UTILIZATION OF ON-LINE METHODS FOR MEASURING QUALITY PARAMETERS IN CARCASSES - FUTURE POSSIBILITIES AND CHALLENGES

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INTRODUCTION

For some years increased attention has been paid to the subject of food quality control in the industrial and public debate, together with increasing amounts of information on new sensing and information technology of a rapidly increasing variety and complexity. Among other effects of this development, a pronounced one is general confusion. What will the requirements be? Which techniques should be used? Which line of strategic development should the industry follow?

Attempts to fully answer these questions will - at best - be incomplete. In the present paper, however, we will try to outline some developments in requirements and possibilities which in our opinion could have a major impact on the future direction for on-line carcass quality measurements. Our definition of this is <u>all methods providing objective information on composition and quality of carcasses, which is available before the carcass is further processed in terms of cutting and deboning.</u>

As a basis for our approach to the subject, we regard any quality measurement as a tool reflecting demands at the market in its broadest sense. We will therefore start the analysis at the consumer and the authorities for consumer protection. Next, we will look at the changes in production methods which may affect the requirements for quality measurements in the future. Then, we will discuss the industrial and technical conditions for on-line measurements in the meat industry. Finally, we will list some of the measuring possibilities becoming available.

Our angle of view will be based on the Danish situation. The meat market as well as the debate on quality seems however to be increasingly international, revealing consensus as well as differences in attitudes between regions of the World (e.g. the growth parameter debate). For the coming years, we believe that both consumer attitudes and technology will be an increasingly international scene.

QUALITY DEFINITIONS

Our general definition of on-line quality measurements is given above. In the following, the various aspects of quality will be divided into:

<u>Carcass quality:</u>
Composition, mass distribution and geometry of the carcass

<u>Meat quality:</u>
Organoleptical, technological and nutritional properties of the meat

<u>Hygienic quality:</u>
Food safety aspects associated with the meat; including shelf-life, residue contents and pathogen contamination

It should be noted, that <u>yield</u> of saleable products is closely associated with carcass quality and therefore included into the subject of this paper.

FUTURE CHALLENGES

As every quality measurement has its price, it should not be forgotten that the basic demand for meat at affordable prices is not going to change for the years ahead, and that price competition may very well increase in the coming years due to new developments in production methods. The cost/benefit evaluation of new quality measurements will therefore be of increasing importance for the industry. Rationally, new methods will only be taken into use if they 1) increase the market value of the product; 2) are compulsory by legislation or other rules; or 3) provide possibilities for increasing productivity and thereby price competition.

As the slaughterprocess only represents a small step in the total meat production from conception to consumption, it is important to take the complete production into consideration when discussing on-line carcass measurements. Thus, the greatest potentials for improvements in product value and productivity associated with on-line carcass measurements will often be associated with the systematic utilization of the results in the animal production as well as in the processing of the meat.

Changes in quality preferences and demand

Some of the main trends in future consumer attitudes are believed to be:

- the changes in family and behaviour patterns mean that a major part of the food consumption moves away from the traditional family dinner towards catering or convenience foods.

- the increasingly international supply will break down regional differences in eating patterns, increase the consumer awareness of quality and price differences, and increase the demand for variety.

- the increasing focus on health and diet will emphasise the demand for guaranteed wholesomeness. Especially the increasing demand for pure food will focus attention on residues in meat and risks associated with microorganisms.

- increased attention towards animal welfare, protection of the environment and biological ethics will affect the requirements to meat beyond what can be associated with measureable quality parameters of the meat itself.

- in association with the break-up in eating patterns and developments in other parts of the food industry, the consumer may not to the same extent regard meat as an indispensable component of his daily meal.

- an increasing proportion of the consumers' requirements will be expressed towards the meat industry by a small number of professional buyers from the retail trade and by health and other authorities. This will be in the form of specifications of production, product and delivery. Biological variation will become less tolerable.

Based on the above expectations (Dawson et al., 1986) the main challenges for on-line measuring technology in the coming years will be:

- to increase the consumers confidence in meat as a healthy quality food

- to convert biological variation into "meat by specification"

- to allow for rapid changes in quality demands

- to make meat more competitive by optimizing the relationship between the properties of the slaugther animal and the final value of all its products

Whereas most of the above challenges are fairly common to most industries, the random quality variation together with the combined production of the many anatomical products dirived from an animal represent challenges in quality control of enormous complexity. On-line measurements are of course only a part of this complex, logistics and other tools are of equal importance.

Changes in production methods

The need for measuring technology will be a product not only of the requirements mentioned above, but also of the way changes in meat production methods might affect the quality traits in question. If quality demands can be satisfied as a result of the method of production, on-line measurements will not be required. New production technologies may on the other hand increase the requirement for on-line monitoring of some quality aspects.

In general, any change in the production of meat which reduces variation (biological or other) will also reduce the need for on-line measurement. Unless this emerges as a side effect, however, a systematic reduction in variation will often imply the use of on-line measurements, which then in the end render themselves unnecessary.

It will be natural to expect that the ongoing worldwide developments of controlled breeding programmes, feeding control methods etc. will tend to reduce the random variation both in carcass and meat quality significantly, although not necessarily at an optimal level (pigs may inadvertedly become homozygotic for reduced water holding capacity etc.). Specified production contracts between farmers and the meat industry will increase this development towards uniformity within specified carcass groups. The specifications may well, however, be used as a tool to ensure the diversity.

A further step towards a reduced or controlled biological variation may be associated with possible developments in growth manipulation technology, including the application of steroid hormones, somatostatine and genetic manipulation (Thornton & Tume, 1988). It seems extremely difficult at the moment to evaluate what will be possible and what will be allowed in this area, but the effects on the need for on-line measurements could be significant as a result of reduced variation and production costs - and perhaps through new requirements for residue control.

For hygienic quality, the future development may not to the same extent as for meat carcass quality reduce variation and thereby the demand for quality measurements. One important aspect of this is the repercussions of the developments in the measuring technology itself: More and more sensitive analytical methods applied at the receiving end of the marketing chain will automatically tend to increase the requirements for on-line measurements in the meat industry. Another aspect is the possible emergence of pathogens adapted better and better to the hygiene procedures of animal production and of the meat industry.

<u>Alternatives to on-line carcass measurements</u>

The measurement of quality traits on the carcass while it is in the production line at the abattoir is for many reasons an ideal solution mainly because the links from the quality measurements to both the production facilities and to the utilization of the carcass are intact. It is, however, for many reasons often a costly solution.

Looking at the complete range of possibilities for monitoring the relevant quality traits, on-line carcass measurements will be competing with alternatives ways of obtaining the same information. Some examples of alternative information sources are:

Production factors:
  Quality control on feeds, water supply, farm technology, growth promotors.

Live animal:
  Genetic composition, feed consumption, daily gain, weight, live body measuring technology at the farm, in markets or in the lairage at the slaughterhouse.

Processing factors:
  Chilling temperatures, stunning parameters, sanitation control etc.

After cutting:
Combining measurements made on individual cuts to carcass information.

It is important to note in this respect, that the application of most of these alternative possibilities implies considerable problems of standardisation and identification, especially if payment or guarantees associated with the individual carcass are involved. It is mainly for this reason that on-line carcass measurements represent a good possibility for standardised and usable measurements, positioned as it is at the intersection between farming variations and meat processing variations.

The developments in information technology (identification systems, data communication etc.) may, however, increase the availability of much of the above mentioned information in the years to come.

Conditions for the application of on-line measurements

Although the basic possibilities for future utilization of on-line quality measurement techniques are dependent on the availability of industrial measuring methods the actual application of these methods may in many cases be just as dependent on the industrial environment and on the infrastructure, as on the methods themselves.

A major source of influence will be the industrial organisation: To which extent will vertical or horisontal integrations take place in the meat industry worldwide? This will influence both the need for methods, the rate of method development and the actual application of methods. We believe that the Danish tradition for practical application of on-line measurements in the meat industry has emerged not by accident, but mainly as a result of the considerable integration between producers and the industry and within industry that has been a tradition in the Danish meat industry for many years. Not least important, this integration has eased national inter-factory method standardisation considerably. More significant, the results of on-line carcass measurements have been expressed in well-known and transparent economic terms between farmers and industry, and within industry.

To exemplify the extent to which industrial organisation and joint development forces can influence the future possibilities for on-line quality control, Table 1 presents an overview based on the Action Plan for pigmeat quality adopted by the Quality Committee of the Federation of Danish Pig Producers and Slaughterhouses. The developments are now progressing according to the plan, yielding not only new methods at controlled rate but also possibilities for optimal integration and standardization of the various methods.

In technical terms, industrial organisation will strongly influence the application of on-line measurements in the future:

Developments in slaughter capacity will significantly influence the financial basis for investments in on-line equipment. Modern pig abattoirs may now have an hourly turnover of DKK one million and will obviously be able to justify considerably more sophisticated equipment than small traditional slaughterhouses which may even operate with different species on the same slaugtherline. We expect a rapid increase in the average capacity and thus a basis for more and more equipment. This process will be self-reinforcing, as a larger market for on-line equipment will attract more attention from equipment producers and thereby more development capacity and perhaps lower unit prices.

Table 1: Extract of Action Plan for developments in pigmeat quality and on-line methods (Federation of Danish Pig Producers and Slaughterhouses, 1988)

Quality trait	On-line method available	Remarks
1. Meat content in carcasses and legs, shoulders, middles, backs & bellies	1989	Being installed
2. Size of intercostal muscles	1990	
3. Water holding capacity	1989	Available for trials
4. Intrinsic muscle colour (pigmentation)	1992	
5. Muscle protein content	1995	
6. Intramuscular fat (marbling)	1989	For trials

The method of slaugther animal aquisition - i.e. live animal trading versus trading on the hook will influence the need for live animal measurements versus carcass measurements as the basis for payment to the producer. Two conflicting trends - technical feasibility and meat quality considerations on the one side, and the visibility of market mechanisms on the other, will influence this balance depending on the industrial organisation. A third alternative - computer aided livestock marketing based on subsequent payment based on actual carcass weight and grade - has already emerged and may to some extent solve the above mentioned conflict (Whan, 1988).

The animal identification system will influence the applicability of on-line measurements considerably. Efficient and standardised identification systems for live animals will be necessary for optimal utilization of the results in the earlier segments of the production chain - including the breeding systems and their organisation. At another level, the technical identification system used within the slaugtherhouse will significantly affect the possibilities for integration of on-line measurements with logistics, computer control, yield control and sales.

Within the individual factory, the potential emergence of systematic quality management and the necessary organisation for this will be able to influence on-line measurement significantly. By building a general and integrated quality management system for the complete enterprise, on-line measurements may in many respects prove to be competitive and efficient integrated tools. On the other hand, successful quality management may in some cases render otherwise indispensable quality assurance measurements superfluous.

The extent of automation of production and transport processes in the slaughterhouse will similarly effect both the need and the possibilities for application of on-line measurements. One aspect of this is the possible need for measurements to guide the automatic machinery and transport - together with the likely technical integration between production machinery and measuring equipment. Another aspect is perhaps an often overlooked one in much of the World's meat industry: The management's and staff's attitudes to - and experience with - complicated technical equipment.

Technical requirements and challenges

The slaughterline environment in terms of humidity, temperature etc. will continue to be hostile towards electronic equipment etc. Experience does, however, already show that these problems can be solved, and that sophisticated and fragile equipment can actually work very well under slaughterline conditions, provided that they are sufficiently well protected. Such problems do, however, add substantially to the cost of the basic equipment. Robust and simple equipment presents significant advantages.

Accuracy and precision of on-line methods must be at high levels not only to comply with the increasing requirements but also to justify investments in on-line equipment instead of alternatives (prediction by other sources of information, laboratory methods etc).

Reproducibility and calibration of on-line measuring systems are especially important as commercial use of the results often implies significant financial consequenses. A special challenge is the high costs often associated with calibration and reference procedures (e.g. anatomical dissection). The development of simple calibration methods presents therefore a special challenge for the future development.

Hygienic and safety requirements are challenges which significantly reduce the number of potential on-line methods and the positions of these. Touchless methods will be one way to exclude risks of cross-contamination and to simplify sanitation procedures. Built-in cleaning or sterilisation equipment may be another possibility where physical contact between carcass and equipment is necessary. Safety demands will influence the design of equipment, and increase the incentive for automatic measuring. For reasons of both consumer concerns and costly safety requirements, some potential methods (e.g. X-ray scanning) may have very restricted areas of application also in the future.

Staff training - both for operatives, maintenance staff, management and authorities - will in most cases be a condition for successful application of on-line instruments. With increasing complexity of equipment, continuous staff training will be a necessity if the industry is to remain competitive.

Position on the slaughterline: The earlier a method can be placed on the slaughterline, the less will dressing procedures affect the method, and the more time will be available before the result is required. On the other hand, the earlier the methods are used, the more difficult will it be to comply with hygiene rules and to get access to the sampling or measuring positions on the carcass. Also, some of the quality traits are influenced by post-mortem development and may therefore not be measurable at early stages of the dressing and chilling processes.

The possibility of measurements on blood or serum samples as an alternative to measurements on the carcass may be of special interest, provided that sufficient correlations can be found to muscle tissue measurements. Use of urine or organ samples are other interesting alternatives. These possibilities will require improvements to identification systems.

Ideally all carcass on-line measurements and sampling should be carried out at the same position in the process - at a "quality measuring centre" - which could then be optimized, manned and equipped for these special requirements. As regards sampling techniques, this will also provide possibilities for integration between methods in terms of sampling, sample transport and sample identification.

Some of the challenges for the measuring technology will therefore be to be influenced as little as possible by dressing procedures, and to be able to predict the post-mortem development.

Capacity and time requirements. The killing rate for e.g. pigs now in some cases exeed 1,000 animals per hour. The capacity requirement for on-line equipment is therefore increasingly high.

Capacity will always be expandable by increasing the number of measuring units so the problem is mainly associated with extra cost of equipment and space at the slaughter line.

The analysis time - i.e. the period from measuring/sampling until the result is available - is more critical, as this affects the possibilities for the on-line application itself.

Ideally, the result should be available immediately, i.e. at the measuring/sampling site itself (in-line measuring). Based on our definition in the introduction, however, application as an on-line sorting method will often be possible with time lags of up to 8-16 hours after slaughter. With increasingly accelerated processing and e.g. hot fat trimming in some industries, this period of availability may in some cases be as low as ½-2 hours after killing.

The magnitudes of measuring times for some typical methods are listed in Table 2:

Table 2: Typical time lags between start of measuring/sampling and availability of results

Method	Time lag	Example
On intact carcasses:		
Conductivity probe	Seconds	Fat and lean thicknesses
Optical probes	Seconds	Carcass and meat quality
Combined probe system	Seconds	Multiple carcass and meat quality measurements
Velocity of ultrasound	Seconds	Lean/fat measurements
Ultrasound scanning	Seconds plus interpretation	Lean/fat measurements
Video image analysis	Seconds	Carcass quality
Electromagnetic scanning	Minutes	Lean/fat ratio
Biosensors	Minutes	Residues, pathogens
MR-scanning	Minutes	Whole body scanning
On samples from carcasses:		
Extraction/spectroscopy	Minutes	Skatole analysis
Mass spectrometry	Minutes	Residue analysis
ELISA, RIA	Hours/days	Residues, pathogens
Impedimetric methods	Hours	Bacterial activity

FUTURE POSSIBILITIES

The range of different methods and developments within sensor, information and analysis technology is overwhelming and increasing year by year. In this paper, we will not attempt to list and comment on all theoretical possibilities, but instead give a brief review of some methods which are either being developed, tested or implemented in the meat industry. By doing this, we may have overlooked some promising developments - especially as much work is carried out as confidential projects.

Carcass quality methods

Measurement of carcass quality is the area where the use of on-line technology has progressed earliest and methods mainly for pig carcasses are now applied industrially in many countries. Among the potential methods are:

a. Manual insertion probes. These techniques are based on the simultaneous recording of a measuring signal and the probe travelling distance while inserting the probe - commonly in the form of a measuring pistol- into one or more specified sites of the carcass, and thereby recording the thicknesses of individual layers of meat and fat.

The earliest example is the Danish MFA-recorder, which is based on measuring the difference in conductivity between meat, fat and air (Pedersen & Busk, 1982). This method is in the process of being replaced by optical probe pistols, which now are available in different commercial versions, all based on measuring the reflectance at a certain wavelength specified to obtain a contrast between lean and fat (Cook et al., 1989).

An important aspect of this technique is the selection of the optimal probing sites giving good prediction of the carcass composition, and being as little affected by dressing procedures as possible.

The optical probe pistols represent the World's most wide-spread on-line carcass measuring system, and the application of these systems are still progressing worldwide for pig carcasses, and has also been introduced for beef. Internationally, these systems will undoubtedly present the main commercial carcass quality method for some years to come. Further development is underway in terms of multiple applicability (combination with meat quality), in calibration procedures etc. Developments in terms of the application of the measuring results - from merely recording fat and lean depths to estimation of carcass composition, sorting of carcasses and cuts etc., will also progress both for pig and beef carcasses.

b. Automatic probe systems. Optical or other probes may be applied in automatic systems, providing full objectivity not only for the measurement but also in selection of the probing sites. At the same time automation increases the possibilities for multiple probing.

The latest development here is the Danish Classification Centre for pig carcasses, using 17 probes for each carcass and thus recording composition and geometry of the individual main cuts in each carcass (Comm. Eurp. Communities, 1988). Coupled directly to branding and sorting of the individual cuts, this presents a significant step towards producing "meat by specification". The centre is now being installed in all Danish export slaughterlines.

The application of automatic probe systems in loin pullers and other production equipment shows the broad potential of this technique. Other new developments in optical probe techniques are mentioned above.

c. Ultrasonic techniques. Ultrasonic techniques offer a wide range of measuring possibilities of which only few have so far been applied in the meat industry. A list of the different tecniques is given in Table 3:

Table 3: Ultrasonic techniques for carcass measurements (Lake, 1988)

Measurement technique	Potential applications
Velocity of ultrasound	Density, composition, rigidity, temperature
Echography	Structural boundaries
Attenuation	Tissue microstructure
Scattering	Tissue microstructure
Low frequency reflectometry	Size, conformation

The main obstacle to application of the imaging ultrasound techniques has been the lack of automated interpretation systems. The quality of the scanning pictures generally allows for human interpretation, but usable automated image analysis has still not been developed.

One of the techniques - the low frequency reflectometry - differs from the others in that it does not require physical contact with the carcass. This method could provide an alternative to video image analysis or other surface scanning techniques.

However, the ultrasound system closest to practical application in the meat industry today seems to be velocity of ultrasound (VOS) now being tested as prototype in the UK (Miles et al., 1987). This system is designated for the measurement of lean/fat ratio in beef carcasses and may well prove to be an interesting future possibility for on-line carcass measurements.

d. Video image analysis (VIA). Video image systems in the form of line or whole picture scanning have been tried for primal cuts or whole carcass measuring in several countries (e.g. Malmfors,1981 and Cross et al., 1983). Applied on cuts or split carcass surfaces the systems provides possibilities for touchless measurement of tissue depths. Applied on intact carcass surfaces they can be used for the measurement of subcutanous fat distribution, and carcass dimensions and conformation.

An important feature of VIA is the dependence on presentation of the subject: Systems can be optimized according to various requirements with manipulation of illumination, angle of orientation, light or camera wavelengths etc. By combination of more cameras or grid illumination techniques, 3-D measurements can also be carried out.

Not surprisingly, most work has been done on beef where conformation is a trait of special importance in many countries. VIA can, however, yield valuable information also on carcass composition either alone or in combination with other techniques. In Denmark, a prototype for beef classification based on the combined use of an optical probe and VIA has been tested, and a final production unit is now in industrial trial (Sørensen et al., 1988).

The use of VIA may be an expanding possibility for the future in many respects. Still more sophisticated cameras with solid state technology and still more sophisticated image analysis software are being developed continuously. Perhaps as important, the technique provides excellent possibilities for combination of quality measurements with automation. VIA systems for robotics or PLC-control are now commercially avaliable. The application of VIA in other wavelength regions apart from the visible spectrum (UV, NIR) may also yield promising possibilities.

e. Whole carcass scanning. The complete scanning of the whole carcass presents in theory an ideal solution to carcass quality measurements, completely eliminating the problems of probing site representativity inherent in most other techniques. So far, however, the problems associated with these techniques have not allowed their industrial application.

Among the potential techniques for imaging carcass scanning systems are CT-scanning (X-ray scanning; Allen & Vangen, 1984) or NMR-scanning (Nuclear magnetic resonance; Fuller et al. 1984). Both systems are widely used in human medicine, and especially the first method has also been widely tested for live animal body and carcass measurements.

By optimising these systems and their image analysis software, it seems evident that extremely good results can be obtained by both of the techniques - probably even more accurately than most dissection reference methods. What prohibits the use of these techniques is the costs of these types of equipment, and the lack of development of commercial systems for other applications than humane medicine. Also, the use of X-ray scanning may prove a phsycological barrier to some consumers, and the use of NMR systems presents significant problems with shielding of the magnetic field. Nevertheless, the developments in this kind of measuring techniques should be followed closely in the coming years. It should not be forgotten, that these scanning techniques also provide potential for meat quality measurements.

A less expensive non-imaging technique for whole carcass scanning is electromagnetic scanning whereby information on conductivity and dielectrical properties can be obtained. Early results based on the so-called EMME equipment were dissappointing, especially in terms of reproducibility (Fredeen et al.,1979), and the method is potentially very dependent on temperature and carcass orientation. However, trials in progress on a modified equipment TOBEC are reported to yield promising results in terms of lean content estimation (Forrest et al., 1988).

f. Mechanical measurements. Measurements of conformation and dimensions by means of mechanically moved systems have been applied for pigs (SKG-system; Branscheid and Schack, 1988) and for beef (COLAVAUG system; anon. 1985)). Also, mechanical sensing is used as a guiding system for probe positioning in the Danish Pig Carcass Classification system. It may be that future developments will favour touchless non-moving sensing systems such as VIA over moving mechanical parts as associated with these techniques. Simple mechanical systems does, however, often provide good pratical alternatives to more sophisticated equipment.

Meat quality methods

In contrast to carcass quality several meat quality traits can be significantly influenced by both slaughtering procedures and by the whole post-mortem production technology including chilling, ageing and processing. This represents a significant challenge for on-line measuring techniques, but it also means in some cases that on-line measurement can be worthless.

a. Optical measurements of various meat quality aspects seems to be the area where the main developments are on their way. Many of these take advantage of the developments in carcass grading probes. However, the use of such instruments may be expanded to other quality aspects by selecting various wavelengths over the entire spectrum and by combining multispectral information. Both the visible and NIR regions are used (Barton-Gade, 1989); also fluorescence is used by some researchers (Swatland, 1987). Fibre optics are used in some probes - in others the optical components are placed directly in the probe tip.

Development and research with optical probe systems are now carried out at least in relation to WHC (water holding capacity), meat pigment content, protein content, fat colour, intramuscular fat content and connective tissue properties.

The use of optical probes provides good possibilities for combining individual measurements into a one probe system. One disadvantage is mainly associated with the post-rigor development in WHC; this cannot be predicted sufficiently precisely by optical probes on the slaughterline, but can be determined some hours later.

b. Mechanical measurements. As most of the variation in e.g. beef tenderness is associated with electrostimulation, chilling rates and ageing time, on-line measurement of tenderness at the slaugtherline will have limited value. In spite of many years' intensive research no industrial method has yet been introduced. We believe that on-line measuring here should be exchanged with process control of chilling and ageing, and sorting after maturity indicators (Sørensen & Buchter, 1985). Fat hardness could perhaps be a candidate for on-line mechanical measurement (Davey, 1988).

c. Biosensors may be used to overcome the problem with measurements of WHC at the slaughterline by measuring small metabolite concentrations predicting ultimate pH or PSE conditions. Biosensors are combined systems of biological receptors (e.g. enzymatic, immunological, bacterial) and transducers (e.g. potentiometric, amperometric, optical, acoustic, thermal or mechanical) providing a measurable electronic signal (Schaertel & Firstenberg-Eden, 1988). Sensors for the measurement of glucose profiles in meat are already being tested (Kress-Rogers et al., 1988).

New developments for measuring e.g. compounds associated with flavour could probably originate from some of these technologies yielding theoretically excellent combinations of specificity, sensitivity and speed at a low cost (Turner, 1986). One should, however, not forget some potential problems for application of biosensor probes at the slaughter line: Durability, desinfection procedures, calibration etc. (Schaertel & Firstenberg-Eden, 1988). People with experience in the problems associated with reliability of pH-measurements in the meat industry may feel familiar with some of these problems.

d. Other methods. Various forms of NMR, X-rays or ultrasonics may well be developed to a stage ready for on-line applications (Kopp, 1988). The measurement of conductivity in muscle by probes applied at the slaughterline has also been found to give some correlation to WHC (Feldhusen et al., 1987). Other techniques, which are not strictly on-line methods, will be possible to apply as such depending on sampling technique, identification systemts etc. One example of this is the Danish system for automated skatole measurement in entire male pig carcasses where sampling is carried out on the slaughter line and the result is available at the chilling tunnel before sorting of the carcasses (Mortensen & Sørensen, 1984). The actual analysis, however, is carried out in an automated laboratory off the slaughterline.

Establishing integrated systems for handling of samples and returning the results for on-line sorting and branding means expanding the range of methods with a number of new possibilities, namely those which have to be based in some form of laboratory. One example could be automated GLC analysis on fat samples for the measurement of fatty acid composition.

Hygienic quality methods

This area can be divided into two categories: 1. Chemical residues including pesticides, drugs, growth promotors, heavy metals, mycotoxins - and perhaps radioactive isotopes.

The risk of contamination with these compounds will be closely associated with the production factors at the farm: Feeds, medication, industrial emissions etc. Direct monitoring of these factors would therefore in many cases be more cost-effective than on-line testing of each carcass. On-line testing could of course be applied on e.g. a sample of the carcasses from each producer.

Unless specific biosensors become available for some of the compounds in question, on-line sampling in combination with off-line automated analysis will probably be the best solution. Analytical techniques capable of detecting a wide range of compounds will be required; one interesting combination could be Mass Spectrometry which in combination with intelligent software - e.g. Automated Chemical Structure Elucidation Systems - would in theory cover most of the required analytical range. Other possibilities are the immunological methods (RIA, ELISA). In both cases, the application of pooled batch techniques would be a way to reduce the number of measurements while retaining guaranteed specifications.

2. <u>Microbiological and parasitic contaminants;</u> either the total number or the presence of specific pathogens. For the general level of microbial contamination we find that monitoring of critical control points as well as microbiological spot checks for sanitation and process control will be superior to on-line carcass control, mainly because the hygiene rarely will be associated with the individual carcass and its production.

In the case of specific pathogens there will be a potential need for on-line measurements provided again that contamination can be an isolated problem associated with an individual carcass (i.e. no cross-contamination), and that the necessary sampling representativity can be guaranteed. Although both these problems will be difficult to overcome, the pressure from the market for pathogen-free meat products may be sufficiently massive to force on-line testing into use. As for the chemical residues monitoring of the herd instead of the single carcass should be regarded as a feasible alternative or supplement.

No technique for specific pathogen on-line testing is available at the moment, the closest probably being ELISA-techniques or some combination of rapid microbiological tests as e.g. turbidometry and impedance methods. Applied for specific pathogens, however, these methods will not yield results until 12-48 hours after sampling. For thricinae control, however, an industrial ELISA-method is now being introduced (Oliver et al., 1985).

The possible development of specific biosensors may also in this area provide the theoretically ideal solution. Applied directly at the source of contamination - e.g. at the gut content of each carcass - specific biosensors for pathogens may be a new on-line possibility in the future. Applied even before slaughter - e.g. in the rectum while the animals are kept in the lairage - also the risk of cross-contamination could theoretically be minimized.

The on-line measurement of hygienic quality is the most problematic in terms of analytical techniques, but is at the same time probably the area of greatest future concern.

<u>Data processing of results</u>

As a common aspect of all methods, the increasing availability of new data processing methods will increase the utilization of measurements and will facilitate their introduction, maintenance and developments.

Included in the possibilities are transformation of measuring signals (e.g. Fourier transformation), interpretation procedures (e.g. Partial Least Squares or Principal Component Analysis), and artificial intelligence systems (e.g. Neural Networks). These methods may especially increase the possibility for deducting extra levels of information from simple and robust sensor and transducer systems.

Another aspect is the increased technical possibility associated with modern data communication systems facilitating integration and optimal allocation of many different measuring systems and the different areas of data utilization. This integration will not stop at the slaughterhouse gate, but will expand to cover producers, customers, authorities, breeding societies, feed-mills etc. An integrated approach to quality improvements will also in this way become a more visible possibility in the coming years.

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