Measurement of body, carcass, and tissue composition in meat animals by non-invasive methods

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There has always been a great demand for evaluation of body composition in meat animals regardless of the production goal. The oldest and most simple way is subjective assessment by visual and/or tactile means. This may be helpful and sufficient in marketing slaughter animals or selecting breeding stock if the variation is large enough for gross differentiation. As variance decreases, however, more accurate and objective evaluation methods are needed. During the last few decades a large number of such methods have been developed but have not been applied to a great extent. Recently, a new drive has been initiated by the introduction of modern computer techniques. High speeds of computers and increasing storage capacity at decreasing costs have opened new opportunities, and in some instances, made the development of certain methods possible. X-ray CT (Computed Tomography) and MRI (Magnetic-Resonance-Imaging), have only recently developed (even though the principles of X-ray and MR were well known beforehand), while others have been improved (e.g. ultrasound B-scan allows rapid evaluation and statistical analysis of results). Quantitative image analysis of large data sets is also in a rapid state of development because there are programs available that allow the evaluation of images from various sources.

Basis for comparison of methods

When evaluation methods are to be compared or chosen, several criteria have to be considered.

Purpose or area of application

- Marketing of live animals or carcasses or wholesale/retail cuts. When applied in a slaughter plant, additional factors have to be taken into account, e.g. speed of operation (animals (carcasses) hour), environment, humidity, temperature, and surrounding materials (for example steel, if magnetic fields are involved).
- Processing of wholesale cuts or somewhat homogeneous mixtures of tissues.
- Performance testing in station or field test or progeny testing. Number of animals to be measured.
- Research, nature of traits, number of animals/carcasses.

Variance between observations (animals/carcasses)

Large variance between items does not require sophisticated or highly accurate methods. Repeatability and accuracy of the methods must be adequate to precisely differentiate between observations.

- Variance in local distribution may be of interest, as for example, in situations where the various fat depots have to be analyzed in addition to the amount of total body fat. Spatial resolution (imaging) then becomes necessary.
- If only the total amount of tissues in a mixture is of interest, methods other than imaging may be applied.

Practical aspects of application

- Practicality: depends on the purpose of the application and the ease of handling.
- Portability (mobility): decides whether the item to be measured has to be brought to the equipment or vice versa.
- Costs: includes durability, maintenance, ease of repair and ease of operation (training of operator). The cost factor is more significant in a commercial application than in research, where it is difficult to estimate cost-benefit.
- Objectivity: possibility of manipulation by the operator. This is particularly important for grading facilities.
- Public acceptability: methods involving radioactivity or X-ray will not be acceptable for food (meat) items.

Reliability of results

To describe a method, the following parameters must be available.

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- Accuracy of information: include correlation (r), coefficient of determination (R^2), bias (systematic under- or over-estimation) and residual standard deviation (RSD). If regression equations are the basis of evaluation of a certain trait, additional information has to be available about their validity. These may be weight and age (allometry of growth) or genetic origin (genetic differences in tissue distribution).
- Repeatability: depends not only on the accuracy of the apparatus but also on the skill and experience of the operator.
- Reproducibility: includes correct location of the measuring site, which may partially depend on the operator or be animal-specific. (It is not easy to count ribs on a fat pig, but ribs can be visually detected by ultrasound, X-ray or MR). A second important factor in grading systems is the standardization of instruments, so that similar measurements yield the same results, for different devices at different plant locations.

Comparison of methods

Although many methods of non-invasive carcass evaluation exist only those that exhibit the most promise for practical application will be discussed.

Video image analysis

Video imaging is an objective approach to overall visual assessment. It offers information relating to carcass conformation, predominantly for beef and lamb, and less for pork. Lean and fat content, however, can only be evaluated to a small extent. The subcutaneous fat covering of beef and lamb may be damaged due to hide pulling, while analysis of pork carcasses is limited to the surface of the median plane where only sacral muscle features can be seen. Although it is not highly accurate, it is used as an alternative grading system in Germany. Video imaging is used in research but has not yet reached the stage of development for practical application.

Ultrasound

Ultrasound systems have benefited from improved data handling techniques and as a result, B-scan systems were developed. Velocity of sound (VOS) has a similar principle to ultrasound but has developed into a separate method.

The A-scan measures linear dimensions of tissue layers. It has been used for selection of live animals for many years. It is easy to handle, mobile, and inexpensive, and is not much inferior to B-scan, which is more expensive and more complicated to position. If only a rough estimate of body composition is required (in pigs), the A-scan ultrasound may become more widely used. It has also recently been adapted for carcass grading. Ultrasound is, however, dependent on temperature. Therefore, grading of chilled carcasses is very difficult without technical changes to the instrument.

The B-scan system produces 2-D images of areas (e.g. eye-muscle or fat areas) that can be directly analyzed by means of additional computer programs. More information can be gained from this system in the form of, for example, shape of muscle and amount of intermuscular fat. Measurement of intramuscular fat has not been fully developed, however. In addition, B-scan can also be a tool in veterinary diagnostics because it provides images of organs, pregnancy, etc. There are some disadvantages in terms of costs, handling and mobility when compared with A-scan in determining body composition.

Both A- and B-scans are useful in pigs but give less information in beef cattle, because beef loin muscle area is not closely related to yield of carcass lean. Only if measurable subcutaneous fat is present will fat thickness become helpful. This, however, does not hold true under West-European conditions, because little or no subcutaneous fat is usually present in ruminant carcasses.

Velocity of Sound (VOS) was mainly used in beef cattle, but has not been sufficiently adapted for pigs. The method is quite simple, but does not allow imaging. In terms of fat, it measures subcutaneous, inter- and intramuscular fat without differentiation. With further development it may be applicable in carcass grading and/or assessment of live animals.

Electromagnetic scanning

Like the other methods, electromagnetic scanning was originally applied in human medicine. Therefore, it had to be adapted for use in the meat industry, because the conditions in a slaughter plant are profoundly different from a hospital. This is especially important for electronic parts, because they have to be protected from extreme temperatures, humidity, and fluctuations in electric power. Surrounding metals may also have an effect on the electromagnetic field. As most of these problems have been solved, electromagnetic scanning tests are being performed under practical plant conditions. The results indicate higher accuracy than conventional grading schemes when total lean in the carcass is evaluated, but give only limited information about lean in individual primal cuts. Primal cuts, however, can be measured separately. There are few possibilities for manipulation of measurements and no objections to acceptability. It is not clear, however, whether live animals can be accurately measured for body composition.

Bioelectrical impedance analysis (BIA)

BIA is another method developed for human application. In principle, resistance and impedance are measure in the body while a constant alternating current is applied. Since these parameters are different for the various tissues, the amounts of lean and fat can be calculated. This, however, does not allow any information about the location of the fat depots. Recently, BIA has been applied to live pigs and chilled carcasses. Initial results look promising, but need further confirmation.

X-ray CT and MRI (Magnetic-Resonance-Imaging)

These systems have many characteristics in common. Even though they are routine methods in human medicine, both techniques are restricted to research in the field of animal production. There are several reasons for this including cost, operation, instrument immobility and sensitivity to interference. Improvements in computer software and hardware have been developed and implemented for both systems. Composition of live animals and carcasses can accurately be evaluated. Both systems can replace total body dissection, which is usually used as a reference, but are also prone to errors.

There are some major differences between X-ray CT and MRI. X-ray images reflect hard bone structure much better while MRI differentiates soft tissues and variations within them at a higher level. Data acquisition time is shorter in X-ray CT, thus motion artifacts are not as problematic as in MRI, where flash sequencing, triggering or gating techniques have to be applied. MR images are a function of several parameters (proton density, T1, T2) which can be weighted to receive an optimal image contrast. X-ray CT offers fewer opportunities to adjust contrast because it is based on only one parameter. Additionally, the MR-system has spectroscopic capabilities if the field strength is sufficient. This opportunity allows investigation of in vivo physiology (e.g. energy metabolism). A simple form of MR spectroscopy is already in use in the food industry as an analytical tool. X-ray poses health risks because of ionizing rays while no hazards are known for MR, particularly for the operator.

Since electronics are becoming more inexpensive and there are new developments in superconducting materials, these machines may be available at lower prices and should open new opportunities of application.

Conclusions

There are advantages and disadvantages of individual systems in their present state. The rapid progress in technical development may lead to further improvements in the future.

Evaluating individual methods does not identify the extent of the measuring potential available. In some instances, only the combination of various principles may be the solution to a certain problem. One example could be the combination of video imaging for conformation assessment and ultrasound or velocity of sound for carcass composition. The present technical status has answers to almost all the measuring problems; the introduction of these novel technologies is largely a matter of cost.

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