Stickwater Recovery

The introduction of comprehensive environmental regulations in several States has imposed tighter waste-water discharge requirements on industry, with increased penalties for noncompliance.

A review of Australian Environmental Legislation in the mid-1990s addressed the discharge of nutrients to receiving waters, and proposed strict limits for discharge as a result. The implementation of these limits has posed a major threat to the abattoir industry as abattoir waste waters typically contain high levels of nutrient.

Existing treatment systems used by abattoirs aren't designed for nutrient removal. Traditional systems for nutrient removal, such as those commonly used to treat sewage, will be comparatively expensive in terms of both capital and operating costs and are not usually designed to produce a saleable end-product.

However, as waste waters from abattoirs contain useable proteins which can be sold if extracted and concentrated, an alternative waste-water-treatment system which allows for nutrient separation in conjunction with reclamation of protein, may have economic advantage over traditional methods. Low-temperature rendering plants, in particular, produce large volumes of waste water containing proteinaceous material and emulsified fat.

To determine the possibilities for protein recovery from this type of waste stream, investigations have been conducted into the nature, composition and potential treatment of stickwater from low temperature rendering plants.

Characterisation of stickwater

Preliminary studies have been carried out to characterise the stickwater obtained as a waste stream from low-temperature rendering plants in an attempt to improve handling of the material and to identify potential uses for this waste stream.

Analysis of stickwater

Samples of low-temperature rendering stickwater—both with, and without, separator sludge—have been analysed. Results showed a total solids content for the samples with and without sludge as 8.37% and 6.28% respectively.

Composition of the total samples are given in Table 1.

Table 1. Composition of low-temperature rendering stickwater samples.

	Stickwater	Stickwater + Sludge
Average Moisture %	93.72	91.63
Average Fat %	1.47	2.83
Average Protein %	4.35	2.30
Total Solids %	6.28	8.37

Centrifugal separation of stickwater

Prior to analysis the samples were heated to 60°C and centrifuged at 3000 rpm for 30 minutes in an attempt to separate the stickwater into two or more phases. After centrifugation three distinct phases were apparent in each sample. The bottom fraction was a light brown colour, the middle fraction an opaque yellow and the top fraction a fatty off-white layer.

The analysis of the various fractions of the stickwater samples is shown in Table 2.

Table 2. Analysis of stickwater fractions from a low-temperature rendering plant

	Top fraction	Middle fraction	Bottom fraction
Density sample A		1.023 g/mL	1.116 g/mL
Comparative Volume Sample A	2%	94%	4%
Comparative Volume Sample B	2%	92%	6%
Total solids content Sample A		5.3%	18.3%

Sample A Stickwater
Sample B Stickwater + sludge

Based on this data, the amount of solids that might be removed in the bottom fraction by centrifugation of untreated stickwater at 60°C is estimated at 12.7% from stickwater and 18.3% from stickwater plus sludge.

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Properties of stickwater

Stickwater is required to be cooled to reduce the mixed waste stream from 50–70°C to below 38°C as required under Trade Waste Agreement Conditions. Cooling of the stickwater to between 10 and 20°C using heat exchangers has previously been suggested.

However, stickwater is known to form a gel at these temperatures. Assessment of the stickwater samples' gel temperature and melt temperature have been determined and are given in Table 3.

Table 3. Gel and melt temperatures of stickwater samples from a low-temperature rendering plant.

	Sample excluding sludge	Sample including sludge
Nature at 25°C	Solid gel	Solid gel
Nature at 27°C	Warm honey-like semi-liquid	Less viscous semi-liquid with some sediment
Nature at 30°C	Free flowing liquid	Free flowing liquid
Gelling complete (cooling)	20.5°C	
Melt complete (heating)	31°C	

Collagenous protein content

With both samples solid at room temperature, it is likely that collagen-like proteins are present in the stickwaters. Analysis of hydroxyproline content (as an indicator of collagen content) showed that the middle fraction contained approx. 32.4% of its total solids content as collagen-like material. This is equivalent to 16 grams of collagen-like material per litre of original stickwater.

Potential recovery of stickwater solids

Sample assessments clearly indicate that centrifugation should be capable of removing some 12–18% of solids from the stickwater as a thick bottom sludge. Fatty material (approximately 2%) may be recovered from the surface of the remaining opaque yellow solution, leaving a gelling liquid containing some 5–6% solids. These solids include a significant content of collagen-like material that can potentially be recovered.

Residual solids are primarily soluble proteins that are likely to be difficult to recover and will remain as BOD load on the waste stream unless some form of pretreatment is applied to coagulate them prior to centrifugation.

Although an identified feasible option, further work will be required to establish a commercial process for recovery of solids and collagen-like proteins from stickwater in this way.

Evaporation of stickwater

A simpler option may be to concentrate stickwater to recover all solids as a dried mixed material or a mixed composition extract. A full-scale double effect evaporator (DEE) has been commissioned for treatment of stickwater from a low temperature rendering plant located on an abattoir site to:

- concentrate the stickwater from the rendering process into a product suitable for drying and hence conversion to a saleable product;
- produce a waste water (condensate) of such a quality to allow river discharge to the requirements of the local Department of Environment.

A double effect evaporator operates under vacuum to lower the boiling point temperature, with steam used as the indirect heat source to facilitate evaporation. In this trial situation the concentrated outfeed from the evaporator is fed to an existing drier at the rendering plant. The dried material can be added back to material from the existing rendering process drier, becoming part of the plant's meat-meal production. However the dried material is high in protein and low in ash, and can be retained separately from the meat-meal stream—if suitable markets are available for its sale.

The rendering unit

The abattoir rendering plant uses a Pfaudler low-temperature rendering unit which was commissioned in 1976. This type of rendering unit has a significant difference in comparison to high-temperature rendering units in that water is not boiled off during the rendering process. As a result a high volume of stickwater is produced.

The low-temperature rendering process used in this plant is as follows.

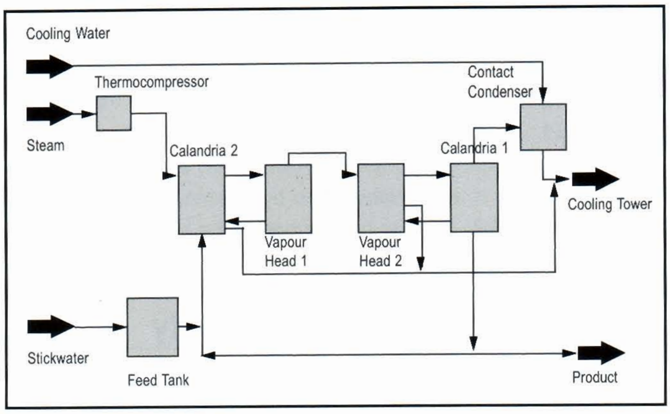
1. The abattoir waste is finely ground and heated to rupture cells and cause tallow release. Heating is not sufficient to cause any significant evaporation.
2. The mixture is fed into a decanter whereby solids are separated from the liquid stream and fed to the drier.
3. The solid stream is dried in a direct- or indirect-fired drier.
4. The liquid stream, consisting of oil and water, is reheated and fed to a centrifugal separator. This separator uses centrifugal force to produce three streams: fat, stickwater and sludge. Sludge is returned to the decanter for recovery in the solid product stream. The fat stream is recovered as saleable tallow.
5. The stickwater stream is at present a waste stream that makes up a significant part of the abattoirs effluent load. Regular weekly maintenance of the unit has ensured that performance and efficiency of the rendering process have been kept at a constant level. Analysis of the stickwater has shown that the amount of fat in the stickwater is maintained at a level of approximately 1.5%.

The double effect evaporator

The DEE system is as illustrated by Figure 1. Unit volumes have been calculated using on-site measurements and published system specifications.

Product from the DEE is directed to the drier when the set point density is reached. Lower density products are recycled back to the No. 1 Effect. Product output is controlled by density since, due to safety and physical constraints, the drier can only handle a product density of between 1.028 and 1.050 kilograms per litre.

Figure 1. Schematic layout of double effect evaporator



Unit volumes are :

Feed tank	9.0 m^3
Calandria 1 (C1)	0.7 m^3
Vapour Head (VH1)	0.8 m^3
Total First Effect (C1 + VH1)	1.5 m^3
Calandria 2 (C2)	0.4 m^3
Vapour Head 2 (VH2)	0.7 m^3
Total Second Effect (C2 + VH2)	1.1 m^3

Nutrient and COD removal ability

The ability of the system to remove nutrient and COD loads from the stickwater stream and produce a 'clean' effluent stream suitable for river discharge was primarily assessed by studying the pollutant concentration and total loadings in the cooling water stream. This was achieved using two methods:

1. calculating the percentage of the nutrient and COD load entering the system that remains in the condensate stream;
2. comparison of the condensate nutrient and COD concentrations with those of the effluent leaving the existing effluent treatment plant and the current licence conditions governing discharge of effluent to rivers.

The nutrient removal via the product stream was calculated—as a percentage of the initial pollutant input. Due to residence time in the DEE vessels and product recycle, it was necessary that the evaluation of the removal efficiency was calculated over each survey period rather than on an hourly basis. This method of calculation required a number of assumptions to be made regarding the quality of the No. 1 and No. 2 Effect contents prior to, and on completion of, sampling. These assumptions in combination with the variability of the raw-feed and end-product have made the calculation of nutrient removal efficiency significantly less accurate than desirable.

However data provides evidence supporting the fact that the DEE system succeeds in removing close to 100% of the nutrient and organic loads of the stickwater, producing high-quality effluent.

The main points to emerge from this data are as follows.

- Less than 0.25% of the stickwater organic and nutrient loads exit the system in the condensate effluent system. This is true for all components analysed with the exception of ammonia nitrogen.
- The percentage of influent ammonia nitrogen leaving the condensate effluent line is more than five times that of the other components analysed. This result is most likely attributable to the fact that ammonia nitrogen is easily stripped from liquid streams.
- In general, the DEE system is effective in concentrating the nutrient and organic loads in the product stream.
- The DEE system has consistently been shown to produce an effluent stream with nutrient concentrations suitable for river discharge.

However, despite less than 0.25% of the stickwater nutrient load leaving in the condensate effluent, levels of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Organic Carbon (TOC) in the effluent remained too high for river discharge. This was attributable to the stickwater having very high levels of total organic pollution relative to nutrient levels and due to the entrainment of these pollutants in the condensate in the absence of baffles in the effects.

Energy consumption

Energy usage was calculated using the total flows measured during each survey period.

Although considerable variation exists in the energy usage results, it was possible to draw these conclusions.

- At full capacity an average of 1700 kW of steam energy is supplied to the DEE every hour; 950 kW of steam energy is supplied to the unit every hour when the DEE is running at reduced capacity to match the throughput of the drier.
- The system has been shown to be energy efficient. The system appears capable of utilising over 70% of energy input to the system in the form of steam. The energy efficiencies of the system are highly variable and were known to fluctuate from 70% to under 30%.
- Mechanical failures, such as a faulty condensate return valve (occurred during evaluation), affected evaporator performance.
- The energy efficiency was considerably higher during the earlier surveys than during the later part of the evaluation. This variation is attributed to scale build-up and consequent fouling resulting from poor cleaning and/or maintenance of the system and has been identified in literature reviews as a common problem of evaporative treatment of waste-water streams. In particular, fouling of the calandrias was noted. This resulted in a decrease in heat transfer and hence an increase in steam requirement.
- It is probable that increased efficiency may be achieved when the system is run at full capacity with a drier of equal capacity to the effects.

Water consumption

Water consumption was calculated using total flows measured during each survey period.

Data obtained indicated that an average of 5,000 kilolitres of potable water would be required by the evaluated system per annum. This usage does not include water requirements for steam production. Over 75% of the estimated volume is attributable to the vacuum pump which uses cooling water on a once-through basis. Installation of a loop system to recycle vacuum pump water could significantly reduce the annual water usage volume.

Economics of evaporation

A Net Present Value (NPV) analysis was undertaken comparing three different-sized evaporative systems with three similarly sized Biological Nutrient Removal (BNR) activated-sludge systems.

Biological Nutrient Removal (BNR) was chosen for comparison with the evaporation system as it was identified as one of the more economically feasible options with proven ability to adequately treat rendering plant waste water. It is also a feasible option at the evaluated abattoir as BNR could be retro-fitted to the abattoir's existing activated-sludge treatment plant.

The NPV analysis was undertaken with and without the drier capital cost. This cost represented over 90% of the DEE option capital cost, significantly affecting the analysis. It may be practical, as is the case at the evaluated abattoir, to utilise existing rendering-plant facilities, in which case an additional drier might not be required. The capital cost used in the NPV analysis for the DEE was for a new unit and not that of the evaluated evaporator system at the abattoir rendering plant. This unit was not used in the NPV analysis as the system was purchased second-hand from a milk-processing operation.

The economic evaluation of the three sizes of treatment systems (DEE including drier capital costs, DEE without drier capital costs and BNR) was based on a number of assumptions.

- The BNR and DEE treatment systems produce essentially the same quality effluent in respect to nutrients, although the BNR effluent would have a lower BOD than the DEE effluent.
- A market exists for the by-product at an average value of $390 per tonne of dry solids.
- Both the BNR and DEE systems have no residual value after either the 10 year or 20 year period of evaluation.
- Using discount rates of 5%, 7.5% and 10% provides a representative comparison of the treatment methods.
- System sizing was based on a large system having an influent capacity roughly equivalent to the evaluated evaporator (3,000 L/h); the medium-sized system with half this capacity (1,500 L/h), the small system half this capacity again (750 L/h).

Conclusions drawn from the NPV analysis were as follows.

- The DEE system is considerably cheaper to operate than the BNR system and consequently becomes more economic at lower discount rates and over greater periods of evaluation.
- The DEE system is generally less economic than the BNR system if the capital cost of the drier is taken into account.
- If an additional drier is not required, the evaporator NPV is consistently less than one-third of BNR system NPV.
- The estimated NPVs are not linear with respect to treatment unit capacity. This is due to the fact that the unit sizes are towards the bottom end of the range in which these units are made and consequently a halving in the unit size represents only a small reduction in unit cost.
- Although the economic analysis assumed all product was sold for revenue, this assumption has minimal effect on the analysis because even without revenue from product sale, the operational expenses of the BNR and DEE are similar and the NPV analysis is again determined by whether or not the capital costs of the drier need to be included in the evaluation.

Enzymolysis to reduce viscosity

Limitations to evaporation of the stickwater result from the high viscosity that occurs at even relatively low concentrations. Trials have been carried out to evaluate the treatment of stickwater with papain enzyme. Treatment was carried out at a concentration of 0.01% (grams of enzyme per gram of total solids) and effectively reduced the viscosity of the concentrated stickwater.

The cost to apply enzyme at this level has been identified at slightly less than $30 per day for the evaluated plant (3,000 litres per hour capacity). Improvements in evaporator performance when the enzyme is used have not been carried out on a commercial scale to confirm the cost efficiency of this enzyme addition.

Further reading

This information is a summary of information from the following projects funded by the Meat Research Corporation.

- Project M734A: Environmental, Technical and Economic Evaluation of Stickwater Evaporation Process
- Project STR.008: Co-products Development.

Further detail is available from the final project reports for these projects which are available from Meat and Livestock Australia.

Related information is given in the MLA Co-products brochures:

- Potential uses for the by-products of IMP production
- Edible meat powders and extracts.

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