

INTERNATIONAL STUDY GUIDE

*REAL-TIME ULTRASOUND
SWINE APPLICATIONS*



*BACKFAT THICKNESS
LOIN EYE MUSCLE AREA
PERCENT LEAN*

OPERATOR TRAINING MANUAL

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UNDERSTANDING ULTRASOUND

To some, ultrasound may seem a new technology just introduced into the field of live animal evaluation with all the pitfalls and shortcomings of a new technology. However, first records include the development of the piezoelectric crystal as early as 1880. On a practical basis, most first remember either hearing or reading about ultrasound in the form of SONAR (SOund NAVigation and Ranging) used in the military in the 1940's.

In the early 1950's, researchers (Wild, 1950) began reporting using A-mode (amplitude modulation) for ultrasonic imaging of biological tissues. The technology continued to progress until today B-mode (brightness modulation) is a widely used technology for imaging tissue. While A-mode is one-dimensional and is limited to measuring depth of tissue, B-mode allows characterization of tissue with different densities.

Ultrasound is really a high-frequency sound wave. Audible sound waves are of the order 20-20,000 hertz (Hz) (cycles per second) while ultrasound waves are in the 1-10 megahertz (MHz) range (Goddard, 1995). An ultrasound image is generated when an electrical current is applied to the piezoelectric crystal located in the transducer and a sound wave is generated and directed into the tissue. The sound wave travels through the biological tissue until it strikes a tissue of a different density and an echo is returned to the transducer. This echo is converted back to an electrical signal and interpreted by the instrument as variations in brightness displayed on the cathode ray tube of a B-mode system as a dot. The brightness of the dot depends on the amplitude, or intensity, of the echo. The time it takes the echo to reflect back to the transducer determines the location or position of the dot or pixel on the screen. B-mode units use grey scale numbers ranging from 1 to 64, and the final image is generated by differences in shades of gray generated from the tissue field. Dense tissues give a bright, white echo (pixel) while lesser density tissues are seen as gray pixels.

Animal tissues have different densities, characterized by differing velocity of propagation through the tissues. Therefore these differences allow the use of ultrasound to characterize these tissues for different purposes. Velocity for common food animal tissues (Powis, 1996) are:

TISSUE	VELOCITY (m/s)
Blood	1,549-1565
Fat	1,476
Connective tissue	1,545
Skeletal muscle	
Longitudinal	1,592
Cross-sectional	1,545
Bone	3,406-4,030
<i>Scanner calibration</i>	<i>1,540</i>

Distance can be calculated as:

$$\text{Distance} = \frac{\text{time x velocity}}{2}$$

Real-time ultrasound is a specialized version of B-mode ultrasound and has the ability to produce images almost instantaneously as “live”, moving objects. By using a linear transducer with multiple crystals and emitting a continuous beam of ultrasound pulses, a picture of the scanned area can be recorded and interpreted.

UNDERSTANDING THE TERMINOLOGY

Competent operators should have a basic understanding of the terminology associated with ultrasound and food animal scanning. The following terms are commonly used in the industry:

Absorption - Loss of energy (principally due to molecular friction forces and the production of heat). As frequency increases, absorption increases.

Acoustic coupling - Since ultrasound is poorly transmitted through air it is necessary to exclude air and link the transducer to the surface of the subject with a suitable coupling gel.

Acoustic enhancement - Tissues distal to an anechoic structure may display enhanced echogenicity.

Acoustic interface - Junction of two tissues with different acoustic impedances. This leads to the reflection of a proportion of the incident beam and possible diffraction of much of the remainder of the beam. The greater the difference in acoustic impedance, the stronger the reflection.

A-mode - Amplitude modulation. A one-element (one dimensional) display with time (distance) on the horizontal axis. The relative strength of the echo is registered as amplitude on the vertical axis.

Amplitude - Height of the ultrasound waveform.

Anechoic (sonolucent) - A tissue failing to reflect the ultrasound beam produces no echoes (e.g. a fluid-filled viscus).

Anterior - Toward the head, may also use *cranial*.

Array - Distribution of crystals along the length of a linear scan head.

Artifact - An on-screen representation of a structure which does not exist or is incorrectly located.

Attenuation - Decrease in power of the ultrasound beam, caused principally by absorption, scatter and reflection.

Axial resolution - Measure of the ability of the system to differentiate two structures lying closely together along the path of the ultrasound beam.

B-mode - Brightness modulation. A compound A-mode scan with amplitude translated into a brightness scale. Location on the display is related to

position and depth.

Bias - Average deviation of an operator's estimates from the carcass measurements. Bias is used to standardize measurements between different technicians.

Calipers - A system for measurement of distance and area is provided on most instruments.

Caudal - Toward the tail, may also use *posterior*.

Certification - A proficiency testing program generally offered at least twice per year. The certification program for beef or swine operators is intended to evaluate operator proficiency against standards established by the Beef Improvement Federation or National Swine Improvement Federation.

Cranial - Toward the head, may also use *anterior*.

Diffuse reflection - An echo from a target(s) less than one wavelength in size.

Distal - Away from the body in a limb of the animal.

Doppler ultrasound - When an ultrasound beam meets a moving object the reflected ultrasound is either of increased or decreased frequency, depending on whether the motion is towards or away from the transducer. Either continuous or pulsed Doppler can be used and some systems can display compound information.

Dorsal - Toward the upper part or back of the standing animal.

Echogenic - A structure causing a marked reflection of the ultrasound beam. A change in echogenicity in a homogenous structure may indicate a pathological change.

Ether extractable fat - Chemical fat determination to estimate *intramuscular fat* or *marbling* in meat.

Focal area - Region of the scanned field where resolution is greatest. Focusing can be achieved by electronic or physical means.

Frame rate - The frequency with which images are updated on the screen.

Altering the frame rate may improve image quality in some applications.

Frequency - Number of ultrasound waves emitted per second. One (1) cycle per second = 1 hertz (Hz).

Gain - The amplification level of a returned signal. On some instruments different depths of the field are handled separately. Incorrect setting of gain controls will lose detail from fine structures.

Grey scale - Range of intensities displayed on the cathode ray tube.

Hyperechoic - Showing increased echogenicity.

Hypoechoic - Showing decreased echogenicity.

Intramuscular fat - Fat that is deposited within muscles and appears a delicate pattern of wavy lines in the meat, also known as *marbling*.

Lateral - Toward the sides of the standing animal.

Lateral resolution - Measure of the ability of the system to differentiate two structures lying side-by-side at the same distance from the transducer.

Linear array - Distribution of piezoelectric crystals along the length of a scan

Longitudinal - Plane running lengthwise, parallel to the mid-line of the animal.

M-mode - Motion mode. Essentially a rapidly updated one-dimensional B-mode display with time on the second axis to allow study of moving structures. Used principally in cardiology.

Marbling - Common term for intramuscular fat.

Medial - Toward the midline plane that separates right and left sides of the body.

Piezoelectric crystals - Crystals of materials such as lead zirconate-titanate, capable of converting applied electrical energy to mechanical deformation and vice-versa.

Posterior - Toward the tail, may also use *caudal*.

Power - Energy of the ultrasound beam. It is generally expressed in watts (or as intensity in watts cm^{-2}). The minimum power consistent with good image quality should be employed.

Probe - The transducer array and its housing.

Proximal - Toward the body in a limb of the animal.

Real-time - Images generated from reflected ultrasound following sequential activation of the transducer array are displayed on the screen at sufficient speed to give the appearance of a live image.

Reverberation echo - An artifact created by the retransmission of a strongly reflected ultrasound signal. The display may show several images of a single structure, which appear at increasing distances from the transducer.

Scan converter - A component of the processing system which converts the electrical output of the transducer to the cathode ray tube image, essentially by aggregating sequential arrays across the screen. A scan converter allows for subsequent analysis beyond the screen display (post-processing) and the use of standard TV accessories.

Scatter - When the ultrasound beam encounters a small object in its path the beam energy is spread in all directions.

Sector scan - A pie-slice/sector-shaped image is produced on the screen. The initial signal is produced by a single vibrating piezoelectric crystal or a small number of rotating crystals (although an electronic phased linear array can produce a sector image). The scan head only needs a limited contact area (small footprint).

Shadowing - Caused by severe attenuation of the ultrasound beam such that it fails to penetrate sufficiently deeply.

Specular reflection - A strong echo created by a highly reflective tissue interface representing an area significantly larger than one wavelength.

Standard error of prediction (SEP) - Standard deviation of the differences between real-time ultrasound and carcass measurements for a given operator. SEP measures the ability of the technician to rank or predict differences between animals correctly.

Time-gain compensation (TGC) - Since the ultrasound beam is increasingly attenuated as it travels deeper into tissue, by applying TGC tissues of similar reflectivity are represented with similar brightness, regardless of distance from the transducer.

Transducer - The piezoelectric crystal or element which converts electrical to mechanical energy.

Ultrasound - Sound of a frequency above that perceived by the human ear. Diagnostic ultrasound lies in the 1-10 MHz region.

Velocity - Speed of travel of the ultrasound wave. In tissue this is usually density dependent and ranges from 1500 to 1600 m/s⁻¹. An average of 1540 m/s⁻¹ is usually adopted.

Ventral - Toward the lower part or belly of the standing animal.

UNDERSTANDING THE EQUIPMENT

While there may be various brands or models of equipment on the market, all possess the same basic components.

Scanner

The basic function of the scanner is to process the image acquired by the transducer and to display this image on the screen. Units used for live food animal work is usually portable and can be used for both reproduction and composition work. The Pie Medical 200 SLC Scanner can be used for a multitude of scanning purposes depending on selection of transducer. The unit is equipped with a keyboard for annotations, provisions for measuring, freezing and storing images, and easy to use pull-down menus. Data and images can be transferred to a computer for storage and retrieval via Optical Data Transfer (ODT) software available from Pie Medical.

Transducer

The transducer (probe) is the “eye” of the scanner. The heart of the transducer are the piezoelectric crystals which generate the ultrasound pulses across its axis, send the generated beams into the tissue and receive the echoes to be processed by the scanner. The recommended transducer for food animal scanning is the Animal Science Probe (ASP-18).

This probe contains a total of 128 piezoelectric crystals arranged in a linear array. The probe is a full 18 centimeters in length allowing for single scan imaging for all food animals (beef, sheep, swine and specialized animals).

Standoff Pad

A standoff pad (wave guide) is used to “fit” the straight, linear array transducer to the curved back of the animal for image acquisition. The standoff pad is essential for measuring cross-sectional loin eye muscle area. The pad is not required for longitudinal scanning common for backfat, muscle depth or intramuscular fat estimation.

SPECIALIZED FOOD ANIMAL SCANNING

During the last 35 years, a considerable amount of research effort has been directed

at developing non-invasive, non-destructive techniques for assessment of live beef animals and swine. Real-time ultrasound (RTU) is a simple and reliable method of estimating composition and quality of meat (Stouffer and Turlington, 1994). Approaches identified by various researchers to develop RTU technology range from simple prediction of carcass fat and loineye area (Stouffer, 1961) to using RTU to estimate intramuscular fat (Wilson et al., 1995). Most of these technologies have used an off-line computer image interpreting system for composition (Hamlin et al., 1995a; Hamlin et al., 1995b;) and muscle quality (Whittaker et al., 1992; Brethour, 1994; Wilson et al., 1995). However, recent advances in RTU technology have made this technology available within the machine for use by the practicing veterinarian or producer. The purpose of this report is to outline the methodology in acquiring and interpreting ultrasound images for use in evaluating live swine.

Figure 2. ASP-18 probe with beef and swine contact pads.

During the last three years, Pie Medical has become the worldwide leader in ultrasound technology for food animal scanning. This is primarily due to the introduction of the Pie 200 SLC Scanner System (Figure 1) and the 18 cm., 3.5 MHz linear array animal



Figure 1. Pie 200 SLC Scanner and ASP-18 Probe.

science probe (Model ASP-18).

While the 200 Scanner has a multitude of uses in the veterinary and animal science fields, the ASP-18 probe is unique for food animal scanning. Pie Medical's leadership is enhanced by introduction of the first on-line system for muscle quality evaluation known as the Quality Ultrasound Index Program (QUIP). This program provides the opportunity for chute-side evaluation of intramuscular fat (IMF). Currently the Pie 200 SLC provides capability for estimation of backfat and loineye area used in most countries to assess live animal composition. Other measurements include the Australian P8 rump measurement (also under evaluation in the US) plus a system to estimate muscle quality or composition important in the US, Australia, Canada, Japan, South America and the European Union. These estimates are made "chute-side" without any additional equipment. Besides the

scanner the only other accessories required are a contour-fitting standoff or contact pad (Fig 2) necessary for use in loin eye muscle area determinations and the calibration phantom

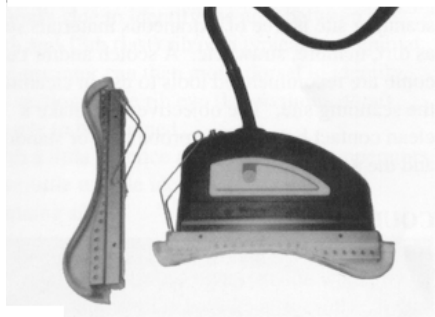


Figure 2. ASP-18 probe with beef and swine contact pads.

(Fig 3) for machine standardization for muscle quality assessment with the QUIP system.

Figure 3. Calibration phantom used to calibrate machine for intramuscular fat estimation. (Beef Applications Only)



Those producers and researchers involved with the food animal industry are well aware of the applications of RTU for food animals. However, most veterinarians have normally thought of RTU in terms of injury diagnosis and reproductive physiology applications. Some of the uses of RTU in the swine industry alone include:

Reproductive Physiology

- 1. Pregnancy detection**
- 2. Fetal sexing**
- 3. Litter size (number) estimation**

There are several uses of RTU in reproductive physiology. One specific use is to monitor ovarian activity to increase the number of cyclic sows and gilts to aid conception. This might include evaluation prior to the breeding season or toward the end of the artificial insemination (AI) breeding period. This is especially important in high-producing operations with the need to maximize utilization of facilities.

Carcass Composition and Quality

- 1. Backfat (subcutaneous fat) determination**
- 2. Loin eye muscle area**
- 3. Percent lean**
- 4. Muscle quality by intramuscular fat estimation**

Composition of swine carcasses is the driving force behind interest in a value-based marketing system that is based on percent lean in the carcass. The producer and packer are both interested in the ability to produce carcasses of consistent composition and quality. RTU offers the ability to accurately assess subcutaneous fat, loin eye muscle depth or loin eye muscle area that are prime contributors to variation in lean composition of animals of similar weights. Loin eye muscle area (LEA) is of particular importance to seedstock producers selecting for muscling in breeding animals as well as to estimate composition in market animals. While intramuscular fat is highly related to market quality of beef, less emphasis has been placed in intramuscular fat in swine. Pie Medical currently has research underway to develop techniques of estimating intramuscular fat in swine using the QUIP system that is currently used for beef cattle.

LIVE SWINE EVALUATION BY ULTRASOUND

A great advantage in using RTU is that it is non-invasive and relatively free of stress to the animal. The scanning operation requires no special handling equipment for the animal other than those items of equipment normally found on farms and in clinics. To reduce animal stress and reduce chance of injury to the animal and operator, most operators find that the best location for scanning swine is either in a crate scale or specially fabricated restraint device (Figure 4).

Figure 4. Illustration of animal restraint device with operator applying acoustical contact.



IDENTIFICATION OF SCANNING SITE

Once the operator has secured the animal in position for scanning, the next choice is identifying the anatomical location for scanning. While there may be differences in scanning sites, the most common scanning site used for RTU evaluation is at the 10th rib. Proper identification of the proper scanning site is more difficult with swine than beef cattle since it is relatively easy to palpate the 12th/13th rib location in cattle. However here are a few suggestions on selecting the 10th rib site on swine that operators might find helpful.

One technique involves first locating the last rib either by physically palpating the last rib or identifying the rib location using the shoulder blade and anterior edge of rump. Figure 5 illustrates the operator palpating the dorsal point of the shoulder blade (scapula) and anterior point of the rump on the opposite side of the animal.



Figure 5. Operator using shoulder blade and rump as reference points to help locate proper scanning site on swine.

After locating reference points (Figure 5), lines may be drawn connecting shoulder blade and rump on opposite sides to form a “X” on the back of the animal. Where the lines cross should approximate the location of the last rib (Figure 6).



Figure 6. Approximation of last rib on swine using “X” technique.

Once the last rib has been identified it is now quite easy to approximate the location of the 10th rib. One technique is for the operator to place his/her hand where the posterior edge of the hand is over the last rib. The opposite edge of the hand should approximate the location of the 10th rib (Figure 7).

Figure 7. Identification of 10th rib using anterior edge of hand when posterior edge of hand is placed over last rib location.



Figure 8 illustrates skeletal structure of swine as a further aid in identifying proper scanning site for a 10th rib scan. Keep in mind that number of ribs in swine is not consistent but will usually total 14-15.

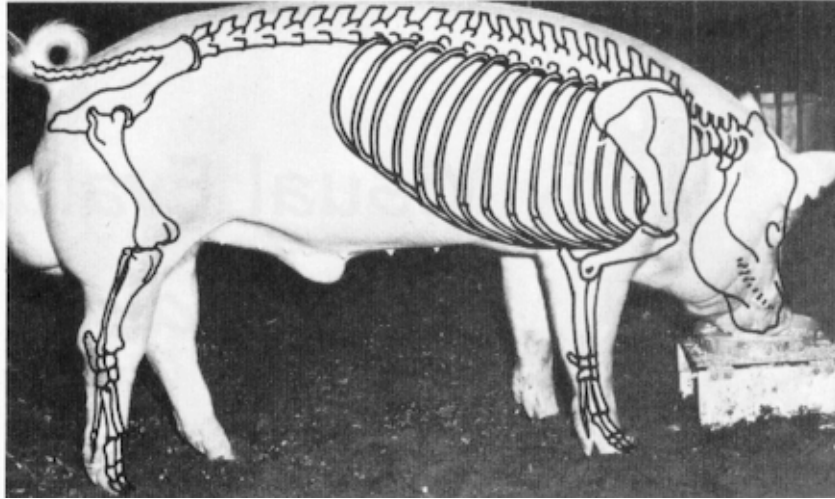


Figure 8. Skeletal structure of swine.
Illustration adapted from publication of
American Yorkshire Club.

ANIMAL PREPARATION

One advantage in scanning swine as compared to beef cattle or sheep is that there is no thick hair coat or fleece to interfere with acoustical contact. However, RTU technicians are well aware of the need for good acoustical contact between the probe and skin surface, and certainly realize that sound waves will not travel through air. Most operators use a scanning gel for acoustical contact, however, the use of gel for swine may be expensive and impractical. Therefore, most scanning operators use vegetable oil for this purpose. This couplant is readily available, inexpensive and is not harmful to the animal or probe. **MINERAL OIL SHOULD NEVER BE USED SINCE IT IS HARMFUL TO THE PROBE SURFACE AND CABLES.** Since most scanning operations are done under less than ideal environmental conditions, oil temperature may have an influence on image quality. Best results are obtained when oil temperature is near 80 degrees Fahrenheit.

It is apparent from observing the ASP-18 linear array probe that some type of adaptation would be necessary for cross-sectional scanning for loin eye muscle area. Therefore, an acoustical contact (Figure 2) is available as an accessory to the Pie 200 scanning system. Contacts of varying curvature are available for either beef or swine

scanning. The contact is easily attached to the probe and a small amount of scanning gel (AQUASONIC 100™) may be used to assure acoustical contact between probe and the curved pad. The quantity used will depend on animal conditions and operator preference. However, temperature may again play a role in image quality, especially in colder climates. Best results are obtained when the contact pad is maintained at a temperature near as possible to oil temperature. Pads should be cleaned with warm soap and water after each use and stored in a container to prevent damage and drying out of the flexible material. Pads should last indefinitely if cared and stored as recommended.

CROSS-SECTIONAL SCAN

The most commonly used scanning technique for swine is the cross-sectional scan at the 10th rib. Previous discussion has suggested ways to correctly identify the proper scanning site. After identification, the operator may now clean the site if needed using a brush or metal comb. Better quality images are obtained if the site is free of dirt or excessive hair. After cleaning, the operator should now apply a liberal amount of scanning oil to the site (Figure 9). Oil should completely saturate the area to be covered by the probe and pad.



Figure 9. Operator applying vegetable oil to scanning site after cleaning free of excess hair and dirt.

After oiling, the probe (equipped with contact pad) is now placed along a plane aligned with the 10th rib site so that it will be perpendicular to the mid-line of the animal (Figure 10).

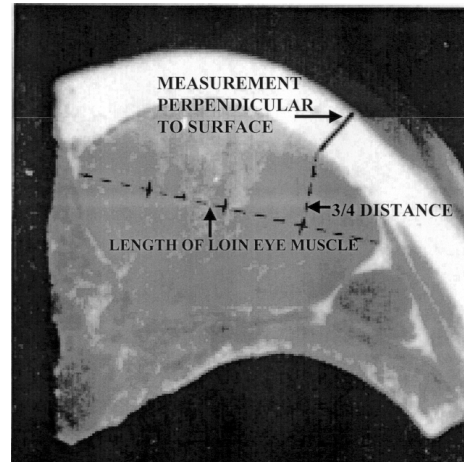
Figure 10. Illustration of probe alignment for cross-section scan. Probe aligned with 10th rib site and perpendicular to mid-line of animal.



For best results, it is recommended that a scanning depth of 4 inches or 10 centimeters (8

tracking ball to highlight ANIMAL SCIENCE, press SELECT, move to SWINE, press SELECT, move to LOIN AREA and press SELECT. Place cross-hair at any site on the surface of the loin eye muscle, press SET and trace the outer edge of the muscle back to the starting point. Muscle area in square inches or square centimeters will be displayed in box as LA . The proper site for backfat thickness measurement is at a point $\frac{3}{4}$ of the distance from the medial to the lateral edge of the loin eye muscle and perpendicular to

Figure 13. Illustration of correct site to measure backfat on swine RTU images. Site is $\frac{3}{4}$ distance the medial to lateral length of muscle and perpendicular to surface. (Illustration adapted from Boggs, et al, 1998)



the surface of the animal (Figure 13).

Tracing of the loin eye area is illustrated in Figure 14. Note the presence of the costarum muscle and exclusion of small muscles around outer edges of *longissimus dorsi* muscle as identified in Figure 15.

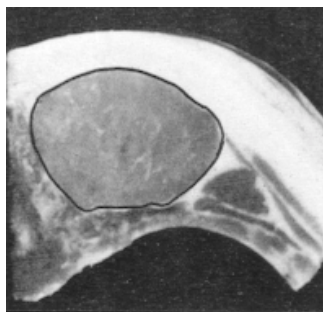


Figure 14. Illustration of area to be traced for measurement of loin eye area (*longissimus dorsi*) muscle. (Illustration adapted from Boggs, et al., 1998)

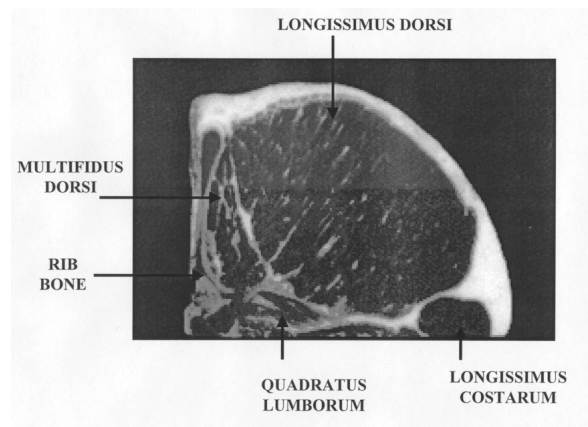
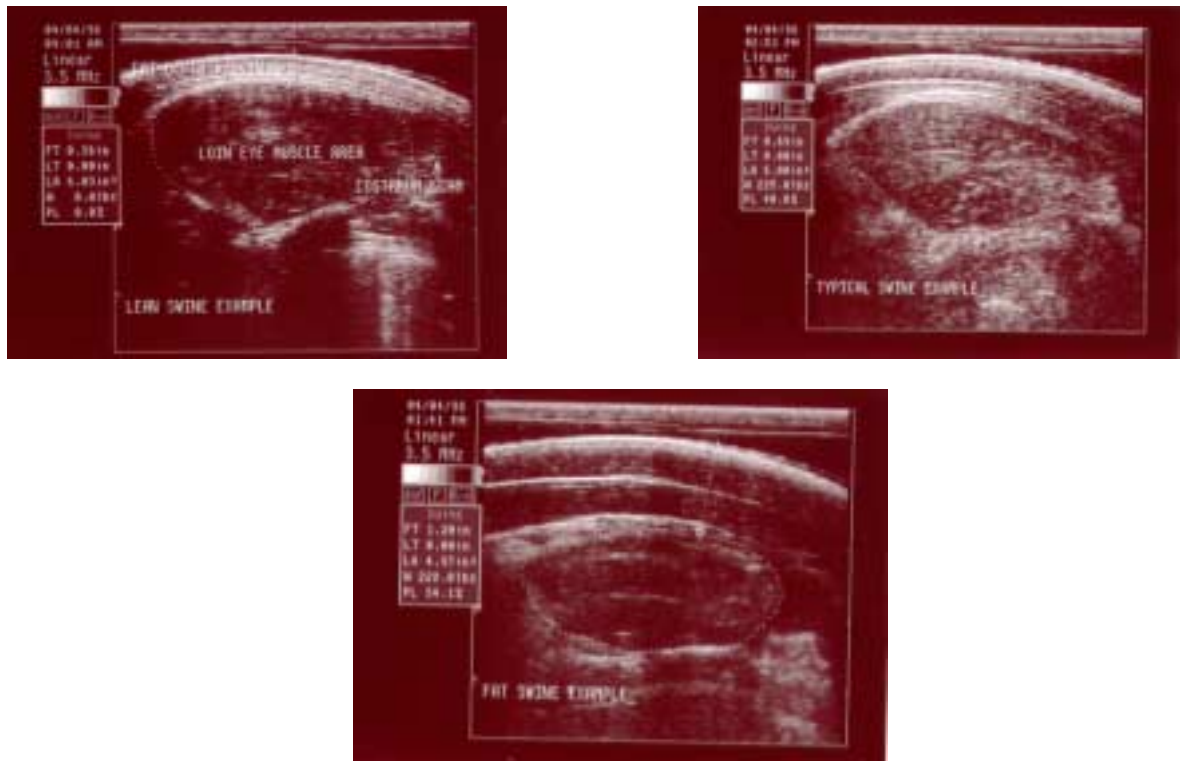


Figure 15. Identification of *longissimus dorsi* muscle (used for loin eye area) and associated muscles not included in tracing.

ILLUSTRATIONS

Figures 16 to 18 illustrate comparison of scans expected for LEAN, TYPICAL and FAT hogs to compare differences in images expected. Images have been measured and fat thickness and loin eye area is indicated for each. The swine software program also has the ability to automatically calculate a PERCENT LEAN estimate based on fat thickness, loin eye area and live weight. To utilize this function, measure the fat thickness and loin eye area as previously described. Then again press SELECT for ANIMAL SCIENCE and highlight and select SWINE. Scroll down to WEIGHT and live weight can be entered and then press SELECT. The PL reading in the box indicates an estimated PERCENT LEAN (live weight basis). Since most producers are more familiar with a PERCENT LEAN (carcass weight basis), the PL value can be divided by expected dressing percentage (72-74%). An updated software version will soon be available that will report PERCENT LEAN on a carcass weight basis. Figure 18 illustrates entry of live weight to calculate PERCENT LEAN (PL).



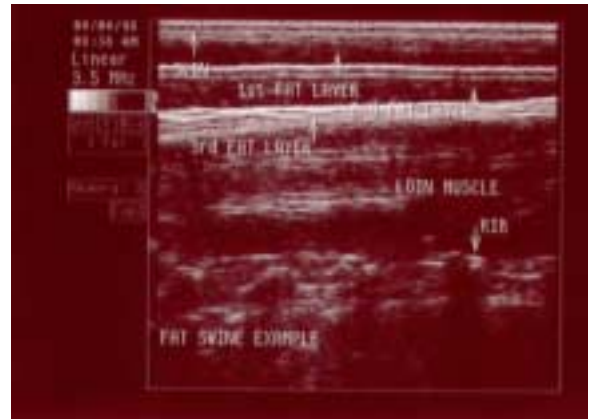
Figures 16 – 17 (L-R, top) and Figure 18 (bottom). Illustration of backfat and loin eye measurement on swine of three fat thicknesses. Figure 16 would be typical of leaner animals especially young breeding boars and gilts. Figure 17 would be typical of market hogs at harvest and also illustrates entry of live weight to calculate PERCENT LEAN (PL). The 40% PL indicated is on a live weight basis and can be converted to carcass basis by dividing by 0.73 which would give a 55% lean value on a carcass basis. Figure 18 illustrates a fat, light muscled hog and the image that would be expected.

LATERAL SCAN

Operators may also elect to use a lateral scan to measure backfat thickness and depth of the *longissimus dorsi* muscle. These measurements are quite similar to optical probe measurements on the carcass used to evaluate percent lean for marketing purposes. In addition, these measurements can also be used to estimate loin muscle area (Liu and Stouffer, 1998) as well as percent lean in the carcass (Gresham et al, 1992; Gresham et al, 1994; Liu and Stouffer, 1998). Preparation for the lateral scan is identical to the cross-sectional scan except that the probe placement is aligned parallel to the mid-line of the animal, centered over the 10th rib and approximately 2 inches lateral to the mid-line. Figure 20 illustrates probe placement for the lateral scan with Figures 21 and 22 illustrating typical images from LEAN and FAT hogs. The three layers of fat can also be identified on Figure 22 with Figure 21 and having two layers. Muscle depth is measured as the distance from the dorsal edge of the *longissimus dorsi* (loin eye) muscle to the ventral edge of the muscle. The ventral measurement is a point to represent the mid-point between rib bone images.



Figure 20. Probe placement (no standoff pad) for lateral scan with probe centered over 10th rib and approximately 2 inches lateral to mid-line of animal.



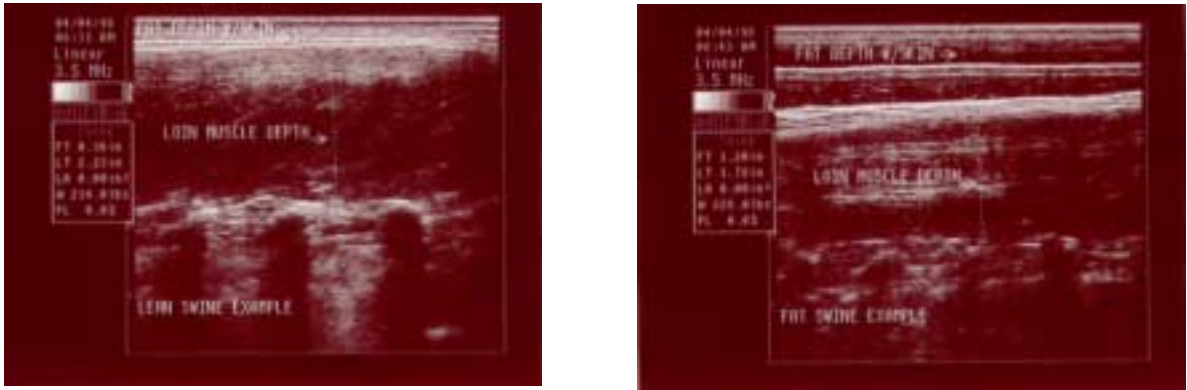
Figures 23 a

Figure 21. Illustration of lateral scan for lean hogs with identification of fat layers and muscle depth and loin muscle image.

t of backfat thickness

Figure 22. Illustration of lateral scan for fat hogs with identification of fat layers and muscle depth and loin muscle image.

LEAN and FAT hogs. Note the echogenic qualities of the 3rd layer of fat as compared to the 1st and 2nd layers. Care must be taken to insure that the ventral surface of the 3rd fat layer is properly determined, otherwise operators may underestimate fat thickness, especially in the fatter hogs.



Figures 23 – 24 (L-R). Illustrations of measurements of backfat and loin eye muscle depth.

SUMMARY

Real-time ultrasonography is the most advanced and safest technology available for estimating composition and quality of live animals. The Pie 200 Scanner SLC is the most advanced form of portable ultrasound for a variety of uses. It is inexpensive, accurate and highly repeatable, all criteria that may be used to describe the needs of the livestock industry in a any part of the world.

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