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PURDUE EXTENSION

Pork Industry Handbook

Using Real-Time Ultrasound for Pregnancy Diagnosis in Swine

Authors
Robert Knox, University of Illinois
William Flowers, North Carolina State University

Reviewers
Tim Safranski, University of Missouri
Wayne Singleton, Purdue University

Introduction

Sows that fail to establish and maintain pregnancy fail to cover costs associated with their daily maintenance and housing. Pregnancy diagnosis can help to: 1) minimize costs associated with non-productive days (NPDs), 2) maintain correct number of sows for farrowing crates, 3) identify open females for rebreeding or culling, 4) prevent unintended culling of pregnant sows, 5) identify the timing and extent of reproductive failure, and 6) help predict future pig flow [(1)].

Records indicate herds average 70 NPDs [(2)] with 20% due mated sows that fail to farrow. Of these failures, 40% return to estrus at ~21 days, while real-time ultrasound (RTU) can be used to identify an additional 35% between days 24 to 35. The remaining 25% of failures, lose their pregnancy after these days [(3-7)]. Early identification of non-pregnant animals can facilitate rapid rebreeding or timely removal to maximize their value as cull sows [(8)].

The development of portable, less expensive RTU equipment has facilitated its integration into modern production operations. This article describes the use and application of real-time ultrasound technology for pregnancy diagnosis in swine.

Objectives

- Introduce the equipment and principles of RTU.
- Explain equipment considerations for purchase of RTU units.
- Describe principles for pregnancy diagnosis and when to perform.
- Describe alternative uses for RTU.

Principles of RTU

Real-time B-mode (brightness mode) ultrasonography displays a 2-dimensional image in gray scale. The image is composed of dots, that vary from white to light gray for very dense tissues such as the uterus and skin, and from dark gray to black, for fluids and less dense tissues. For pregnancy diagnosis, decisions are based on the appearance of fluid vesicles (black) within the surrounding uterine tissue (white-gray, Figure 1).

Real-time ultrasound is based on the ability of specialized crystals within a transducer to vibrate and emit ultrasonic waves when an electric current is applied. Certain characteristics of ultrasound influence its ability to produce an accurate image for pregnancy diagnosis. For example, an ultrasonic wave is characterized by the distance it travels (wavelength), and the number of times the wave repeats within a second (frequency, [(9)]). The size of the crystal determines the wave, and the larger the crystals, the longer the wavelength and the lower the frequency. Larger crystals such as the 3.5 MHz, produce low frequency ultrasound waves that penetrate deep into the soft tissues of the animal. However, they provide lower image resolution (ability to distinguish between different structures) since fewer waves return since more are lost waves over the increased distance traveled. In contrast, the smaller crystals of the 5.0-7.5 MHz transducers produce signals that travel shorter distances, but produce higher image resolution, since fewer waves are lost. These characteristics allow choices to be made for selection of transducers, since one will provide greater depth penetration but with lower resolution, while the other will facilitate shallow imaging, but with higher resolution. The correct choice of transducer involves the design of the equipment, the cost, and the anatomical depth of the structures to be visualized.

Figure 1. Representative transabdominal ultrasound images of a day 30 pregnant sow using a 3.5 MHz sector transducer. In each image, the multiple, irregular black shaped structures are the fluid-filled embryonic vesicles surrounded by the dense tissues of the uterus.

Equipment Considerations

Most ultrasound systems can be divided into the console and the transducer. The console contains the imaging screen, control panel, and computerized hardware. The transducer houses the crystals and is the only piece of equipment that is applied to the animal. Most of the ultrasound machines fall into one of three classes: hospital grade, medical grade, and portable, veterinary grade. Choosing the correct piece of equipment for use in a swine facility must take into account the practical aspects for its intended use. For example, use in many swine gestation buildings involves evaluation of sows housed in stalls, with access only by long, narrow alleyways, and with limited electrical outlets. This makes imaging with large, heavy, equipment difficult to accomplish. Similarly in loose housing systems, non-portable equipment is impractical except when imaging can be performed in a centralized scanning area. The hospital grade machines provide the highest quality imaging, but may cost $100,000 or more, and weigh hundreds of pounds. The medical grade units generally provide high quality imaging, cost between $12-25,000, weigh 20 to 30 pounds, and may require an electrical source. These units typically provide additional features, which may include interchangeable transducers, and improved image quality, which may or may not have an effect on the ability to accurately diagnose pregnancy in pigs. However, as the number of additional functions increases, the units become more expensive and heavier.

The portable veterinary ultrasound machines have been designed for use in modern swine facilities and contain many of the features of the larger more expensive units. Over the past several years, the equipment has achieved a good track record for longevity and accuracy within breeding units. The portable units are typically priced between $5-10,000. The portability classification arises from their design for mobility, which includes the unit weight, durability, and self-contained batteries. In general, they provide good quality imaging, and most have some additional features such as image enhancing or image storage capability. When examining these machines, practical ease of use in the barns must be evaluated. The ease of screen visualization should be considered since reflection of light off the screen is a common problem and makes fast diagnosis more challenging. In addition, access to the control panel, and ease of image adjustment should be tested, since image adjustment is often required between animals, and can be more difficult with certain equipment designs. The inability to quickly adjust or freeze the image can lead to misdiagnosis of pregnancy, and inefficiency in the pregnancy diagnosis procedure. Other items to consider may include battery life and additional batteries, since some self-contained battery systems last for hours while others last for days. Most portable machines have batteries that are scheduled to operate continuously for ~3 hours, and most ultrasound evaluations typically require 1 minute per female.

When selecting a RTU unit, image quality is one of the most important factors for consideration. It is influenced by the quality of the electronics in both the transducer and console and is the sole factor limiting image resolution. The quality of the image is important for rapid and accurate diagnosis of pregnant and non-pregnant females. To optimize the image, the visual display must maximize contrast, with fluid as black and tissue as light gray to white. This allows optimal imaging for identifying the fluid vesicles of the embryo surrounded by the uterus (Figure 1). In addition to the machine, the manufacturer or distributor service arrangements should be considered. Since the duty of the machine is considered rough, breakdown or damage is likely to occur. The harsh environment of a swine production setting can easily damage the transducer, the protective wrappings around the cords, and even the sensitive electronics of the ultrasound console. For this reason, a service contract with the manufacturer or distributor should be considered. The service contract may address provisions for a temporary replacement unit, or costs associated with certain types of repairs for the damaged unit.

Transducers

Transducers contain the crystals for transmitting and receiving the ultrasound waves and are available in different frequencies and crystal arrangements. Transducers may have linear or convex arrangement of the crystals, which produce a screen image similar in shape to the rectangular or convex shape of the transducer. Sector transducers may have only a few crystals, and unlike linear arrangements, these crystals physically move in an oscillating or rotating motion within the transducer. Both the convex and sector transducers, by their shape, provide an image in the shape of a wedge (Figure 1). The resulting image is narrow nearest the transducer, and becomes progressively wider at further distances from the transducer. This type of imaging system is useful when the target for scanning is deeper in the body and its precise location is unknown, and is one most commonly used for routine pregnancy diagnosis.

Transducer options also include the ability to purchase a fixed or multiple-frequency scanning head. Transducers in the 3.5 to 5.0 MHz frequency range are frequently used for routine pregnancy diagnosis. A fixed-frequency transducer contains crystals of one size, and produces waves of only one type (3.5, 5.0, or 7.5 MHz), while the variable frequency transducers contain crystals of multiple sizes. For variable frequency transducers, the selection mechanism for a particular frequency is on the control panel of the console. Multiple frequency transducers sometimes provide lower image quality, but have greater flexibility in imaging range.

Procedure for Pregnancy Diagnosis: Hygiene

Since RTU equipment is costly, it is not uncommon to have one machine used on different farms. Because of this, it is essential to make sure that the RTU equipment does not carry disease-causing organisms between farms. To prevent this from occurring, the equipment should be cleaned and disinfected after every use. Cleaning the equipment after use is important for reducing the numbers of disease causing organisms and also to prevent fecal deterioration of the rubber components of the RTU unit. Clean the unit using a soft brush and a clean, damp, disposable towel. Keep all components clear of running water. Once cleaned, it can be disinfected using one that is safe and approved for use on the plastic and rubber components of the RTU unit. The choice of disinfectant should adhere to the manufacturer's recommendations, but may also need to meet the standards for biosecurity for a specific farm. The disinfectant can be applied as a spray or may be wiped on using a disposable paper towel. The cleaned and disinfected unit should be placed inside an unused disposable plastic bag and sealed. The sealed bag can be placed inside the carrying case until arrival at the next farm. The carrying case should also be cleaned and disinfected but some protective parts of the carrying case cannot be properly disinfected and therefore should not enter the facility.

How To Perform RTU Pregnancy Diagnosis

To obtain good quality images, a coupling gel or lubricant is applied to the end of the transducer. This allows the ultrasound waves to penetrate into the animal, since these waves do not travel well through the air space between the transducer and the skin of the animal. The coupling gel should be fluid enough to remain on the probe and the animal's skin upon contact, without the necessity of repeated application. Thicker gels provide for less air interference and result in better transmission of ultrasound waves into the skin. The best coupling substances can often be found through trial and error. However, although certain substances may appear to have the desired characteristics, some of these can reduce image quality, damage the transducer, or cause premature deterioration of RTU components. Before choosing any alternative coupling substance, it is recommended that the owner-operator check with the manufacturer of the equipment.

For diagnosing pregnancy, the animal may be in a stall or in loose housing. The surface of the transducer is lubricated and applied to contact the abdomen just lateral to nipple line and ahead of the rear leg (Figure 2). In a standing sow, the early pregnant uterus is located just ahead and below the pelvis. The transducer should be aimed toward the opposite side of the spine at a 45-degree angle with a slight 10 to 20 degree tilt towards the head of the sow, and then slowly rotated in small 45-degree arcs. This scanning procedure allows quick visualization of the multiple fluid pockets within the uterus and generally requires only 5-10 seconds per animal to confirm the presence of fluid pockets. Both the 3.5 and 5.0 MHz transducers can easily penetrate this distance for good imaging. If the animal is in loose housing, and moves away, it is usually not difficult to maintain or even re-establish contact during or after she has moved.

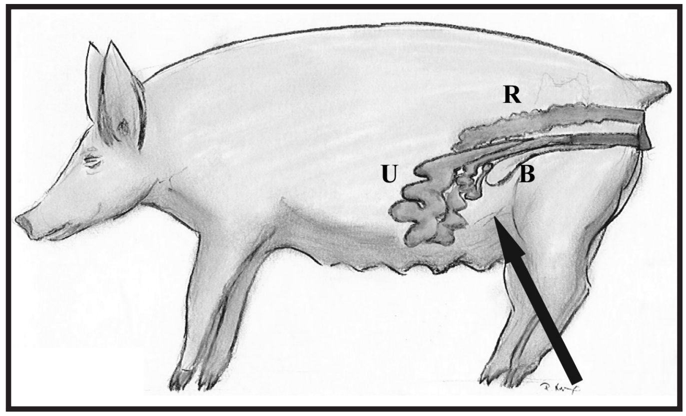

Figure 2. Arrow shows approximate placement for positioning the transducer on abdomen. Uterus (U), Bladder (B), and Rectum (R) are shown.

When To Perform

Because of the timing and amount of fluid accumulation, combined with the timing of fetal bone formation and calcification, the optimal time to diagnose pregnancy in swine is between 24 and 35 days following breeding. The accuracy of the equipment is >90% for identifying pregnant females in this period with an average time to make a diagnosis between at less than 10 seconds per sow [(10)]. Optimal diagnosis is based on fluid accumulation, which begins at day 18 but remains low until about day 24. Thereafter, between days 24 to 35, fluid volume peaks in early pregnancy (Figure 3). The ability to distinguish fluid in the uterus is relatively easy at this time because of the large amount of fluid and limited interference from the embryo and fetus. The highly echogenic tissues of the uterus, which surround the large fluid compartments of the embryos, appear bright white. Since the embryonic fluid vesicles after day 24 are relatively large (>4.0 cm or ~1.5 inches wide), and considerable contrast can be seen between the uterus and the fluid, detection becomes relatively fast and reliable. However, after day 35, the amount of fluid temporarily declines, while the fetus grows and bone calcification begins. During this period, visualization for pregnancy based on fluid contrast from the surrounding uterus is much more difficult, and increases the chance of error and time required to make a diagnosis.

Interpreting the Image

The ability to visualize clear, multiple, fluid-filled pockets within the uterus, is a requirement for positive real-time pregnancy diagnosis in pigs. The observation of multiple pockets is important because multiple segments of the uterus should be observed during scanning, and if pregnant, multiple fluid pockets are expected to be visualized in each segment of the uterus (Figure 1). Visualizing only a single fluid pocket during d 24 to 35 of gestation should be interpreted cautiously, since this image may be due to visualization of the bladder, a pseudopregnant uterus, a small litter, a degenerating pregnancy, a cystic ovary, or a uterine infection.

Special Considerations that Influence Accuracy of Pregnancy Diagnosis: Transducer Frequency

At very early stages of pregnancy (day 21), there is an effect of technician and frequency of transducer on overall accuracy. In a comparison [(11)] of two technicians (A and B), a higher accuracy of technician A (90%) to technician B (79%) was observed when pregnancy diagnosis was performed using a 3.5 MHz transducer. However, this difference was not evident when both technicians used a 5.0 MHz transducer (95% vs. 88%). It is also possible to perform pregnancy evaluation with a 7.5 MHz frequency transducer using transrectal evaluation. With this methodology, the higher image quality allows better visualization of the uterus and embryos in early gestation. Using this methodology, the transducer is attached to a flexible rod and then the transducer is inserted in the rectum. This procedure has been reported to allow earlier and more accurate pregnancy diagnosis at days 20 to 22 when compared to transabdominal ultrasound [(10)]. However, the procedure requires additional time, is labor intensive, and because most portable equipment does not have these high frequency transducers, the method may not be practical for routine pregnancy diagnosis. Yet transrectal RTU has been useful for determining the underlying causes for reproductive failure [(12)].

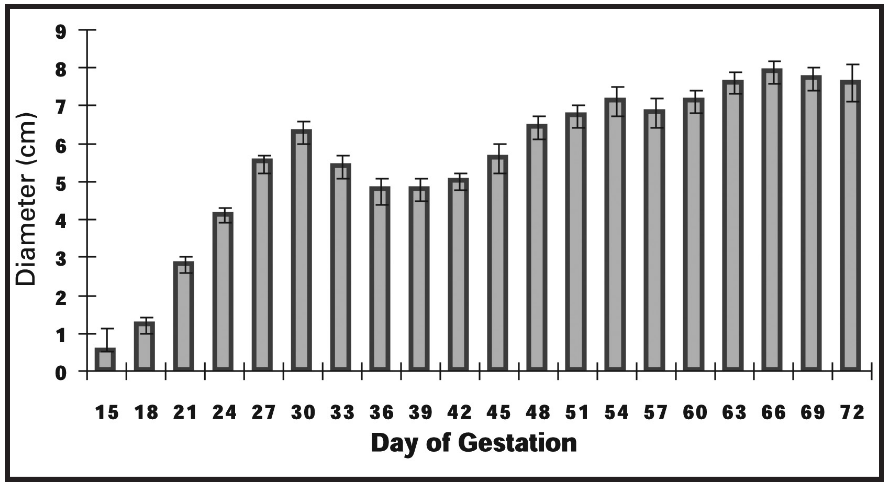

Figure 3. Average diameter (cm) of the fluid vesicles of the pregnant pig uterus throughout the first 70 days of gestation (adapted from Miller et al., 2003).

Accuracy

Accuracy for pregnancy diagnosis is determined by three factors: Sensitivity (the number of sows diagnosed as pregnant that farrow), Specificity (the number of sows diagnosed as not pregnant that fail to farrow), and Overall Accuracy (the correct number of diagnoses for pregnant and not pregnant combined). The values for each are far from equal, and although Sensitivity can often be >90%, Specificity frequently is low and ranges between 40 to 70%. Yet the overall accuracy of the method remains high (>90%) since in any breeding group, the greatest percentage of sows are pregnant and are diagnosed correctly, when compared to the smaller percentage of non-pregnant females that are diagnosed. One concern with this method of calculation is the fact that it assumes that all females that are diagnosed pregnant that fail to farrow were diagnosed incorrectly. This is in fact, incorrect, and accounts in part, for what is known as real-time ultrasound fallout.

Real-Time Ultrasound Fallout

Rodibaugh [(7)] outlined the classification of sows to examine and aid in identifying sources of pregnancy failure (Table 1). This table devised is based on the use of real-time ultrasound, and may help to identify where sow fallout occurs. Flowers [(13)] reported that real-time ultrasound has also been used to identify cases of pseudopregnancy. These failures (not in pig) represent sows that were diagnosed as pregnant at d 24 to 35 of gestation but upon testing again at 65 to 75 days of gestation, are diagnosed as open. In this report, pseudopregnancy occurred in 14.5% of sows, which is similar to the 19% reported by Koketsu et al. [(4)], but substantially higher than the 3.9% reported by Rueff [(6)], and 7.3% reported by Rodibaugh [(7)]. The reasons for the large variation in pregnancy fallout may be related to numerous factors, such as season, disease, and even failure classification, but the Flowers [(13)] report, clearly shows that identification of these non-pregnant animals is highly accurate (83%). Therefore when troubleshooting poor farrowing rates, examining for the presence of fetuses is necessary for confirming pregnancy, since fluid alone is associated with pseudopregnancy. This procedure is only recommended when problems arise due to an increase in sows that are classified as Not In Pig. In this case, the method should be performed between days 65 to 85 of pregnancy. It is important to note that the transducer placement will be the same as for conventional pregnancy diagnosis, but that the angle of aim should be between 0 to 30 degrees, since most of the fetuses are low in the abdomen at this late stage of pregnancy. Allow more time to diagnose a sow as pseudopregnant, since it will take more time to confirm the presence of fetuses, compared to only fluid, since the observer must rule out all possibility of fetuses being present.

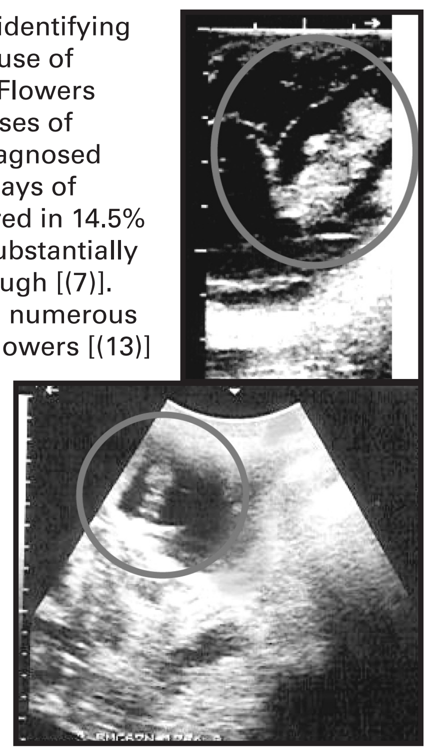

Figure 4. Real-time ultrasound images of a 35 to 40 day fetus using a 7.5MHz transducer (a) and a 3.5 MHz transducer (b). Circles show the location of the fetus.

Embryo and Fetal Diagnosis

When using a 5.0 or 3.5 MHz transducer, the embryo may be observed as early as day 24. However, it is easier to observe the fetus after day 30 due to its greater size. However, the embryo can be visualized as a white dense tissue mass within the fluid of the uterus (Figure 4). Once the limbs begin to form the embryo is classified as a fetus. The fetus is also observed as a white structure within the fluid pockets of the uterus and will continue to grow in size and become more prominent within the fluid pockets as pregnancy progresses. At about day 40, the fetal skeleton begins to calcify, and rib and spine patterns can be observed from this point forward (Figure 5). The ability to visualize the vertebrae and ribs of the fetus is often used as a measure to assess the presence of live healthy fetuses. However, determining the number of embryonic vesicles or counting vertebrae and ribs for determination of litter size is not reliable, since the start and end of one vesicle or fetus is difficult to determine [(14)] and use of RTU for determining the potential numbers of piglets in a litter is not advised. However, one additional use for RTU has been reported and includes identifying sows with retained piglets after farrowing. This procedure was used after farrowing house personnel had identified sows as having completed farrowing. It was demonstrated by Johnson [(15)] that this method was ~98% accurate, and identified 5.7% of the sows as having retained pigs. This methodology may prove useful in the future for reducing piglet losses at farrowing and also for reducing the incidence of sow mortality associated with retained fetuses.

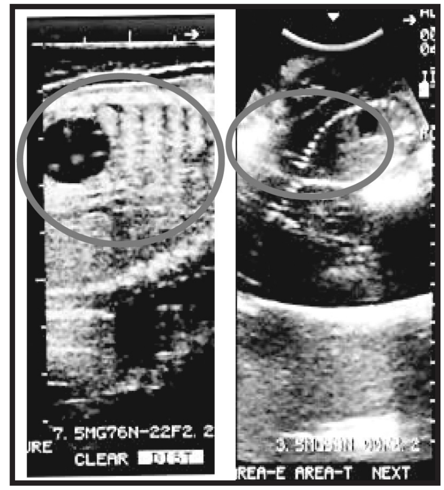

Figure 5. Ultrasound images of single day 70 fetus using 7.5 MHz (a) and 3.5 MHz transducers. Pink circles indicate the location of the vertebrae and ribs and the fetal stomach (black circle).

Problems and Pitfalls: Evaluating Pregnancy Too Early

One of the clear pitfalls when using real-time ultrasound, involves improper timing for diagnosis. This is critical, especially at day 24, since some females may not have ovulated and begun gestation on the first day of mating. In fact sows on day 24, may in reality, be only at day 22 of pregnancy. At this stage of pregnancy, limited fluid within the uterus could cause a pregnant sow to be classified as open. Therefore, caution should be used when diagnosing pregnancy at day 24 or less. If animals are identified as open at day 24, they should be re-checked a few days later to confirm the diagnosis. However, if females are diagnosed as pregnant, they need not be re-checked until a later period in gestation.

Figure 6. Real-time ultrasound image of 2 large 3.0 cm ovarian cysts (in pink circle) detected using a 3.5 MHz transducer. Note that these structures have a smooth circular appearance in contrast to the irregular shape of the fluid filled uterus during pregnancy.

Evaluating Pregnancy Too Late

At some stages of gestation, the amount of visible fluid decreases (Figure 3), and the fetus, which appears as white, may blend in with the surrounding uterine tissues, making pregnancy detection more difficult and prone to error. A rapid increase in the allantoic fluid volume of the embryo occurs between days 24 and 30 of gestation, followed by a decrease from day 35 to 45. At the same time as fluid declines, fetal size increases. Because of the reduced volume of fluid and increasing size of the fetus, pregnancy diagnosis based on visualization of fluid may be less accurate near day 40 of gestation. Late pregnancy checks or re-checking using real-time ultrasound between days 38 and 50 can be problematic, since females previously identified as pregnant, could mistakenly be diagnosed as open. If diagnosis occurs during this period, and females are clearly identified as pregnant, no further re-check is required. However, if open females are identified, a second ultrasound examination should be performed after day 50 to confirm the earlier diagnosis. This management system may be expanded to identify pseudopregnant sows between days 60 to 80 of gestation if needed.

NO. OF SOWS DETECTED NOT PREGNANT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Returned to estrus																	
Pregnancy checked negative																	
Not in pig																	
Culled, reproductive reasons																	
Culled, non-reproductive reasons																	
Aborted																	
Deaths																	
Total																	

Table 1. Example of a pregnancy failure sheet that can be used to track the frequency of pregnancy failure classes during gestation. (Adapted from Rodibaugh, 2002)

Misinterpretation of Signal

A reduction in the accuracy of real-time ultrasound, can occur in cases of misinterpretation of fluid pockets within the abdomen. One instance involves females that were recently mated, and which contain fluid within the uterus. In other cases, ovarian cysts can be quite large and appear to be fluid in the uterus. In this case, the cyst fluid is circular, located in a single area, and not separated by any distance, typical of the uterine fluid vesicles of pregnancy (Figure 6). In some cases, fluid can be present, but it appears cloudy or with white specks, and often is an indication of uterine infection, or visualization of the contents of the intestines.

Economics

The usefulness of ultrasound arises from its ability to improve reproductive management of the herd and to reduce costs associated with non-productive days. This is accomplished through discerning pregnant from open sows. However, one additional benefit may involve an improvement in detecting regular returns to estrus. As employees get immediate feedback on pregnant and non-pregnant sows from RTU, their efforts typically increase to identify these open females using boar exposure at 21 days following first service. Yet, in order to obtain the full value from real-time ultrasound efforts and equipment, once a non-pregnant sow is identified, the female must either be culled from the breeding herd or targeted for re-breeding at the next estrus. The value from ultrasound is based on an average value of a non-productive day, use of ultrasound for identifying open females and culling them or re-incorporating them into the breeding herd at next estrus, the farrowing rate, and the value of the litter [(8)]. The economic return from ultrasound is greatest when farrowing rates are low to moderate (<85%) and the value (profit) of a litter is low to moderate (<$100). However, even in cases of high farrowing rates and high litter values, ultrasound is justified for reducing the costs in pig production. Under average conditions of profit potential, such as a litter profit of $70, and a farrowing rate of 75%, break-even costs for real-time pregnancy diagnosis are estimated at $19.00/sow. A 500-sow operation that purchases an $8,000 ultrasound will have $16.00 invested per sow. In almost all cases for test and removal, a reduction of 15 days more within the breeding herd can be expected, with the improved early accuracy of the systems, which could improve profit by ~$80/sow [(16)]. This value is determined from the reduced costs associated with daily sow maintenance, and increased opportunity for profit from market pigs sold. Hollis [(17)] suggested that for those that purchase and provide ultrasound-scanning services, it is advisable to have the equipment paid for within 1 year of purchase. It was also suggested that the cost in scanning time and purchase of the equipment be included in the billing cost. In comparison, those that own both the equipment and facilities can spread the equipment costs over a 3-year time period [(5, 17)].

Summary

- Real-time ultrasound accuracy for positive pregnancy diagnosis is based on the ability to visualize clear, multiple, fluid-filled pockets within the uterus. These are maximal in size between days 24 and 35 of pregnancy.
- Sows that are identified as pregnant between days 24 to 35 do not need to be re-checked prior to farrowing.
- If animals are identified as open at day 24, they should be re-checked a few days later to confirm the diagnosis, and then identified for culling or targeted for re-breeding at the next estrus.
- Due to fluid decline, fetal growth and calcification, avoid pregnancy checks between days 38 and 50. If females are checked and identified as open during this period, re-check once more after day 50 before culling.

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