

3 CLEANER PRODUCTION OPPORTUNITIES

Meat processing typically consumes large quantities of water and energy, discharges significant quantities of effluent and generates by-products. For this reason, Cleaner Production opportunities described in this guide focus on reducing the consumption of resources (water and energy), increasing product yields and reducing the volume and pollutant load of effluent discharges.

Although many processes in the food sector can be automated, it is difficult to automate many of the processes within an abattoir because of the irregular shape and weight of the animal carcasses. This means that individual operators' practices have a significant impact on the overall performance. Therefore, many of the Cleaner Production opportunities described in this guide relate to housekeeping practices, work procedures, maintenance regimes and resource handling, as opposed to technological changes.

Section 3.1 provides examples of general Cleaner Production opportunities that apply across the entire process, whereas Sections 3.2 to 3.11 present opportunities that relate specifically to individual unit operations within the process. For each unit operation, a detailed process description is provided along with Cleaner Production opportunities specific to that process. Where available, quantitative data for the environmental indicators applicable to each unit operation are provided.

3.1 General

Many food processors that undertake Cleaner Production projects find that significant environmental improvements and cost savings can be derived from simple modification to housekeeping practices and maintenance regimes. Table 3—1 contains generic housekeeping ideas that apply to the process as a whole.

Table 3—1 Checklist of general housekeeping ideas ¹

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| <ul style="list-style-type: none"> • Keep work areas tidy and uncluttered to avoid accidents. • Maintain good inventory control of consumables, such as cleaning chemicals, packaging materials, food additives etc., to avoid waste. • Ensure that employees are aware of the environmental aspects of the company's operations and their personal responsibilities. • Train staff in good cleaning practices. • Schedule regular maintenance activities to avoid inefficiencies and breakdowns. |
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¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.1 Water consumption

Water is used extensively in meat processing, so water saving measures are common Cleaner Production opportunities in this industry. The first step is to analyse water use patterns carefully, by installing water meters and regularly recording water consumption. Water consumption data should be collected during production hours, especially during

periods of cleaning. Some data should also be collected outside normal working hours to identify leaks and other areas of unnecessary waste. Water consumption data should be presented and discussed at management meetings to formulate strategies for improved water efficiency.

The next step is to undertake a survey of all process area and ancillary operations to identify wasteful practices. Examples might be hoses left running when not in use, excessive flowrates, and so on. Installing automatic shut-off equipment and flow restrictors, for example, could prevent such wasteful practices. Automatic control of water use is preferable to relying on operators to manually turn water off.

Once wasteful practices have been addressed, water use for essential process functions can be investigated. It can be difficult to establish the minimum consumption rate necessary to maintain process operations and food hygiene standards. The optimum rate can be determined only by investigating each process in detail and undertaking trials. Such investigations should be carried out collaboratively by production managers, food quality and safety representatives and operations staff. When an optimum usage rate has been agreed upon, measures should be taken to set the supply at the specified rate and avoid manual control.

Once water use for essential operations has been optimised, water reuse can be considered. Wastewaters that are only slightly contaminated could be used in other areas. For example, defrost water from refrigeration systems and vacuum pump water is usually clean, and could be reused for non-critical applications. Water used for carcass washing could be recirculated. Wastewaters from the slaughter floor, washbasins, knife and implement sterilisers and carcass washing could be reused for gut cutting and washing. Treated effluent from on-site effluent treatment systems may be reused for stockyard washing, hide cleaning and livestock washing, as long as fresh water is used for the final livestock rinse. Some of these options may require screening, filtering or in-line bacterial control. It should also be noted that some water reuse and recycle opportunities may be prohibited by some authorities.

Wastewater reuse should not compromise product quality and hygiene, and reuse systems should be carefully installed so that reused wastewater lines cannot be mistaken for fresh water lines, and any reuse plans should be approved by all food safety officers.

The option to fully recycle treated effluent for use within the process may become viable in the future, as effluent discharge quality standards become tighter. As quality standards approach those of potable water, there will be a powerful incentive to take advantage of the investment that goes into effluent treatment. For this to occur however, treatment processes would probably have to incorporate techniques such as membrane filtration to remove dissolved solids. This would be necessary to avoid progressive concentration of salts in the recycled water.

Table 3—2 is a checklist of common ideas for reducing water consumption. Many of these opportunities are discussed in more detail later in this chapter.

Table 3—2 Checklist of water saving ideas ¹

- Undertake dry cleaning of trucks prior to washing with water.
- Install high-pressure, low-volume spray nozzles.
- Use high pressure rather than high volume for cleaning surfaces.
- Use automatically operated scalding chambers rather than scalding tanks for the de-hairing of pigs.
- Use offal transport systems that avoid or minimise the use of water.
- Use dry dumping techniques that avoid or minimise the use of water for the processing of cattle paunches and pig stomachs, instead of wet dumping techniques.
- Reuse relatively clean wastewaters from cooling systems, vacuum pumps etc., for washing livestock.
- Reuse final rinse waters from paunch and casings washing for other non-critical cleaning steps in the casings department.
- Reuse wastewaters from the slaughter floor, carcass washing, viscera tables and hand wash basins for the washing of inedible products.
- Reuse cooling water from the singeing process for other application in the pig de-hairing area.
- Reuse the final rinse from cleaning operations for the initial rinse on the following day.
- Use dry cleaning techniques to pre-clean process areas and floors before washing with water.
- Use automatic control systems to operate the flow of water in hand wash stations and knife sterilisers.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.2 Effluent

Cleaner Production efforts in relation to effluent generation should focus on reducing the pollutant load in effluents. The volume of effluent generated is also an important issue. However this aspect is linked closely to water consumption, so efforts to reduce water consumption will also result in reduced effluent volumes. Opportunities for reducing water consumption are discussed in the previous section.

Opportunities for reducing the pollutant load of abattoir effluent principally focus on avoiding the discharge of polluting substances, such as blood, undigested stomach contents, fat and scraps of meat, to the effluent stream. This means capturing materials before they enter drains and utilising dry cleaning methods wherever possible. Improvements to cleaning practices are therefore where the most gains can be made. Table 3—3 is a checklist of common ideas for reducing pollutant loads in effluent.

Since blood is one of the major sources of organic pollution for abattoirs, its recovery is an important Cleaner Production initiative. Blood recovery can decrease organic loads by approximately 40% (Jones, 1974).

Table 3—3 Checklist of ideas for reducing effluent loads ¹

- Maximise the segregation of blood by designing suitable blood collection facilities and allowing sufficient time for bleeding, typically seven minutes.
- Sweep up solid materials for use as by-products, instead of washing them down the drain.
- Fit drains with screens and/or traps to prevent solid materials from entering the effluent system.
- Use offal transport systems that avoid or minimise the use of water.
- Use water sprays with a pressure of less than 10 bar for carcass washing to avoid removing fat from the surface.
- Use dry cleaning techniques to pre-clean process areas and floors before washing with water.
- Segregate high-strength effluent streams, such as rendering effluent and wastewaters from casings and paunch washing and treat them separately.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.1.3 Energy

Energy is often an area where simple plant optimisation efforts can provide substantial savings almost immediately with no capital investment. Significant reductions can be made through simple housekeeping and optimisation of existing processes. Additional savings can be made through the use of more energy-efficient equipment and heat recovery systems. Table 3—4 is a checklist of common ideas for reducing energy consumption.

Table 3—4 Checklist of energy saving ideas ¹

- Implement switch-off programs and install sensors to turn off or power down lights and equipment when not in use.
- Improve insulation on heating and cooling systems and pipework.
- Insulate and cover scald tanks.
- Recover waste heat from effluent streams, vents, exhausts and compressors.
- Recover evaporative energy in the rendering process, using multi-effect evaporators.
- Maintain a leak-free compressed air system.
- Favour more efficient equipment.
- Improve maintenance to maximise energy efficiency of equipment.
- Maintain optimal combustion efficiencies on boilers.
- Eliminate steam leaks.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

In addition to reducing a plant's demand for energy, there are opportunities for using more environmentally benign sources of energy. Opportunities include replacing fuel oil or coal with cleaner fuels, such as natural gas, possibly purchasing electricity produced from renewable sources, or co-generation of electricity and heat on site. For some plants it may also be feasible to recover methane from the anaerobic digestion of high-strength effluent streams to supplement fuel supplies.

3.1.4 By-products

Almost all animal by-products can potentially be used to produce a useful commodity. It may not always be possible, however, to find economic markets for all by-products. This will depend on the scale of the operation, the cultural and culinary characteristics of the region and the distance to suitable markets.

The ability to use all animal by-products to their full extent will often depend on whether rendering facilities are available to convert inedible components into useful products such as bone meal and tallow. Large plants typically incorporate integrated on-site rendering and blood processing facilities or generate sufficient material to be attractive for off-site renderers.

Table 3—5 Checklist of ideas for maximising utilisation of by-products¹

- Segregate all by-products.
- Ensure that by-products are not contaminated with water or materials that would limit or prevent their reuse.
- Store by-products correctly to maintain quality and maximise the viability of reuse opportunities.

¹ UNEP Cleaner Production Working Group for the Food Industry, 1999

3.2 Livestock reception

Process description

Animals are delivered to the abattoir in trucks, which are unloaded at the reception area. Trucks are generally washed and sometimes disinfected before leaving the site.

Most abattoirs hold livestock on site for a period, typically 1 to 2 days, prior to slaughter. During this period animals are usually fasted to reduce the quantity of stomach contents, thereby making cleaning of the intestines easier. Livestock for the following day's kill are held in stockyards adjacent to the plant, whereas livestock being held for longer periods may be grazed in paddocks around the plant.

Some plants may use holding periods to de-stress cattle, which helps to improve final meat quality. Pigs are susceptible to heat stress and therefore it is common for pig holding facilities to incorporate sprinkler systems, which spray water on the pigs to keep them cool, especially in summer. The water sprays can also assist in suppressing dust.

In some regions, bedding may be used in trucks and in holding yards for animal welfare reasons and also to facilitate the collection of manure.

Prior to being slaughtered, livestock are also washed with water to minimise the amount of dirt and manure introduced to the plant.

Inputs and outputs

Figure 3—1 is a flow diagram showing the inputs and outputs associated with livestock reception, and Tables 3—6 and 3—7 provide data on the key inputs and outputs for pig and cattle reception respectively.

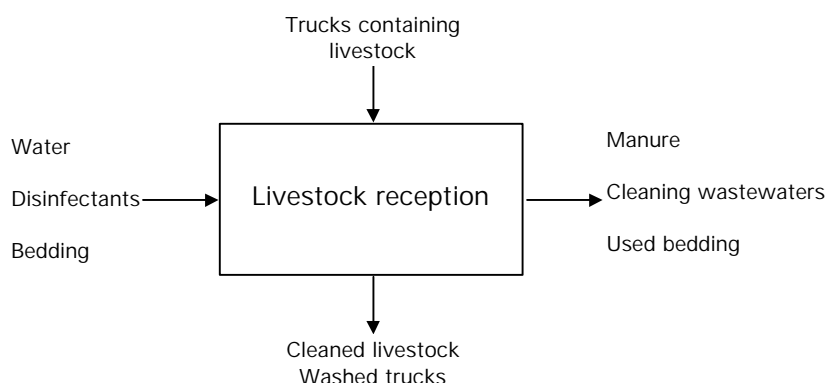


Figure 3—1 Inputs and outputs for livestock reception

Table 3—6 Input and output data for the reception of a 100 kg pig

Inputs		Outputs	
Live pig	100 kg	Live pig	100 kg
Water for cleaning	15 L	Wastewater	15 L
Bedding (if used)	2.5 kg	BOD ₅	0.02 kg
		Solid waste	1.5 kg

Table 3—7 Input and output data for reception of 250 kg beef cattle

Inputs		Outputs	
Live cattle	250 kg	Live cattle	250 kg
Water for cleaning	75 L	Wastewater	75 L
Bedding (if used)	7.5 kg	BOD ₅	0.1 kg
		Solid waste	5 kg

Environmental issues

Water is used for truck washing, cattle watering and washing and hosing out holding yards. Waste of water can occur due to overflowing drinking troughs, leaking hoses and poor washing practices. Excessive use of water or poor containment of water can also lead to ponding of water in holding yards or paddocks. This can result in the need for extra washing to remove accumulated mud from livestock.

The wastewaters generated from these activities contain manure and urine and therefore have a high organic load and solids content. They also are a significant contributor to phosphorus loads.

Cleaner Production opportunities

Manure along with bedding can be a valuable source of nutrients and organic carbon, but can also cause pollution problems if not used or disposed of correctly.

Dirty livestock should be segregated on arrival and given a preliminary wash before joining the rest of the herd. This will reduce the amount of washing required for the herd as a whole.

Water troughs should be designed and located to avoid overflowing and production of muddy areas. They should be set on a concrete base and protected from damage by livestock.

For truck washing, water should be used only after dry cleaning has been undertaken. Using a high-pressure water supply and hoses fitted with trigger nozzles will help reduce water consumption.

Manual cleaning of livestock should be restricted to those that need it. A 20–35 mm diameter hose fitted with a 9–10 mm nozzle will maximise efficiency. Large diameter hoses should be avoided as they are cumbersome and inefficient and nozzles are easily damaged (McNeil and Husband, 1995).

Recycled water from other areas of the plant, such as cooling systems and vacuum pumps, can be used for washing trucks. Recycled water could also be used for washing livestock. However for some markets, such as the European Union, the use of recycled water for stock washing may be prohibited.

Wastewaters from truck and livestock washing should be screened before being discharged to the effluent system. This will help reduce the loads of organic matter, suspended solids and also phosphorous entering the wastewater treatment system. Screening can best be achieved using rotating screens or static run-down screens.

3.3 Stunning and bleeding

Process description

For pigs, stunning can be carried out by electric shock or by anaesthetisation with carbon dioxide. Mechanical stunning with a bolt pistol is not often undertaken because of problems with skull penetration. Electric stunning is carried out using a pair of tongs with two electrodes positioned behind the animal's ears. Carbon dioxide anaesthetisation is undertaken by passing pigs through an atmosphere containing about 60–70% carbon dioxide. For cattle, concussion devices or bolt pistols are the most commonly used stunning techniques.

After stunning, carcasses are shackled by the hind legs to a conveyor. Bleeding, also referred to as sticking, takes place by cutting the cervical vein and one of the arteries.

Bleeding is commonly undertaken using a hollow, sterilised knife, which feeds the blood to a collection facility. Blood accounts for about 5% of the live weight of beef cattle and pigs. However only about 70–80% of this is collected during bleeding, the remainder typically being lost to the effluent stream.

The proportion collected will depend on the bleeding time. Time required for effective bleeding is generally not less than seven minutes. Some blood loss continues during subsequent dressing operations—up to the point of hide removal, in the case of cattle.

Inputs and outputs

Figure 3—2 is a flow diagram showing the inputs and outputs associated with the stunning and bleeding process, and Tables 3—8 and 3—9 provide data for the key inputs and outputs for pigs and cattle respectively.

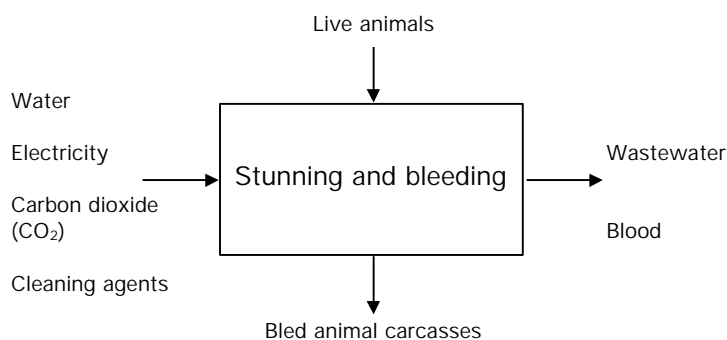


Figure 3—2 Inputs and outputs for stunning and bleeding

Table 3—8 Input and output data for the stunning and bleeding of a 100 kg pig

Inputs		Outputs	
Live pig	100 kg	Bled pig	95 kg
Water	5 L	Blood (assuming 80% recovery)	4 kg
Carbon dioxide	0.16 kg	Wastewater	6 L
		BOD ₅ (blood loss)	0.2 kg

Table 3—9 Input and output data for the stunning and bleeding of 250 kg beef cattle

Inputs		Outputs	
Live cattle	250 kg	Bled cattle carcass	238 kg
Water	5 L	Blood (assuming 80% recovery)	10 kg
		Wastewater	7 L
		BOD ₅ (blood loss)	0.4 kg

Environmental issues

Of all the components present in abattoir effluent, blood constitutes the highest pollution load. The bleeding area of the slaughter floor is the main source of blood contamination. Blood has a very high organic content, with its organic load equivalent estimated to be 0.14—0.18 kg BOD₅ per kg. If it is discharged to the effluent stream, the effectiveness of any downstream effluent treatment system will be greatly affected due to the increased organic loads.

Blood is also the main contributor to nitrogen loads in effluent. This can have serious implications for the disposal of the treated effluent, since nitrogen is not readily removed in standard effluent treatment systems. The release of treated effluents containing high levels of nitrogen can cause eutrophication problems downstream.

If collected blood is allowed to become contaminated with water, the effectiveness of its subsequent processes is reduced. The presence of water reduces the efficiency of coagulation processes, and if the blood is to be dried, increases the energy required to evaporate the water content.

After blood, fat is the next most important contaminant in effluent generated from the slaughter area. Fat blinds screens in the effluent treatment system, resulting in the need for greater use of hot water to clean them.

Cleaner Production opportunities

Every effort should be made to maximise raw blood collection and its subsequent processing into blood meal or other value-added by-products. Blood recovery yields should be routinely assessed to check the effectiveness of the blood collection system.

Design of the bleeding area should ensure that all blood is directed to the blood collection facility. Animals should not be bled until they are located over the blood collection facility and they should be allowed to bleed in this location for a minimum period of time, generally no less than about seven minutes (McNeil and Husband, 1995).

A shallow, inclined, stainless steel trough under the bleeding area, extending through to the hide removal area, is a suitable mechanism for collecting blood. The trough should be elevated some distance above floor level to exclude cleaning water (McNeil and Husband, 1995). Coagulated blood collecting in the trough will need to be scraped away at regular intervals.

The most effective method of continuously recovering blood is a belt conveyor under the bleeding area. The belt should be troughed or have side skirts to contain the blood and be fitted with scrapers to recover blood from the conveyor. This type of system comes at the expense of some water consumption due to the requirement to clean the belt itself. However fixed spray nozzles can provide efficient cleaning (McNeil and Husband, 1995).

To avoid cross contamination of blood and wastewater, two-way drain diversion systems can be used in the bleeding area. Two drain outlets are provided in the blood collection area, one to the blood tank and the other to the effluent system. During slaughtering, the outlet to the effluent system is closed off so that all blood drains to the blood tank. When slaughtering is finished, the outlet to the blood tank is closed and the outlet to the effluent system is opened so that cleaning wastewaters are directed to the effluent system.

Removable plugs or valves can be used to close off the outlets to these drains. Full-flow ball valves are preferred as they can be mechanically interlocked so that as one valve opens, the other valve shuts. Control of the changeover of plugs or valves should be the responsibility of a designated operator who also gives the go-ahead to start cleaning the area.

Blood is highly perishable, therefore it should be chilled quickly and promptly processed into value-added products. The investment required for installation of a well-cooled storage tank and processing equipment is high, but necessary if the blood is to be sold as a by-product.

3.4 Hide treatment of pigs

Process description

The objective of surface treatment is to remove dirt and hair from pig carcasses, prior to further processing. In some processes, skins may be removed and sold for tanning. However skinning is usually restricted to the slaughter of large sows for sausage manufacture or to small-scale plants where the costs of scalding and dehairing equipment makes it prohibitive.

Carcasses are scalded with water at 60°C in a scald tank or in scalding cabinets, to soften the skin in preparation for hair removal. Alkaline reagents may be added to the scald water to help remove the layer of accumulated oil, dirt and epidermal cells from the skin surface, making the skin whiter.

After scalding, hair is partly removed by manual shaving or for larger operations, in de-hairing machines. Any remaining hair is singed with a gas-fired hand-held torch or, for larger plants, by passing the carcasses through a singeing oven. The singeing operation may be followed by flushing with cold water. Any skin discolouration is then removed by scraping, either manually or in a scraping machine.

If the hide is to be removed, the surface is first cleaned by showering and brushing, then the skin is loosened and pulled off. Fat is removed and the skins are salted or iced immediately and before being sold for tanning.

Inputs and outputs

Figures 3—3 and 3—4 are flow diagrams showing the inputs and outputs for the dehairing and hide removal processes respectively. Table 3—10 provides input and output data for the more common dehairing process.

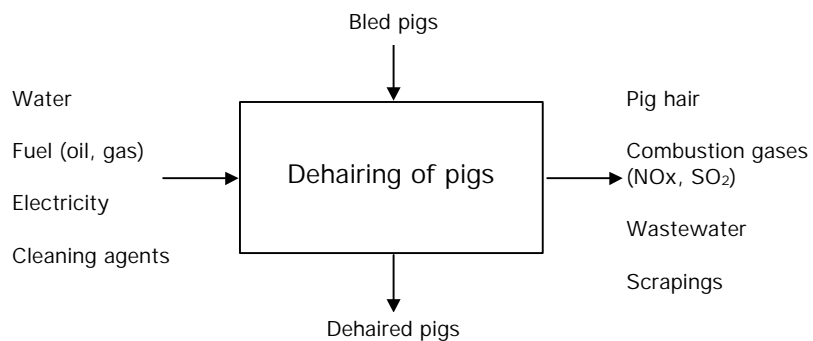


Figure 3—3 Inputs and outputs for dehairing of pigs

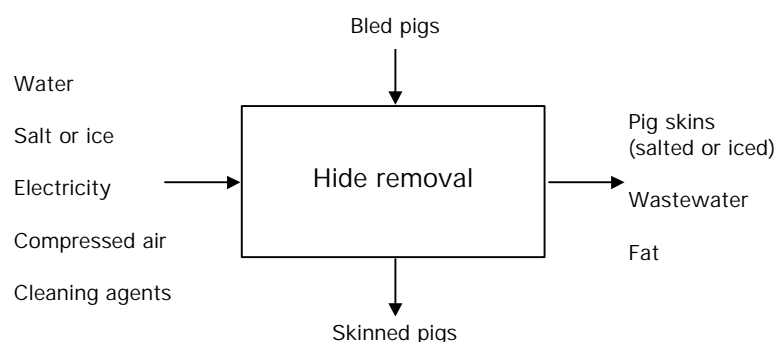


Figure 3—4 Inputs and outputs for skinning pigs

Table 3—10 Input and output data for the dehairing of a 100 kg pig

Inputs		Outputs	
Bled pig carcass	95 kg	De-haired pig carcass	93 kg
Water	60 L	Wastewater	60 L
Oil	0.6 L	BOD ₅	0.3 kg
Gas (if used instead of oil)	0.5 m ³	Pig hair	1 kg
		Scrapings	1 kg

Environmental issues

Water consumption can be high, especially for the de-hairing process and for cooling after singeing.

Wastewaters from this process contain high levels of organic matter, fat and dirt. In particular, wastewaters from scald tanks or from in-line scalding cabinets can have temperatures of up to 75°C. If they are discharged while hot they will melt fat and allow it to pass through the primary effluent screening system. This increased loading of fat will cause problems for downstream effluent treatment systems.

The process consumes a lot of energy, particularly for heating water and for operating singeing ovens.

Cleaner Production opportunities

If scalding tanks are used, they should be insulated and covered by a lid to avoid heat and evaporation losses. This will save both energy and water. The payback period depends on the existing heat losses, but should be 1–2 years.

To reduce water consumption for cleaning of the scalding tank, the tank bottom should have a steep gradient towards the outlets. The wastewater should pass through a sedimentation tank, interceptor trap or sand trap before discharge. The investment required is high, but these measures should be considered when replacing an existing scalding tank.

Water consumption for de-hairing can be minimised by applying water only as required and ensuring that water pressure and the number, placement and size of water nozzles are optimal.

There are also a number of opportunities for water reuse in this area. Cooling water can be collected in a tank and reused for other purposes, such as water sprays in the de-hairing machines. Boiler condensate can also be used as make-up water for the scalding tank.

Automatically operated scalding chambers use less water than scalding tanks. Using such systems, water consumption can be reduced by 50–70%. The investment required is high, and the payback period may be more than 5 years.

The de-hairing process results in substantial quantities of hair collecting on the floor where it can enter the drainage system. Strainers should be fitted to floor drain outlets to collect the hair and avoid blockages.

The singeing oven must be insulated and provided with automatic doors that close during singeing. If not, significant energy is lost. Payback on investment for insulation and automatic doors will be at most one year.

Gas consumption in singeing ovens can be reduced by using solenoid switches to initiate the singeing flame only when carcasses are passing through and to regulate flame intensity in line with line speed.

Overhead rails in singeing ovens are sometimes cooled using cold water. In these situations, the consumption of cooling water can often be much greater than necessary. Installing thermometers to measure the temperature of cooling water can allow flow to be regulated to the minimum required.

Case study 3—1: Reducing water consumption for pig de-hairing

At a pig abattoir, water consumption for dehairing, singeing, scraping and brushing amounted to 141 L/pig before the water-saving campaign began. By reducing the water pressure and installing on-off regulation controlled by the carcass conveyor, consumption was reduced to 96 L/pig, a 32% reduction. The next step was to collect all cooling water from the singeing oven and use it in the other machines instead of disposing of it. In addition, the trickling system in the hide treatment machines was replaced with nozzles which give a well-defined direction and angle of spray. This resulted in a further decrease in water consumption from 96 to 26 L/pig, a 73% reduction.

The investment for a slaughter line treating up to 400 pigs per hour was about US\$33,000, resulting in a saving of US\$0.2–0.3/pig, depending on water and wastewater charges.

(Hansen and Mortensen, 1992)

3.5 Hide removal and dressing of cattle

Process description

Prior to hide removal, the head, hoofs, feet and tail are removed. In some smaller operations, hides may be removed manually. However, in medium to large plants hide removal is generally performed mechanically. Most hide removal equipment is either pneumatically or hydraulically powered. Electrical stimulation is often applied to 'stiffen' the carcass during the hide-pulling operation.

Before hides can be processed further at a tannery, the flesh must be removed and the hides washed and immersed in brine. The fleshing process may take place at the abattoir, thereby recovering the fleshings for rendering, or at the tannery. If they are to be sent to the tannery without fleshing, hides are packed unwashed in salt. Fleshings are made up of fat and flesh and represent about 15% of the weight of the hide.

The cattle hide accounts for 5–9% (average 7%) of the live weight of beef cattle (Ockerman and Hansen, 2000). Consequently it is one of the most valuable by-products from beef cattle.

Inputs and outputs

Figure 3—5 is a flow diagram showing the inputs and outputs from this process, and Table 3—11 provides data for the key inputs and outputs.

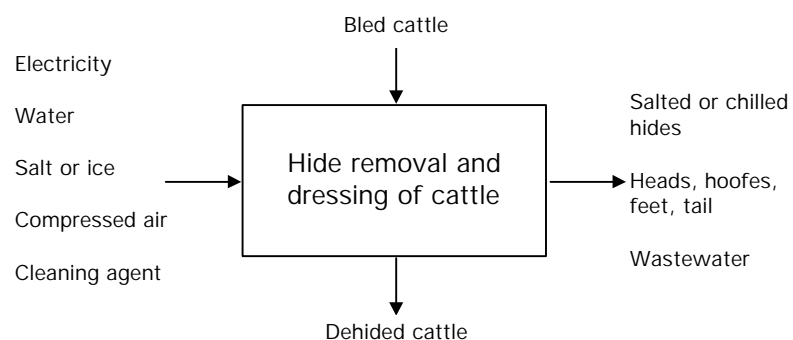


Figure 3—5 Inputs and outputs for hide removal and dressing of cattle

Table 3—11 Input and output data for hide removal and dressing of cattle

Inputs		Outputs	
Bled cattle carcass	238 kg	Dehided cattle carcass	207 kg
Water	5 L	Hide	15 kg
		Head, hooves, tail etc.	16 kg
		Fleshings	3 kg
		Wastewater	5 L

Environmental issues

When hides are preserved by salting, saturated brine or salt crystals are used. Up to 4 litres of saturated brine can be lost for each hide treated. These spent brine solutions can pose substantial disposal problems.

Cleaner Production opportunities

A typical consumption of salt for conserving hides is about 350 kg per tonne of hide. However, if hides are to be stored for 6 weeks or less, salt use can be reduced to 150 kg per tonne of hide. If a biocide is added, the consumption of salt can be further reduced to 50 kg per tonne.

Reduced salt consumption would also be advantageous for the receiving tannery, since many tanneries experience problems with too much salt in their wastewater.

Process description

3.6 Evisceration and splitting

The objective of evisceration is to remove the edible organs, the intestinal tract (casings) and the thoracic cavity (pluck). For pigs, the head is also removed as part of this process.

Edible organs consist of the liver and kidneys etc., and the intestinal tract consists of the stomach (or paunch in the case of cattle), intestines and spleen. The pluck materials consist of the heart, esophagus, lungs and trachea.

Offal, casings and pluck materials are collected in trolley bins (for small operations), or on a moving-top viscera table (for larger operations) and then transferred to other areas of the plant for further processing.

The carcasses are split into two using saws and knives, and then trimmed and graded. This is followed by washing, either manually using hoses or in automated carcass washing units.

Finally, the carcasses are sent for chilling or directly to the boning area for further processing. Carcasses are chilled to temperatures between 0.5°C and 1.5°C for at least 24 hours.

Inputs and outputs

Figure 3—6 is a flow diagram showing the inputs and outputs from this process, and Tables 3—12 and 3—13 provide data for the key inputs and outputs for pigs and beef cattle respectively.

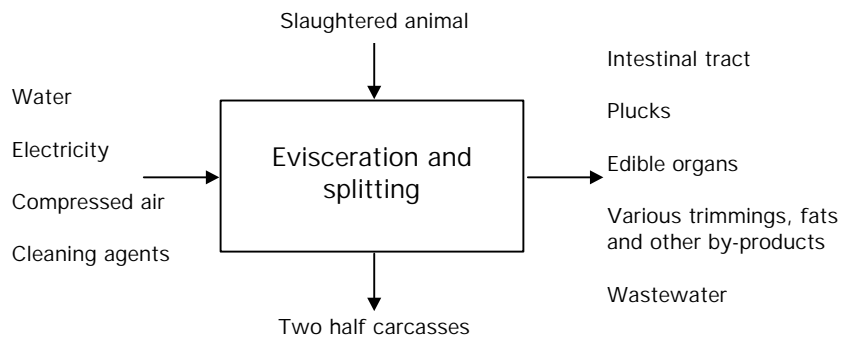


Figure 3—6 Inputs and outputs for evisceration and splitting

Table 3—12 Input and output data for the evisceration and splitting of a 100 kg pig

Inputs		Outputs	
Dehaired pig carcass	93 kg	Split pig carcass	74 kg
Water	40 L	Intestinal tract	10 kg
		Plucks and edible organs	3 kg
		By-products	5.5 kg
		Wastewater	40 L
		BOD ₅	0.05 kg

Table 3—13 Input and output data for the evisceration and splitting of 250 kg beef cattle

Inputs		Outputs	
Dehided cattle carcass	207 kg	Split cattle carcass	125 kg
Water	100 L	Intestinal tract	60 kg
		Plucks and edible organs	9 kg
		By-products	12 kg
		Wastewater	100 L
		BOD ₅	0.12 kg

Environmental issues

Evisceration and splitting are generally undertaken without water. However large amounts of hot water (82°C) are used for the cleaning and sterilisation of knives and equipment (saws, trays, gambrels, hooks, rails etc).

Carcass washing can be a significant source of water waste and effluent contamination. In manual operations there is a tendency for operators to use more water than is necessary. In contrast, in automated carcass washing units sprays are activated only when a side of meat is in the washing cabinet. The amount of water used can be set to the minimum required.

Water pressures greater than 10 bar for carcass washing can remove fat from the surface. This fat contributes to high oil and grease levels in the effluent stream. Water temperatures greater than 30°C can further exacerbate fat loss.

The use of water for cooling and transport of by-products results in high water consumption and high organic content in the effluent.

Cleaner Production opportunities

By-products should be transported dry on conveyors or in small containers with wheels. Container systems are a cheap and easy solution, whereas conveyors can be very expensive to install.

If water sprays are to be used on conveyor systems, variable-speed drives and flow-control valves should be used to regulate water flow as the conveyor speed alters.

The pressure of water sprays used for carcass washing should be less than 10 bar and cool water should be used to reduce the removal of fat from the surface of the carcass.

If carcasses are chilled in chill tanks, the rate of water discharge from the tanks should be reduced to the minimum level required to maintain acceptable bacterial counts. In addition, counter-current flow system should be used on chill tanks.

3.7 Casings processing

Process description

The term 'casings' refers to the intestinal tract of the animal or gut set. For pigs, it consists of the stomach, small and large intestines, middle cap, bladder and bung. For cattle the casings consist of the stomach (paunch, honeycomb, bible and rennet), bladder, small intestine, middle intestine and bung.

Certain parts of the casings can be processed into a number of value-added products, such as sausage skins, surgical sutures and strings for musical instruments and tennis rackets. Processing of casings involves de-sliming to remove the inner lining 'mucosa', and washing.

If casings are not processed into value-added products, they are generally sent for rendering with or without prior washing.

Inputs and outputs

Figure 3—7 is a flow diagram showing the inputs and outputs from this process and Tables 3—14 and 3—15 provide data for the key inputs and outputs for the processing of casings from pigs and cattle respectively.

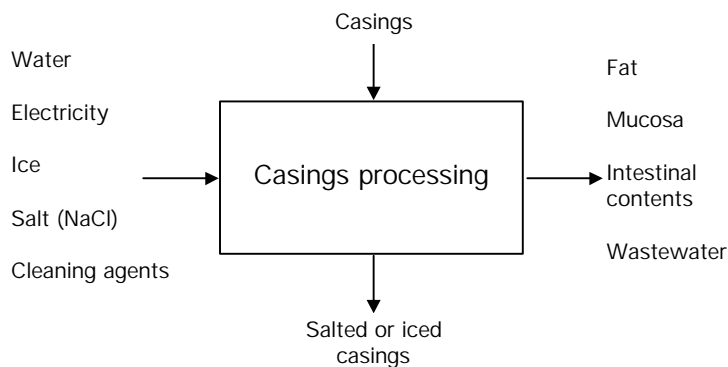


Figure 3—7 Inputs and outputs for casings processing

Table 3—14 Input and output data for the processing of one set of pig casings

Inputs		Outputs	
Pig casings	10 kg	Washed casings	~ 10 kg
Water	50–100 L	Wastewater	50–100 L
		BOD ₅	0.1–0.3 kg

Table 3—15 Input and output data for processing of one set of beef cattle casings

Inputs		Outputs	
Cattle casings	30 kg	Washed casings	~ 30 kg
Water	300–500 L	Wastewater	300–500 L
		BOD ₅	1–1.5 kg

Environmental issues

Water consumption for casings processing is very high, and can be up to 20% of total water consumption in plants where it is undertaken. Casings processing can also be a significant contributor to the organic and fat load in the effluent stream.

Cleaner Production opportunities

Fasting of animals for a period of 12 to 24 hours prior to slaughter reduces the quantity of undigested materials in the intestinal tract, making the evisceration process easier.

Since the water consumption and effluent loads generated by this process can be considerable, an assessment should be made of whether casings cleaning is a profitable choice. It may be better to send the empty intestines for inedible rendering, especially if water resources are scarce and the wastewater is poorly treated.

Water from the final rinse of the casings could be collected and recirculated or used for cleaning the large intestines and bungs. This would require a collection vessel and pipework.

If casings are to be washed for rendering only, recycled water from the slaughter floor, carcass washing, viscera tables and hand wash basins could be used, as it is still of high quality. To prevent blockages of nozzles or jets, the water should first be screened to remove gross solids (McNeil and Husband, 1995).

New techniques for emptying gut sets from pigs, without the use of water, have been developed in Denmark. Pig stomachs are conveyed over a rotating slitting blade and the stomach contents fall into a chute. Whether this option is feasible depends on the cost of water and the charges on wastewater.

3.8 Paunch washing (cattle)

Process description

In ruminants (cattle, sheep etc.), the paunch or first stomach contains a large amount of undigested material, referred to as paunch manure. For cattle, it is estimated that about 36–45 kg of wet paunch material is produced per head, but this depends on the size of the cattle being slaughtered and their history.

In some plants paunches are slashed, emptied and washed with water (wet dumping), so that edible products can be recovered from the paunch. Alternatively, paunches can be emptied and sent, without washing (dry dumping), to be rendered or used in pet food production.

Wet-dump systems generate 145–390 L effluent per paunch processed, whereas dry-dump systems generate 7–19 L effluent per paunch (MIRINZ, 1996). In the dry-dump system however, the paunch sack is not used as an edible by-product, due to the residual contamination with paunch manure.

Paunch manure is usually collected as a separate stream and screened to remove solids. Screened paunch solids are a good source of nutrients and are often applied to land or composted. The screened effluent is generally sent to the effluent treatment plant along with other effluent streams. At some plants the entire paunch manure stream is sent to the effluent treatment plant, but this practice is becoming less common as companies attempt to reduce the organic loads entering treatment plants.

Inputs and outputs

Figure 3—8 is a flow diagram showing the inputs and outputs from this process and Table 3—16 provides data for the key inputs and outputs.

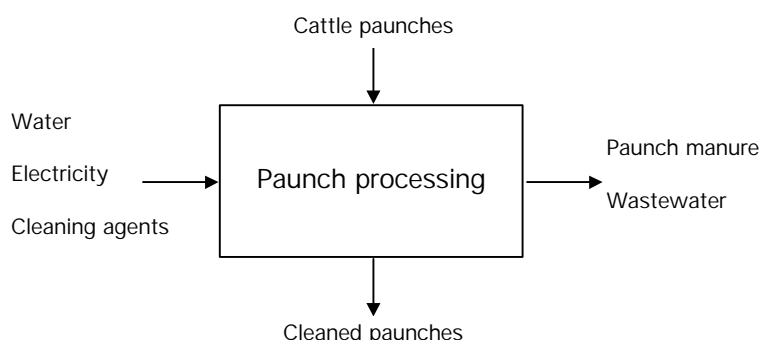


Figure 3—8 Inputs and outputs for paunch processing

Table 3—16 Input and output data for paunch processing

Inputs		Outputs	
Cattle paunch	50 kg	Washed cattle paunch	10 kg
Water	200 L ¹	Paunch manure	40 kg
		Wastewater	200 L ¹
		BOD ₅	0.5 kg

¹ This applies to wet-dump systems

Environmental issues

In plants where paunch washing takes place, water consumption in the casing process can be very high.

Paunch manure contains high concentrations of organic solids and other pollutants. BOD₅ concentrations have been estimated to be about 50,000 mg/L (Baumann, 1971). If paunch manure is discharged to an effluent treatment plant, problems can arise due to the resultant high total solids concentration. The undigested solids are not easily degraded in biological treatment systems and build up as sludge in the system, reducing its overall treatment capacity.

Cleaner Production opportunities

Fasting animals for a period of 12 to 24 hours prior to slaughtering reduces the quantity of paunch material, making the evisceration process easier.

Since the water consumption and effluent loads generated by this process are considerable, an assessment should be made of whether paunch washing is a profitable choice.

As with casings processing, use may be made of recycled water from other parts of the plant.

For cattle, a technique which allows for the recovery of the paunch sack, while reducing water consumption and effluent loading, is the two-step dry dump/spray wash system. The paunches are first emptied of their contents, without the use of water, and then rinsed using an efficient water spray system. See case study below.

Case study 3—2: Reduced effluent generation in paunch wash system

A survey was undertaken in New Zealand at five beef processing plants to evaluate different paunch handling operations and to trial a two-step dry dump/spray wash system.

It was found that the two-step system reduced water consumption and the pollutant load of the effluent stream, while allowing the paunch sack to be used as an edible by-product.

It was estimated that converting a wet-dump system to a two-step system could reduce the total effluent loading of a typical beef abattoir by 18–33% for total solids, 16–31% for COD, 9–18% for total nitrogen and 20–46% for total phosphorus. Potentially, the conversion could reduce a plant's effluent treatment or disposal costs by a similar proportion.

(MIRINZ, 1996)

Paunch manure from cattle is an ideal medium for composting or vermiculture (worm composting) along with other waste materials. After composting it can be used or marketed as a fertiliser and soil conditioner. Under some circumstances, paunch manure may be spread directly onto agricultural land; however prior composting is preferable.

3.9 Rendering*Process description*

Rendering is an essential part of the meat processing industry. Rendering converts highly perishable meat by-products that are unfit for human consumption into useful commodities such as meat meal, bone meal, tallow and also pet food. Materials that are commonly rendered include inedible offal and fat from the slaughtering process, dead animals and animal that have been classed as 'condemned' as a result of the post slaughter inspection.

The basic aims of rendering are:

- Sterilisation to make products safe;
- Recovery of fat to make the meal suitable for milling and stabilise it against oxidation; and
- Drying, to prevent bacterial growth and to facilitate transportation and storage.

Rendering is carried out using a number of different systems ranging from simple batch cooking systems in which fat is removed by hydraulic presses to highly sophisticated continuous systems. Pre-crushed raw materials are loaded into the rendering cooker. The material is heated to high temperatures, which evaporates the water and sterilises it. Fat is allowed to drain from the mixture in a percolator pan and the remainder of the fat is pressed out mechanically, either in a hydraulic press (batch process) or continuously in a screw press. The press cake is milled to produce meat meal and bone meal and the fat is further refined to remove impurities, by precipitation, centrifugation etc.

Inputs and outputs

Figure 3—9 is a flow diagram showing the inputs and outputs from a typical small rendering process. Table 3—17 provides data for the key inputs and outputs.

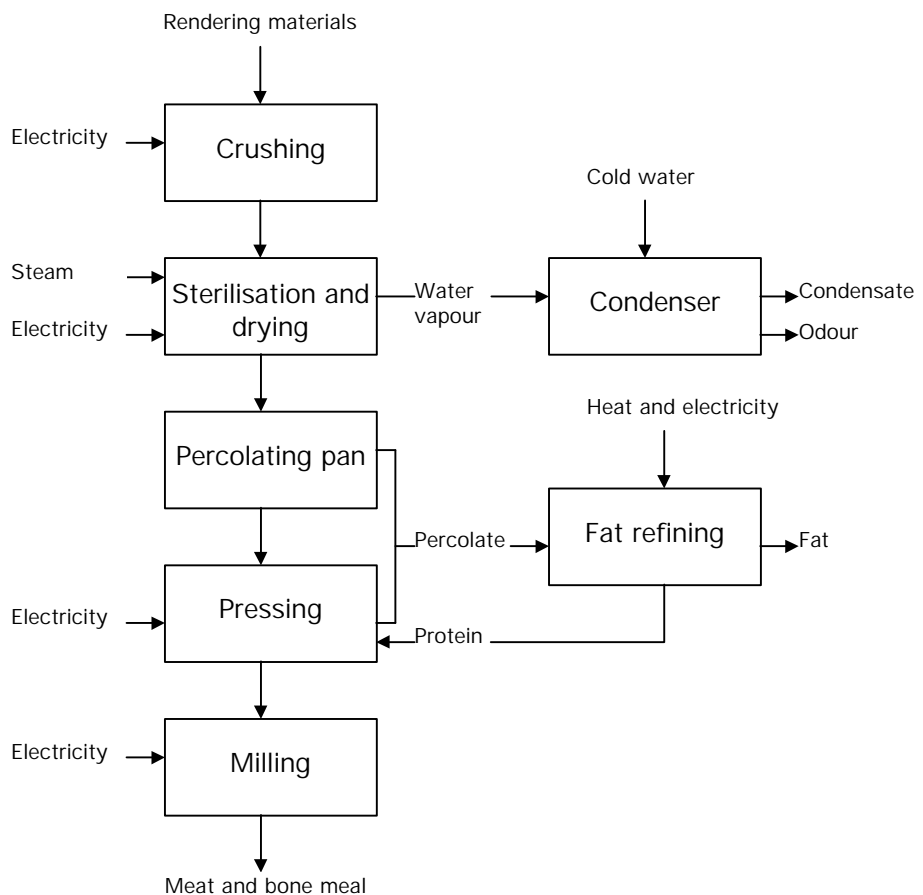


Figure 3—9 Inputs and outputs for rendering

Table 3—17 Input and output data for rendering

Inputs		Outputs	
Raw materials (offal, dead animals, etc.)	1000 kg ¹	Bone meal	280 kg
Fuel oil for steam generation	60 kg	Fat	110 kg
Electricity	70 kW.h	Wastewater	1000–1600 L ¹
Water for boiler	150–200 L	COD	5 kg
Water for condenser	200–500 L	Total nitrogen	0.6 kg
Water for cleaning	200–300 L		

¹ Approximately 60% of the weight of the raw materials is water, which ends up as condensate wastewater as a result of the rendering process.

Environmental issues

Water consumption for rendering is relatively low with a usage rate of about 1m³/tonne raw material and typically represents less than 10% of total water use at an abattoir.

Effluent from the rendering plant contains very high loads of organic matter, and at those plants where it is undertaken rendering is the largest single source of effluent contamination. Rendering effluent comprises condensate from dry rendering, stickwaters from wet rendering, decanters and blood coagulation and from polisher centrifuges.

The energy consumption for rendering is very high, especially for the drying step. However modern systems can be quite energy efficient, especially when multiple effect evaporators are used.

Rendering materials are highly putrescible, and if not handled and treated correctly can cause extremely bad odours. The exhaust fumes from the rendering process are also extremely odorous. It is often necessary to install odour control systems to reduce odour emissions to within required limits.

Cleaner Production opportunities

Since the rendering process converts 'waste' materials into useful, value-added products, rendering in itself is a Cleaner Production option.

Raw materials for rendering should be received at the rendering plant as soon as possible, and processed promptly to avoid odour. Delays in processing result in poor quality raw materials which lead to lower yields, lower quality products, and difficulties in processing the raw materials. Rendering materials should also be kept cool on ice, at about 10–15°C or preferably lower.

The heat contained in the vapour from the cookers can also be recovered in multiple effect evaporators etc. and used to pre-heat raw materials. This can reduce energy consumption from about 60 kg to 35–40 kg oil per tonne of raw material.

The effluent stream from rendering along with other high-strength streams, such as that from paunch and stomach dumping, could be collected and treated separately. By treating these streams separately from the low-strength streams from the rest of the plant, overall treatment performance is improved. Segregated, high-strength effluent

streams could be anaerobically digested to produce methane-rich biogas. The biogas could be used to supplement energy supplies on site.

3.10 Cleaning

Process description

All work areas and equipment are cleaned daily, usually at the end of each production shift. A common cleaning regime is as follows. First, equipment and floors are roughly hosed down. Then detergents and foam are applied, followed by washing and scrubbing. The detergents normally used are alkaline to remove fat and protein. The detergents and dirt are removed by hosing and/or scraping. Finally, there is a rinse with clean water to remove all detergent or disinfectant.

Areas that have high levels of fat residues such as boning and cutting rooms require high-pressure, low-volume water at approximately 60°C to give the most economical water usage. Higher water temperature will increase the amount of steam vapour and associated condensation problems, without any increase in cleaning efficiency (McNeil and Husband, 1995).

As well as the major cleaning that occurs at the end of each shift, knives and some items of equipment are washed and sterilised frequently throughout production. Hygiene regulations usually require that knives be sterilised in hot water and that the water in the sterilisers be replaced at set frequencies. Operators also regularly wash their hands. Knife sterilisers and hand wash stations are located at work-stations on slaughter floors and in processing areas for this purpose.

Hand basins provide a flow of hot water (35–43°C) at about 15 L/min (McNeil and Husband, 1995). The flow is controlled by thigh or pedal operated mechanisms; however microprocessor controlled units are also used. Knife sterilisers can be bowl-type or spray-type systems. Bowl-type sterilisers contain hot water that is continuously replenished to maintain the required temperature of about 82°C.

Inputs and outputs

Figure 3—10 is a flow diagram showing the inputs and outputs from this process.

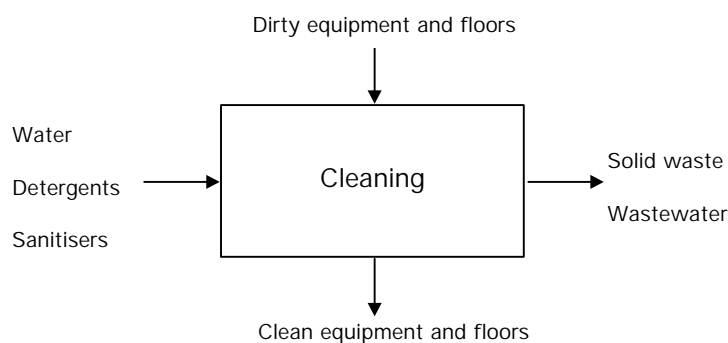


Figure 3—10 *Inputs and outputs for cleaning*

Environmental issues

Cleaning is one of the most water-intensive operations at abattoirs, typically accounting for 20–25% of total water consumption. Wastewater from cleaning contains a high organic load, as well as detergents and disinfectants.

Cleaner Production opportunities

The best way to reduce water consumption in cleaning is to undertake dry cleaning before washing with water. Solid materials should first be scraped and swept from all surfaces, including boning, slicing and packing tables, cutting boards, work platforms and floors.

Case study 3—3: Proper work procedures and control of water consumption in cleaning

Changes in cleaning practices at a pig abattoir resulted in a 31% reduction in water consumption and a 67% reduction in the use of detergents, without impairing hygiene. Undertaking dry cleaning to remove solid materials from floors and equipment prior to washing also resulted in a 30% decrease in overall man-hours used for the cleaning operations. The investment was low and water saving amounted to 10 litres per pig. This is a saving of US\$0.02–0.03 per pig. Labour costs and costs for cleaning agents were also substantially reduced.

Industrial vacuum cleaners have been used successfully in boning rooms for dry cleaning operations at abattoirs. Solids may have to be loosened and scraped free from surfaces, before the vacuum cleaner can be used to collect the solids for transfer to a rendering plant (McNeil and Husband, 1995).

Case study 3—4: Collection of waste from floors with a vacuum cleaner

Experiments have shown that collection of waste materials from floors in the slaughter, bleeding and evisceration areas using a vacuum cleaner can reduce wastewater loads by 50 g BOD₅ per pig. The investment required is approximately US\$25,000. The annual savings depend largely on costs for discharge of wastewater and surcharges for pollution load, but can amount to US\$4000–37,000 per year.

After thorough dry cleaning, work surfaces, walls and floors can be washed down in preparation for cleaning with detergents. The following measures will help reduce water consumption for this step:

- Hoses should be fitted with spray nozzles, since a pressurised spray is far more effective for cleaning surfaces and therefore uses less water. A pressure of 25–30 bar is advisable.
- Flat-jet nozzles should be used to provide maximum impact and velocity. Spray angles of up to 60° provide wide coverage and a sweeping effect to propel solids towards floor drains.
- The first rinse should be with cold water, because warm water will make protein materials stick to the surfaces. The temperature of the water for the subsequent cleaning depends on the kind of contamination. Cold water is often sufficient.
- The wastewater from the final rinse can be collected and used for the initial rinse on the following day.

Detergents and disinfectants can be a significant source of pollution if the amounts used are too great. It is very important, therefore, to monitor their consumption.

The following measures will help reduce detergent consumption:

- Determine the required amount or concentration for effective cleaning;
- Use a set concentration of detergents so that detergent use reduces as water consumption reduces;
- Use new detergents, some of which are more effective and more environmentally friendly than older ones. Alternative detergents should be evaluated on the basis of their cleaning performance as well as their cost and environmental attributes.

Sanitisers should be applied as a fine spray to cleaned surfaces, rather than as a final rinse with hot water. Chemical sanitisers can be more effective in bacteriological control, less damaging to the building and safer for personnel than large quantities of hot water (McNeil and Husband, 1995).

Spray nozzles, commonly used for cleaning operations, are subject to wear that causes deterioration of the orifice and distortion to the spray pattern. This results in an increased flowrate of water and reduced effectiveness. In general, 10% nozzle wear will result in a 20% increase in water consumption (McNeil and Husband, 1995). Nozzles made from different materials have varying abrasion resistance, as shown in Table 3—18.

Regular monitoring of spray nozzle wear should be incorporated into maintenance programs. Nozzles in service can be compared with new nozzles to determine the extent of wear. The flowrate of a nozzle can be determined by measuring the time taken to fill a container of known volume.

Table 3—18 Abrasion wear index for nozzle materials ¹

Material	Abrasion wear index
Brass	1 (poor)
Stainless steel	4–6 (good)
Hard plastic	4–6 (good)
Ceramic	90–200 (excellent)

¹ McNeil and Husband, 1995

Microprocessor-controlled hand wash stations, which use an infrared beam to initiate the flow of water for a pre-set period help overcome the problem of water wastage that can sometimes occur when operators tie down the controls of manually operated units.

Double-skin insulated knife steriliser bowls use less water than conventional bowl-type sterilisers, since they minimise heat loss and therefore reduce the rate of overflow required to maintain the required temperature. For a 3-litre bowl, this can mean an overflow rate of 15 L/hr compared with 36 L/hr for conventional bowl sterilisers. (McNeil and Husband, 1995).

For spray-type knife sterilisers, continually running sprays should be avoided and the flow should be initiated only when the implement is introduced into the unit and the sprays should run for a pre-set period of time. Control of steriliser flow rates should be the responsibility of a designated person and flow rates should be checked regularly.

3.11 Ancillary operations

3.11.1 Compressed air supply

Process description

Air is compressed in an air compressor and distributed throughout the plant in pressurised pipes. Usually, compressors are electrically powered and cooled with water or air.

Figure 3—11 is a flow diagram showing the inputs and outputs from this process.

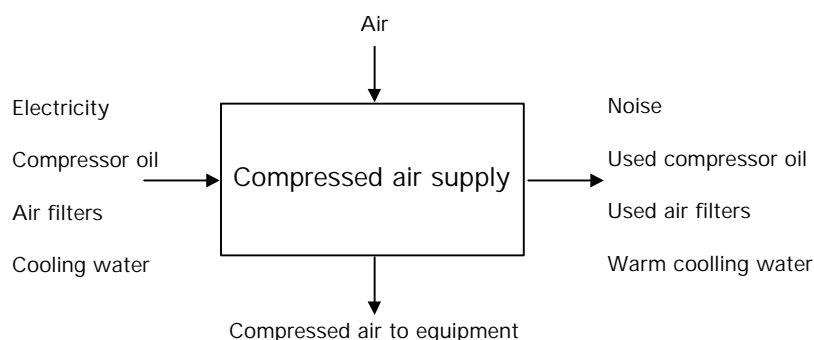


Figure 3—11 Inputs and outputs for production of compressed air

Environmental issues

Even a few small holes in the compressed air system (pipes, valves etc.), result in the loss of a large amount of compressed air continuously. This results in a waste of electricity because the compressor has to run more than is necessary. Table 3—19 lists unnecessary electricity consumption that can be caused by leaks in a compressed air system.

Table 3—19 Electricity losses from compressed air system leaks (6 bar)¹

Hole size (mm)	Air losses (L/s)	kW.h/day	MW.h/year
1	1	6	3
3	19	74	27
5	27	199	73

¹ UNEP 1996

Air compressors are often very noisy, and can be a nuisance for noise-sensitive receptors in some circumstances. If the air compressor is water cooled, water consumption can be quite high.

Cleaner Production opportunities

It is very important to check the compressed air system frequently. The best method is to listen for leaks during periods when there is no production. Maintenance (e.g. change of compressor oil) and the keeping of accurate logbooks will often help identify the onset of system leaks.

Shutting the system off when not in use and reducing the operating pressure of the system can also reduce the use of compressed air.

A temperature-sensitive valve, ensuring the optimum cooling temperature and minimum use of water should regulate the consumption of cooling water. Furthermore, cooling water can be recirculated via a

cooling tower. Alternatively, the cooling water can be reused for other purposes such as cleaning, where hygiene requirements are low.

Case study 3—5: Reuse of air compressor cooling water

An air-cooling system for an air compressor was replaced with a water-cooled one. The water absorbs the heat from the compressor and is then reused in the boilers. Energy is saved in the boilers because the water is preheated.

The installation of the water cooling system cost US\$18,000 and provided a payback period of less than two years.

3.11.2 Steam production

Process description

Steam is produced in a boiler and distributed throughout the plant through insulated pipes. Condensate is returned to a condensate tank, from where it is recirculated as boiler feed water, unless it is used for heating in the production process.

The amount and pressure of the steam produced depends on the size of the boiler and how the fuel is injected into the combustion chamber. Other parameters include pressure, fuel type, maintenance and operation of the boiler.

Inputs and outputs

Figure 3—12 is a flow diagram showing the inputs and outputs from this process.

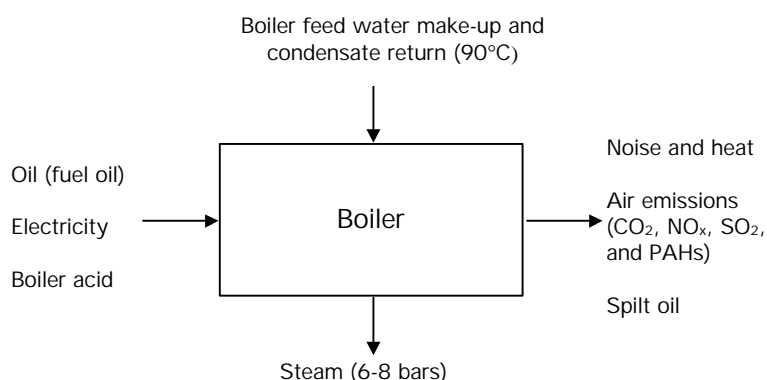


Figure 3—12 Inputs and outputs for supply of steam

Environmental issues

Inefficiencies in boiler operation and steam leaks lead to the waste of valuable fuel resources as well as additional operating costs.

Combustion of fuel oil results in emissions of carbon dioxide (CO₂), sulphur dioxide (SO₂), nitrogen oxides (NO_x) and polycyclic aromatic hydrocarbons (PAHs). Some fuel oils contain 3–5% sulphur and result in sulphur dioxide emissions of 50–85kg per 1000 litres of fuel oil.

Sulphur dioxide converts to sulphuric acid in the atmosphere, resulting in the formation of acid rain. Nitrogen oxides contribute to smog and can cause lung irritation.

If the combustion is not adjusted properly, and if the air: oil ratio is too low, high emissions of soot can result. Soot contains PAHs that are carcinogenic.

Table 3—20 shows the emissions produced from the combustion of various fuels to produce steam.

Table 3—20 Emissions from the combustion of fuel oil

Inputs		Outputs	
Fuel oil (1% sulphur)	1 kg	Energy content	11.5 kW.h
		Carbon dioxide	3.5 kg
		Nitrogen oxides	0.01 kg
		Sulphur dioxide	0.02 kg

1 kg of oil = 1.16 litre of oil (0.86 kg/L)

1 kW.h = 3.6 MJ

Oil is often spilt at the oil storage area and at the boiler. If the spilt oil is not collected and reused or sold, it can cause serious pollution of soil and water.

Although most condensate from steam systems is returned to the boiler, some fresh water make-up is required. For inefficiently operated boilers, the amount of feed water required can be excessive. As well as higher water consumption, this results in the need to add additional boiler chemicals and increased fuel consumption to preheat the feed water.

Cleaner Production opportunities

Instead of using fuel oil with high sulphur content, it is advantageous to change to a fuel oil with a low sulphur content—less than 1%. This will increase the efficiency of the boiler and reduce the emission of sulphur dioxide. There are no investment costs related to this option, but the running costs will be higher because the fuel oil with a lower sulphur content is more expensive.

It is essential to avoid oil spills and, if they do occur, to clean them up properly and either reuse or sell the oil. A procedure for handling oil and oil spills should be prepared and followed.

If the boiler is old, the installation of a new one should be considered. Changing from coal to oil, or from oil to natural gas, should also be considered. In some burners it is possible to install an oil atomiser and thereby increase efficiency. When purchasing a new boiler, emphasis should be placed on purchasing the minimum sized boiler that is sufficient to meet the steam demand of the plant. Purchasing an over-sized boiler for the sake of contingency may not really be necessary.

Insulation of hot surfaces is a cheap and very effective way of reducing energy consumption. Equipment such as valves, flanges, autoclaves, heated vessels and pipe connections to machinery should be insulated: Proper insulation of these surfaces can reduce heat loss by 90%. The payback period for insulation is often less than 3 years.

The way in which a boiler is operated will affect its efficiency. If the air:fuel ratio is wrongly adjusted burning will be poor, causing more pollution and less efficient utilisation of the fuel. Proper operation of the boiler requires appropriate training of employees and, if the expertise is not available within the company, and possibly frequent visits of specialists.

Condensate return to the boiler should be maximised to minimise water consumption and improve boiler efficiency. If condensate from some areas is not returned to the boiler, piping systems to return it should be installed. Steam trap performance should be monitored regularly to ensure efficient return of condensate and to ensure they are not leaking.

Case study 3—6: Poorly operated coal-fired boiler

Samples of coal and waste ash were taken from coal-fired boilers and were measured for specific energy (kJ/kg), ash percentage and moisture percentage. Results showed that up to 29% of the total fuel supply was not being combusted in the boilers, with the least efficient boiler generating an additional 230 kg of unburnt material per tonne of coal. This unburnt material was retained in the ash and disposed of in landfill.

To improve performance, the company trained employees in efficient boiler operation, so that boilers could be run on automatic control. After this training, boiler efficiency increased by 25%, and the specific energy of the ash reduced to 6 kJ/kg.

Coal use was reduced by 1500 tons, making an annual saving of US\$45,000. Improved boiler operation also reduced annual landfill disposal by 275 tonnes. The company hired a specialist company to monitor boiler efficiency on an ongoing basis. The cost of this service is US\$2100 per month.

3.11.3 Water supply

Process description

High-quality domestic water supplies may not need any treatment before use in the plant, however if the available water is of poor quality it may be necessary to treat it to meet hygiene requirements. Treatment normally consists of aeration and filtration through gravel or sand, and chlorination may also be necessary.

Inputs and outputs

Figure 3—13 is a flow diagram showing the inputs and outputs from this process.

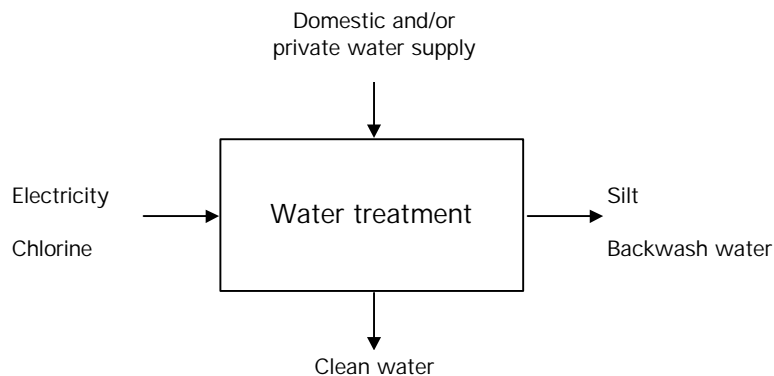


Figure 3—13 Inputs and outputs for supply of water

Environmental issues

Water is a valuable resource so its use should be minimised wherever possible. Since electricity is needed for pumping water, energy consumption also increases with increasing water consumption.

The losses that occur due to holes in water pipes and running taps can be considerable. Table 3—21 shows the relationship between size of leaks and water loss.

Table 3—21 Water loss from leaks at 4.5 bar pressure ¹

Hole size (mm)	Water loss (m ³ /day)	Water loss (m ³ /year)
0.5	0.4	140
1	1.2	430
2	3.7	1,300
4	18	6,400
6	47	17,000

¹ UNEP, 1996

Cleaner Production opportunities

To ensure that water consumption is optimised, usage rates should be monitored on a regular basis. It is helpful to install water meters for separate departments and even for individual processes or pieces of equipment. Whether this is feasible depends on the level of water consumption and the expected savings in each instance. Water consumption can be reduced by 10–50% simply by increasing employees' awareness and by educating them on how to reduce unnecessary consumption.

Energy-efficient pumps should be installed to reduce the energy consumed for pumping of water. New and efficient pumps can reduce energy consumption by up to 50% compared with standard pumps. It is very important to select a pump with optimum pumping capacity and position it close to the required work area.

3.11.4 Refrigeration and cooling

Process description

In refrigeration and cooling systems a refrigerant, typically ammonia or a chlorofluorocarbon (CFC)-based substance, is compressed, and its subsequent expansion is used to chill a closed circuit cooling system. The refrigerant itself can act as a primary coolant, recirculated directly through the cooling system, or alternatively, it can be used to chill a secondary coolant, typically brine or glycol.

CFCs were once extensively used in refrigeration systems, but they are now prohibited in many countries, and their use is being phased out as a result of the Montreal Protocol on ozone-depleting substances. All cooling systems should be closed circuit systems and free of leaks. However, due to wear and tear and inadequate maintenance, leaks may occur.

Inputs and outputs

Figure 3—14 is a flow diagram showing the inputs and outputs from this process.

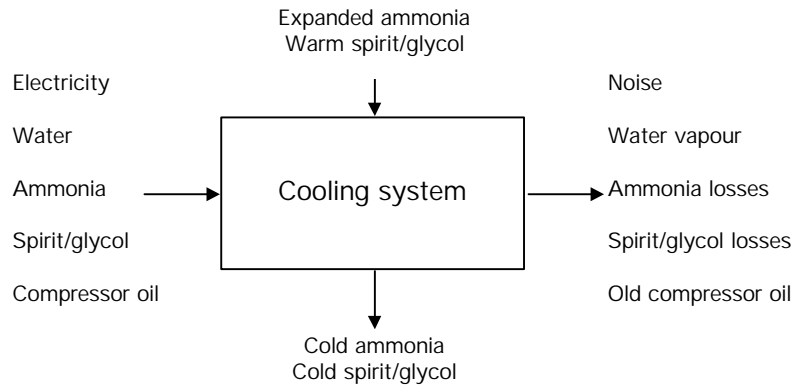


Figure 3—14 Inputs and outputs for cooling system

Environmental issues

The consumption of electricity and of water can be quite high.

If CFC-based refrigerants are used there is a risk that refrigerant gases will be emitted to the atmosphere, contributing to the depletion of the ozone layer. There is also a risk of ammonia and glycol leaks, which can be an occupational, health and safety problem for workers, and can also result in environmental problems.

Cleaner Production opportunities

CFC-based refrigerants should be replaced by the less hazardous hydrochlorofluorocarbons (HCFCs) or, preferably, by ammonia. In the long run both CFCs and HCFCs should be replaced by other refrigerants according to the Montreal Protocol. Replacing CFCs can be expensive, as it may require the installation of new cooling equipment.

Minimising the ingress of heat into refrigerated areas can reduce energy consumption. This can be accomplished by insulating cold rooms and pipes that contain refrigerant, by closing doors and windows to cold areas, and by installing self-closing doors.

If water and electricity consumption in the cooling towers seems high, it could be due to algal growth on the evaporator pipes. Another reason could be that the fans are running at too high a speed, blowing the water off the cooling tower.