2 - 1 MEAT PRODUCTION, MECHANIZATION AND ROBOTIZATION, SANITATION AND MEAT QUALITY.

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The future meat production will be based upon early detection of stress meat, hot boning, stimulation of hot boned meat cuts and direct processing of prerigor trimmings.

"Agri-mation" is increasing rapidly. Microprocessors and computers together with mechanization and robotics will make the operators in the meat industry more effective. Advanced machine-3D-vision inspection systems are already seen in use.

"Third generation" robots with finger-like manipulators will take their cues from computers via data-communation networks instead of human operators. Voice-recognation equipment is taken into use where human interactions are required. An evolution will probably come in the near future as electronic components,sensing and vision technology is getting better and software cheaper. Optic fibers instead of electric wiring make the use of microprocessors more stable in tough environments.

Sanitation will be made easier by robots. Washing of carcasses will become more attractive when using sophisticated machines after automatic weighing and laser based vision-grading. Meat quality will be better when new developed fiber optics and quality registration equipment is available together with the increased know-how of the meat technologist who will be helped by computerized memories.

A. Transport and Stress Reduction.

The Roman Forum was the head place for slaughtering in Rome and most probably little attention was paid to animal stress. Container transport of pigs is in the Soviet Union among other places, found to give only half as much bruised meat when compared to truck transport (Tatulow). Modern CO_2-systems do not appear to create as much stress as the conveyor system. The pigs are being supplied in a tranquille state at good rate. It is easier to stick gas stunned pigs than electrically stunned. CO_2-based systems should also be developed for lambs. Many researchers have, and hopefully will, work on reducing animal stress and the incidence of PSE- and DFD meat. We should put into practical use what we have learned from for instance Danish meat researchers and Temple Grandin.

B. Slaughter and Washing Technology.

New systems for scalding the pigs are not based upon water baths, but the pigs are hanging in a "sauna" for more hygienic scalding. The unit condenses steam on to the carcass. Only a small amount of water is used which is claimed to give 30-50% savings in energy consumption. Automatic polishing systems for pigs are developed and an automatic measuring device is constructed which measure the individual pig as it approaches the polisher and scraper unit and thereby adjust the rollers and scrapers accordingly. In the poultry industry mechanical defeathering devices and vacuum to aid the evisceration is more used than in the red meat industry. We have tried to use vacuum for taking out the rumen from beef carcasses. The tests have not yet been finished.

Electronically operated conveyor systems are used to take the carcasses for further veterinary inspection into parallell tracks and electronic control is used for switching devices. US-plants use in the chilling rooms the "walking beam system" which is not found to a great extent in Europe.

Early chilling in order to reduce the incidence of PSE is recommended (Braathen, 1971). Some modern slaughterhouses in Holland) have a relatively low temperature on part of the slaughter floor. We propose that cold air inlets are placed between each operator on the slaughter line giving an effective chilling effect on the carcasses during the dressing operation. Spraying and washing the carcasses with extra cold water might reduce the incidence of PSE. Removal of the head will also give faster chilling of the pig carcass. Hot boning of the pig head will give less bacteria on the finished head meat and energy is saved.

Removal of the backfat, and also skinning the pig carcasses have an effect on the incidence of PSE. Evaporative chilling of pork is used in Norway. By this method the loss of water from the pig carcass is reduced and more important, and the pig skin is kept soft for easier and more effective cutting thereby reducing the labour cost and the bodily damages to the workers. By using extra cold water sprays and very low chill temperature, this method at the same time reduce the amount of PSE-meat. Hot boning and thereby rapid chilling of the pork cuts give less PSE. The pale colour and the exudation of the pig meat are two factors which are influenced by the chilling method without being directly connected. We might get pale coloured meat without getting exudation.

Carcass washing was recommended already in 1962 (Jörgen Baltzer). Danish researchers found that 95°C hot water prolonged the shelflife 2-3 days when the carcasses were stored at cooler temperature. Of course it is not useful washing beef carcasses having a low bacteria count as for instance below 100 per square centimeter, but as this low count is not often found on normal carcasses except on the back, the effect of carcass washing should be taken advantage of. The use of a washing machines for carcasses is more widely utilized in the United States than in Europe. A microbial count reduction from 92,4% and down depending upon the hygienic quality is to be expected. Already several automated cleaning processes are found on pig slaughter lines. Also conveyors are used for transporting the carcasses to singeing and polishing without being touched by hands. Hygiene research should perhaps be done on the ability of bacteria to fasten on carcass surfaces. (B.Eriksson).

Future cleansing systems will be so smart that they will make clean -in-place systems absolute. Self propelled cleaning units will clean specific equipment. Because the machine can work on it's own without people in the room, it will be able to use more high powered energy cleaning methods. The machine will also be intellingent enough to inspect it's own work and make corrections (G.C.Clarke).

C. Hot-Boning, Prerigor Meat and Cold-Shortening.
Different methods are seen:

1. Hot boning of unstimulated carcasses, vacuum packaging and holding the primal beef cuts at an elevated temperature for a specified period of time.
2. Electrically stimulating the carcass followed by hot boning and chilling of the meat cuts.

3. Braathen's idea which includes:

A. No stimulation of the whole carcasses.
B. Stimulating an indicator muscle in the carcass just after deskinning for early detection of DFD-meat.
C. Hot boning of the unstimulated carcasses.
D. Use of prerigor warm or salted and chilled or early frozen prerigor meat trimmings for sausage manufacture and restructuring.
E. Electrical stimulation of the prerigor hot boned meat cuts.
F. Chilling and ageing of the electrically stimulated cuts.

Hot boning requires 40-50% less refrigeration input and results in a 50 - 55% reduction of cooler space, reduces labour costs by 25% and decreases shrinkage up to 2% as well as reduce product in-plant residence time (Taylor 1984). Also the length of cooking time is reduced by 82%. All this give significant savings in energy, yield, materials and supplies, labour and interest of fixed capital and inventory.
Many reports show that organoleptically acceptable beef steaks and roasts can be obtained after hot boning. The hot boning and chilling of beef may be easily carried out in four hours, and for pork, the hot boning should be finished before one hour post mortem. (Honikel & al. 1983). It is of course important that the sarcomeres in steaks are not allowed to shorten during hot boning. This may be avoided by keeping the temperature in the meat not lower than about +10°C or by using electrical stimulation of the hot boned meat cuts. More and more boning is carried out on carcasses hanging down from the rail. This we have in seen in Australia already in 1976. In Norway vertical polyethylene tiltable boning tables are used. The tilt is operated by the foot and the carcass part may also be adjusted up- and downwards.

By using gravity force boning is less tiresome for the boners. Griping arms for use on these vertical tables for easier boning are being developed. Systems for better mixing of hot boned meat trimmings are desired.

The freezer storage temperature for hot boned frozen meat trimmings should at all times be below -20°C. If the temperature is -12°C, the ATP may be broken down and the extra high prerigor water binding capacity may be lost.

By keeping prerigor frozen lamb carcasses at this temperature for 12 days, thaw shortening and toughness is avoided. It is known that thaw shortening result in shortening of the muscle fibers down to 40% resulting in a great loss of meat juice and reduction in water holding capacity. Cold shortening is only reducing the sarcomere length to 60%. When hot boning, the water binding capacity of the trimmings is about 200% higher than in normally chilled (post rigor) meat trimmings. Frozen prerigor meat trimmings should be chopped in a frozen state without breakdown of ATP.

D. Product Flow, Electronic Identification and Electronic Coding.
Microelectronics may be used for electronic identification of animals. A very small device implanted in the body of the animal by injection, may follow it's carcass through the slaughter- and cutting operation. Bar-codes may be fastened to every meat cut in order to make optical scanners to keep track of what is inside your refrigerator and what needs to be added to the shopping list. Cooking instructions would be in the bar-code and it would be necessary to merely passing the bar-code stip over a sensor link to a microwave or conventional oven in order to set proper cooking time and temperature.

E. PSE-DFD Early Detection.
It is a desire to be able to detect which pigs will give DFD and which pigs will give PSE after slaughter. An infrared temperature monitoring system might be used to pick out sick pigs and perhaps stressed pigs as well.
A method for early detection of DFD-meat is developed (Braathen, 1984). By this method a part of a muscle is locally stimulated during dressing of the carcasses. This electrical stimulation results in development of "the ultimate pH" already before the carcass is passing the scale. Systems based upon for instance optic probes should be made better for early detection of PSE-meat. When knowing that carcass is on its way to develop PSE, the carcass may be instantly deboned or frozen for the prevention of PSE-development.

F. Electronic Grading.
New technology incorporating 3-dimension photography as well as whole body NMR and computer recognition, will permit exact grading based upon actual yield and quality. Electronic probing may be used for electronic grading combining technology of both optics and electronics to detect and measure the location of the fat- and meat interface.

The Hennesy grading system is well known to meat researchers. P.B.Newman (1984) showed equipment for measuring the fat content in meat trimmings by videocamera. Miles and cooworkers used infrared- reflection measurements for the same purpose also using a transport belt together with the analyzing unit.

G. Electrical stimulation.
Research on this topic has been popular among meat researchers for the last years. Equipment for high- as well as low voltage electrical stimulation has been developed and taken into use. Low voltage electric stimulation after bleeding and later carcass chilling at +2°C to +4°C results in a rapid pH decline, lighter initial red colour, but more rapid discoloration during display and a softer and coarser textured lean and reduced water holding capacity.
By using low voltage electrical stimulation,a tenderness quality guaranty is given in Sweden and Norway (Gilde). In Australia carcasses from cattle with one or two permanent teeth that have been electrically stimulated are branded with an orange-gold colored food dye. This gold brand assures it is an excellent quality. (C.R. Luckock). Perhaps other electronic devices may be used for preventing cold shortening in muscles in the future. A device developed in Norway for electrical stimulation of hot boned meat cuts makes its possible to take advantage of the high prerigor water binding capacity in unstimulated meat trimmings.

H. Computerization in the Meat Industry.
It may be a fact that the computer boom may be overstated. Electronics are becoming widely used in all sectors of agriculture. Nowhere is computerization in the slaughterhouse as advanced as in the poultry industry where computers are employed on the factory floor and used to control the intake of livestock and distribution of the finished product. (Jerry Leese). Also in Norwegian slaughterhouses the manager may read from his computer screen how many animals are sold by the producers to be slaughtered and how many animals are on transport, in the slaughterhouse stables and how many animals are slaughtered until he looks at the computer screen. In the poultry plant,the computer offers the possibility of a tight control of the chickens through six and even more computerized weight-grading lines. When factories run at speeds up to 7200 birds per hour, this system is necessary. Loading dock computer transfer its accumulated information to the company's main computer. The development of software for the meat industry is growing rapidly.

The demand for advanced electronics within space research and within military operations may give advantages also to the meat industry as well as the total agricultural industry. Integrated circuits which have been developed today, will be buildingstones in the slaughter technology of tomorrow. Through electronic planning monitoring and control systems, the production of meat will be better giving productivity improvement.

I. Robotization in the Meat Industry.

In the litterature many articles are found about how processes in the meat industry might perhaps be automated and how hand labour is going to be done by robots. The development many authors dream about night eventually come true, but very little is presently being put into practical operation. The electronic technology together with laser and other technologies is now developed to a suitable extent,and the instrumentation is becoming less expensive. The use of new technology is more and less up to our fantasy. One might think that in Japan this new technologies have been taken into use in the meat industry.

This seems not to be the fact (Toft Fensvig,personal comm.1985). In the meat industry we are dealing with a product which is shaped by nature and is not well designed for automation. Therefore it seems to be necessary to introduce these processes gradually into our slaughterlines. (Nico Westerink).

We have to remember that robots are slower than people and a problem is that the slaughterlines are buildt so compactly for years that very little space is available for placing a robot on a working spot for a certain task. Some developments have been made. We call for your remembrance automatic stunning devices, automatic splitting of carcasses, automation of the carcass quality grading and a semi-automatic belly trimmer etc.

In slaughter machines smart-power chips can facilitate diagnostic systems that warn of such problems as burned-out indicator lamps and also they could eliminate a lot of copper wiring in the machines. At this point it is no longer a question of whether appliances and other equipments use microprocessors, it is how many microprocessors they will use.

The Swedish company MIT AB has developed a robot to scribe the carcass for braking into primals and also into shoulders, legs, bellies and middles. One of the biggest advantages is that a pig is cut while still on the gambrel. People are looking for systems which only need 3-4 men to kill 250 pigs per hour compared to todays average of between 10-15. Researchers are working on automated eviseration systems and robots for spinal cord and brain removal are around the corner (Keven Gaffney). We are looking for an automatic machine for branding the meat inspection mark on to the carcasses.

The separation of meat from bone, recovery and utilization of waste, and introduction of novel food products, are all becoming increasingly important. (Newman,1979). The are two main approaches to meat recovery: removal of bone from meat and retrieval of meat from bone.

Alternative techniques including cutting and centrifuging (Lapeyre,1975), shot blasting with ice particles (Lindall, 1963), and cutting with water jets (Draper and Rejsa,1971) have neither got into extensive commercial use.

Machines for mechanical desinewing should be menthioned. Many methods have been tried as for instance taking off the meat with water followed by sentrifugation, using rotating chains, shredding or scraping and tearing. Also running the meat through a hammer-mill-like machine is described.

The labour in the meat industry is intensive and most operations are repetitive, and knife work is dangerous as well as the work with bandsaws and powerful chains. Automation in the area will improve the level of safety (P.T.Clarke). The nature of the work in the meat industry makes it difficult to satisfy its labour requirements. From this point of view the meat industry is therefore ideally suited for development of automatic- and robotic systems (Paul Newman). One problem is to identify the operations which can be modified by automation. As meat carcasses vary in 3 dimensions, robot control cutting must be able to adapt to the individual sizes. In the future boning plants the properties of the muscles will be determined automatically and those muscles best suited to various products,will be directed to those areas producing these products. When boning "muscle seaming technics" will be used. (G.C.Clarke). The most important seems to be the development of equipped robot controllers with sufficient information on carcass characteristics. Robots are well suited for jobs in the food industry because they are uneffected by environments, whether it be in a blast freezer or in a steam house.

Voice- recognititon equipment is also being heard from in applications where human judgement and interaction are required. Socalled "third generation" robots that can observe and react to their environment are under development.

We should have in mind that in the meat cutting department, the finished cuts could perhaps be "designed" again som that they may be "created" by robotic equipment in the future. It is necessary that the biologists take part in the development of robotics and at all times pay attention to the animal, the operator and the consumer (Bengt Eriksson,1984).

In California robotics ara applied in human brain surgery to remove a tumour in a living man. Why should we not use robotics to remove the fatback from pork loins? (D.Kinsman).

J. Biotechnology in the Meat Industry.

Only about 50% of the meat animal is meat. In the future more attention, should be paid to byproducts and the utilization of the dead animal and animal offal. The possibilities for such utilization has been described by E.Divakaran 1981. The production of biogas and other processes should be developed makeing products for the pharmaceutical industry and the consumer such as hormones, enzymes and others. The "intelligentia industry" now look for new applications of biotechnology.

K. Future Plants.

The future plants should be constructed in such a way that the extra high prerigor water binding capacity of hot boned meat could be taken advantage of. This is, due to geographical reasons,done to a large extent in Norway. The slaughterhouses are built in "rail connection" with the cutting department and the sausage factory. These plants,which may be called "combinates",are very suitable for doing what we recommend:

1. Normal killing of the animal carrying out rodding for better hygiene.
2. No electrical stimulation of the whole carcass, but of a small section of the Longissimus dorsi on the carcass immediately after dehiding or deskinning.
3. 3-dimension video-laser grading of the carcass and pH-measurements for early DFD-detection.
4. The carcasses are passed the scale while grade and weight are put into the computer as well as the identity of the carcass by the electronic chip implanted in it.
5. Hot boning. Carcasses having a pH when passing the scale above 6,0 are used only for meat trimmings for emulsion products. Primals and cuts like filet, entrecote, standing rib, etc. are stimulated for preventing cold shortening when still prerigor before packaging in vacuum or controlled atmosphere for further ageing for increasing the tenderness.

Future plants may be ultrasanitary and located away from cities because few people need to be employed. Increased production will be handled by increased production hours not by larger facilities thus reducing the need for future expansion. The process line will move through the plant in a straight line. This will be far less expensive and trouble free. All rails, tables and conveyors will be operated by hydraulic motors which would be speed selective and use 35 % less energy and be easy and safe to clean. (Richard Wagner).

Technical advantages will give larger multispecies- and multiproducts plants in favour of small facilities producing a limited product line. Optic computers will be used to weigh and grade meat on the line and carcasses be moved to chambers where they are irradiated with cobalt to lenghten the shelflife. Several institutions have decided to invest in automation in the meat industry so a great boom is expected in the near future. In a not too distant future processing lines will be totally unmanned as the various processing stations are increasingly being taken over by machines.

Where should the meat researcher put the attention in the future? We know very much about meat as such,and how to make meat emulsions is known to most meat researchers. The slaughter operation is an interesting field. From experience it is known that most research results are not immediately taken into practical use in the meat industry. Perhaps more research should be put on mechanization and robotization which is more clearly reducing the costs by reducing labour intensity. It is easier to measure investments and savings on labour than to measure the value of better quality resulting from increased detail knowledge about meat.