Production Management and Process Control

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SUMMARY: The Danish pigmeat industry, with an annual production of 16 million pigs, has for a number of years employed a quality strategy as the main basis for retaining its competitiveness in the world markets.

The main components in this strategy have been a continuous improvement in the quality of Danish slaughterpigs and an extensive use of measuring equipment and computer technology for control and sorting of the raw materials. Measurement and selection of raw materials become an important basis for trading based on quality rather than on volumes and prices.

The decision to aquire an ability to supply high quality products tailored to individual customer requirements leads to demands for the future production management systems, particularly in the areas of planning, coordination and logistics.

The raw material cost dominates the direct production costs. It is therefore the major task for production management to utilise the raw materials in the best possible way, and at the same time to satisfy the customers' needs for receiving products of the required quality at the correct time and place.

The current possibilities in the Danish pork industry are illustrated, based on the equipment for measurement, selection and product control in use today. Future possibilities e.g. for further application of information technology and for quality management based on certification according to ISO 9002 are indicated on the basis of current development projects in Denmark.

INTRODUCTION: The Danish pigmeat industry, with an annual production of 16 million pigs, has for a number of years employed a quality strategy as the main basis for retaining its competitiveness in the world markets. The main components in this strategy have been a continuous improvement in the quality of slaughterpigs based on breeding and pig management progress combined with an extensive use of measuring equipment and information technology for improved control in the Danish meat industry.

We will attempt to outline the requirements and problems such a strategy gives for the practical production management in the industry. The Danish solutions to some of the problems will be illustrated with examples.

It must be emphasised that this description is related exclusively to the Danish model in its handling of general production management and factory floor control. The solutions selected for practical production management problems must always be designed to provide effective support for an industry's main strategies.

Results and examples from this description should therefore not uncritically be transferred to productions which are not subject to the same main strategy. A meat company using volume production and cost reduction as its main competitive strategies should, for example, be managed in a way which in many aspects differs from the examples given here. Some of the higher level management tasks will, however, be similar but it is important to be aware of the limitations.

MAIN STRATEGY: The main, long term strategy for the Danish meat industry can be expressed as follows:

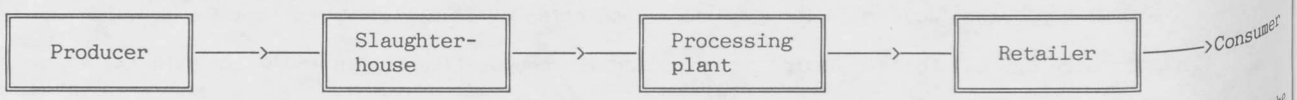
- To be able to supply products which closely satisfy each customer's varying requirements to quality, quantity and delivery time.

This strategy is the main method used in order to fulfil the industry's main objective:

- To achieve maximum profitability from the conversion of slaughterpigs into meat and meat products.

The strategy is often mentioned as "meat according to specifications" and the most important key words for the strategy are quality and flexibility. The strategy can be illustrated by using the simple model of the selling chain shown in figure 1.

Figure 1: Selling chain (simplified)



The Danish meat industry sells the majority of the production as tailormade, boneless pork cuts to the international meat processing industry. These raw materials are converted to processed meat products which are sold in retail shops to the consumers. The strategy of the Danish pork industry is supported by the following tendencies:

- The consumer is generally becoming more demanding and requires exact information about food products. This consumer demand goes back via the retailers and processing industry and leads to a requirement to the slaughterhouses of well defined raw material supplies produced to tight tolerances.
- The meat processing industry, which is the main customer of the slaughterhouses, is being re-structured into large companies as a result of amalgamations. The European market is expected to become dominated by a handful of large meat processing companies in a few years. Increased requirements to slaughterhouses for uniform raw materials and for quality assurance are natural consequences of this development.
- Denmark has a long tradition for a close collaboration as a result of the co-operative movement - this collaboration covers both the primary production and the development of sophisticated equipment for use in the meat industry. As a result the Danish pig population is uniform with respect to important quality parameters, and advanced measuring and analysis equipment has been installed in Danish slaughterhouses. These conditions are important as basis for a realisation of the strategy aimed at supplying "meat according to specifications".

We will in the following illustrate the consequences and challenges this strategy imposes on slaughterhouse management with special emphasis on general production management.

PRODUCTION MANAGEMENT: When production management in slaughterhouse operations is compared with production management in a traditional production company e.g. a machine manufacturing factory a number of important differences can be seen.

- The Danish pig producers have a contractual relation with their slaughterhouse and as a result of this the slaughterhouse must accept all pigs supplied by its members. Therefore the company cannot adjust the quantity and quality of the pigs it purchases to the current market situation. In other companies the buying function will normally be controlled by the sales situation.
- The raw materials for a slaughterhouse will always have a natural biological variation with respect to important quality characteristics. Other companies can normally purchase materials and components of the required quality and can at delivery inspect the supply for any quality faults. The slaughterhouse cannot measure some of the quality parameters until rather late in the process.
- The traditional production company normally performs an assembly process. The planning in such a company is often reversed, starting with the finished product and working backwards in the process with a stepwise analysis of the order. This results in parts lists, stock consumption, machine times etc. A slaughterhouse receives one raw material (i.e. live pigs) and this raw material is separated (opposite to the assembly process) into many different products. The traditional reverse planning method based on the finished product

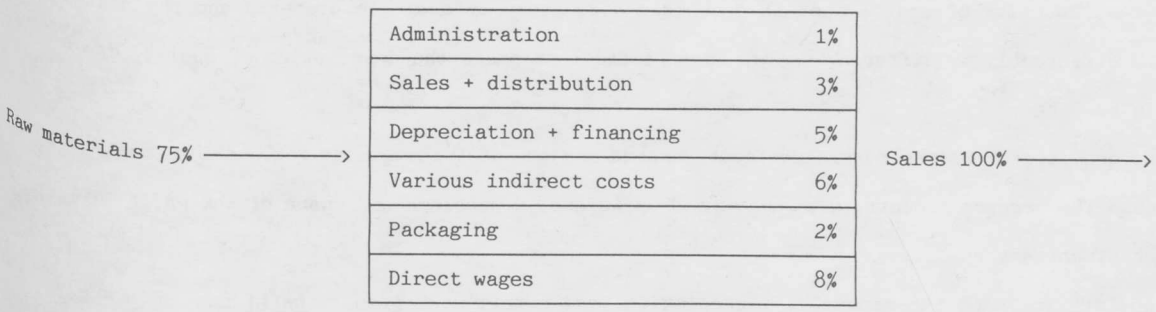
therefore cannot be used in slaughterhouses.

- In a traditional factory one order is only rarely related to other orders. An important factor in production management is to allocate the required production resources for each order to ensure that the required delivery time can be maintained and that the production equipment is utilised in a rational manner. The production plans are normally Gant diagrams showing the timing and machine time consumption for each order.

- Slaughterhouses have a combined production - a decision to produce a specific product results in a simultaneous production of a given quantity of a number of other products.

The simple comparisons given above between slaughterhouse operations and operations in other production plants show that production management in slaughterhouses is more complex. The main strategy calls for flexibility and well defined quality characteristics on the sales side. The purchase side (input) is, however, inflexible due to the uncontrolled quantitites and unknown and varying quality. Production management systems must bridge the gap between raw material supply and sales/marketing.

Figure 2: Value added in a slaughterhouse (typical figures)



A simple financial model for a pig slaughterhouse which can contribute to a clarification of some important areas for production management is shown in figure 2. This model shows the added value contributed by the main functions in a slaughterhouse. It is characteristic for slaughterhouse operations that the raw material cost dominates the direct costs (75%). As a comparison the direct wages are only approx. 8%.

Such a model can be used to compare the consequence of various actions. Let us assume that e.g. a supply of more customer specific products results in a 1% higher sales price or that this gain could be achieved by marketing products of a higher quality. If the same net gain should be realised e.g. as a result of labour rationalisation it would require approx. 12% reduction in the labour force to achieve the same effect. The model can thus assist by indicating the areas where the most effective action could be achieved. Compared to other industries the raw material cost in the meat industry is very high in relation to the total costs.

A significant task for the production management will therefore be to ensure optimum raw material utilisation combined with effective quality assurance in a close collaboration with the sales and marketing activities. The quality assurance is in principle superior to the economic optimisation. The production management must not circumvent quality requirements for a short term financial gain.

This background means that the main tasks for the production management are concerned with product control and logistics in the plant. Product control is here defined as all the actions which ensure that the raw materials are controlled in the production according to production plans ensuring optimum use of raw materials and fulfilment of quality requirements.

Application of on-line measuring equipment and selection systems thus become important tools and necessary requirements for the realisation of the main strategy.

ON-LINE MEASURING TECHNOLOGY: A successful use of the quality strategy outlined above is dependent on a range of measuring methods which can provide objective information about composition and other quality characteristics of slaughter animals, carcasses and meat raw materials in time for application in the management of the further processing stages.

There are possibilities for such on-line measurements in the complete chain from conception to consumption. The slaughter proces is, however, at an important junction between the primary production and the further handling and processing of the meat. Carcass measurements therefore provide a potential for a systematic utilisation of the results both in animal production and in meat handling with a view to improve product quality, yield and productivity. On-line measuring techniques for quality traits which can be measured in carcasses on the slaughterline have therefore received the main attention.

The hostile environment in a slaughterhouse with high humidity and varying temperatures gives special problems e.g. for electronic equipment. The design of measuring equipment for industrial application in a slaughterhouse must ensure that the equipment is robust enough to produce accurate and reliable results under these conditions.

Quality of meat. Quality of meat cannot be described adequately by a single property and the optimal quality level is viewed differently by different users. For practical purposes the description of quality can be divided into three main headings:

- Carcass quality covers the total lean meat content and the distribution of fat and lean meat in carcasses and cuts. The carcass geometry e.g. expressed as weight, dimensions and shape of the major cuts is also a feature of carcass quality.
- Meat quality includes the sensoric, technological and nutritional properties of muscles and fat. Muscle structure (PSE/DFD characteristics) is important for appearance and eating quality.
- Hygienic quality covers wholesomeness and safety aspects - particularly contamination with pathogens and the potential presence of unwanted residues e.g. antibiotics and other drugs, growth promotors, pesticides, heavy metals and mycotoxins. The influence of bacteria on keepability is also an important factor in the hygienic quality.

Ethical aspects are subject to an increasing emphasis by some consumers and by the media. Environmental factors in animal production and animal welfare are examples of what could be listed as a fourth quality heading. These factors normally cannot be measured in carcasses or finished products and are therefore not subject to carcass measurements.

Current measuring methods and future possibilities. Objective measurements have been used for carcass grading in Denmark for more than fifty years. With the accelerating developments in measuring technique, sensor and analysis technology in recent years a wide range of methods have been established in the meat industry and even more are under consideration in order to satisfy the growing need for rapid measurement of quality parameters. We will here mainly review methods which are in use or are expected to become relevant in Denmark.

Carcass quality methods. Objective classification of carcasses as basis for graduated payment to producers and for trade classification is the area where on-line measurements have been applied industrially for the longest period of time. In the European Community objective grading of pig carcasses based on lean meat content has recently been made compulsory and requirements to the accuracy of determination of lean meat content in pig carcasses have been given in EC regulation 2967/85. The equation used to estimate the lean meat content must be based on a sample of at least 120 carcasses which are representatitve for the pigs slaughtered in each region or country. The

carcasses must be dissected using a nationally approved method which can be compared to the official EC method. The determination coefficient (R^2) must be at least 0.64 and the residual standard deviation (RSD) must be lower than 2.50%. This development has accelerated the development of objective pig carcass classification equipment for use both in small and larger slaughterhouses.

From 1975 all pigs in Denmark have been classified with the MFA-system (automatic meat and fat measurement). In this system an operative placed a probe measuring electrical conductivity in three positions of each carcass. The three readings of depth of fat and one measurement of the thickness of the eye muschle (longissimus dorsi muscle) were fed into a microcomputer and combined with the carcass weight to calculate the total lean meat content in the carcass. The reliability of the prediction of carcass composition by manual probe measurements is affected by the ability of the operative to use the same position and angle of probe insertion in all carcasses.

This has been one of the reasons for the development of the fully automatic classification centre for pig carcasses which is now in use in all Danish pig slaughterhouses. This equipment is independent of operative variations and can classify both the complete carcass and the major cuts (hind leg, loin, belly and fore-end). The equipment will also brand the carcasses automatically with EC health certificates and grade marks. The capacity of the centre is 360 carcasses per hour.

In the early stages of the development project a range of possible measuring methods for the new classification system were evaluated. For hygiene reasons, methods which employed scanning (e.g. NMR, ultrasound and CT scanning) were examined closely. The requirements to robustness in the slaughterhouse environment and to measuring speed resulted in the selection of a system using probes.

Optical probes are therefore used for the thickness measurements in the classification centre. A light emitter in the tip of the 6 mm diameter probe sends light into the meat or fat, and a light receiver records the amount of reflected light as the probe is withdrawn. The reflection value is recorded four times per mm of movement. Computers in the classification centre will automatically calculate thicknesses and meat contents.

The same optical probe is used in the Danish Fat-o-Meat'er instrument which is used for manual carcass grading in many countries all over the world. The Fat-o-Meat'er is also used for manual classification of carcasses which for one reason or another cannot go through the centre.

The mechanical system for the classification centre consists of a series of work stations, a transport system and frames holding the carcasses during the passage of the centre as shown schematically in figure 3. In the probe measuring station probes are inserted in the 15 positions indicated in figure 4, guided by the anatomical measurements.

Two spare stations are provided in the centre to facilitate future on-line carcass measurements such as measurement of intrinsic muscle colour or automatic sampling e.g. for boar taint analysis.

Figure 3: Schematic plan of pig carcass classification centre

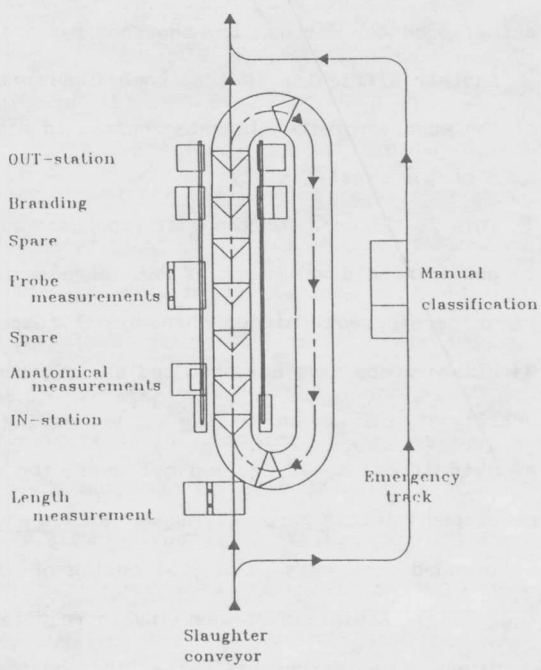
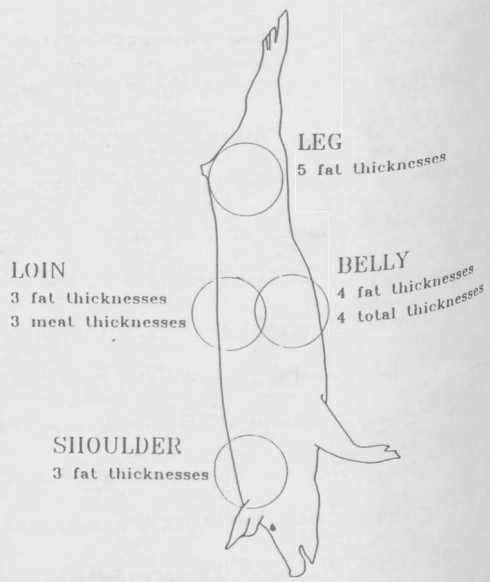


Figure 4: Probe positions for pig carcass classification centre



The classification centre has improved the accuracy of pig carcass classification as a result of the automatic operation and the measurements in all important parts of the carcass. A comparison of approx. 300 carcasses has given the relations to the true meat content (measured with total dissection) for the MFA system, the classification centre (CC) and the manual classification instrument (MC) which is a modified Fat-O-Meat'er system shown in table 1.

Table 1: Determination coefficient (R^2) and residual standard deviation (RSD) for prediction of lean meat content in pig carcasses.

	R^2	RSD
MFA	0.68	1.73
CC	0.81	1.34
MC	0.70	1.66

Developments in computer technology has made it possible to apply neural network techniques to modify the algorithms used to interpret the probe profiles into thickness measurements and for a prediction programme used in the meat content equation in the classification centre. As a result of this development it will be possible to reduce the number of probes for meat content measurement in the classification centre to 7 without loss of accuracy. Dissection of 240 carcasses has resulted in a determination coefficient (R^2) of 0.82 with a residual standard deviation of 1.29. This development will reduce the maintenance cost for the classification centres. Further probes positions can still be activated when required by each slaughterhouse for optimum selection of the required raw materials.

Meat quality methods. In contrast to carcass quality many of the quality characteristics dealt with under meat quality are strongly influenced by pre-slaughter treatment, slaughter technology and post mortem processing (chilling procedure, maturation and processing). This makes it difficult to justify deduction in payment to the animal producer for quality shortcomings which the producer might not have caused.

Another difficulty is that some important quality characteristics develop progressively during the conversion of the muscles of the slaughter animal to meat. Measurements on the slaughterline are therefore not always able to predict the final quality.

This is the case for the most important meat quality parameter for pigmeat - the PSE/DFD status. Danish attempts to predict the development of PSE characteristics based on measurements on the slaughterline of pH_1-values, early rigor development, higher than normal temperature 45 minutes post mortem or with the Danish MQM (Meat Quality Marbling) probe have not produced satisfactory results. Due to the serious effect of PSE characteristics on eating quality of pork and on cutting and processing yields there is a need for methods for effective selection of PSE meat even if it cannot be carried out until the day after slaughter. A number of optical probe instruments have been developed for this purpose. The Danish MQM equipment is now being applied for practical selection at slaughterhouses of branded pork cuts with good eating quality. This instrument can also measure the intramuscular fat content (marbling). A minimum of marbling is required to achieve a good eating quality.

Other probe instruments using fibre optics combined with spectrometric measurement of reflected light are being developed. A method measuring intrinsic colour (pigment content) in muscles using visual light (400-600 nm) is

nearly ready for practical application. A similar method for determination of the protein content in unhomogenised meat using near infrared light is under development. Both properties are important for the selection of cuts for specific products.

Sampling of carcasses on the slaughterline combined with a secure handling and identification system with analysis carried out in an automated laboratory could provide opportunities for a range of on-line measurements. An example is the Danish system for skatole analysis in backfat from entire male pig carcasses. In this system the samples are transported from the slaughterline to the automated laboratory by pneumatic tube conveyor and the analysis results are available 10-12 minutes after sampling. The method therefore fulfils the definition for on-line measurement given in this paper. It is expected that all Danish slaughterhouses will have this equipment installed by the end of 1993. Another meat quality possibility for such a system could be automatic GLC analysis of fat samples for measurement of fatty acid composition.

Hygienic quality methods. The hygienic quality of meat products is probably the area where the consumer - and major meat buyers - show most concern.

New knowledge about pathogenic microorganisms combined with elimination of some classical diseases which could be transferred via meat products has meant that meat inspection based on macroscopic examination of organs and carcasses no longer serves to safeguard public health. The "new" pathogens do not result in pathological conditions in the slaughter animals which can be discovered at meat inspection.

Screening at herd level for animals carrying specific pathogens using immunological (e.g. ELISA) or DNA (e.g. PCR) techniques could give important information to the slaughterhouse. Animals from herds free from specific pathogens could be sheduled for slaughter separated from herds with contaminated animals. Longer term the conditions at contaminated herds should be improved to alter their status.

No suitable on-line method for testing carcasses for specific pathogens on the slaughterline is available at the moment. The best available methods are currently too slow to give meaningful results. An industrial ELISA method for Trichinellosis testing has been developed.

We expect that the general hygiene at slaughterhouses and meat processing plants will be monitored, particularly at critical control points. Use of rapid microbiological methods will make the results available earlier.

Check of carcasses for absence of residues is likely to be carried out in a laboratory on samples taken at the slaughterline. Blood or serum samples would be preferable due to simpler pre-treatment and the higher concentration of residues than in muscles, but such a procedure requires development of a safe identification system. Pesticide checks will have to be based on fat samples. Analytical techniques which can detect trace quantities for a wide range of compounds are required. A possibility could be automated mass spectometry which can detect very small quantities combined with computer library searches of the spectra for compound identification. A considerable development effort is required to create a practical on-line system and the equipment will be rather expensive. A development project has started in Denmark.

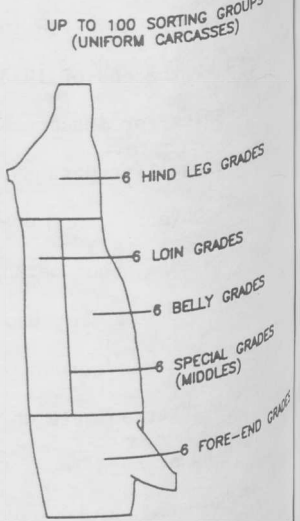
PRODUCT CONTROL AND SELECTION: The method employed in Denmark to ensure optimum utilisation of raw materials and fulfilment of the customers' quality requirements is selection and sorting of the available raw materials. After measurement of relevant carcass properties (carcass weight, visual evaluation, classification data, skatole analysis etc.) these data are used for selection and sorting of carcasses and cuts in order to ensure that the cuts with the best possible match to a customers requirements are used for products destined for this customer.

Introduction of the pig carcass classification centre (CC) and thus of cut grading has altered the sorting system

in Danish slaughtering plants from carcass sorting to a combined sorting of carcasses and major cuts.

In addition to the measurement of the total lean meat content in the carcass, the CC can grade each major cut (hind leg, loin, belly and fore-end) in up to 6 grades. In addition special cuts (e.g. middles) can be graded into 6 special grades as shown in figure 5. These cut grades and special grades can be programmed as required by each slaughterhouse using the measured quality parameters. This gives an opportunity to define grades with the properties required by the buyer.

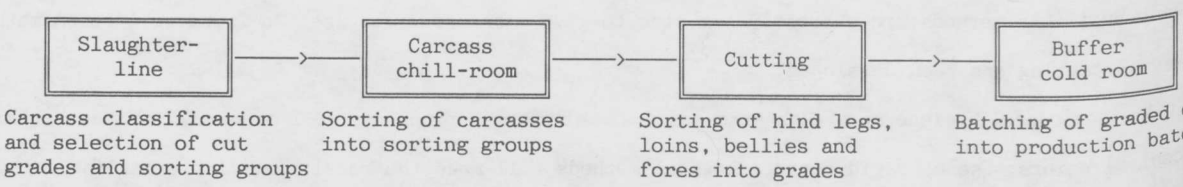
Figure 5: Sorting groups, cut grades and special grades



In theory a sorting of carcasses into identical groups would require 1296 different grades (6 hind leg grades * 6 loin grades * 6 belly grades * 6 fore-end grades) plus special grades when selected. It is practically impossible to select that many different groups - the CC computer has facilities for up to 100 different sorting groups of carcasses which are identical with respect to one or more main cuts. After primal cutting the possible number of variables is reduced to 24 i.e. 6 for each major cut (hind leg, loin, belly and fore-end).

The figures given above show that a complete sorting of the carcasses in identical groups in the chill rooms is impossible. Typically the carcasses in the chill rooms are sorted into groups which are identical with respect to one or two cuts. The remaining sorting must then take place during primal cutting as indicated in figure 6.

Figure 6: Selection of raw materials



Sorting in carcass chillers. The sorting in the carcass chill rooms (or conditioning rooms, when tunnel chilling is used) has the following purposes within the total selection of carcasses and cuts.

- To ensure that carcasses with known properties can be brought out when required.
- To simplify the sorting during cutting.
- To ensure that cutting of carcasses e.g. with uniform hind legs and/or loins can be carried out in batches without a need for further sorting.
- To ensure that the chillers can be emptied in a sequence which allows for the planned need to supply raw materials with specific properties to the boning room.

The possibilities for sorting in the carcass chillers can be limited by chiller capacity or lay-out. The need for sorting in the carcass chillers is related to the production structure of the company, but experience shows that most companies wish to achieve as detailed a sorting as possible in the chillers. Before introduction of the CC Danish slaughterhouses typically sorted carcasses into six groups. Today most Danish companies sort carcasses into 13-25 groups in the carcass chillers and the number of groups is increasing.

Sorting at primal cutting. The purpose of the sorting during primal cutting is to complete the sorting started in the carcass chillers. When the cuts leave the cutting area they should all be sorted according to cut grade. This

sorting ensures that all cuts of the same grade are placed in the same box or hung on the same multiple hook (Christmas tree). The sorting is carried out manually according to the CC grade brand on each cut. When the carcasses in the chiller have been pre-sorted e.g. according to the loin grade, only the fore-ends, hind legs and bellies have to be sorted manually.

Buffer cold room and boning/trimming room. In order to ensure that a cut which has been graded for a specific finished product is used for this product, it is necessary to have a buffer facility for cuts between the cutting area and boning/trimming area. This buffer facility provides a balancing quantity of specific raw materials.

The need for buffer capacity is controlled by the variation in raw material availability and by the flexibility in transfer between different cutting specifications and capacitites in the boning/trimming area. This flexibility is influenced by the following conditions:

- Number of boning lines (more lines give greater flexibility).
- Possibility for producing to different cutting specifications on each line (many specifications give greater flexibility).
- Individual incentive system versus line system (individial incentive system gives greater flexibility).
- The ability of each operative to handle different products (many products per operative give greater flexibility).

Basic production planning. The principles in basic production planning can be illustrated by the relationship between sorting of carcasses (sorting groups) and grading of cuts. There is a systematic relationship between the meat content in the complete carcass and in each cut. If a sorting group is based on e.g. lean loins it is likely that many of the other cuts are lean as well.

A simplified example with only two sorting groups can illustrate this point. One group (X) has lean loins, the other (Y) has fat loins. The relation between lean and fat hind legs, bellies and fore-ends in these groups is shown in table 2.

Table 2: Example of relationship between sorting groups and cut grades

	Sorting group X (lean loins)		Sorting group Y (fat loins)	
	% lean	% fat	% lean	% fat
Hind legs	80	20	15	85
Bellies	90	10	10	90
Fore-ends	70	30	25	75

If the carcasses with lean loins are cut early in the day and the carcasses with fat loins later, the frequency of fat and lean hind legs, bellies and fores will change when cutting of the new sorting group starts. This results in a change in the cut grades arriving to the buffer store or the boning/trimming area. The production plan must allow for such changes by having the required buffer capacity and by adapting the production plan for the boning area.

Figure 7: Planning principle

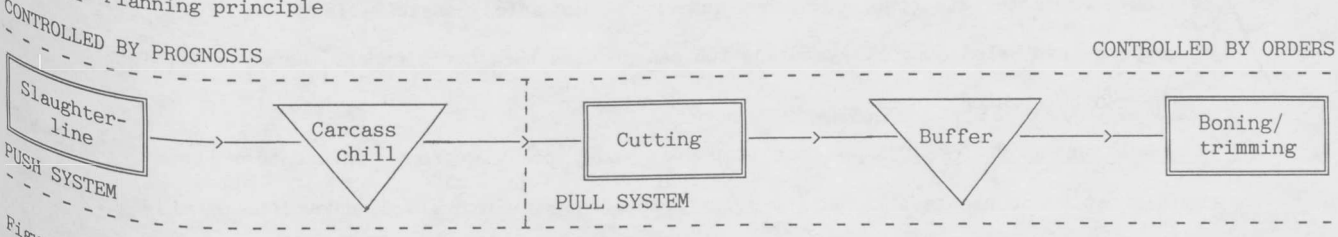


Figure 7 illustrates a planning principle based on carcasses being pushed from the slaughterline to the carcass chill rooms, sorted in groups based on the expected production requirements. After carcass chilling the carcasses

can be pulled forward to the production they are best suited for. The pull system can only be used for the cut or cuts which were used for the sorting into the carcass chiller. If the carcasses were sorted according to e.g. loin grades the following process can pull carcasses with the loins required for a specific production from the chiller. When these carcasses are pulled from the chiller various qualities of the other cuts will follow as shown earlier.

A full utilisation of the possibilities for quality and yield optimisation which can be achieved with the carcass classification centre can only be realised with a production planning system which controls the raw material flow through the carcass chilling, primal cutting, boning/trimming and packaging functions. The supply and usage of each type of raw material must be coordinated and the details for the production of each batch in the boning area must be scheduled. Information about current production possibilities and limitations must be transferred to the sales and planning departments.

APPLICATION OF INFORMATION TECHNOLOGY: The use of information technology is an important tool in slaughterhouse management. This is the background for work at the Danish Meat Research Institute aimed at identification and description of the future applications of information technology for effective management in the meat industry. The following areas have been selected as having major strategic importance:

- Planning and raw material use. An important aspect of short term planning is the selection of raw materials for each order. The raw material utilisation should provide the optimum financial yield, but must also satisfy quality requirements for each order and be adapted to current production limitations. Information technology is well suited for this task which requires calculation, optimisation and simulation which with advantage can be carried out in computers. A series of simulation and optimisation programmes are today used in the Danish meat industry to assist production planning. Development and improvement of such programmes are carried out continuously and are expected to be intensified during the coming years.
- Control of production. Production floor equipment integrated with data equipment has been an area where information technology has been applied extensively in the meat industry. Advanced equipment for weighing, carcass classification, measurement of quality parameters, automatic carcass identification and subsequent automatic sorting are examples of data technology as an integral part of factory floor equipment. The most recent developments in data networks and data-base technology have provided new possibilities for a better integration and a more flexible data exchange. The large quantities of data captured e.g. as a result of raw material measurements can via data networks and data-bases be used effectively for sorting systems and higher level planning functions.
- Sales support systems. An important basis for a succesful application of the strategy "meat according to specifications" is a close contact between production and sales/marketing functions. A meat company often have a large number of sales possibilities and the raw materials can be converted to different finished products. An important basis for the optimum decision for a sales executive is information about the available raw materials combined with a summary of the sales possibilities. Development and introduction of computerised sales support systems which can provide this overview are therefore important in relation to the chosen strategy.
- External data exchange. Danish meat companies today use electronic document exchange for a number of administrative documents such as order confirmations and invoices. The development of data networks and international public data services gives possibilities for electronic exchange of other documentation. The data captured by a slaughterhouse for a batch of products as a result of measurements during production

could be of value in the later processing of this batch, and at a later stage a meat company could provide important quality data for a specific production batch. Such data will, in addition to providing a form of quality certificate, in some cases be useful as imput to the data systems at the processing plant. For the primary production the data captured at the slaughterhouse could be made available to the individual pig producer and could act as guidance for future management of breeding and production conditions.

- Quality management. Quality management is not an isolated data system but should be incorporated as an integral part of the other systems. It is mentioned here to emphasise that information technology is an important tool in the establishment of a quality management system. This subject will be dealt with later.

In addition to identifying the most important areas for application of information technology the Danish Meat Research Institute has also provided guidelines for the future system design. A system architecture has been proposed giving details about future data systems and their interconnections. The purpose of producing a system architecture has been to produce a reference framework enabling the development and implementation of individual sections of the system over a period of time. The system architecture has been designed on the basis of top-down analyses aimed at supporting of the business strategies of the companies. However, the implementation of the systems is carried out bottom-up. The system architecture is thus a future ideal for the information systems. The practical application of this ideal is a step-wise adaptation of new systems to the structure. The overall principles for system design and system connections should ensure that the final target can be reached. The developments in information technology are, however, rapid and it might be necessary to revise the system architecture frequently.

The overall system architecture is shown in figure 8. The production of the company is separated into a number of separate areas (cells) covering the following functions: - Reception of raw materials - Slaughterline - Primal cutting - Boning/trimming - Packaging - Dispatch.

Each of these areas is in principle an independent production function connected via an intermediate store. The lairage building is the store between reception of raw materials and the slaughterline. The carcass chiller is the store between the slaughterline and primal cutting etc. Each production area is an autonomous unit with respect to management and detailed planning, but is controlled by the company's overall planning. Integration and direct production management is carried out at a higher level which also covers quality management and operational control.

Figure 8: Data network for slaughterhouse

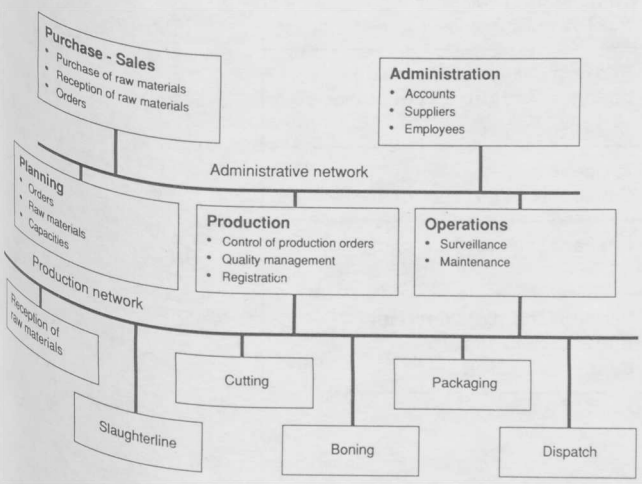
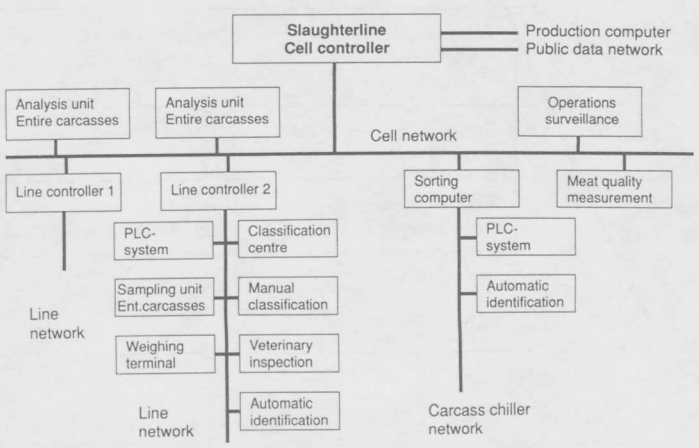


Figure 9: Data network for slaughterline



The individual production areas are tied together by a production network. The technical surveillance and maintenance are in a separate area having the main function of ensuring maintenance and operation of the technical equipment. The company's administrative functions are also separated in some main areas tied together with an administrative network.

In each production area (cell) the system design can be made with reference to the overall architecture. Figure 9 shows the structure of the slaughterline systems in Danish slaughterhouses. The installation of the equipment shown in this figure has started and will be completed by the end of 1991. The figure illustrates a slaughterhouse with two slaughterlines. The activities of each slaughterline is controlled by a line controller. Measuring equipment and machine control systems (PLC equipment) are connected via an industrial data network. The coordination of the activities in the area is carried out by a cell controller. The main functions in the area are capture and storage of quality data for each carcass. These data are used as input for a sorting of carcasses at the entry to the carcass chillers. The figure also shows the connection of the analysis equipment for entire male pig carcasses to the other data equipment on the slaughterline.

THE QUALITY MANAGEMENT SYSTEM: Unlike quality assurance, which focuses on post-production inspection, quality management emphasises defect prevention as illustrated in table 3. In quality management there is a strong focus on customer requirements and cost reduction through continual improvement. The responsibility for quality is well defined and is managed through documented systems and operations.

Table 3: Comparison of quality assurance and quality management

	Quality assurance	Quality management
Philosophy	Inspection	Prevention
Responsibility for quality	Quality control department, inspectors	Systems and operations and well defined responsibilities
Goals	Defect detection	Cost reduction and conformity to specification via continual improvement
Inspection	Post production inspection	Process control and in-process inspection
Cost	Specified quality at specified cost	Cost reduction through quality improvement
Improvement	Improvement by increased inspection	Project-based improvement by doing it right first time
Focus	Product	Process. Customer requirements
Techniques and problem solving	Rework and destruction	Corrective action programme
Benefits		Production to customer specifications. Cost reduction

Quality management is based on four principles:

* meeting customer requirements
* doing the things right first time
* management by prevention
* measuring the cost of non-quality.

Meeting customer requirements. Quality is meeting the agreed requirements of the customer. The customer is defined as anyone who has an interaction with the employee. There is of course a focus on the external customers, but equally important are the internal customers, who are co-workers, people in other departments and sales.

To meet specifications it is necessary to measure central quality parameters such as lean meat content, fat thicknesses, carcass weight and dimensions, protein content, pH, pigment content and residues. In all sections of the process well defined accept/reject criteria and procedures for verification should be established, and adequate measuring equipment should be available. The pig carcass classification centre is important in this respect. Every carcass is measured and data for each carcass are available for production planning.

Right first time/management by prevention. The company no longer operates on the basis of an acceptable level of defects. Instead the company is trying to create an environment, which seeks perfection in all operations and motivates the employees to ask why an error has ocurred and take action to prevent it happening again. Consequently operatives must be given the power to influence problem solving and changes to processes to prevent errors.

To assure quality it is necessary to have well defined responsibilities for quality. It is important with established procedures for handling products out of specifications. It is essential to keep records. All records should be analysed systematically to prevent failures from happening again.

Measuring the cost of non-quality. The cost of non-quality is the money spent on detection, correction and prevention of errors. Measuring the cost of non-quality gives the management a strong tool to monitor productivity and quality at the same time. There must be a system for calculating all defect costs, identifying factors influencing the costs and recording defect costs at critical control points.

ISO 9000, an international standard. The international standard series for quality management systems, ISO 9000, gives guidance for implementation of a quality programme. The standard is obviously designed for use in the production of "nuts and bolts" and not for use in the food industry - certainly not for use in slaughterhouses. The standard is a specification of a quality management system. The standard specifies the requirements for documentation, verification and records to be kept.

The Danish Meat Research Institute in cooperation with the STEFF-HOULBERG meat company is developing a quality management system in compliance with the ISO 9000 standard series in the slaughterhouse in Ringsted. An interpretation of the ISO-standard for use in Danish pig slaughterhouses will be the result of this work.

Expected results of the Danish quality management project. The company's **policy and objectives for quality** will be stated in a Quality Manual and communicated to all employees and customers. A contract review is essential to assure that the requirements of the customers are agreed, and that any requirement that cannot or will not be met is identified. **Purchasing** is an important activity and the ISO 9000-standard is very explicit about purchasing data. An approved suppliers' list must be kept, and it must be possible to determine exactly what a supplier has been approved for. Danish slaughterhouses are in a special situation here, because the companies are owned by the suppliers and must therefore accept all delivered animals. For the production of entire male pigs and for special contract productions it is possible to keep approved suppliers lists.

In a quality management system **product identification and traceability** is essential. In the slaughterhouse there is a full identification and traceability of the carcass to the point of cutting. After cutting traceability is lost and the only identification is the EC and grade brands applied in the classification centre. All non-conforming products will be positively identified, which is especially important for entire male pig carcasses with too high skatole contents.

The **process control** required to ensure that the company can meet the requirements of the customer will be applied. In the slaughterhouse the processes are manual operations and the documentation is work-instructions. To decide whether work-instructions should be fully documented, it is necessary to consider the skill and training of the operative. The standard does not ask for "guides for fools", and it is therefore not essential to fully document normal operations, that are only performed by trained operatives.

Inspection and testing will be carried out as defined in a quality plan. Inspection of the carcass, quality grading in the classification centre and measurement of skatole content are examples of in-process inspections. All inspections will be documented in formal procedures pointing out where verification is to be carried out, the type of verification and the methods used. The responsibility for verification and the required qualification of the inspectors will be defined. Measurable accept and reject criteria will be established and necessary records will be kept to prove performance.

The ISO 9000 standard is clear on what to do once a product has been found to be **non-conforming** to any of the requirements specified by the customer or by the slaughterhouse itself. The responsibility for review and the authority for the handling of non-conforming products will be defined. All non-conforming products will be reviewed and reworked to meet specifications, regraded for alternative use, destroyed or accepted with concession by the customer. A **corrective-action programme** will be implemented to prevent failures from happening again.

Training programmes are generally designed to improve an employee's technical skills. However to create an organisational environment which is customer driven and which emphasises quality first time, it is necessary to change the company culture. This is especially true in a slaughterhouse. The training and educational needs will be identified, and an educational programme will be developed in cooperation with the Danish Meat Trade School.

The quality management system at STEFF-HOULBERG's slaughterhouse in Ringsted will be evaluated according to the requirements of ISO 9002. The issue of a certificate, showing full compliance with the requirements of the ISO standard, is the expected result of the project.

ORGANISATION: The introduction of a more market orientated production management system will also produce new requirements for the organisation of meat companies. The following tendencies should be considered:

- The need for coordination between production departments increases. The supply of customer specific products and the sorting of products into many quality grades result in a larger influence in a department of the work carried out in other departments.
- The freedom to make decisions in an individual production area becomes more restricted. The main target of fulfilling quality requirements, quantities and delivery times has a direct influence on the production floor and the freedom to make alternative decisions is limited.
- The introduction and extensive use of new technologies produce a requirement for a higher level of training/education. Information technology, advanced measuring equipment and equipment for product identification and sorting are new disciplines which must be mastered in the production departments. The companies will become more dependent on the correct function of the technical equipment and the maintenance

departments must be able to ensure this.

- Wage systems must be modified to support the companies' target of being able to supply products with the right quality, quantity and delivery time. The importance of incentive wage systems based on production volume is therefore reduced in relation to the main targets for quality and planning.

Development and installation of new technology is often seen as the most important task and the need to modify the organisation in order to make the technology work is often neglected. When the new technology can be introduced according to a well defined plan, the organisational changes can be implemented over a period of time and in some cases new staff with specialised skills are employed. The budget cost for implementation of new technology is often based on the purchase price for the equipment. The cost of making the new technology work is often forgotten. Experience indicates that this cost often is at least as high as the equipment price. It is therefore important to consider the organisational consequences of new technology at an early stage.

CONCLUSION: The Danish strategy based on selection of raw materials guided by on-line quality measurements in order to produce products of the required quality for the export markets has been strengthened as a result of new developments in measuring techniques and information technology. A framework for the future production control system has been created and is gradually being installed in the meat industry.

The organisational changes which are needed for full utilisation of the new technology will require an intense training of staff at all levels in the industry.

The Danish meat industry has had experience in the application of special measuring equipment and carcass selection for a number of years. Information technology and quality management are in comparison new disciplines. The results achieved with these technologies are positive and the development is expected to continue according to the framework which has been agreed. The creation of a complete production management system to support the main strategy for quality and flexibility is a process in continuous development. We expect that the further development of methods and management principles will continue for several years.