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Christel Benfalk
Kristina Lindgren
Mats Edström
Qiuqing Geng
Åke Nordberg

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– equipment, docking, animal handling, working environment and waste handling

Christel Benfalk
Kristina Lindgren
Mats Edström
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Summary

The transport of animals to slaughter is well documented and often the animals suffer from stress and injury. This can be caused by bad conditions during the loading, transport and unloading and by aggressiveness between animals. Many measures are needed to improve the situation. In some cases, mobile slaughter could be used to reduce the transportation of animals. It is possible that the consumers' will view mobile slaughter as a system that promotes animal welfare therefore meat slaughtered in mobile abattoirs could be more attractive. This requires that the consumer should be able to inspect the slaughter at any time, and find that the animals are handled in a good way from the pen in the stable until they have been stunned and killed.

According to the EU regulation on the hygiene of foodstuffs (EC) No 853/2004, mobile abattoirs are approved for all kinds of animals. It is crucial that the requirements of a good hygienic standard and good animal welfare are obtained when mobile slaughter is practised. Some critical points are summarised below.

Water and chilling

It is recommended to investigate water access and quality well ahead of time, before the start of a mobile slaughter operation. The water used for slaughter must be of the same quality, as water intended for human consumption and it should be analysed regularly. Water of good quality can be transported to the mobile abattoir in water tanks. The amount of water used depends on the technique and less water is needed for skinning (~3-5 m^3) compared to scalding (~10 m^3).

The chilling process should be thoroughly planned and its capacity should be checked by a practical study before starting the slaughter at full scale. If a hydraulically folding out chill room is used the mobile abattoir cannot be moved until the chill room has been emptied. Before moving the mobile abattoir, the carcasses can be transferred to a separate container for continued chilling. The carcasses could also be placed in a stationary chill room on the farm. A third solution, which substantially reduces the chilling space that is needed, is to cut warm meat (cattle meat). This can also contribute to a better working environment since cutting cold meat is bad for the hands and fingers.

Connection to the stable and stunning

The time to set up the mobile slaughter unit at e.g. a farm is about 1 hour and it takes about 1.5 hours to clean and pack up before the unit can be moved. It is very important to construct a good connection between the stable and the mobile abattoir. A well adapted connection is necessary to achieve a good animal handling and working environment. If the animals are kept outdoors and the climate is suitable, other solutions may be adequate. It is crucial however to solve the handling of the animals so that the time (distance) from stunning to sticking and bleeding is extremely short especially with electrical stunning (17 sec).

Stunning by using gas (CO_2) has not yet been developed for mobile slaughter. The recommended stunning method today is captive bolt (cattle) and electrical stunning (pigs).

Skinning and parting of carcasses

There is a need for technical development if both cattle and pigs are to be slaughtered in the same mobile. A method for skinning that is suitable for pigs is also needed since they have weaker skin. Skinning pigs has several advantages compared to scalding in a mobile abattoir such as less water consumed, less space required and faster chilling.

With the new regulation, the post-mortem inspection can be done after splitting the carcass or after parting it into quarters. When the mobile abattoir is moved the inner ceiling is so low that full size cattle must be parted into quarters. The conditions are the same in a container for chilling.

Working environment

There is a high possibility that the working environment could be improved by developing equipment that is adapted to the restricted space in a mobile abattoir. Some of the problems with the working environment that are difficult to solve in large stationary abattoirs could probably be avoided in a mobile system.

The working environment in stationary abattoirs involves several risk factors. Heavy workload and highly repetitive tasks causes musculoskeletal injuries in the shoulders, arms, hands and back. There is an increased risk for occupational diseases compared to other work groups because of the occurrences of cuts on the fingers and hands as well as additional work to cut and pack the meat in cold environments. No study on the working environment of mobile abattoirs has been carried out yet. Therefore, a pilot study was conducted to identify positive and negative factors of the working environment in mobile abattoirs as compared to stationary abattoirs.

The results showed that the working environment in mobile abattoirs was good as all the furniture and equipment are developed with the latest technologies and modern materials that allow workers to operate with more ease. The work tasks in mobile abattoirs probably involve more variation than in stationary abattoirs, and a large number of repetitive one-handed tasks are reduced, which could imply positive effects on the workers' health. In mobile abattoirs the rate of slaughter is moderate and it is easy to achieve the necessary logistic needed to cut warm meat (cattle meat). This leads to shorter exposure to the cold environment, which could result in a reduction of cold injuries. The major negative aspect is the limited area, which leads to a restricted working space for manual handling, e.g. taking off the skin and splitting of the carcass. The operator must make sure that the volume of water does not affect the hygiene of the personnel or the equipment. The stainless steel sheet, which covers the interior walls, provides good hygienic conditions.

Further research should focus on some key factors for the future development of mobile abattoirs. Smaller machines for automatic removal of the skin and splitting of the carcass need to be developed. Support for good hygienic conditions involving sufficient water is also needed.

Waste management

The waste generated during slaughter is divided into different categories based on the risk of infection. These categories differ in chemical and physical composition, which makes it necessary to employ different treatment strategies.

After the outbreak of BSE the animal by-products presenting a risk for transmissible spongiform encephalopathy (TSE) have to be sorted out. This fraction is classified as specified risk material (SRM) and must be completely disposed of by incineration. The new EC-Regulation No 1774/2002 regulates the processing requirements and possible uses of animal by-products. Waste generated during slaughter of animals should be divided into three categories. Each category includes a number of different waste fractions generated during slaughter. Category 1 contains specified risk material and Category 3 comprises of those animal by-products that would be fit for human consumption, but are not (for commercial reasons) intended for human consumption. Category 2 includes all slaughter waste, which cannot be allocated to either Category 1 or Category 3.

In this study, the emphasis has been on waste treatment methods that facilitate energy recovery and/or methods for using the produced residue as fertiliser on farmland. Focus has been on the anaerobic digestion method, but possibilities for composting and incineration have also been considered and commented on.

Category 3 material minced to a maximum particle size of 12 mm can be digested if it has gone through a pasteurisation unit at 70^{o}C for a minimum of 60 minutes. Manure and digestive tract content can be treated in a biogas or composting plant without pasteurisation as a pre-treatment. It can also be applied directly on arable land. Screened wastewater from the mobile abattoir can be handled together with the manure and digestive tract content.

The animal by-products, including blood, represent 70-80 % of the total biogas potential from waste generated during slaughter of animals. In addition, the animal by-products contain 60-80% of the nitrogen and phosphors, in all waste generated during slaughter, which is important to consider from a sustainable point of view. Anaerobic digestion offers a sustainable treatment method to facilitate energy recovery in combination with using the residue as a fertiliser on farmland.

All the animal by-products can be incinerated. This method facilitates energy recovery but possibilities for nutrient recycling will be limited.

Composting facilitates nutrient recycling but possibilities for energy recovery are limited. According to EC-regulation 1774/2002, a composting plant has the same demand on pasteurisation for Category 3 materials as an anaerobic digestion plant.

Economy

Some cost calculations for mobile slaughter at different slaughter capacities (number of animals per day) from the year 2002 are presented. A case study from a group of farms producing fattening pigs is reported. A theoretic remodelling of the slaughter delivery was made. The average delivery per week as well as the length of slaughter events at the same farms is presented. In 78% of all slaughter days the mobile could slaughter one whole day or more at the same farm after remodelling.

Background

The countries of Scandinavia have been the forerunners in discussing mobile slaughter. In reindeer production, mobile slaughter has been in practice since 1960 when the Sandstrom Company in Lulea built the first unit. Ever since, the units have developed in accordance to the regulations and recommendations concerning hygienic practices from the Swedish authorities. Reindeer used to be the only animal allowed in mobile slaughter units, but today according to the EU regulation on the hygiene of foodstuffs (EC) No 853/2004, mobile abattoirs are approved for all kinds of animals. This report deals with mobile slaughter of cattle and pigs only.

The view of the consumer

High quality meat is of great importance for most consumers, although an increasing interest in animal welfare is also observed (Barton Gade, 1997). Consumers' perception of good animal welfare is equal to production conditions that "look good". For instance, the view of pigs walking by themselves is nicer than shrieking pigs being forced ahead with electric prods. As a result of this perception, when the handling of animals is to be evaluated, studies of animal behaviour have to be included (Barton Gade, 1997). To make such a study consequential, the need for knowledge on ethology, stress theory, animal welfare, meat quality, microbiology, legislation, ethics etc is crucial (Algers et al., 2000).

At the EU conference, *Food Chain 2001, Safe-sustainable-ethical*, in Uppsala, March 2001, the importance of food being produced in unison/harmony with the consumer's and society's standards on food safety and ethics was emphasised in several sessions. It was declared that methods for measuring animal welfare are available (Keeling, 2001), that such methods can be used for studies of the impact of ways of housing and handling animals (Wechsler, 2001) and that good welfare in many cases are profitable (Oltenacu, 2001).

Investigations of Swedish consumers' willingness to pay (WTP) for farm animal welfare has revealed an increased WTP for meat from pigs slaughtered in mobile abattoirs (Liljestolpe, 2003; Andersson et al., 2004; Carlson et al., 2004).

Mobile abattoir

Equipment and flow chart

The Swedish mobile slaughter units available today, "SANMO Multi-Spieces," are designed by the Swedish company Gillteknik in Gallivare and built by Sandstroms Transport Products in Lulea. The units are mainly used for reindeer and buffalo. The companies have also designed a unit for pigs for a potential British customer. The set-up for this pig unit has been approved by MAFF (Ministry of Agriculture, Fisheries and Food) in London, USDA (United States Department of Agriculture) in Washington and AAC (Agriculture and Agrifood, Canada) in Ottawa. In Figure 1, an example of the equipment for mobile slaughter of pigs is given. If scalding is used there must be a separate trailer with a container for chilling. The scalding tub is so big that there is no room for the hydraulically extended chill room, which otherwise can be included in the mobile abattoir.

Equipment:

- trailers where slaughter and chilling is conducted,
- trailer or lorry for transport of meat (possible also used for chilling of meat),
- container for slaughter waste.

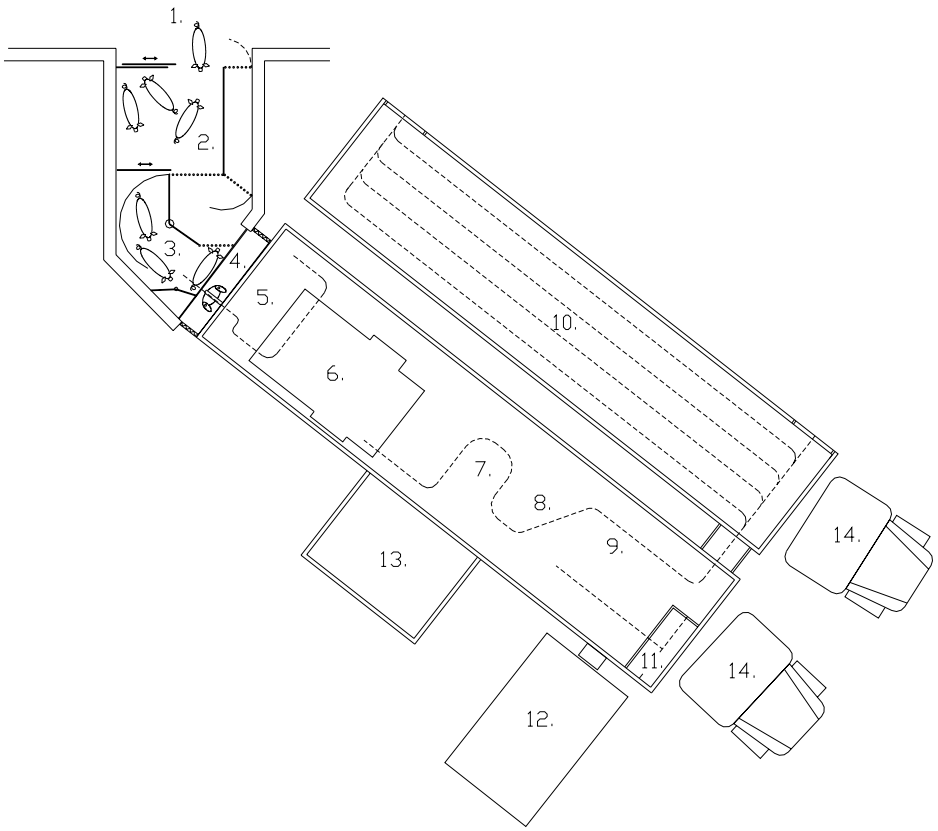

Figure 1. Example of the equipment for mobile slaughter of pigs connected to a stable. When scalding is used there must always be a separate trailer with a container for chilling.

1. Inspection (ante mortem) of living animals (within the last 24 hours before slaughter)
2. Raceway up to stunning
3. Stunning
4. Schackling and hoisting
5. Bleeding chamber
6. Skinning or scalding and dehairing
7. Evisceration and splitting
8. Post mortem inspection
9. Classifying and registration
10. Chilling, refrigerated section
11. Chill room for detained meat
12. Waste container
13. Staff premises
14. Separate lorry for transport of mobile abattoir and chill container

The slaughter unit for pigs weighs 22 tonnes and has a length of 13 m in transport, 17.5 m when parked for use. Corresponding figures for the unit for big animals are 32 tonnes, 15.5 and 19 m (www.atlweb.net). The units are built either on a

3-4-axis trailer with drawbar or on a 2-axis semi trailer. To tow the trailers, a heavy lorry is needed. There is also a separate vehicle to transport the container for chilling the meat. The waste is transported in containers with a vehicle that is capable of hauling any other regular container transports.

It takes around one hour to park and prepare the unit for operation, packing-up the unit is somewhat shorter. During slaughter, six personnel are needed for highest efficiency: two for bringing the animals forward and for stunning, one for bleeding and one for skinning or scalding, one for evisceration and one for weighing and classifying. In addition, one official veterinarian shall be present throughout both ante-mortem and post-mortem inspection.

The economic analysis for mobile pig slaughter in this report is based on the plan for the British unit. The calculations for the slaughter of cattle are based on data from the units for reindeer and buffalo. Generally, the chilling capacity of the units set the overall slaughter capacity. In the case of reindeer this is of less importance due to the naturally low temperature in the production area, as compared to slaughter in most other geographical areas.

Location and docking of the mobile abattoir at a farm

The possibilities for operating a mobile slaughter unit are dependent on the conditions of specific farmsteads. In a Swedish case study, the conditions for mobile slaughter on 12 farms with pig production were documented.

At most of these farms it was quite easy to find a way to place the mobile abattoir in front of the existing loading door. In one case it was very difficult to make room also for the chill container. For situations like that, the best alternative would have a mobile unit with a hydraulically extended chill section that is possible to fold in and out. This requires, in the case of pigs, that the animals be skinned instead of scalded, since a scalding tank is too large to be combined with the extending chill section.

It is an advantage if there is access to the back door of the chilling container for loading of carcasses to a transport vehicle. If not, they can be loaded through the front door, or the container has to be moved prior to loading. The placing of the unit also needs to leave enough room for a tractor to empty the waste container.

When unloading the mobile to be standing on legs, an area 20-m long is needed for the lorry to drive straight forward.

This case study was based on mobile abattoirs being available on the market at the time of the study, where the chilling unit was on one side and the staff premises and waste container on the other. These mobile abattoirs have an intake for the animals on the rear gable, but there is no area to stun the animal. An area for stunning must be created in connection to where the mobile abattoir is attached to the stable. This is described under "Docking unit with stunning area". Possibilities for different ways of docking the mobile unit are discussed under "Development of the docking of the mobile abattoir".

All farms must be equipped with a "unit" where the stable and the mobile abattoir are docked together. Amongst other things, the size of this unit depends on the design of the mobile abattoir, already existing loading areas in the stable, the wanted

time interval between collections of more pigs, feeding routines and number of staff. Also, the conditions in front of the building may have an impact. The docking unit should be easy to clean with water and possible to close up with doors.

The transport vehicle places the mobile abattoir approximately 0.5 m from the stable on its support legs at a level adjusted to the level of the stable floor. The present versions cannot be lowered below 0.4 m from the ground. The floors at several of the studied farms were just 0.1 m above the ground. This implies either a docking unit with a floor higher than the floor of the stable, or an insulated tightening wall along the bottom of the exit in the stable wall.

It is necessary to make the docking tight to avoid ice formation on the floor during winter and undesired draft on animals and people. There are air filled bellows with which it is possible to get a tight docking on all sides between slaughter unit and building.

Development of the docking of the mobile abattoir

To reduce the need of investments for each farm, the stunning pen should follow the slaughter unit. The unit could have an extendable part in the rear, which could also be possible to lower (pers. comm. Sandström, 2003). The feasibility of arranging this is somewhat dependent on what slaughter equipment is used. The preconditions are probably better with skinning than with scalding. The extendable part could be 3-4 m long and slightly narrower than the rest of the mobile abattoir, which today is 3.45 m (dependent on what equipment there is) (pers. comm. Sandström, 2003). Such an overhanging part would eliminate the need for a stunning pen in connection with the stable. For this arrangement to work, the inside of the stunning part of the mobile unit must be designed so that the animals do not hesitate to enter.

At some farms, it will be difficult to completely replace the need for a special docking construction on the stable. If there is not enough room in front of the building to let the mobile attach at right angle to the wall, the unit must be placed further from the stable to make room for the extending parts (chill section and staff unit) and the waste container.

If the extended stunning section of the mobile slaughter unit could open to the side instead of in the rear, the necessary stretch of the docking corridor would be shorter, when placing the mobile abattoir parallel to the building. It is possible to develop the extendable stunning section so that one can change between opening in the rear or to the side from farm to farm (pers. comm. Sandström, 2003).

Handling of animals and food hygiene

Animal welfare

According to a draft proposal for the organisation of official controls on products of animal origin for human consumption the official veterinarian shall supervise the animal welfare during transport and slaughter. If the rules concerning protection of animals are not respected, measures such as slowing down or stopping the process, may be taken by the official veterinarian (EC) No 854/2004.

The personnel's skills and experiences

The most important condition for good animal and food handling is interested personnel with adequate and continuous education as well as personnel, who possess other skills and are permitted to take their own initiative. Well-educated persons can and should take on responsibility. Appropriate education and responsibility leads to a higher degree of professional pride. To be the most proficient, the personnel must have good equipment and work in well-planned systems. Important experiences from Denmark and Sweden are that several measures taken to improve animal welfare are also economically profitable.

Another important condition is that the personnel has a given right to express their opinions concerning work management and the work environment and to take part in the planning of both. This means that the management person has to have adequate education in good animal and food handling and for managing personnel. He or she should also be in close contact with the actual work being done in the slaughter unit.

Environment and heredity

Animals can be difficult to handle during transport and slaughter dependent on both their heredity and the environment where they were raised. Results from research showed that regular good animal handling and access to toys such as chains or rubber parts to reduce inactivity resulted in pigs that were easier to handle. Pigs from larger groups were less aggressive and outdoor pigs were calmer in new environments than intensively reared pigs.

Impact of transport

Just about all animals are transported before slaughter in Europe today. With an ongoing decrease in the number of abattoirs, the transportation distance in remote areas increases. An important advantage of mobile abattoirs is that the animals do not need to be transported. However, there is a limit on how often the mobile unit can be moved. There may be situations where the following question arises: should a small group of animals be transported to a nearby farm where the mobile unit is set up or should the mobile unit be moved?

In reviewing field research on the impact of transports on animals it was revealed that many studies have been conducted. Nevertheless, only few studies are comparing animals that are transported prior to slaughter to animals that are not: Brown et al. (1998) compared the meat quality from two groups of pigs. One group was exposed to minimum stress and had close contact with their personnel. The other group was commercially handled. Samples of blood showed differences in the level of both physical and mental stress. In most of the parameters concerning meat quality the differences were small or none. Fàbrega et al. (2002) compared one slaughter process (transport time, lairage time) that was long (3.25 h transport and 12 h lairage) and one that was short (30 min transport and 2 h lairage) by measuring the heart beat frequency, for example. The measurement showed that loading induced more stress than transport. Wiklund et al. (2001) had similar results in a study on reindeers, where the level of cortisal increased in connection to loading and unloading.

The rate of slaughter

At a big stationary abattoir, a high slaughter rate is economically essential. This high rate is difficult to pair with good animal treatment. To solve this issue and to minimise the use of electric prods, systems where pigs are handled and even stunned in groups have been developed. Danish abattoirs have been leading in this field as a result of the research at the Danish Meat Research Institute.

With mobile slaughter units, the rate of slaughter is lower and the demands on quick handling of the animals are not extreme. Individual stunning in a well-planned system can probably be used without lowering the slaughter rate. It is always important however to adapt driving and stunning techniques to the expected slaughter rate. Otherwise, there is an obvious risk for stress leading to bad working conditions, bad animal handling and damaged meat.

Premises and handling of animals

In designing waiting pens, driving paths and stunning areas, the following criteria need to be fulfilled in order to reduce stress and facilitate the handling of the animals:

- uniform floor material,
- carefully prepared light,
- low noise level,
- appropriate temperature and ventilation, and no draft,
- access to drinking water.

If there are differences in the floor surface, this can be camouflaged with e.g. sawdust or chopped straw.

Ways to take advantage of an animal's curiosity is to have closed walls instead of grills and to let them move towards lighter areas. Cattle e.g. prefer uniform softened surfaces and tend to walk better on an upwards incline. Animals that are kept loose in groups should be moved in groups for stunning. One method that is working very well in weighing situations and in stationary abattoirs is having cattle move in a curved walk.

Slaughter

There is a lot of research on the physiological impacts of the stunning method. In contrast, knowledge about how often stunning fails in practice is very limited (private comm. Algers B., 2001). Research and practical experiences indicate that an animal is not stressed standing beside another animal being stunned as long as the first animal is not stressed by other factors (Grandin, 2000). For herd animals, it is better not to separate the animal from the others in the group before stunning. However, the sticking and bleeding is often done away from living animals.

Spare equipment must be kept at the place of slaughter for emergency use 93/119/EC.

Stunning of cattle

For cattle, captive bolt or bullet is suitable for stunning. The pistol shall be placed at a right angel to the skullbone. Before stunning, cattle are to be restrained in an appropriate manner to spare them any avoidable pain, suffering, agitation, injury or contusion. They can be restrained in a restraining box. Since it has to be very steady, adaptable to different sizes of cattle and have one side, which can be opened, the restraining box where cattle are to be stunned should preferably belong to the mobile abattoir. From there, the animals need to be moved quickly to where they are drained of blood. Draining by cannula and pipe may be preferred instead of above the grid in the slaughter area. It is important that the personnel are well protected against kicks from the stunned animal.

Stunning of pigs

For stunning of pigs gas, electricity and captive bolt or bullet can be used. At stationary abattoirs the method of gas stunning is becoming more common. The advantages are that pigs can be stunned in groups, no restraints are needed and the flock behaviour can be utilised. The technique for stunning by gas has not been adapted for mobile slaughter units. The other methods for stunning and a suggestion on how to handle pigs during stunning and bleeding in a mobile abattoir are described in the Case study (page 20).

Bleeding

Before sticking and bleeding, the personnel should make sure the animal is unconscious. The bleeding should begin immediately after stunning and before the animal regains consciousness 93/119/EC. This implies that after electrical stunning the bleeding should begin within 17 seconds (pers. comm., Barton Gade) and when using captive bolt, bullet or gas within 60 seconds. After bleeding, the personnel should make sure that the animal is dead before further processing.

Bleeding in a mobile unit

Today bleeding of reindeers is made above a grid. An alternative is to use a cannula attached to a tube. With this method, separate sterilisation equipment for the cannula is necessary.

Scalding and skinning

Pigs are traditionally scalded. The hide of cattle is usually pulled off by attaching ends of the hide to a drum with chains. This method can also be used for reindeer, sheep and older pigs e.g. sows, which have strong hides. Fattening pigs have weaker hides, therefore, they can be skinned by drums pulling the hide from each side of the body, from the belly and towards the back. This method was found useful for pigs in several studies in Denmark and Sweden. When pigs are skinned the best hygiene was achieved when using a conveyer to move the carcasses on the rail rather than manually.

Scalding and skinning in a mobile unit

Pulling off the hide in a mobile abattoir, from e.g. cattle, differs from the technique used in stationary abattoirs in that the drum is mounted on the floor instead of in the ceiling. This means the pulling starts from the hind legs instead of the front legs. This method cannot be used for fattening pigs since the hide is too fragile. An alternative, to scald in a tub, which is used in stationary abattoirs is to scald hanging pigs, however it takes up a lot of room and is too expensive for use in a mobile abattoir. Scalding in a tub could be a viable alternative.

If the same equipment is to be used for skinning both pigs and cattle, it needs to be adjustable for different carcass sizes and adaptable to the weaker pig hide. An alternative technique could be developed, where the carcass is placed in a cradle on its back. The hide is parted over the belly and fixed to the cradle on the sides and as the carcass is lifted some manual cutting is being done. This technique does not work for products that are traditionally sold with the rind left on.

Evisceration

The viscera should be taken out as soon as possible after stunning and bleeding. The parts of a slaughtered animal (viscera, carcass etc) must remain identifiable as belonging to a given carcass until post-mortem inspection is completed (EC) No 853/2004. The carcass of cattle should be marked in a way so that their origin can be traced until cutting of the meat.

Official inspection

Inspections in question are:

- veterinary control of living animals and of meat,
- audits of HACCP-based procedures,
- general hygiene check of the premises, equipment, personnel and collection of samples for checking the presence of specific bacteria, diseases, antibiotics etc,
- water quality,
- waste management.

In abattoirs, at least one official veterinarian shall be present throughout both ante-mortem and post-mortem inspection. However, an authority may adapt the veterinarians' presence in certain abattoirs (EC) No 854/2004.

Post-mortem inspection and detained meat

Before the post-mortem inspection is completed the carcass and viscera must not come into contact with other carcasses or wall surfaces (EC) No 853/2004. The new regulation (EC) No 853/2004 allows post-mortem inspection after splitting the carcass or after parting it into quarters. When the mobile abattoir is moved the inner ceiling is so low that full sized cattle must be parted into quarters. The conditions are the same in a chilling container.

There must be lockable facilities for the refrigerated storage of detained meat and separate lockable facilities for the storage of meat declared unfit for human consumption (EC) No 853/2004.

Food business operators shall not place on the market pork or beef unless it has a health mark (EC) No 853/2004, which the carcasse receives after a successful post-mortem inspection. This probably implies that, the carcasses must be either approved by a health mark or discarded before they may leave the mobile abattoir. Whether the abattoir may be moved, while containing detained carcasses, (e.g. while awaiting results from laboratory tests), will have to be decided by the local veterinarian authorities for each abattoir.

Most suitable is probably to place detained carcasses in separate lockable facilities for chilling and storing detained meat inside the mobile abattoir. If the viscera are put into plastic bags they can hang with the carcasses in the chill facility but they should be discarded when the inspection is completed. Meat that has been declared unfit for human consumption must always be stored in separate lockable facilities (EC) No 853/2004.

Chilling system

Meat and offals should be chilled immediately after slaughter to no more than +7 °C for meat and +3 °C for offals (EC) No 853/2004. The chilling process of a carcass may take several days without causing any negative consequences. In Sweden, it is common to cool a pig to +7 °C within 24 hours and cattle within 48 hours. Chilling pigs too fast or to slow can lead to different quality problems depending on the stunning method. The best way to chill pigs depends on the stunning method and is discussed in the passage on stunning (page 21).

To maintain good hygienic conditions, the carcass should quickly become cool and dry on the surface. It is extremely important that partly chilled meat is not allowed to increase its temperature or surface moisture, which can happen due to lack of chilling capacity when warm carcasses are added. The carcasses must not hang so that they contact each other or the walls, otherwise the chilling process is disturbed and the meat quality affected. The food business operator must ensure a continuous decrease in temperature during chilling of the meat (EC) No 853/2004.

Premises specific to chilling must have equipment to take care of condensation, which containers for transporting chilled goods usually do not have. The containers are not built for chilling, but rather to maintain the goods at a low temperature.

Refrigeration in a mobile abattoir

With mobile slaughter, quick chilling is of more interest than in stationary slaughter. The mobile chill room has limited space and may need to be emptied during the day. If the carcasses are chilled in a hydraulically folding out chill section, attached to the mobile abattoir, the chill section must be emptied before the mobile abattoir can be moved. Before moving the mobile unit the carcasses can be transported to a separate container for continued chilling. A chilling container 14 x 3.1 m can hold about 25 cattle (parted in four parts) or 110 pigs (split in half). It is recommended that the chilling capacity is practically studied before starting the slaughter at full scale. The carcasses could also be placed in

a stationary chill room at the farm. The authorities can allow transport of the carcasses with a temperature above stipulated storage temperature; however, the transport time must not exceed 2 hours (EC) No 853/2004. The carcasses should not be transported until the surface of the carcass is dry and cool.

Cutting warm meet (cattle meet) can substantially reduce the chilling space needed. This can also contribute to a better working environment since cutting cold meat is bad for the hands and fingers. In this case, the meat must be transferred to the cutting room either directly from the slaughter area or after a waiting period in a chilling or refrigerating room (EC) No 853/2004.

Normal transport vehicles for carcasses only have refrigeration units with the capacity to keep chilled meat cold, not for chilling it. If the mobile unit is used for slaughter all year around a chilling system with high capacity must be used unless the climate is cold in summers.

Water

It is recommended to investigate the access of water and its quality well ahead of time. Water used for consumption, cooking or preparing food is regarded as drinking water. Consequently, the water used for slaughter must have the same quality as drinking water and it should be analysed regularly. After December 25th 2003, applicable regulations for drinking water quality are 98/83 EC, adapted to the EG-directive 2000/60/EC.

A considerable part of the water used for slaughter is heated, which has some cleaning effect, but cold water is also used for rinsing, for instance. Furthermore, heat alone cannot eliminate chemicals. Chlorine can be used for cleaning the water from bacteria but is not effective on chemical substances.

By completing a thorough investigation of and planning according to the water supply from the beginning, one minimises the risk of setbacks during slaughter later on. High quality water can be transported to the mobile abattoir in water tanks. The amount of water used depends on the technique and less water is needed for skinning (~4-7 m^3) compared to scalding (~8-10m^3).

Responsibility of producer, flow and quality

If water is to be taken from an internal well on a farm, the quality must be checked and approved in advance. The supplier, in this case the farmer, is responsible for the quality. Sampling for microbiological and chemical analysis (audit monitoring) needs to be done. It is also advisable to let a geological expert consider the position and construction of the well. The pressure and flow capacity at the tap point must be sufficient. Deep bore wells will work in many cases, while dug wells are more questionable to use. After the analysis, the water supply should be discussed with the local veterinarian authority.

Commercial use of water implies routines for cleaning of reservoirs. A reservoir in this case can be a pressure tank or something similar. There shall also be a description of the water distribution system and a specified person responsible for the operation of the system.

Quality requirements and frequency of sampling

If the enterprise wants to haul water from private wells, the water must be analysed in advance as mentioned above and regularly thereafter (check monitoring). This is to guarantee that the water quality has not deteriorated by poor hygienical conditions in the well, reservoirs or pipes. Water used for slaughter shall fulfil the requirements for drinking water, 98/83 EC. Before the water is used, an audit monitoring must be completed. The purpose of audit monitoring is to provide the information necessary to determine whether all of the Directive's parametric values, of microorganisms and chemical substances, are complied with. All parameters must be subject to audit monitoring unless it can be established by competent authorities that a parameter is not likely to be present. Parameters for radioactivity have special monitoring requirements.

The purpose of check monitoring is to regularly provide information on the organoleptic and microbiological quality of the water. This is done by analysing some chosen parameters stated in the Directive. Member States may add other parameters if they deem it appropriate. The sampling requirements can for instance be included in a HACCP-based procedure for the mobile abattoir. The Member State authority may decide about the frequency of sampling when the water distribution is less than 100 m^3 per day.

Rate of use and the addition of chlorine

Whenever there is a break in the use of the slaughter unit for vacation or for another reason, it is advisable to chlorinate the water to avoid microbiological growth in tanks and pipes. The old chlorinated water must then be replaced with new fresh water before the mobile abattoir is operating again.

Origin labelling

One of the interesting advantages with mobile slaughter units is the possibility to easily label and handle small quantities of meat separately. The meat can be delivered fresh to the local market.

Case study – some special considerations concerning pigs

In meat especially pork, a too large decrease in the pH-value during the slaughter process caused by stress will result in PSE meat (Pale, Soft and Exudative). In Sweden, the breeding programs have successfully reduced the risk of death and PSE due to stress before slaughter. However, the risk of PSE meat due to a pH drop in the muscles after slaughter still exists. Also, the kicks and cramps caused by electric stunning can contribute to the occurrence of PSE.

The object of this case study (Benfalk et al., 2003) has been to suggest a method to slaughter pigs in a mobile abattoir that is based on comprehensive and proper animal handling practices. The choice of method for stunning the animals, as well as the demand for high meat quality, has impact on how the premises of where the animals are handled should be designed. This chapter begins with an exposition of

factors, especially choice of stunning method and its affect on meat quality. Thereafter suggestions on how to design waiting areas (lairage), stunning areas and how to dock the mobile abattoir are made. There is also a presentation on the labour requirements for handling the animals from their pen in the stable to stunning.

Stunning methods

The recommended method to use on pigs in mobile abattoirs is stunning with electricity. Combining electrical stunning with cardiac arrest (heart stop) with electricity is another method discussed for pigs. Stunning with bolt or bullet is less suitable and as mentioned before gas stunning has not been developed for mobile slaughter.

Stunning with electricity

In smaller abattoirs, electric stunning is often practiced. The animals need to be used to being handled by people. Heavy strains on the animals, such as internal bleeding and broken shoulder-bone, often lead to deterioration in the meat quality. Electrical stunning leads to more bleeding than does the use of CO_2. During electrical stunning the blood pressure increase is higher and this, in combination with the heavy contraction of the muscles, is probably the reason for more frequent bleeding in the meat. Fractures, sometimes completely without bleeding, occur only with electricity. By holding the tongs around the pig's head to make it fall slower the risk of fractures is lowered. Bleeding should start within 17 seconds.

A Danish study concludes that electric stunning gave more tender meat, but also more PSE meat, than did stunning with gas. To limit the reduction of the pH-value after electric stunning and the occurrence of PSE induced thereafter, especially in the deepest part of the ham, it is important to effectively chill the meat. To reduce the frequency of PSE, there is also a need to reduce muscle cramps after stunning. By reducing the cramps, the bleeding will also be less frequent (Økologisk jordbrug, 2002).

Electrical stunning and cardiac arrest

With electrocution, the animal cannot wake up before bleeding and the contractions after stunning are reduced. The animal is put to death directly after (2 sec) it has been stunned by electricity, by putting the electrodes against the heart, which will then stop. Before cardiac arrest the animal must be stunned, otherwise the animal will suffer from severe pain. A well performed stunning should affect the brain and knock out the consciousness without any pain or discomfort for the animal.

After stunning, if the pigs are killed by electrocution there would be less time stress between stunning and bleeding. The stop of the heart does not reduce the amount of blood released from the animal (Warriss & Wotton, 1981). Still, it is advisable not to wait more than two minutes after death before starting the drainage. If so, some blood will stay in the big veins, liver and guts. However, there will not be more blood in the meat due to postponed drainage.

Equipment for electrical stunning and stopping the heart

Common equipment for electric stunning is the size of a shoebox and connects to an ordinary single-phase socket. From the transformer there are 3-4 m long spiral cords attached to the tongs. The transformer box is prepared for wet environments. German equipment has been developed to combine stunning and heart stop, which includes transformer, control unit and tongs. The amperage and voltage need to be lower for the heart (1.3 A, 50 Hz, 300 V) than for the head (1.5 A, 50 Hz, 380 V).

Stunning with bolt or bullet

Stunning with bolt or bullet is not as suitable for pigs as for cattle. One reason is that it can be difficult to approach a pig from the front and to touch its head. Also, the animals vigorous kicking that follows the stunning with bolt or bullet can easily result in poor quality pork.

Animal handling, feed and water

The areas where the animals are moved should be designed in a way to make the animals move in the right direction by themselves. The environment should resemble as closely as possible the environment in the stable, until the animals are stunned. Big differences in floor levels must be avoided. It must be possible to bleed the animals immediately after stunning (within 17 sec after electrical stunning). The handling of the animals must always be such that it can be shown to any consumer.

Feeding the pigs

Pigs should not be fed the morning before slaughter. This makes them easier to move and less sensitive to stress. There are also advantages in less manure and less content in the intestines. When mobile slaughter is practised it is important to have a strategy for how to feed and water all the animals in the stable. In pig production there is usually a variation in body weight between animals in the same pen. The first pigs to be slaughtered are together with those who will be slaughtered at a later date. Mobile slaughter will also have an impact on the feeding of pigs that will not be slaughtered. It is very stressful for pigs to experience other pigs being fed, but not them. Hence, the remaining pigs, in the same section, should not be fed until all the pigs that will be slaughtered are removed. Instead, all the pigs can be fed during the night before slaughter. This can replace the morning ration. At the next feeding time, all pigs in the section could be given some straw and fluid feed (diluted).

In many stables the gates to the dung area will be shut as pigs are hauled for slaughter. This will lead to some littering in the pens. However, the amount of manure will be less than a usual day due to the different feeding times.

Water

When the pigs are in a waiting pen (lairage) they must have access to water (93/119/EC). If they are taken directly to stunning and slaughter, water can be omitted in the slaughter area. However, it is important that the rest of the pigs in the stable can access a water point at all the time. They must also be able to drink when the gates to the dung area are closed. Some farmers reported that they can solve this by distributing wet feed with very low dry matter content.

Prevention of stress and tail biting

In some big stables, there could be hauling of pigs going on for five hours or more. One farmer pointed out the risk of stress when there is activity in the stable all day long. Another farmer noted that his pigs were not bothered at all if he was busy repairing something in the stable for a day. Most likely, there are differences between herds in this matter, depending on e.g. automatic or manual feeding. When there are pigs left for slaughter at a later event or even the next day, one needs to pay attention so that tail biting does not occur. To prevent this, extra straw or something of a similar nature can be given. Also, during lunch break the gates to the dung area (if pigs are moved from the pen through the dung area) should be opened and the light adjusted.

The pain and stress associated with identity branding can be avoided with mobile slaughter. The pigs do not have to be marked with their identity since they do not leave the farm alive. It is sufficient to mark the slaughtered pig.

Stunning area

When relocating pigs, the animals should move themselves because of their curiosity. The need for driving them should be minimal. It is important that the more cautious individuals don't loose contact with the "leaders" bringing the group forward. Labyrinth design tends to slow down the leader and keep the group together. Narrow paths (one-line traffic) leading to stunning are proved to have high stress impact on the animals. It is better to move and stun pigs when they are in a group.

Pigs tend to walk towards lighter areas, if not blinded. Lamps should preferably light up the floor without creating shadows. The climate in the premises needs to be adapted to what the animals prefer. This means appropriate ventilation, and in Sweden also isolation from cold. Draft should be avoided. When designing driving paths, stunning area and pens for waiting, the following criteria must be fulfilled in order to reduce stress and facilitate the handling of the animals:

- uniform floor material,
- carefully prepared lightning,
- low noise level,
- sufficient ventilation and no draft,
- access to drinking water.

Pigs walk upwards, but the slope in a raceway should not exceed 17 %. The floor of the stunning area should be plain and in the same material, or at least similar, to the rest of the stables. The most common floor is concrete. All farms in the case study had concrete. To make it easier to move the animals, changes to the floor material need to be avoided. Changes make the animals hesitate. They might register the change as a hole or barrier, which scares them. If there is a change, it could be camouflaged by straw or another bedding material.

Pigs like to walk towards lighter areas, as long as they are not blinded. This is easy to arrange with a well-lighted stunning area. It is important that the floor is lighted without any shadows.

It is also important that the noise level in the stunning area is low, in spite the fact that it is close to the slaughter activity. Sounds from the slaughter unit can be diminished by transparent plastic strips, 5 mm thick. These strips are easy to rinse with water, and to pass by.

The climate in the waiting pen and the stunning area shall be adjusted to the thermal comfort preferred by the animals. This means the premise needs to be isolated and have sufficient ventilation. The ventilation should be designed such that the animals do not need to walk against the airflow when approaching the stunning area.

Docking unit

The suggestions on how to attach the mobile abattoir to stables presented below are based on the design of the mobile units in use today. All these units have animal entry placed in the rear. Stunning with electricity is assumed to be conducted in the docking unit of the stable, while bleeding is done inside the mobile unit. To minimise the time between stunning and bleeding the tongs can be kept around the pigs head until it has been shackled and hoisted. In the examples below, a minimum of one waiting pen and one stunning pen is installed at each farm.

The alternative described above in "Location and docking of the mobile abattoir at a farm" implies a floor in the docking unit on the same level as the floor of the mobile. If there is a downward facing slope in the building, the rear of the mobile unit will have to be lifted. Special consideration must then be put into how to construct an opening that will be possible to dock and be tight.

To be independent from the slope of the ground, a technique for lifting the pig into the mobile abattoir after stunning but before bleeding is needed. This could for instance, be a lifting device combined with an inclined plain or a lifting table. It is important, that this technique is sufficiently examined to ensure a good working environment in spite of the difference in floor level.

In Figure 2, one suggestion on how to design the docking unit between the stable and the mobile abattoir is provided. By demoting gates in the lower corner, the stunning pen can also be used for sows.

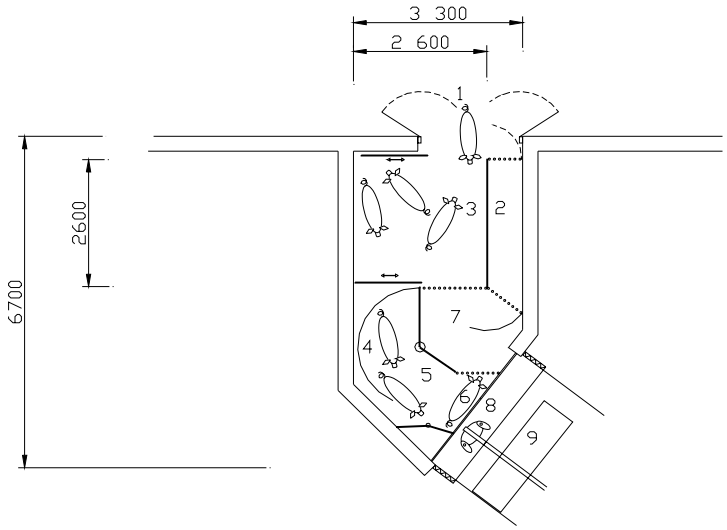

Figure 2. Docking unit with waiting pen and pen for stunning designed for pigs.

Explanation to Figure 2:

The animals are moved from the stable (1) to the waiting pen (3), then to the pen for stunning (4) and to the stunning area (6). The personnel executing the stunning are in the pen (5). There is a path for personnel to enter and exit the mobile abattoir (2). (7) is a path and reserve area.

The animal's body is lifted by a hoist from the stunning pen (6) with the electric tongs still on its head. The body is then transported on a rail (8) to the bleeding area (9) and onto the scalding tub.

Several gates are used. Some of them are opened sideways to let the pigs through while others can be used for moving the pigs forward. Arrows and dotted lines indicate the functions of the gates.

The objective of the corner of the stunning pen (6) is to make the stunning safer without separating the animal from the rest of the group. The pen walls should be made so that the pig can easily see other pigs in the waiting pen.

The idea behind the reserve area (7) is to be able to open up and let the animals walk through, in case more than one pig enters the pen and the animals refuse to walk backwards.

The following provides an alternative method for lifting the animal at area (8). For staff to avoid bending down to hook the animal body there could be a shutter in the wall of the stunning pen. On the other side of the shutter, approximately 15 cm below the floor in the pen, there would be a tray. Immediately after the animal is stunned the shutter will open so the animal falls on a tray, which is then lifted mechanically to a convenient height for the personnel. With this alternative electrocution (cardiac arrest) will probably be needed after the electrical stunning to avoid any risk of the pig regaining consciousness before bleeding.

Waiting area (lairage), alternative 1

One alternative is to have a rather small waiting area, at the docking unit, with 1-3 pens (Figure 2), holding 6-18 animals. With a slaughter rate of ~30 pigs per hour the animals will be slaughtered within approximately half an hour. One person needs to be available for moving animals from the pen in the stable to the waiting area. The advantages of this alternative are: the animals only need to be in the waiting area for a short period, the costs for the building extension (docking unit) is minimised and the person doing the stunning receives some assistance. It is probably most efficient that personnel from the slaughter team handle the pigs from pen to slaughter. This means more work for the team and that the farmer will not have to sort out and fetch pigs.

Following safety procedures to prevent transmission of infection i.e. showering and changing clothes and footwear between farms is especially important in this alternative.

Waiting area (lairage), alternative 2

Another alternative is to build a waiting area to keep pigs for half a day's slaughter; approximately 70 pigs (figure 3). The floor area of the pens in Figure 3 corresponds to a situation where 50 % of the pigs have a living weight below 120 kg (i.e. 91 kg slaughtered weight). Should all of the pigs weigh less than 120 kg, the area could be diminished by 30 %. In alternative 2, the farmer and a helper sort out and move the animals to the waiting area. The slaughter staff move the animals from the waiting pens to the stunning area.

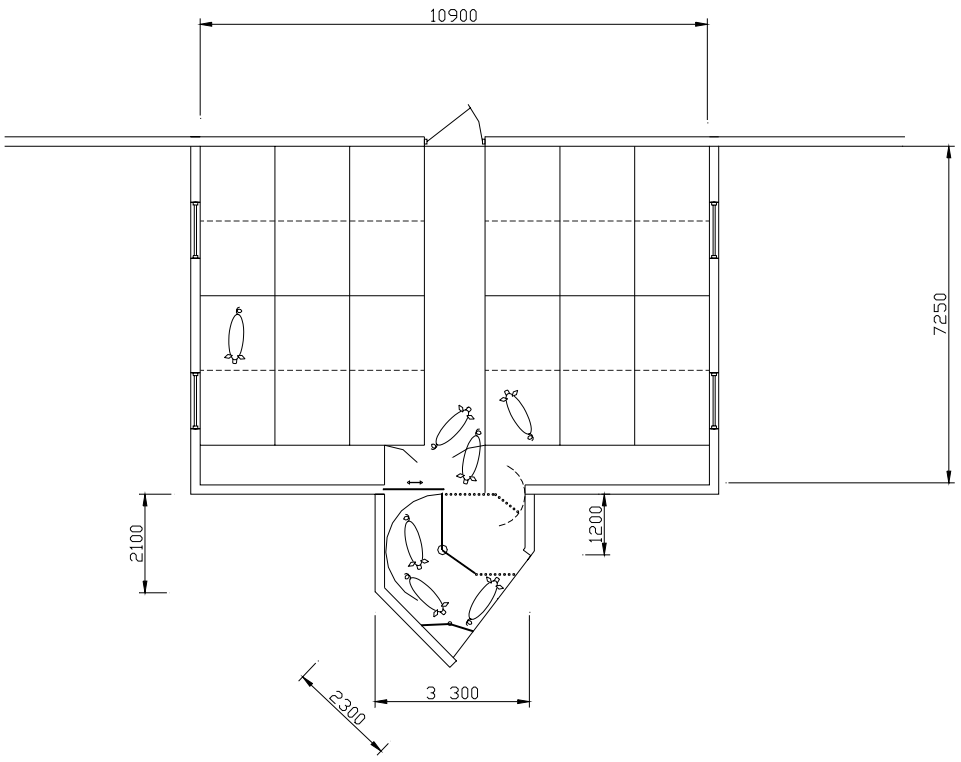

Figure 3. A building extension holding 12 pens for six pigs each. The pens can be parted into two. Docking unit with stunning area.

A big waiting area lets the farmer concentrate on other tasks between the morning and lunch. However, this second alternative is not preferable when slaughtering only a few pigs from each group/pen. Pigs from different pens should not be mixed together until a few minutes before slaughter. If they have to wait together, unfamiliar individuals will start to fight with each other, which will lead to stress and possibly injuries. Ideally, these pigs should wait one by one. This, however, makes it more difficult to concentrate on the fetching.

With a big waiting area that has several pens, the slaughter personnel do not need to sort animals. Still, one should calculate for two persons to fetch pigs from the waiting pens and to stun and bleed the animals, at a slaughter rate of 30 animals per hour. Although the amount of work is less than alternative 1, it is too much for only one person. In some stables the fattening pens are close to the exit, which explains why the difference between fetching the animals in their fattening pen or a waiting pen is small.

Waiting area (lairage), alternative 3 – a mobile unit

A couple of farmers have suggested a mobile unit that holds waiting pens could follow the slaughter team. If such a unit could fit into a lorry platform of 9 x 2.4 m, it would hold 35 animals, with no personnel aisle. The unit would need to have gates, insulation, ventilation and a water distribution system. The main advantage would be to divide the cost of waiting pens on all producers. The disadvantages are that the unit would only keep pigs for one hour of slaughter and that the unit needs to be transported and docked from the slaughter container to a stable. It will take up more space on a most likely already full farm yard. Slopes and other level differences may make this alternative very complicated on some farms.

Labour requirements with waiting (lairage) areas of different sizes

Labour requirements for animal handling

The time needed, to fetch pigs for slaughter, depends mainly on how the pigs have been handled during raising, the skill of the personnel and the design of the driving aisles and waiting pens. Based on information and time studies at the farms in the case study and a farm with a connected slaughterhouse, the time needed for fetching 120 pigs was calculated, if waiting pens according to alternative 1 or 2 (above) would be used.

Assumptions: Ten fattening pigs per pen. At the first slaughter occasion one pig is picked from each pen. Second slaughter occasion three pigs are fetched per pen. And at the final slaughter occasion the remaining six pigs per pen are slaughtered and all the pens are emptied. The average time to move 120 pigs from the pen to the waiting pen was calculated:

In **alternative 1**, with only one to three waiting pens, the time calculated to move the 120 pigs to the waiting pens was two hours, with only one person. Moving the animals onto stunning, a task integrated with the stunning, was assumed to take an additional half hour.

In **alternative 2**, with a large waiting area, the time calculated for two persons to move 120 pigs to the waiting pens was about one hour. On top of this comes the

labour requirement for moving the animals from the waiting pen to stunning, which was assumed to take ~ one hour.

The calculations indicate that labour requirements might be higher with the big waiting area, **alternative 2**, since the animals need to be picked up twice and the distance from waiting pen to stunning is longer.

With **alternative 1** it is likely that slaughter staff will be engaged in moving pigs to the waiting pens and further to the stunning pen as this work is going on all day. If there is time left, this person will assist in stunning and bleeding when not fetching pigs.

An economic analysis was made for two levels of production: ~2000 and ~4000 fattening pigs per year (Benfalk et al., 2003). The results indicate that at both production levels, the cost of using slaughter staff for fetching pigs from the stable (alternative 1) was substantially lower than building the large extension (alternative 2) for waiting pens.

Chilling

The possibility to chill pigs in a mobile container was theoretically investigated using the following data:

- pig carcasses were chilled to +7 °C within 16 hours under Swedish conditions;
- slaughtered weight, 88 kg (fattening pigs), the carcass is scalded, skull is taken off;
- slaughter rate 30 pigs per hour. U-value of walls, ceiling and floor a maximum 0.4 W^2/m^2 °C, room temperature in chilling container 0-2 °C;
- carcasses are hanging on a hook from a rail 2.15 m above the floor (sows are parted) and distance between the rails was assumed to be 55 cm and the distance between the hooks 25 cm. Each hook must have a stop because it is difficult to place the container completely horizontal.

If the pigs are scalded it is not possible to have a hydraulically extending chill section because the scalding tank takes up too much space.

The electrical effect needed for chilling was calculated in two examples with fully insulated containers and the refrigeration unit placed inside the container:

1. Container: 7.25m x 2.45m x 2.9m (height) inside, 4 rails: 38 pigs – 28 kW

2. Container: 13.6m x 2.95m x 2.9m (height) inside, 5 rails: 111 pigs – 56 kW

It is important to ensure the cold air is evenly spread. One technique that has already been used in some abattoirs is to hang textile channels below the ceiling. The channels have plastic cones to spread the air. Another technique that is interesting is one that is used for freezing bread (“Polarbröd”). In order to have control of the cold air a double ceiling is used and the air is sucked through the products (pers. comm. Larsson).

Provided the chilling effect has been correctly dimensioned, it will be the slaughter rate and the warm air coming through the door that will have most impact on the chilling process. To minimise the warm air coming through the door, the temperature could be lowered in the sealed link between the abattoir and the chill container.

When the carcasses are being chilled a lot of condensation is formed. The slaughter of 125 pigs gives about 200 litres of condensed water that must be removed from the chilling container.

Carcasses must not come in contact with other carcasses or the walls until the post-mortem inspection is completed (EC) No 853/2004. When handling detained carcasses it will probably be most suitable to place them in separate lockable facilities for chilling and storing detained meat inside the mobile abattoir. If the viscera are put into plastic bags they can hang with the carcasses in the chill facility but they should be discarded when the inspection is completed. When meat has been declared unfit for human consumption it must always be stored in separate lockable facilities (EC) No 853/2004. An approval from the local veterinarian authorities will be needed, if the abattoir is to be moved, while containing detained carcasses.

Working Environment

Working environment consists of all factors that can affect the working situation. It concerns the technique design, work organisation/activity, the design of physical working stations such as local, machines and other technical devices, use of chemical material as well as hygienic work conditions. It also deals with the personnel's psychosocial conditions, for instance, variation of tasks, social contact and the co-operation and influence in work situation as well. Social contribution to this aspect is aimed at prevention of illness, accidents and improvement of the work environment. This is ensued with help of legislation and investment by authority for oversight and research. However, there has been no specific labour legislation related to abattoirs. Experience shows that frequent care of the surroundings is positive for the work environment, but there is no absolute coupling between smaller environmental load and work environment. In addition, application of new technology sometimes causes some problems in working conditions, which requires studies on working environment.

A pilot study of working environment in stationary compared to mobile abattoirs was conducted. Working conditions in stationery abattoirs were investigated by a literature review and an in-situ survey for a stationery abattoir for cattle and pigs. Some workers were interviewed with a questionnaire during the survey. The working conditions in a mobile abattoir were investigated by a video recording showing the whole procedure of slaughtering cattle. Positive and negative factors in the working environment in mobile abattoirs as compared to stationary abattoirs were identified and discussed.

Literature review of work environment in abattoirs

The literature review has shown that workers in the abattoir are exposed to high-force, high-velocity and repeated manual work tasks. Research on the improvements of the working environment in the abattoirs has been studied for many years. The environment has been improved with newly developed technologies and occupational training for the workers over the last 5-10 years. Frequent labour turnover due to musculo-skeletal injuries in spines, shoulders, arms and cuts to hands/fingers have been reduced after improving the working environment and occupational training. (Veibäck, 1991; Jönsson, 1992; Sonesson, 1994; Olausson, 1995; Wenander, 1995)

Some studies have shown that an elevated risk for rotator cuff tendonitis occurred when workers were operating at or above shoulder level. Even with shoulder elevation above 30 degrees, muscle blood flow in the supraspinatus could be reduced (Hagberg *et al.*, 1987; Järvholm m.fl. 1988). Anderson *et al.,* (1995) found that repetitive work at shoulder level with upper arm abduction or flexion above 30 degrees was associated with risk for subacromial pain. Exposure duration and age were both important factors. Based on this knowledge, it could be proposed that reduction of daily exposure time is the most effective preventive action among workers performing high-speed monotonous work with the upper arm elevated. In order to reduce the risk of shoulder pain, the workstation should be adjusted so that the upper arm is lifted as seldom as possible.

Many tasks involving heavy lifting were eliminated through the improvement of the working environment in a Swedish abattoir. For instance:

- installation of hanging evisceration of large slaughter cattle,
- replacement of manual skin removal and splitting of the carcass by automatic machines,
- rebuilding of the cutting line workstation with an elevator, etc.

After the introduction of the new production system, the personnel are able to rotate work stations more often. Work-related diseases were reduced, resulting in a decreased in sick leave from 60 days/employee in 1991 to 23 days/employee in 1993 (Sonesson, 1994).

One abattoir reported that there were some problems related to the working environment, such as lifting heavy things, a one-sided workload and work under cold condition, etc (Johansson, 1995). In a project on the working place program, staff was allowed to individually adjust their own working place. The cold outdoor work was replaced by indoor work as much as possible. Also, work organisation was changed through communication of responsibility for competence in the project. It was shown that the employees were more motivated and satisfied with their work due to the improvement in the work environment.

However, abattoir workers are still one of the groups with the highest incidence of occupational disease according to statistics from the Swedish Work Environment Authority and Statistic Office (Arbetsmiljöverket, 2001).

A heavy workload and highly repetitive tasks readily causes musculoskeletal injuries in the shoulders, arms and hands (Hägg, 2001). Occurrences of cuts and

thrust injuries to the fingers and hands as well as cutting-up and packing meat in cold environments (additional cold exposure) cause a higher risk for occupational diseases than among other work groups (Rintamäki, *et al*, 2000).

High-force and high-velocity tasks as well as insufficient protection could be major reasons for the occupational injuries. It is important that the personnel use protective equipment to diminish the risks of occupational injuries, such as protective clothing against cold or cutting injuries. It is required that cut protection equipment must be applied when cutting meat (Olsson, 1998).

A field study in stationary abattoirs

A survey of working conditions in a stationary abattoir for cattle and swine in Sweden was carried out. Some workers were interviewed with a questionnaire during the survey. The purpose of this field study was to describe what kind of work tasks could cause problems with respect to working environment.

Slaughter of cattle

There were four male butchers aged 25 to 53 years. One of them takes care of live animals at barn and the others are responsible for the slaughtering. They did work rotations every week. About 200 cattle were slaughtered during 8 hours per day. When bleeding the cattle, the operator has to bend at an angle of about 90 degrees to the floor level and manually stick the animal hard with a knife. The worker has to do this high-force task repeatedly in the awkward posture about 67 times per day. They often felt pain from the ergonomic load in the shoulders, arm and hands.

In the slaughter line, all the operators stand and twist their posture to manually cut out the viscera from the slaughtered animal. A repetitive operation is therefore present in the slaughter line. It was also shown that the cutting line has the same working posture as that used when cutting meat. Time pressure on the operators also exists, particularly in the case of increased product demand.

Slaughter of pigs

Five persons worked on killing about 1400 swine per day. One worker had to slaughter about 300 pigs per day. In the slaughter line, workers start with washing and scalding of the slaughtered swine bodies in hot water, then automatic scraping away of hair, brushing, and splitting in machines, and then cutting off the feet on a desk and hanging them up etc.

Although the process of slaughtering pigs is different from slaughtering cattle, cutting off the feet and removing the inside organs from the slaughtered pigs are manual, repetitive and monotonous tasks, which are similar to workloads in slaughtering of cattle. There were 28 employees (five of them were female workers), but there was often only 20 persons working at the slaughter line. They slaughtered 180 pigs per hour, thus they had to perform the manual tasks quickly. They changed tasks about 5 times per day, as well as the working duration with the same working postures every 60-90 minutes. This work rotation could be a way to reduce risk for musculoskeletal injuries.

It was assessed that cutting injuries occurred 2-3 times per month. The main reason for the injuries was that the workers did not wear protective gloves due to uncomfortable feeling of the gloves. The injuries also took place on the lower arm because the gloves used didn't protect to the arm (insufficient protective clothing from the organisation). These cut injuries resulted in the injured worker either going on sick leave for 2-5 days or being reassigned to other temporary tasks.

Cutting meat in cold

The environmental temperature and the surface temperature of the products are <7 °C at the meat cutting and packing workshop. Hands with or without gloves are in contact with cold surfaces during working. In the workshop at the stationary abattoir 15% of the personnel were reported as being on sick leave. Workers ignore the protection against cold from time to time, which caused cold pain and numbness of fingers. Therefore, a risk of hand cumulative cold injury may occur, especially by touching wet, cold meat. Manual tasks like slicing and packing are repetitive. Highly repetitive tasks will lead to monotonous responses from the workers. The repetitive tasks on the assembly lines result in low autonomy and low job control, which negatively influence the motivation of the workers.

Other environmental factors

In addition, the following physical factors that have essential effects on the working environment were observed.

Noise

High level noise in the slaughter workshop is generated from working machines, electric hand tools and cutting lines. Noise is a stress factor that can cause psychological disturbances and start somatic reactions. Long exposure to noise can lead to high blood pressure (Jönsson, 1991). Operators must use hearing protection while working. However, the use of hearing protection leads to a difficult communication among the workers. Further improvements on this aspect should be considered, for instance, through encapsulation of the machines or the hearing protection with earphone that can receive radio programmes or music, etc.

Ventilation

There was an unpleasant smell in the slaughter workshop due to slanted animal products and poor indoor air ventilation. Improvements to the mechanical ventilation system in the workplace should be considered so that the air can be ventilated expeditiously at the times when annoying smells are being produced. Technique depends on the construct design of the locale. Generally speaking, indoor air quality should be satisfactory to the workers.

Wet floors

The floor in most of the workplace is wet with blood. This leads to a higher risk for slips or falls. Prevention of slips and falls should be achieved. For instance, the floor surfaces should be an open grid made of metal or hard rubber. In this way, the dropping of blood, water, etc can fall through the open grid onto the floor. The grid will easily keep the walking surfaces clean and dry, resulting in less falls. Wearing of anti-slip footwear to protect against slipping is also recommended.

Working environment in mobile abattoirs

Mobile abattoirs have previously been permitted for slaughtering of reindeer in Sweden. To our knowledge, not one study on the working environment of mobile abattoirs has been carried out yet.

In operation, with a well-trained staff of eight people, the abattoir has a capacity to process 40 large cattle or buffalo per 8-hour shift. The mobile abattoir with a bleeding section, chill section and personnel room is manufactured from aluminium strengthened insulated sandwich panels with an external white fibreglass weave and stainless steel sheeting with fully welded joints internally. The floor consists of a fully welded, patterned aluminium sheet. The floor slopes towards the middle where there is a sunken stainless drainage channel with hatches that may be raised up for cleaning. Internal lighting consists of covered neon-strips/fittings mounted under the roof. Furthermore, the following equipment mounted in the slaughter and evisceration section has been designed with ergonomic considerations:

- one electrical slaughter bench with various speeds for the removal of hides with automatic hide discharge through a hatch in the floor,
- stainless steel electric elevator for hide removal and transport of the carcass onto the hang rail,
- three height adjustable platforms at workstations,
- two air driven flaying knives,
- a splitting saw with dedicated sterilization, and has a breastbone divider.

Ergonomic Load

It is clear that stresses and risks of occupational injuries caused by the transport of living animals will be avoided in the mobile slaughter system and there will be no lairage work. The work tasks in mobile abattoirs probably involve more variation than in stationary abattoirs, and a large amount of repetitive, one-handed tasks are reduced, which could imply positive effects on workers' health. Another positive effect of working in the mobile abattoirs is limited exposure to the cold environment, which could lead to a decrease in the amount of cold injuries. The major negative aspect is the limited space, causing a restricted working area for manual handling, e.g., taking off the skin and splitting of the carcass. Also, the limited volume of water might affect personnel and offal treatment.

Proposal for development of work environment in the mobile abattoir

The results indicate that the work environment in mobile abattoirs is superior as all the furniture and equipment are developed with the latest technology and modern materials. Ergonomic intervention for the design of the furniture and equipment has also been used. A comparison of positive and negative aspects in the stationary and mobile abattoir together with possible actions for the mobile abattoir is outlined in Table 1.

*Table 1. Comparison of positive (**P**) and negative (**N**) aspects in stationary and mobile slaughter systems as well as possible actions for the mobile system.*

Stationary slaughter	Mobile slaughter	Possible actions in the mobile slaughter system
N: transport of animals causes extreme stress and risk for occupational injury	**P:** non-transport of animals, stress and risk for occupational injury can be avoided	
N: need of lairage work in the slaughterhouse stables	**P:** work with lairage is spared	
N: bent and twisted postures for heavy, repetitive manual work during bleeding	**P:** more variation can result in less heavy, repetitive manual tasks for workers	
P: hide discharge and splitting of the carcass by fully automated machine	**N:** limited space for installing a fully automated machine	Smaller machines with the same function could be developed
N: standing still and one-sided repetitive tasks at meat dissecting and separating band	**P:** standing still and one-sided repetitive tasks are reduced by increased task variation	
N: cold stress during meat slicing, casing and packing assembly line in cold room	**P:** exposure duration to the cold environment is shorter	Sufficient protective clothing, especially gloves against cuts, the cold and the wet have to be worn
N: loud noise, poor indoor air ventilation, unpleasant smell and wet slipping floors	**P:** installation of ergonomic instruments and equipment with new technologies can easily be done from the beginning	
P: sufficient supply of cold /warm water for hygiene	**N:** limited supply of cold /warm water	Can refill water from the farm where slaughtering is performed or install larger tank
P: large space for manual handling tasks and a big room for workers to change clothes	**N:** limited space	A tent as work place or change room for workers could be built at the farm temporarily
P: sufficient room for handling of waste	**N:** finite room	Manage waste locally
N: long distance for distribution of meat products	**P:** distribution of fresh meat products to local retail store	

The mobile abattoir enables workers to operate more safely and conveniently since the furniture and equipment in the mobile abattoirs are developed with the latest technology and modern materials.

It is very important to provide good and convenient working conditions for safe and efficient work, if the mobile abattoir is to be introduced as an effective alternative. Therefore, further studies of some major factors on the development of mobile abattoirs could be performed. Smaller machines for automatic removing of the skin and splitting of the carcass need to be developed. Development of good hygienic practices, while using limited amounts of water, is also needed. The recently developed mobile abattoir brings new requirements and standards to the working environment, which will need further investigations.

Waste management

The waste generated during slaughter is divided into different categories based on its infectious risk. These categories differ in chemical and physical composition, which makes it necessary to employ different treatment strategies. Animal by-products generated during slaughter are energy-rich and have a high content of nitrogen and phosphorous. Thus, from a sustainable point of view it is important to find management strategies for extracting renewable energy and recycling nutrients back to agriculture.

Legislation

Definitions of waste categories

Waste with animal origin is grouped into three categories, according to the Regulation (EC) No 1774/2002 laying down health rules concerning animal by-products not intended for human consumption. Braun & Kirchmayr (2003) describes the regulation and the possibilities for anaerobic digestion.

In this chapter a very short description of the definition of categories is done, based on waste management for the mobile abattoir.

Category 1, 2 and 3 materials shall comprise of animal by-products with the following description, or any material containing such by-products:

Category 1

- all body parts from animals suspected of being infected by a transmissible spongiform encephalopathies (TSE) or in which the presence of a TSE has been officially confirmed;
- specified risk material and where, at the time of disposal specified risk material has not been removed, entire bodies of dead animals containing specified risk material;
- combination of Category 1 material with either Category 2 material or Category 3 material or both, including any material destined for processing in a Category 1 processing plant.

All Category 1 material should be incinerated.

Category 2

- Manure and digestive tract content. This fraction can be treated in a biogas- or composting plant without pasteurisation as a pre-treatment. It can also be applied directly on arable land;
- all animal materials collected when treating waste water from abattoirs including screenings sludge and materials removed from drains from those premises. This fraction can be treated in a biogas- or composting plant, if it has been pre-treated in a sterilisation plant (if the particle size of the fraction had been reduced to less than 50 millimetres before sterilisation and is then subjected to at least 20 minutes of temperatures higher than 133 °C, without interruption, at a pressure of at least 3 bars);

- animals and parts of animals that die other than by being slaughtered for human consumption, including animals killed to eradicate an epizootic disease. This fraction can be treated in a biogas- or composting plant, if it has been pre-treated in a sterilisation plant (if the particle size of the fraction had been reduced to less than 50 millimetres before sterilisation and is then subjected to at least 20 minutes of temperatures higher than 133 °C, without interruption, at a pressure of at least 3 bars);
- combination of Category 2 material with Category 3 material. This fraction can be treated in a biogas- or composting plant, if it has been pre-treated in a sterilisation plant.

Category 3 material

- Parts of slaughtered animals, which are fit for human consumption in accordance with Community legislation, but are not intended for human consumption for commercial reasons;
- parts of slaughtered animals, which are rejected as unfit for human consumption but are not affected by any signs of diseases communicable to humans or animals;
- hides and skins, hooves and horns, pig bristles and feathers originating from animals that are slaughtered in an abattoir, that undergo an ante-mortem inspection, and are considered acceptable, as a result of such inspection.

All Category 3 material can be treated in a biogas- or composting plant, if it has been pre-treated in a pasteurisation plant (if the particle size of the fraction is reduced to less than 12 millimetres before pasteurisation and is then subjected to at least 60 minutes of temperatures higher than 70 °C without interruption).

Amounts, composition and classification of waste

Definitions to classify different waste generated at slaughter

In this report, the definitions of different waste fractions generated at slaughter are mainly based on regulation (EC) No 999/2001 of the European Parliament and of the council together with the old council directive of the European Communities 90/667/EEC.

Since the EC-regulation 1774/2002 has slightly changed the definitions, we have tried to refer the waste fractions mentioned to both the old and the new definitions in the following text.

A. Animal by-products: In this case this fraction includes the entire bodies, parts of animals or products of animal origin not intended for human consumption, with the exception of animal excreta. This definition is based on the old council directive of the European Communities 90/667/EEC.

B. Specified risk material (SRM): Animal by-products suspected of being infected by transmissible spongiform encephalopathies (TSE) or in which the presence of a transmissible TSE has been officially confirmed (SRM is a Category 1 material in regulation 1774/2002). This fraction includes:

1. skull, including brain and eyes, tonsils, spinal cord from cattle older than 12 months, and the bowels from duodenum to rectum from cattle of all ages;
2. the whole carcass or part of it, if any of the parts mentioned in point 1 are included;
3. *low risk* and *high risk material* handled together with *specified risk material.*

C. High risk material: Animal by-products that could lead to other serious risks for man or animal health (high risk material is a Category 2 material in regulation 1774/2002) than those mentioned for specified risk material. This includes:

1. animal by-products including blood originating from animals which show, during the veterinary inspection carried out at the time of slaughter, clinical signs of diseases communicable to man or other animals;
2. all those parts of an animal slaughtered in the normal way which are not presented for post mortem inspection, with the exception of hides, skins, hooves, feathers, wool, horns, blood and similar products;
3. all meat of animal origin which are spoiled and thus present a risk to human and animal health;
4. *low risk material* being handled together with *high risk material.*

D. Low risk material: Animal by-products not defined as *specified risk material* or *high risk material*. This fraction is a Category 3 material in regulation 1774/2002.

E. Content in stomach and intestines: This fraction includes manure and digestive tract content and is a Category 2 material in regulation 1774/2002.

F. Blood: In this study, all collected blood is defined as an animal by-product and is a Category 3 material in regulation 1774/2002.

G. Tibial and fibular bones: in this study, it is an animal by-product and a Category 3 material in regulation 1774/2002.

Pig slaughter

In the following example, the slaughter capacity is assumed to be 700 pigs per week. The daily amount of waste produced and the content of plant nutrients in the waste fractions are given in Table 2.

*Table 2. Calculated daily amount, **kg/day**, of animal by-products and stomach and intestinal contents during slaughter of pigs with a capacity of 700 pigs per week. The composition of plant nutrients in the waste fractions is also included. Weight of the bowels is excluded due to lack of data. DM gives the amount of dry matter included in the given amount. OM gives the amount of organic matter included, i.e. DM minus the content of ashes.*

kg/day	Amount	DM	OM	N	P	K
Animal low risk material, excl. blood	1 698	526	477	47.9	7.4	2.3
Blood	319	61	58	8.5	0.1	0.3
Stomach and intestinal contents	686	69	58	2.1	1.4	1.7
Sum	**2 702**	**655**	**590**	**58.4**	**8.9**	**4.2**
Animal high risk material	100	31	28	2.8	0.4	0.1

Cattle slaughter

In the following example, the slaughter capacity is assumed to be 70 adult cattle per week. The daily amount of waste produced and the content of plant nutrients in the waste fractions are given in Table 3.

*Table 3. Calculated daily amount, **kg/day**, of animal by-products and stomach and intestinal contents during slaughter of cattle with a capacity of 70 adult animals per week. The composition of plant nutrients in the waste fractions is also included. Hives are not included. DM gives the amount of dry matter included in the given amount. OM gives the amount of organic matter included, i.e. DM minus the content of ashes.*

kg/day	Amount	DM	OM	N	P	K
Animal low risk material, excl. blood, tibial and fibular bones	1 086	337	303	30.6	4.7	1.4
Tibial and fibular bones[1)]	82	44	28	2.9	0.4	0.1
Blood	181	34	33	4.8	0.1	0.1
Stomach and intestinal contents	932	98	87	2.2	0.7	0.8
Sum	**2 281**	**513**	**452**	**40.6**	**6.0**	**2.6**
Specified risk material	380	151	110	11.1	1.7	0.5
Animal high risk material	50	16	14	1.4	0.2	0.1
Sum	**430**	**166**	**124**	**12.5**	**1.9**	**0.6**

1) Regarded as unsuitable for biological processing due to the need for crushing before treatment.

Waste handling during cattle slaughter will probably be more expensive than during pig slaughter because intestinal content, tonsils, scull and spinal cord must be handled according to the rules for *specified risk material.*

Use of water

In Sweden, the use of water in large-scale stationary abattoirs is reported to be between 7 and 14 m^3 per product tonne. A small Swedish abattoir, that does not clean the stomach or intestines, consumes 1.4-1.5 m^3 per product tonne (pers. comm. Hellström). The use of water in a mobile unit is 4-5 m^3 per day

(pers. comm. Sandstöm, 2001). With the capacities suggested in Tables 2 and 3 above, the mobile abattoir will consume around 1 m^3 per product tonne or less.

Collecting and pre-treatment of waste in the mobile unit

The only mobile abattoirs in use in Sweden are those for reindeer slaughter. Legislation for this operation differs a lot compared to other kinds of slaughter. For instance, burial of waste is in practice.

The waste from mobile abattoirs could be managed according to the following suggestions:

Irrespective of how the waste is to be sorted, the abattoir would have a separate waste unit managed by only one member of the personnel. This person should not take part in the slaughter and not enter the compartments where slaughter is performed before accurate cleaning and change of clothes is undertaken.

Dependent on how the waste is to be processed, incinerated or biologically treated, the design of the waste management unit may be different.

Handling of specified risk material, high risk material and tibial and fibular bones from cattle

It is assumed these fractions are incinerated in all situations. They should be collected in a separate container with a lid, sorted according to the waste treatment unit and labelled with a colouring matter or other type of marker. It should be possible however, to add the SRM fractions, produced in the slaughter compartment, to the container without having to leave that area. The intestines are emptied before being placed into this container. The particle size of these fractions has to be reduced by a grinder before incineration.

Since the tibial and fibular bones of cattle also need to be crushed and ground before incineration, it is considered most rational to handle them together with the SRM, although the tibial and fibular bones are not risk material.

Low risk material

Soft parts and bones, tibial and fibular bones from cattle are excluded:

- If it is to be treated biologically, these fractions have to be ground in the mobile's waste unit. The ground material shall be collected in a separate container together with the blood.
- If it is to be incinerated, the grinding could take place wherever it is considered cost effective.

Content in stomach and the intestines

Cattle

The stomach and the intestines are emptied and the digestive tract content is collected. Foreign objects, like bale twine and metal pieces, are removed to prevent stoppage of the mechanical equipment later on. One way to do this is to produce a slurry by adding water and subsequently separating these objects through a screen. Then the slurry and the manure can be handled together. If biological treatment is included in the waste management system, this fraction is handled together with the ground animal low risk material. Otherwise, the low risk material is deposited into the manure storage at the farm.

Pigs

In systems with a biological treatment unit, the stomach and the intestines are not emptied before grinding. In systems with local incineration, emptying could be preferred in order to raise the heat value.

Wastewater

Wastewater is collected and screened for particles. The particles are defined as a Category 2 material. The water is handled together with the manure and digestive tract content.

Storage and transport

To have a cost-effective organisation, the collected waste materials will often have to be stored on the farm for a day or two. It might therefore be necessary to use several small sealable containers.

Fractions with the option to be placed in the farm manure storage

Manure, digestive tract content and screened wastewater could be put in the farm manure storage. The content of nutrients and energy in these materials are proportionately small. Economic considerations will determine whether these fractions are to be used on the farm or transported away from the farm.

Methods for treatment of slaughter waste

In conventional stationary abattoirs, the animal's by-products are transported to one centralised plant for production of meat meal or biogas where materials from different origins meet. Obviously, waste from a mobile slaughter unit could be integrated in such a system.

Composting

Composting is a biological method to hygienize and stabilize the waste, i.e. make it more homogeneous and dry and thereby more easy to handle.

Liquid composting

Wet composting has been tried on black water, food waste and manure for instance, but so far not on animal by-products, which is why it is necessary to research before starting this practice. It is, however, in the context of mobile slaughter, a very interesting method. This is due to the possibility of working locally in a moderate scale in combination with the circulation of nutrients.

Composting of solids

With this method, slaughter waste is composted together with material that has higher carbon content, straw for instance. The optimal mixture of straw and waste is expected to be about 50/50 on mass base. Probably, water will have to be added often too to avoid excessive drying.

A disadvantage with solid composting is a considerable loss of nitrogen through ammonia emissions. Also, for hygienic reasons the material will most likely have to be treated with heat separately. The production of heat in the solid compost will not be sufficient to keep the material at or above 70° C for a minimum of one hour, which is required according to EU-regulations.

Anaerobic digestion

Anaerobic digestion will stabilize the waste and make it useful as a nutrient in farming. During the process, a gas is produced. The gas is composed mainly of methane, a fuel of high value, which is possible to use, after refining, in vehicle motors. This gas could also be used to produce the heat and hot water needed for the process without refining. The net energy output, after reduction for efficiency losses in the boiler and heat used for the process, is estimated to be in the region of 2 MWh/day in hot water (rate 70 cattle/week, about 3 MWh/day with 700 pigs/week).

With the anaerobic digestion, the material will also have to be heated to 70°C in a separate pre-treatment step. Anaerobic digestion of slaughter waste in combination with other wastes is a relatively common practice. However, this waste alone has not been well studied from what we know.

Local incineration

Incineration (burning) is a thermal method for hygienisation and stabilization of waste. With incineration, the nitrogen will be lost in the form of exhaust gas through the chimney. The phosphorus and potassium in the waste will end up in the ashes, which could be used as fertiliser.

The lower calorific heat value of carcasses with 35 % dry matter content is 8.7 MJ/kg raw material (Schuster & Sundquist, 2001). Before burning, the material has to be crushed and ground. Then, it is suggested that sawdust and vegetable oil is added. After that, the heat value is approximately 8.0 MJ/kg raw material in the case of cattle (6.7 in the case of pigs). The net energy output, is estimated to be 3.4 MWh/day in hot water (rate 70 cattle/week, about 4.7 MWh/day with 700 pigs/week). Combustion of dried meat meal is a well-known technique, while combustion of wet slaughter waste has only been performed in small trials.

Economy

Stationary slaughter houses

Hermansson (1996) studied the economics of Swedish stationary slaughter. The study was based on the bookkeeping from 14 companies. The results showed that this kind of activity has obvious advantages in being organised in large-scale units. The three most important factors for the economic results were found to be:

- size of the abattoir,
- rate of cost reduction overtime,
- composition of animals slaughtered (i.e. cattle/pigs/other animals).

Cattle were more expensive to slaughter per weight unit than other animals.

Mobile slaughter units

Helgesson (2000) presented a comparison between stationary and mobile abattoirs. The cost for the stationary activity was taken from Hermansson (1996) and transportation costs were added.

Transportation costs vary, between different regions in Sweden, due to different density and size of animal farms. While the cost was found to be 0.35 SEK/kg slaughtered weight in the south of Sweden, it was 0.93 SEK/kg slaughtered weight for a company in the north.

Table 4 presents real costs for today's stationary abattoirs based on the works of Helgesson and Hermansson and estimated costs for mobile slaughter in three regions of Sweden (Benfalk et al., 2002). The costs for mobile slaughter are mainly based on data from the Swedish manufacturer of mobile units. Costs for transporting the animals, calculated for Swedish conditions, are included in both systems.

Table 4. Real costs (SEK/kg slaughtered weight) for today's stationary slaughter system and calculated costs for mobile slaughter in three regions of Sweden (Benfalk et al., 2002).

	North	Middle	South
Stationary today	4.51	2.93	2.81
Mobile, cattle	4.80	4.76	4.78
Mobile, pigs	3.10	3.06	3.08

As already mentioned, the cost for today's stationary slaughter abattoirs differs a lot between regions. In this study, the cost differences between mobile slaughter abattoirs are smaller. However, with mobile slaughter the density of farms is also of great importance. In regions with many small, sparsely situated farms, a lot of time will be spent on setting up and packing up the unit as well as travelling between the farms.

The amount of meat produced in the mobile per year is of crucial importance for the economy, Figures 4 and 5.

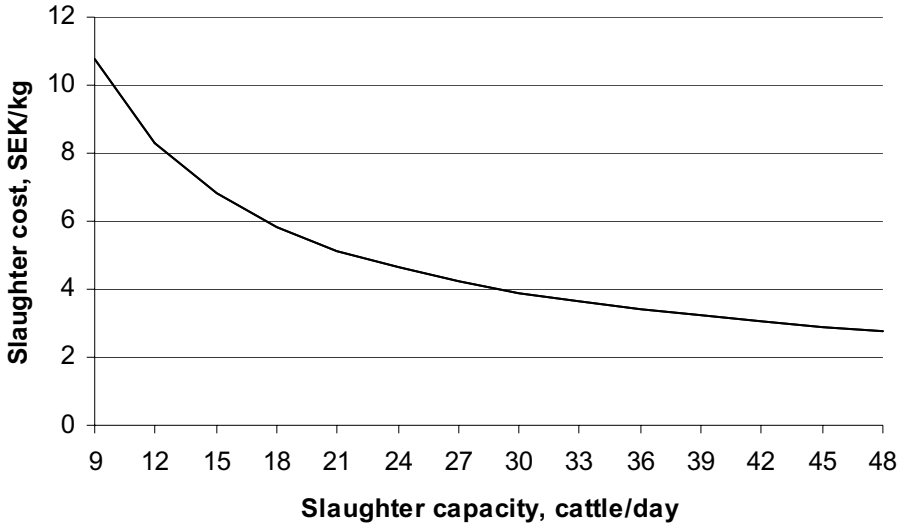

Figure 4. Calculated relation between the capacity (number of cattle per day) and cost of slaughter (SEK/kg), example of conditions in the middle of Sweden.

The calculations for Figures 4 and 5 were based on the assumption that 5 hours per day were available for slaughter after the time for transportation, set-up, cleaning, breaks, etc had been drawn from 8 hours. A slaughter rate of 30 pigs or 5 cattle per hour could be possible with 5-6 personnel but since the chill section has a limited holding capacity, only 23 cattle or 120 pigs was calculated per day.

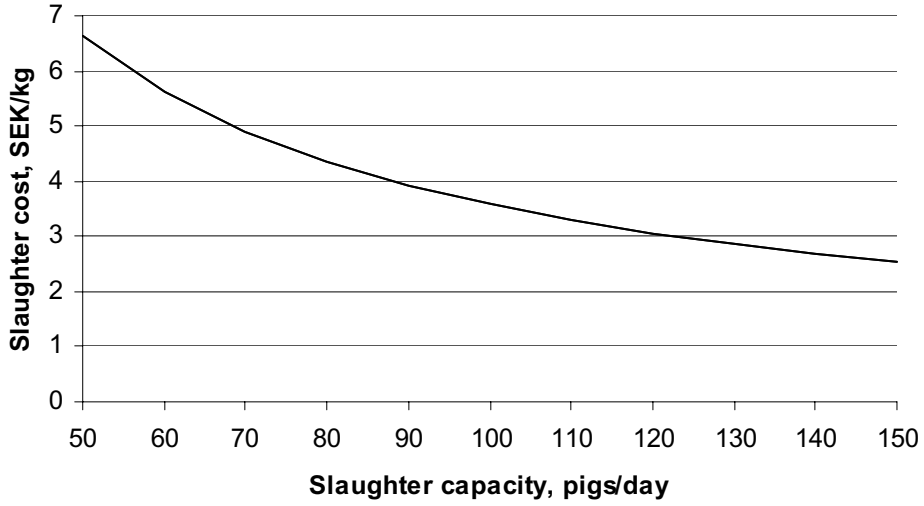

Figure 5. Calculated relation between the capacity (number of pigs per day) and cost of slaughter (SEK/kg), example of conditions in the middle of Sweden.

The full cost for personnel was calculated independently on the number of kg slaughtered per day. However, if there was alternative work for the personnel with e.g. meat cutting and packing on days with few animals to slaughter, the slaughter cost could be reduced (compared to Figures 4 and 5).

Case study

In the Case study (Benfalk et al., 2003) concerning pigs, a theoretic remodelling of the delivery structure was made to fit a mobile abattoir. Initially, the slaughter deliveries from 11 farms that were connected to the same sow pool were investigated. The farms delivered on average 2 721 pigs (from a min of 1872 to a max of 5056) during 2001. The average delivery from all the farms per week was 576 pigs (min 255 – max 1317). The aim of the theoretic remodelling was to come close to the average slaughter delivery without changing the delivery by more than one week. The aim was also to move the mobile abattoir a maximum of two times per day (that is slaughter at two different farms on the same day).

The result of the remodelling was that on 78 % of all slaughter days the mobile could slaughter one whole day or more at the same farm (Figure 6).

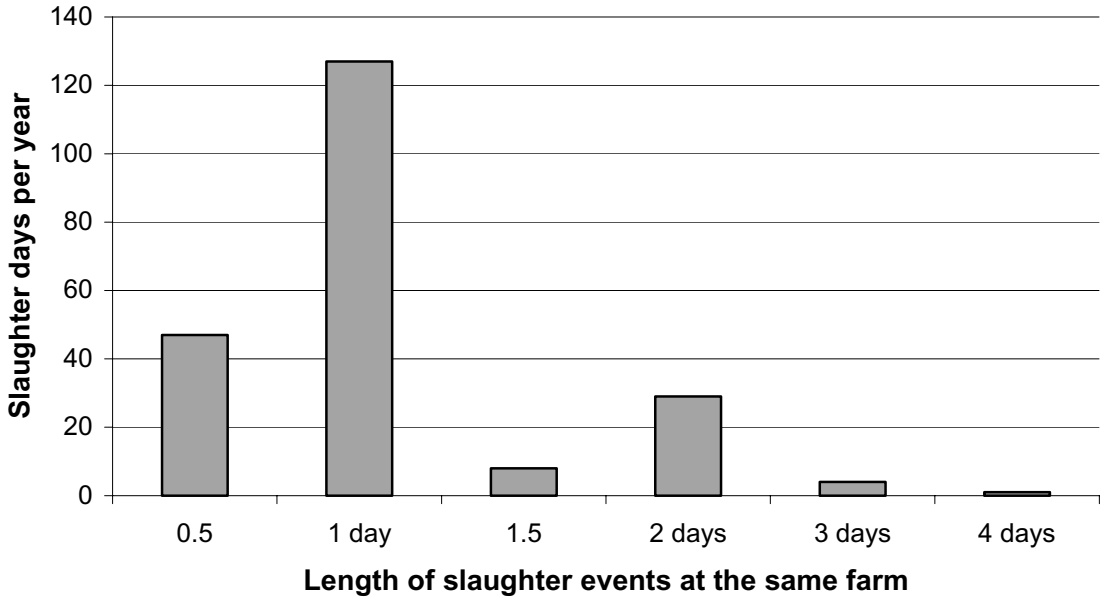

Figure 6. Number of days the slaughter could continue at the same farm.

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