boars and all other boars were castrated. Pigs were again scanned and harvested according to the protocol previously described. From Generation 3, a total of 626 pigs were scanned and 145 pigs were harvested for carcass evaluation.

After three generations of selection, a total of 217 control line and 182 select line pigs have been harvested. Least squares means for carcass and quality traits were estimated using PROC MIXED in SAS with a model that included fixed effects of line, generation, harvest group within generation, sex, and a linear covariate for carcass weight. Sire and dam within line were random effects in the model. Results from this analysis are presented in Tab. 2. Pigs in the select line had more ($P < 0.01$) IMF (3.94% vs 3.40%) than pigs evaluated from the control line. Differences between the lines for Hunter L^* color, Minolta reflectance, and ultimate pH were not significant. Control pigs had significantly less tenth rib backfat (20.1 mm vs 22.1 mm) and significantly more loin muscle area (43.3 cm^2 vs 41.2 cm^2). There was a trend for control line pigs to have less last rib backfat but the difference was not significant.

Tab. 2 Carcass and quality data from pigs harvested in three generations from a selection project for intramuscular fat in Duroc swine $n = 399$

trait	control	select	$P > F$
tenth rib backfat /mm	20.1	22.1	< 0.001
last rib backfat /mm	23.6	24.9	N. S
loin muscle area /cm^2	43.3	41.2	< 0.001
intramuscular fat /%	3.40	3.94	< 0.01
hunter L^* color	48.7	49.4	N. S
minolta reflectance	23.9	24.5	N. S
ultimate pH	5.82	5.82	N. S

Table 3 gives the results for the 626 pigs scanned in Generation 3. The average breeding value for IMF for select line pigs after three generations of selection was 0.81% compared to −0.02% for control line pigs. Line comparisons for STAGES backfat, loin muscle area, and terminal sire index (STAGES, 2004) indicated a significant advantage for control line pigs compared to pigs in the select line. Control line pigs also had an advantage in days to 114 kg (176.5 vs. 180.9), but the difference was not significant.

Tab. 3 EBV for intramuscular fat and STAGES data for Generation 3 pigs from a selection project for intramuscular fat in Duroc swine $n=626$

trait	control	select	$P>F$
EBV for intramuscular fat /%	−0.02	0.81	<0.000 1
stages data[1)]			
days to 114 kg	176.5	180.9	N. S
backfat /mm	18.3	20.6	<0.001
loin muscle area /cm^2	43.0	40.9	<0.05
Terminal Sire index	111.3	101.2	<0.000 1

1) http: //www. ansc. purdue. edu /stages /

5 Conclusions

After three generations of selection for IMF using real-time ultrasound in an Iowa State University study, the average EBV for select line pigs is 0.83% greater than for control line pigs. Selection for IMF has, however, resulted in slightly more backfat and less loin muscle area, and a trend toward more days to 114 kg in the select line compared to the control line. Carcass evaluation of a sample of pigs from each litter indicated a similar increase in IMF, increase in backfat, and reduction in loin muscle area for select line pigs. No differences were found for Hunter L^* color, Minolta reflectance, and ultimate pH.

Real-time ultrasound has been, and will continue to be, one of the most important tools in enhancing genetic improvement in the U. S. Recent advancements in the technology have allowed ultrasound to be used in evaluating intramuscular fat in live animals. Together with other genetic improvement tools, ultrasound technology will offer seedstock producers the opportunity to select for improved IMF in potential breeding stock replacements and hence speed genetic progress for the improvement of this trait.

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(**Edited by ZHOU Zhi-hong**)

译文

猪遗传改良计划中肉质测定和超声波技术的应用

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摘要: 实时超声波已经、而且将继续是加快美国猪遗传改良最重要的工具. 最新的技术进展使我们能够对肌内脂肪含量进行活体评估. 配合其他遗传改良手段, 超声波技术可以使种猪生产者有机会对 IMF进行选择, 从而加快该性状的改良速度. 爱荷华州立大学利用实时超声波已经对 IMF进行了 3个世代的选择, 选择系该性状的 EBV比对照系高 0.83%. 不过, 对 IMF的选择使背膘厚略有上升, 眼肌面积略有下降, 达 114 kg日龄比对照系也有推迟的趋势. 从选择系每窝猪抽取的一组个体进行胴体评估, 发现与对照组相比, 选择系的 IMF略有上升, 背膘厚增加, 眼肌面积下降。肉的 Hunter L^*颜色值、Minolta反射值和最终 pH值则没有变化.

关键词: 猪; 肉质; 肌内脂肪含量; 超声波技术

任何猪遗传改良计划都是为了使经济上重要的性状获得迅速的遗传改良。要获得较高的遗传进展有 2个关键因素, 即确定哪些是最重要的性状和对这些性状进行准确度量。在过去的几十年时间里, 养猪业在降低背膘厚和提高瘦肉率方面取得了巨大进展。近年来, 肉质性状受到更多关注, 在育种计划中变得更加重要。

本文将介绍实时超声波技术及其如何在猪遗传改良计划中运用。此外, 还将介绍猪肉品质的重要特性及其与养猪业的关系。最后将阐述怎样利用实时超声波对猪活体进行猪肉品质的测定, 以及该技术如何在养猪业中应用。

1 超声波及其原理

养猪业中超声波已被广泛地用于活体和屠体组成性状评估, 最近还用于猪眼肌的肌内脂肪含量估计。此项技术可应用于遗传选择、瘦肉生长拟合、体型评分和销售体系中胴体品质评价。超声波测定技术员能够准确测定胴体组成性状的能力, 为养猪业在种猪和商品猪的胴体组成方面创造了获取更大的遗传进展的条件。在胴体组成上获得的可观进展得益于高质量的超声波仪器和通过美国国家猪改良联合会(NSIF)认证的熟练技术员。

超声波技术应用于生物领域始于 20世纪 50年代。早期的超声波仪是利用一种单相的超声传感器(A超), 可以向动物组织发射和接受单向声波, 可对指定解剖部位的脂肪和肌肉厚度进行单点估计。技术的进步扩大了超声波仪的用途, 把多重传感器组成一个阵列, 就可获得猪体解剖部位的二维扫描图像。通过荧屏中显示的二维图像, 可以准确和重复地测量出膘厚、肌肉厚度、肌肉面积和肌肉的周长。这种改进的超声波仪称做 B超或实时超声波, 能非常准确地得到动物组织图像。实时超声波从 20世纪 80年代商业应用以来, 提高了背膘和眼肌面积活