Waste Minimisation in Meat Processing

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INTRODUCTION

The processing of animals into meat and by-products traditionally uses large volumes of water and produces similar volumes of wastewater requiring treatment and disposal. Solid wastes are also produced. With increasingly strict standards and restrictions being imposed on how wastes can be disposed of, most meat processing companies are facing the challenge of improving their waste management practices, while keeping costs to a minimum.

To do this, meat processors have to develop waste management strategies based on the following hierarchy:

1. Waste reduction at source
2. Re-use and recycling
3. Treatment and disposal

The wastewater is the main waste stream in meat processing requiring treatment and disposal. At animal slaughter and processing plants, various amounts of blood, fat, gut contents, faeces and other organic materials, are washed into the effluent stream from a range of plant operations. The resulting effluent typically contains high concentrations of biochemical oxygen demand (BOD), nitrogen, phosphorus and faecal microorganisms, which are the main pollutants of concern in the treatment of the wastewater and its discharge to the environment.

Once the organic materials enter the effluent stream, they are likely to add to its treatment and/or disposal costs. Some of the effluent particulate solids can be removed by primary treatment systems, such as screens, sedimentation tanks (save-alls) and/or dissolved air flotation (DAF) systems. However, only a small proportion of the wastewater loading can be removed by these simple physical means. Most of the wastewater load is in a soluble or colloidal form, and can only be removed by using more complex secondary treatment techniques such as ultrafiltration, chemical treatment, biological treatment or land application. The cost of such treatment is high, and is directly related to the volume of the wastewater, the concentration of pollutants it contains, and the degree of pollutant removal required.

As the required standards, and therefore costs, of waste treatment and disposal increase, there is an increasing economic incentive for processors to reduce waste production at source.

Source reduction, as applied to minimising the contamination of a process water stream, can be achieved by either changing the process to avoid the use of water, or by reducing the amount of material that enters the process water. In meat processing, the latter approach often involves recovering potential contaminants by dry-cleaning techniques, and either disposing of the recovered material or processing it into valuable by-products. Thus, an added incentive for source reduction is that it can increase product yield, and thus revenue.

Where reduction of wastewater loadings at source is not viable, opportunities to recover wastes from the effluent stream should be considered as a potentially lower-cost alternative to treatment and disposal. In meat processing, it is often necessary to segregate certain waste streams and then to recover the materials from these segregated waste streams as close to the waste sources as possible, to maximise the quantity and potential value of materials recovered.

In assessing opportunities for reducing and recovering waste in meat processing, it is useful to distinguish between the potentially useful wastes derived from animal tissues (e.g. blood, fat, meat, connective tissue and bone) and low or no value wastes consisting of the animal gut contents, faeces and urine. Any animal tissue waste material saved from entering the wastewater stream can be processed into valuable by-products such as tallow, meat and bone meal or dried blood, as appropriate. Thus, these materials contribute to "waste" only if they are mixed with washwater and discharged down the drain.

Waste minimisation applied to gut contents and faecal material is more complex. As with the animal tissues, collecting the gut contents and faeces in a "dry" form (e.g. dry-dumping paunch contents and dry-collection of lairage wastes) can considerably reduce the effluent pollutant loading and treatment/disposal costs. However, the "dry" collection of these solids can be difficult, and the collected solids themselves can present a significant disposal problem for many meat processing plants.

This paper discusses the application of waste minimisation techniques to these two main waste categories, with particular reference to processes in meat plants that generate the greatest wastewater loadings.

ANIMAL TISSUE WASTES

Blood Collection

Raw blood contains about 20% dry matter, consisting primarily of soluble proteins. Once discharged into an effluent drain, the blood cannot be recovered or removed by simple means. Blood proteins and their associated pollutant loading can be recovered from the wastewater by ultrafiltration (Fernando, 1978) or chemical treatment (Cooper and Russell, 1982), but such recovery is costly.

Blood has a high BOD and nitrogen content (Table 1). Thus, any blood saved from entering the wastewater stream, or recovered by the above means, could significantly reduce the costs of subsequent treatment of the wastewater in a biological nutrient removal system or by land application. For example, by reducing the volume of blood lost to the effluent stream by only 100 L each day, a meat plant disposing of its effluent by land application could reduce the land area required by 2.5 ha (assuming a maximum allowable nitrogen application rate of 300 kg N ha^{-1} y^{-1}, and 250 processing days per year). This blood, if recovered for blood processing, also represents an annual gain in product revenue of NZ$3000 at today's dried blood price of about NZ$600 per tonne.

It is normal practice in New Zealand meat processing plants to collect the blood that issues from the animal after sticking. The blood drains into a collection pit or trough for a period of typically 6-10 minutes for cattle slaughter, and 2-3 minutes for sheep and lambs. By the time the carcass has moved past the blood collection area, the blood flow usually has ceased to be continuous and has slowed to a drip. However, blood loss from the carcass tends to increase again at times, depending on the carcass orientation on the chain and on carcass manipulation, including the physical shaking of the carcass, hide pulling, brisket cutting and head removal.

Table 1.
Typical characteristics of undiluted beef and sheep blood with respect to pollutants of concern in wastewater management (MIRINZ unpublished data).

	Concentration ($g\ m^{-3}$)
Total solids	200,000
Chemical oxygen demand (COD)	280,000
Five-day biochemical oxygen demand (BOD_5)	200,000
Total nitrogen	30,000
Total phosphorus	200

In a recent MIRINZ study (full report in preparation), the volume of blood drip from carcasses at two beef and two sheep/lamb processing plants was measured during various stages between the end of formal blood collection and evisceration. The recovered blood loss ranged from about 1.2 to 2.4 L per animal for beef processing, 0.12 to 0.22 L per animal for lamb processing, and 0.14 to 0.31 L per animal for sheep processing. More detailed results for one of the beef plants are summarised in Table 2.

The animal bleeding rate, and thus the efficiency of blood collection, can depend on stunning and sticking procedures (Blackmore and Newhook, 1976; Kirton *et al.*, 1981). In the MIRINZ study, the recovered blood loss (after the collection pit/trough) tended to be lowest for Halal-slaughtered animals (for both beef and sheep/lambs), which is consistent with the finding by Kirton *et al.* (1981) that lambs stunned in a manner that allowed the heart to continue beating for a period (consistent with Halal slaughter practice) bled out more rapidly following sticking than lambs that were stunned in a manner that caused cardiac arrest.

The blood drip that occurs after the collection trough/pit can be easily collected by regularly dry-cleaning the floor under the carcasses and detached heads using a squeegee, and pushing the amassed blood into the blood collection system or scooping it into a temporary holding bin. Where any of this blood contains a significant amount of trimmings or other contaminants, it could be collected separately into an offal bin for rendering. A low (e.g. 30-100 mm) concrete nib wall or similar structure should be built on the floor around the areas to be dry-cleaned. This will help contain the blood and minimise its dilution by washwater. These troughs would need to be designed so they do not hinder personnel movement around the slaughterfloor, and so they facilitate easy cleaning.

Another significant source of blood loss is the large clots of congealed blood that can sometimes be found on beef viscera trays, due possibly to poor sticking technique. If passed through a gut cutter and washer with the intestines, a large proportion of the clotted blood will be washed into the effluent. At one of the beef plants studied, the volume of clots found in 100 viscera trays was measured. The overall average volume of these clots was 255 mL per carcass. However, only 27 carcasses had clots, so the average volume per animal with clots was 943 mL. Manual recovery of this potential product/source of effluent loading is a possible option.

Table 2.
Volume of blood drip collected from carcasses and detached heads during selected periods between the end of formal blood collection and carcass evisceration at a beef processing plant. The animals were killed by captive bolt and electrically stimulated immediately after sticking.

Site of blood drip measurement	Period after sticking (min:sec)	Number of samples	Blood volume ($mL\ animal^{-1}$)	
			Mean	Std. dev.
Between collection trough and hide puller	6:00-14:00	10	1538	563
During hide removal	14:00-16:00	20	572	211
From detached head	15:45-16:00	30	223	98
Between hide puller and evisceration	16:00-18:00	30	101	39
Total		-	**2434**	-

Thorough dry-cleaning is important for all areas where blood drip occurs and congealed blood accumulates, including the blood collection pit, and raw blood storage tanks. For example, at one of the beef plants studied, on average 96 L of congealed blood lined the blood collection pit, and this blood was washed into the effluent at each break in the working day. The loss of blood from this source was equivalent to about 1 L per animal processed. This loss occurred because the pit was poorly designed, making access for dry-cleaning difficult, and because staff did not fully appreciate the quantity of blood loss and its effects. Both good management and an understanding of "downstream" consequences are essential to achieving success in waste minimisation.

Another common problem leading to blood wastage is staff forgetting to close the effluent drain in the blood collection pit/trough after washing the pit/trough. This risk could be minimised by fitting an audible or visual alarm system that activates if the valve is open when the processing chain is operating. Blood wastage to effluent also sometimes occurs due to overflow of blood storage tanks or failure of blood pumps. Appropriate alarms, together with sufficient backup storage capacity and pumping systems, are important in minimising these risks.

Solid Tissue

Some amount of animal tissue "waste", including meat and fat trimmings, is unavoidable in meat processing, but a primary aim should be to minimise the amount of this material generated. Dry-cleaning methods should be used to collect the solids as close to source as possible, to maximise recovery for rendering. If washed into the effluent, a proportion of the solids cannot be recovered by screening and in save-alls, producing a significant wastewater load requiring further treatment.

FAECAL MATTER AND GUT CONTENTS

Another important source of waste in meat processing is the faecal matter and gut contents of slaughtered animals. These wastes enter the effluent stream in various amounts during the following plant operations:

- Stock-truck washing
- Washing of yards used for preslaughter holding of stock (lairage)
- Paunch opening and tripe recovery
- Viscera cutting/washing
- Casings and runners processing

These wastes consist predominantly of digested or semi-digested vegetable matter from the diet of the slaughtered animals. Sheep and cattle diets vary significantly, both seasonally and depending on whether the animals were raised on pasture or grain, and so the nature of the faeces and gut contents is also variable.

The usual practice for managing the faeces and gut contents is to wash them, using large amounts of water, into the wastewater stream. For meat plants that do not carry out on-site rendering, blood processing or other major by-products processing operations, it is estimated that faeces and gut contents would typically account for more than 75% of the phosphorus and 50% of the nitrogen, sodium and organic loading in primary screened or settled effluent from the plant [estimates based largely on data from Swan *et al.* (1986), Johns *et al.* (1995), van Oostrom and Muirhead (1996), and MIRINZ unpublished plant surveys].

For the faecal/gut content waste category as a whole, the only practicable opportunity for reduction at source is to keep the animals off feed for a period before transport to the meat plant. This, however, is sometimes difficult for meat processors to control, and may be incompatible with animal welfare and product yield/quality objectives. For example, recent MIRINZ studies found that a lack of food during holding can exacerbate detrimental animal responses to pre-slaughter handling, and that holding the animals in yards with supplementary feed might improve welfare and produce carcass weight gains (Jacobson and Cook, 1997)

There are, however, opportunities to minimise the loading of faecal and gut content material on the wastewater stream, mainly by recovering the solids "dry" at source. There is also the opportunity of efficient recovery of the solids (e.g. by milliscreening, sedimentation or DAF) from a segregated wastewater stream to which only faecal material and gut contents are discharged. In either case, large volumes of solid waste will be produced. However, in most situations, managing the waste in solid form is more cost-effective than allowing it to enter a secondary wastewater treatment system. Gut contents and faeces, if relatively free of animal tissues, can be stabilised by simple windrow composting techniques (van Oostrom, 1993), or potentially can be spread directly onto land (Hughes and Howatson, 1996). Another possible means of managing the collected solids may be to anaerobically digest them for methane recovery with minimal water addition, with disposal of the digested solids and nutrient-rich liquor to land. Landfilling is increasingly becoming uneconomic ,or its use for the disposal of nutrient-rich animal wastes is sometimes restricted.

Segregation and Wet Recovery

The initial segregation of the wastewater containing faeces and gut contents has the advantage of allowing the solids in these streams to be recovered with minimal contamination by animal tissue. The presence of animal tissue increases the potential for the recovered solids to generate odour, which would restrict how they can be utilised or disposed of. An added advantage of segregation is that animal tissues recovered by primary treatment are not contaminated with faecal matter, and thus are of higher quality as a rendering feedstock.

Many meat plants in New Zealand provide separate primary treatment for at least a majority of waste streams comprising the two categories of waste. Often milliscreens and/or screw-presses are used to recover and de-water the faecal and gut content solids. To maximise the recovery of these materials from the effluent by screening, the screen should have a fine aperture (e.g. 0.5-0.75 mm aperture), should have a flow-balanced influent, and should be large enough to avoid hydraulic overloading. Also, if the recovered solids require dewatering in a screw-press or similar device, only the minimum amount of liquid should be pressed from the solids.

A few New Zealand meat plants discharge their wastewaters containing faecal matter and gut contents to dedicated sludge lagoons without primary screening. In the lagoons, the solids separate from the liquid, consolidate and are broken down by anaerobic degradation processes, releasing nutrients that are subsequently discharged with the lagoon liquid to the secondary treatment system. The accumulated solids are regularly removed from the lagoons for land application or composting, but the nutrient recovery by the removal of the digested solids will be only a fraction of that which could have been achieved by preliminary screening or by dry collecting the solids at source.

Dry Recovery

As with other meat plant wastes, dry collection of faeces and gut contents gives much better recovery of the organic matter and nutrients in the solids than any practicable form of wet recovery. An added benefit of dry recovery is that water is conserved.

The dry-dumping of beef paunches is one of the best single methods of reducing the wastewater loading at beef plants. Beef paunches are usually manually slashed and emptied by wet-dumping using large amounts of water to both clean the paunch sac (for tripe recovery) and carry the paunch contents out of the plant. The material in a typical beef paunch contains about 4000 g total solids, 100 g of total nitrogen (mostly organic nitrogen) and 35 g of total phosphorus (van Oostrom and Muirhead, 1996). When wet dumped, only about 10-30% of the nitrogen and phosphorus, and 40% of the total solids in the paunch contents can be readily recovered from the effluent by milliscreening. A two-stage dry-dump and spray wash system could allow over 90% of the total solids and nutrients to be recovered. Conversion to a dry-dump process could reduce a beef plant's total effluent solids, nitrogen and phosphorus loadings by 18-33%, 9-18% and 20-40%, respectively (van Oostrom and Muirhead, 1996). Potentially the dry dumping of sheep and lamb paunches could result in similar percentage reductions in wastewater loadings.

Cooper and Caddigan (1979) measured the dry matter and nitrogen content of faeces voided by sheep and lambs during 24 hours of pre-slaughter holding. The dry-matter content averaged 80 and 187 g per sheep and lamb, respectively; and the nitrogen content averaged 6.7 and 3.7 g respectively. Stockyards for the preslaughter holding of sheep and lambs in New Zealand are covered with a roof and typically have a raised floor consisting of metal grating through which the faeces and urine fall. Most of the urine drains to effluent, but the faeces are often allowed to accumulate under the grating for a week or more before being typically washed to the effluent stream. The accumulated solids consolidate and dry-out somewhat, and appear to be recovered quite efficiently if screened from the effluent close to source to minimise solubilisation of the solids. Improved recovery could be achieved by collecting the solids dry. This could be done manually or by using a small wheel loader if the grating floor is raised high enough to give appropriate access underneath.

The "dry" recovery of faecal matter from cattle is more difficult than for sheep and lambs, as cattle lairages often have a solid floor and need to be frequently washed. The best opportunity to reduce the amount of cattle waste (both urine and faeces) that enters the effluent stream from the stockyards is to tailgate slaughter (slaughter straight off the truck). However, the tailgate slaughtered animals will have fuller paunches, and thus most of the waste management benefit of tailgate slaughter will be realised only if the paunches are dry dumped. (Even without such dry dumping there may be a small benefit to tailgating because a greater proportion of the semi-digested solids in the paunches of tailgate slaughtered animals should be recovered by effluent screening than the fully digested solids in the voided faeces.) Tailgate slaughter may also benefit meat quality and animal welfare by reducing the opportunities for preslaughter stress and bruising.

Where paunches are not recovered for edible purposes they are usually slashed open, together with other waste gut material, in some form of mechanical gut cutter. The macerated gut tissues are then separated from the gut contents, usually in a rotating wash screen. The washing makes the gut tissues more valuable as a rendering feedstock, but the large volume of effluent from this process contains a high pollutant loading consisting of a large proportion of the gut contents as well as a significant quantity of pea fat. Swan *et al.* (1986) found that amount of nitrogen and total solids in the effluent from four different gut cutting and washing systems was 490 to720 g and 19 to 21 kg per tonne of dressed carcass weight, respectively. A proportion of the gut solids can be recovered from this effluent by milliscreening, but the collected solids will be contaminated with fat, which may restrict how they can be utilised or disposed of. Currently there are no methods available for mechanically separating the gut tissues and contents without the use of water. Thus, this is a development opportunity.

The wastewater from gut washing can be avoided altogether by rendering the whole gut material. The rendering of gut contents degrades tallow quality and value by increasing the fatty acid content and imparting colour, and reduces the meal nitrogen content. However, this loss of revenue might be balanced by: I) reduced fat losses because of little or no gut washing, ii) a reduction in wastewater and solid waste loads, and iii) streamlining and simplification of materials handling equipment (Cooper, 1977). The economic feasibility of this option for reducing waste needs to be considered on a case by case basis.

The dry recovery of faecal/gut content solids during stock-truck cleaning and the processing of casings and runners would probably be more difficult and of lower priority than from the sources described above.

CONCLUSIONS

The meat processing industry, although it has made major advancements in waste reduction and by-product recovery and processing, remains a large producer of waste. Many opportunities remain for reducing the amount of animal tissues and faecal/gut content material from entering the processing wastewater. These opportunities mainly involve techniques that recover wastes in a dry form before they are washed into the wastewater. Where such wastewater loading reduction at source is not viable, the pollutant loading on costly secondary wastewater treatment systems can be reduced by appropriately segregating waste streams and recovering the waste solids and potentially valuable materials from these waste streams as close to the source as possible. As the costs of wastewater treatment and disposal increase, the economic incentives to improve waste reduction, at or near the waste source, increase. Both good management and an understanding of "downstream" consequences of processing practices and technologies are essential to achieving success in waste minimisation.

REFERENCES

Blackmore, D.K. & Newhook, J.C. (1976) Effects of different slaughter methods on bleeding sheep. *Vet. Rec.*, **99**, 312-316.

Cooper, R.N. (1975) Pollution abatement within departments, a discussion. In: Proceedings of the Seventeenth Meat Industry Research Conference. Meat Industry Research Institute of New Zealand, pp. 57-62.

Cooper, R.N. & Caddigan, M.S. (1979) Faecal material voided by stock during holding in freezing works stockyards. Part I: sheep and lambs. Meat Ind. Res. Inst. N.Z. Report No. RM 97.

Cooper, R.N., Russell, J.M. & Adam, J.L. (1982) Recovery and utilization of protein from slaughterhouse effluents by chemical precipitation. In: Upgrading Wastes for Feed and Food, Butterworths, London, pp. 31-49.

Fernando, T. (1978) Application of ultrafiltration for protein recovery in the meat industry. *N.Z. Instn. Engrs. Proc. Tech. Groups*, **4**(6), 871-886.

Hughes, G.R. & Howatson, I.R. (1996) Land disposal of meat processing by-products: a win-win solution. In: Proceedings NZWWA Annual Conference. New Zealand Water and Wastes Association, pp. 221-225.

Jacobson, LH. & Cook C.J. (1997) The effect of pre-transport cattle management on stress, metabolism and carcass weight of bulls. This Proceedings.

Johns, M.R, Harrison, M.L., Hutchinson, P.H. & Beswick, P. (1995) Sources of nutrients in wastewater from integrated cattle slaughterhouses. *Wat. Sci. Technol.*, **32**, 53-58.

Kirton, A.H., Frazerhurst, L.F., Woods, E.G. & Chrystall, B.B. (1981) Effect of electrical stunning method and cardiac arrest on bleeding efficiency, residual blood and blood splash in lambs. *Meat Sci.* **5**, 347-353.

Swan, J.E., Fox, G. & Pooley, E.J. (1986) Assessment of four viscera cutting and washing systems. Meat Ind. Res. Inst. N.Z. Publ. No. 843.

van Oostrom, A.J. (1993) Meat . . . a reliable source for composting. *Waste Manag. Environ.*, **4**(6), 66-68.

van Oostrom, A.J. & Muirhead R.W. (1996) Evaluation of beef paunch handling practices. Meat Ind. Res. Inst. N.Z. Publ. No. 967.

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