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PROJECT LEADER: James Tetlow

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Adding Value by Sustainable Waste Processing
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Researcher Contact Details

James Tetlow
c/- 39 Tram Rd
Doncaster, VIC 3108

Phone: 0447 380 308
Email: james.tetlow@btopenworld.com

In submitting this report, the researcher has agreed to the Poultry CRC publishing this material in its edited form.

Poultry CRC Ltd Contact Details

PO Box U242
University of New England
ARMIDALE NSW 2351

Phone: 02 6773 3767
Fax: 02 6773 3050
Email: admin@poultrycrc.com.au
Website: http://www.poultrycrc.com.au

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Executive Summary

The chicken meat industry along with egg producers are clearly the market leaders in terms of meat production, processing and distribution, to the point where improvements are now measured in small increments and major cost reductions are difficult to identify.

The exception to this level of development is the management of waste –grower mortalities, dead birds including spent hens, processing and hatchery waste. The driver for this project is cost reduction, regulatory compliance and sustainable manufacturing. The study starts at better understanding the nature of the feedstocks and follows through to the business case conclusion to build and operate a commercial scale facility.

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Introduction

This document outlines the need for and the aim of this research. Some background information about Anaerobic Digestion (AD) and the specific technology used by Active Research (AR) is provided. The methodology of the trial is discussed along with results of the trial. Finally, the report looks at conclusions of the trial, equipment and recommendations for future work.

A business case is given to construct and operate waste to energy plants at an operational hatchery (site 1) and a processing plant (site 2).

Understandably, with production cost pressures at an all-time high, waste management represents the next frontier for the poultry industry where large gains can and will be made. The work undertaken by Active Research thus far clearly demonstrates the potential for reduction of landfill costs, energy and nutrient recovery for fertiliser manufacture from the digestate to provide yet another income stream for the poultry industry as a whole.

The highlights of the trial work include a developed high level of understanding of the mechanical and analytic issues likely to be confronted when digestion is undertaken. Of particular benefit are investigations of the pre-treat processes required, including management of foaming and rafting issues as a component of the digestion process.

Background

Despite many advances in production methods approximately 5% of any poultry broiler flock die before reaching an age suitable for processing. In Victoria alone this represents nearly 7,000 tonnes of resource each year. This tonnage is a resource not only being wasted but one that is becoming increasingly difficult to manage. The current practice of burying dead birds on farm sites risks contaminating water catchments, ground water or storm water and also represents amenity loss by neighbours. Where it is still done, the local Council and or EPA must be in agreement and they are becoming increasingly resistant to the practice.

Poultry waste disposal problems are also being encountered by processors and by generators of hatchery waste, even after treatment by methods such as dissolved air flotation.

Local landfills have high operational and environmental costs. Once a cheap and unsophisticated disposal method, standards in landfill practice are becoming increasingly sophisticated, increasingly costly and are also running out of capacity. Landfill levies are and will continue to rise at rates well above CPI. These cost rises are a clear price signal from government to producers of waste to re-evaluate their production processes and seek alternative disposal methods.

Environmental issues in waste disposal are therefore becoming increasingly important and what may have been standard practice in the past is no longer acceptable. In addition, the costs of carbon-intensive energy are escalating quicker than farm gate prices. These two pressures will both erode farm profitability if they are not addressed; neither do they represent sustainable farming or processing practice.

Whilst being problematic, these processes also represent a significant loss of raw materials in the production process that with the right treatment could instead have their value recovered.

Aim

The project sought to test and refine the pre-treatment, digestion and post-digestion processes for the effective anaerobic digestion (AD) of mixed poultry waste (but not litter) in order to transform it to biogas and a stabilised soil nutrient. The project used an existing small mobile AD plant based in Victoria.

Background to AD

Whilst the science of anaerobic digestion is well understood there is still considerable work to be undertaken with specific feedstocks, particularly those with a very high chemical oxygen demand (COD), large volumes generated from industrial processes and those with particular pre-treatment requirements such as bird mortalities. Where a particular generator is situated in a highly populated urban area, real estate values will demand a small footprint, and very close control over odour emissions are paramount.

With digestion of poultry “waste” where mixed organic material as diverse as fathers, fat, blood and bone is received as a co-mingled stream for on-processing, considerable challenges exist to convert the mixture into a suitable material for digestion. The pre-treatment of that feedstock is paramount to a successful outcome and therefore developing the technology to cater for mixed poultry product has been particularly time consuming. Of particular interest in the pre-treatment process was the use of ultrasound for cell lyses as a means of presenting the organic matter to the microbes in such a way as to promote rapid digestion. The widely variable structure of the particles has proven to be a challenge for the management of ultrasound technology and further work is required in this regard.

Methodology

Overview

The trial was planned to occur in two phases where Phase 1 comprised batch and then continuous treatment of the wastes at the premises of Active Research. Phase 2 would then apply the knowledge gained in Phase 1 to generate a desk-top derived business case for a specific poultry facility. However the opportunity arose to conduct the continuous operation component at the Inghams processing facility at Somerville so the plant and machinery was moved to this site for the continuous operation component of Phase 1.

To provide some third party oversight, the global engineering consultancy GHD was engaged for the activity at Inghams to provide oversight and comment.

Equipment

The trial used an existing truck trailer containing a 1,600L balance tank, a 1,800L (working volume) insulated reactor vessel, a 1kW UltraWaves ultrasound unit and various continuous measurement devices for gas flow and pH and reactor temperature. A positive displacement pump transferred the various waste types from a ground-based 140L open mixing tank that was filled with waste material to be homogenised by frame-mounted handling and maceration equipment. Further details can be found at Appendix 1.

Batch Testing

Mortality Birds

Mortality birds (morts) were picked up from local growers and if frozen were allowed to partially thaw before maceration.

Handling and Preparation

A key first step is converting the whole and fully feathered carcasses of up to 3.5kg each into a pumpable homogenous material with a particle size of <5mm. Experience and abattoir industry advice indicates that this requires a two rather than single stage maceration process as cutting teeth that are large enough to accept, rip and tear whole carcasses cannot also grind to a sufficiently small particle size output.

The trial used commercial off the shelf (COTS) equipment from the German manufacturer Vogelsang, marrying a heavy duty macerator to a Rotocut 1500 followed by a lobe pump to keep the material moving. The macerator was gravity fed by hand and cut to a large particle size. Material was then vacuumed through the Rotacut by the lobe pump where it was ground to a finer particle size and then pumped into the mixing tank. Particle output size on the Rotacut is related to lobe pump speed and an output <3 mm was found to be ideal.

Sonication

This technology utilises sound waves to disrupt cell structure, and presents the contents of the cells to the microbes in such a way that the digestion process effectively starts immediately as the microbes do not have to penetrate cell walls. In addition to the reduction in time required for digestion, less sludge will be produced and CH_4 production enhanced.

The sound waves, in this instance 40 kHz, caused the contents of the cells to vibrate rapidly and implode, exposing the inner material to microbial attack. This took place in 6 milliseconds.

As described earlier, sonication worked well where the structure of the organic matter was similar, for example blood, as the required frequency required to lyses the cells was consistent, however this frequency was not appropriate for feathers. The ultrasound technology worked very well particularly for removing flesh from bones or destructing soft bones. At the end of the digestion process there was little remaining evidence of most bone structures due to the effects of ultra sound and microbial attack.

Further details on the maceration equipment can be found in Appendix 2.

Loading Rate

Two batch runs were carried out. In the first, introductions started at 40kgww/day with loads steadily increasing to 100kgww/day. With dilution and mains wash water, total introduction volumes approached 200L/day which lead to an approximate Hydraulic Retention Time (HRT) of 8 days (1,600/200=8). In the second run there were 6 inputs of approximately 30kgww/day over 8 days with similar overall volumes and hence similar HRTs.

Measurements

The principle measure for digestion activity was a continuous reading gas flow meter complete with totaliser and pH monitoring. COD values were also taken throughout the process.

Dilution Water

The macerator does not need water to operate other than for flushing through, but the Rotacut does. It was found that water use could be maintained at little more than 2L per kgw/w of bird if necessary.

Hatchery Waste

Hatchery waste comprises a mix of unhatched whole eggs (comprising unhatched chicks and varying volumes of residual yolk and egg white) and the remains of successfully hatched eggs (comprising residual yolk, white and shell). Some hatcheries also waste unwanted male chicks that have successfully hatched.

Handling and Preparation

Originally it had been thought possible to pass the whole hatchery waste mix through the reactor process with an expectation that shell would remain undigested but be stripped of its soft organic material and sink to the bottom of the reactor for collection. However, shell has a very high specific gravity of 2.2 and a high propensity to agglomerate, being essentially a two dimensional structure, and these two properties caused significant blockages in pipe-work and pumps and general handling problems. As a result, a method was sought to separate out the shell from the organic fraction.

There are COTS systems used in the egg processing industry to separate unfertilised eggs, but suppliers indicated that these would not work with chick carcasses. Therefore, Active Research designed and built a bespoke device that macerates and then uses a Dissolved Air Floatation (DAF) and screw conveyor to remove the shell from the liquid fraction (see Appendix 3).

By the process described, the shell fraction is received in clean condition without soft organic matter attached. The size of the shell particles range from 3mm and lower. Finely ground eggshells can be used as a superior substitute for ground limestone, an abrasive ingredient in toothpaste manufacture, an absorbent for CO_2 in very high temperature smoke stacks and as a deterrent to slugs and snails. Work to establish a market for shell product is ongoing.

Loading Rate and Hydraulic Retention Time

Due to the disruption to the apparatus caused by shells and the time taken to devise a shell separation system, no batch testing of hatchery waste was carried out. Instead, the yolk liquor was tested as part of the continuous operation at the Inghams trial site.

Processor Waste

Processor waste is a broad term that can encompass a wide variety of different waste types that are generated as part of processing whole birds into food products. At the Inghams processing site at Somerville, processor waste includes whole birds that are dead on arrival (DoA's), various chicken and feather parts that cannot be used in a production process, and by-products that are formed in the treatment of general process water such as DAF sludge, fats/oils/greases (FOG) from settlement tanks or the solid fraction of centrifuged sludge. The technology development for processor waste will also be of benefit to egg processors and spent hen management.

DoA and associated carcass parts were considered sufficiently similar to mortality birds to not warrant separate batch testing. Assessment of the Inghams water treatment process indicated high energy concentration (ie. a strong organic load) in the first stage, named the "DAF 1" sludge which, if treated effectively, should subsequently reduce the final output of their most problematic waste - the residual solids from the centrifuge. The centrifuge sludge as delivered recorded a COD of 200kg/tonne and was greasy to the touch. Once the foaming issues were under control the feedstock displayed excellent treatment characteristics and high methane values (80%). The digestate from DAF sludge will need to be blended with a fibrous carrier when utilised for fertiliser production.

The DAF 1 sludge is the DAF-extracted solid fraction derived from all wash water generated throughout the processing facility that prior to DAF has had large solids removed by contra-shear and removal of grit etc. by settlement. This makes it a relatively untreated but homogenous and strong liquid organic substance that is easy to handle and a good material for the Active Research AD process.

Similarly, with waste from egg production, no batch testing was undertaken of this material prior to deployment to the Inghams site.

Continuous Operation

Dead on Arrivals (DoA's)

Handling and pre-treatment

The handling and maceration of this material was similar to that used for the batch process for mortality birds i.e. birds and associated waste were taken from the skip and manually introduced to a two-stage maceration process, into an open mixing tank and then pumped into the balance tank. Water from the Inghams sequencing batch reactor (SBR) settlement tanks was used for flushing and suction for the lobe pump. The balance tank was then topped up with further SBR water to dilute.

Sonication

Once in the balance tank the total diluted volume was circulated through the ultrasound chamber. The duration of circulation aimed to provide a minimum of 1.4kWh/m^3 of material. This is discussed in more detail below.

Loading Rate and Hydraulic Retention Time

The waste material in the balance tank was topped up with SBR water to a working volume of 400L. Each increase in daily wet weight increased the concentration of TS and COD flowing into the reactor, however maintaining the total volume at 400L ensured a consistent HRT of approximately four days[1]. Waste was processed and introduced into the reactor on a daily basis, 900kgww in all, over approximately 10 weeks with daily weights ranging from 15-73kgww.

It had been intended to introduce waste 6 days a week (no waste was loaded on Sundays in order to reflect likely real-world operating conditions) with a gradual increase in wet weights over time but in practice, runs were highly disrupted and only two uninterrupted 6 day runs were achieved.

Transfer

After sonication, the material was transferred from the balance tank across to the main reactor over a 15-20 hr period. Six to seven L/m was the lowest practical flow rate for the pump, so the overall transfer was slowed by setting this rate along with a time-clock that allowed for 1-2 mins of flow and 15-18 mins rest. As fresh material was introduced into the bottom of the reactor, the level of the reactor rose and liquid overflowed from pipe work near the top of the reactor to be captured in a holding or 'outflow' vessel.

[1] For a small number of days at the start of the continuous phase a 1 day HRT was attempted but then considered too short and also too demanding of the thermal energy required to bring such volumes up to temperature.

Sampling and Testing

Gas flow rates and pH values were monitored continuously and logged on a data recorder. Pressure was measured with gauges at the head of the reactor and near the flow meter. Reactor temperature was monitored with a probe inserted 2/3 of the way up the height of the reactor. Samples were taken for subsequent analysis of: a) the diluted composite input post-sonication, b) from the ‘bottom’ of the reactor (taken from a circulating loop 1m up from the base of the reactor) and c) from the outflow vessel (which was then emptied daily). Several samples were also taken over the 10 weeks from the very base of the reactor cone by opening up the bottom valve.

DAF 1 Sludge

Handling and pre-treatment

The process for testing DAF 1 sludge was similar to that for DoA’s except that the homogenous and liquid nature of the material meant that it could be pumped directly from the Inghams DAF 1 apparatus via the mixing tank straight into the balance tank. The balance tank was then topped up to 400L with SBR water.

Sonication

Due to the homogeneity and small particle size of the solids this material was not sonicated prior to introduction.

Loading Rate and Hydraulic Retention Time

The first introduction of this material comprised 100L of the sludge with 33kg of DoA’s, with a similar combination repeated 24hrs later. This generated so much foam that foam passed out of the reactor, through the gas lines and filters and permanently damaged the gas flow measurement instrumentation. Due to delays in obtaining replacement instrumentation it was only then possible to test a single slug of DAF 1 sludge with gas measurement equipment. The remainder of the time was taken up adjusting the foam dispersal mechanism (dispersal pump) against lower loading rates and in total 350 litres of sludge was tested.

WAS Sludge

Two hundred litres of WAS was tested in the reactor. Gas generation was poor due to the low concentration of COD – 16 kg/tonne. Acknowledging the gross volume of material produced at the Inghams plant however, it may be prudent to utilise the WAS stream as diluents, for example, for the whole bird processing phase where additional water will be required.

Hatchery Waste

Handling and pre-treatment

Whilst the shell separator designed by Active Research was tested with waste from the Inghams hatchery at Pakenham, it was not practical to generate the volumes required for the trial using the separator. The Pakenham hatchery already crudely produces a shell-free liquid fraction by using drainage holes in their waste skips, so this fraction was used for the trial. The material is similar to what would be produced by the shell separator but it contains little or no chick carcasses and it is more concentrated as no water has been added as part of the separation process. Nonetheless it represents a close approximation to the actual material that would be handled.

Loading Rate and Hydraulic Retention Time

Delays reduced the extent to which hatchery waste could be properly assessed so testing was confined to processing small amounts to investigate foaming or rafting and a single slug of waste with gas measurement equipment.

Combined Waste Streams

It was intended to combine at least two waste streams and operate continuously for a period but time did not permit this.

Results

Overall

The project tested the handling, pre-treatment and digestion processes for each of the three types of waste, although no waste types were tested together save for mixing in the reactor when a new stream was introduced. Handling and pre-treatment processes were established and successfully operated for all wastes at this scale, although the beneficial effects of sonication could not be empirically established.

Anaerobic digestion was successfully achieved across all waste types in so far as high strength, difficult to handle materials were successfully converted to biogas and a much lower-strength liquid with a minimal residual volume of undigested material remaining.

However, a significant amount of trial time was consumed in engineering solutions to cope with the high propensity for foam and rafting to build up in the head of the reactor and in separating shells from the hatchery waste. Whilst it is believed that these two challenges have been met, this heavily limited the ability of the researchers to conduct extended runs of material and consequently, robust data on gas yields was difficult to obtain.

The biogas produced at all stages contained a high proportion (in the order of 70%) of methane.

An overall graph of material inputs, COD values and liquid and gas outputs is contained in Appendix 5.

Batch Testing

The only significant batch testing was carried out with mortality birds. This was due to the fact that following the first attempts at processing hatchery waste, effort was then directed to seeking and then designing and building a shell separator.

Mortality Birds

Handling and pre-treatment

The maceration and handling equipment operated well, although the macerator throat needed to be larger in order to reduce the risk of bridging in the hopper. Pure mortality birds are approximately 30% total solids (TS), the maceration process needs at least an equal amount of water for flushing, and positive displacement pumps are able to handle this concentration so long as the macerated particle size is less than circa 8mm.

Behaviour in the Reactor

The batch runs showed that the first limitation on a loading rate was the build-up of foam and of rafts of material on the surface of the reactor. Foam is gas entrapped in greasy liquid so represents a trapped source of energy in two senses, as well as expanding to cause blockages in gas lines. Rafting included foam with elements of undigested material such as a very small amount of quill or small grease droplets.

Biochemical

On both 5 day runs, the gas and outflow measurements were compromised by significant volumes of foam and rafting. The foam blocked gas lines and contaminated the outflow on a number of occasions, making it impossible to accurately assess a gas production rate or determine whether the organic loading rates (OLRs) were approaching a design limit from a chemical oxygen demand destruction perspective.

Effects of longer term operation and mixed wastes were not significantly tested.

Hatchery Waste

Whilst waiting for a replacement gas meter from the USA, exploratory work on hatchery waste continued. A series of 20L batches of yolk fraction from Inghams were introduced into the reactor to monitor the effectiveness of the dispersal pump and sweeper arm, and the degree of foaming.

The 1L bottles containing 800mL yolk and 200mL reactor bottom seed were also disassembled and the residue examined. Having started at around 50% total solids (TS) and produced significant volumes of gas compared to previous substrates, the residual liquid contained 22% TS.

Altogether, 300 litres of yolks was introduced into the reactor over a three week trial period. Digestion was completed without complication. COD was measured at 500kg/tonne resulting in a gas flow of 15 litres biogas per litre of yolk. The non-digestible solid matter, being somewhat fibrous to the touch, may be ideal as a carrier of very fine particulate matter when water is removed via a screw press.

Continuous Operation

Dead on Arrivals (DoA's)

Handling and pre-treatment

Overall nearly 1 tonne of DoA's and associated factory floor waste was processed. The handling and maceration equipment performed well - except that a larger first stage maceration throat would reduce the risk of bridging of large birds.

TS values were similar to morts (i.e. 30% TS) although sometimes marginally lower depending on how much additional factory floor waste was contained in the sample. A short term reaction in the reactor, for example foaming and rafting, was encountered. This was caused by lighter than water fractions, particularly feathers and fat, rapidly rising to the surface and forming a thick mat reducing microbial activity while trapping gas within the matrix. This problem, which had the potential to disrupt the entire program, was eventually solved with some re-engineering of the head space in the reactor.

Sonication

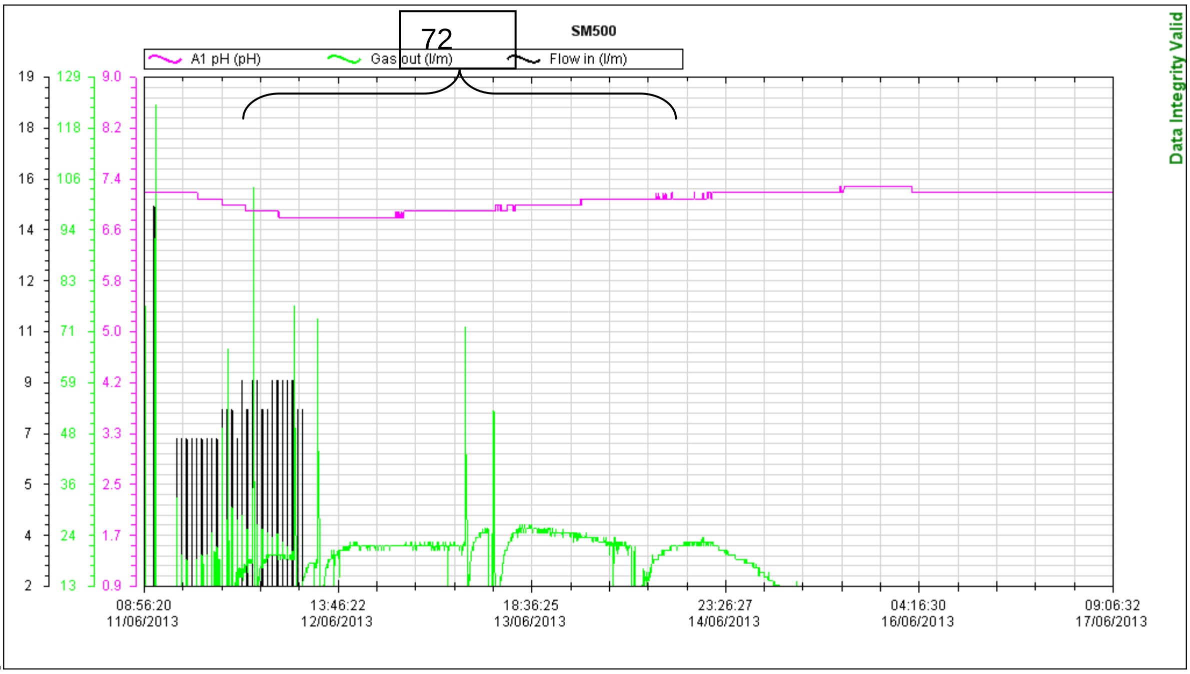
The degree of sonication - measured in kWh/m^3, was difficult to maintain at the higher TS values without significantly increasing the exposure time beyond what was practical. However, tests indicated that this was not due necessarily to the increase in TS per se but the rapid accumulation of solids in the sonication chamber when each run was performed. The chamber was not supplied by the supplier of the sonication equipment. This meant that the degree to which material was sonicated could not be kept constant, making it impossible to verify manufacturer claims of increases in gas yields of circa 15%.

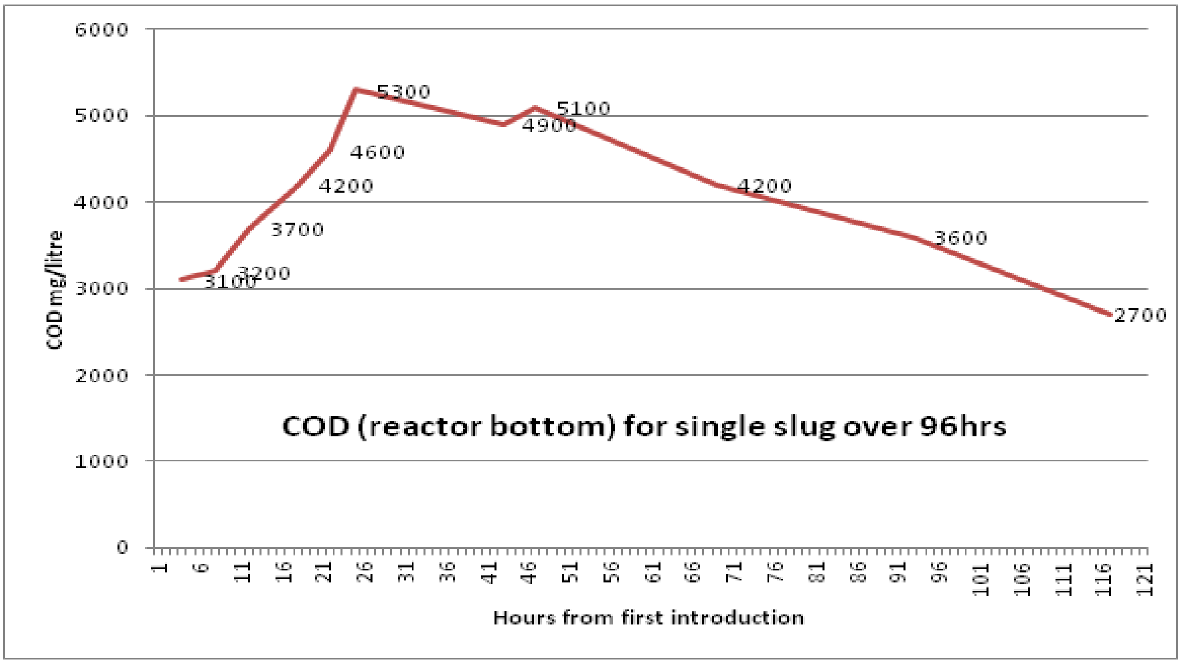
Balance Tank

The bottom of the balance tank is flat. The mixer arm impellor sits some 300mm from the bottom and material is drawn by pump from a point 100mm from the bottom. These factors conspired to cause a significant separation of material in the balance tank with lighter solids floating on the surface, not being drawn into the reactor by the pump and hence accumulating over time. Changes to the mixer were made but remained imperfect, with the main change requiring a deeper mixer and a cone-shaped bottom.

Hydraulic Retention Time

Once it was felt that the reactor was firmly inoculated and all gas escape problems resolved, a single introduction of 45kg was made to observe the COD and gas production profile and confirm a HRT. Gas production and COD trailed off after 4-5 days.





Behaviour in the reactor

Day	Mon 24	Tues 25	Wed 26	Thur 27	Fri 28	Sat 29	Sun 30	Mon 01
input (kg)	52.3 + recycled	60.4	67 + material fm Mon & Tues	72.6	Remainder of balance tank	0	0	46
Volume(l)	439	521	395	687[1]	605	0	0	tbc
daily gas (l)	-	32,948	38,810	44,237	24,754	24,536	12,497	9,159

Table 1 Wet weight, total volume and gas production over the period

Notes.

1. Includes 238 litres used to empty the balance tank of accumulated material from the Monday and Tuesday inputs.

A bench-scale test of the DAF 1 sludge was also set up on Saturday to identify whether the sludge might inhibit gas production. No inhibition was apparent over the first 48hrs.

Discussion

Hydraulic Retention Time

COD values for the single 45kg load are now available and are shown alongside gas production values in Figures 1 and 2 of Appendix A. They show that gas production and COD declines at the 72-96 hr point which further supports use of the 3-4 day retention time. At the 96 hr point biogas production had totalled 106,465L, equating to 2,366L/kgww of biogas for this single input.

Gas Yield

Day	Mon 24	Tues 25	Wed 26	Thur 27	Fri 28	Sat 29	Sun 30	Mon 01
input (kg)	52.3 + recycled	60.4	67 + material fm Mon & Tues	72.6	Remainder of balance tank	0	0	46
Volume(L)	439	521	395	687[1]	605	0	0	tbc
daily gas (L)	-	32,948	38,810	44,237	24,754	24,536	12,497	9,159

Table 2

Maximum Loading Rate

Several days of good production at [40]kg/day then no commensurate increase when OLR increased to 80kgVS/day. The researchers looked at a number of questions: What was the effect on COD? Did COD values start to climb? If so, then perhaps the limit had been reached – but perhaps it needed a correction of a limiting factor i.e. toxic ammonia – meaning that the maximum OLR could be greater.

The consistent and good gas production indicated that the lower original load and gas production rate was sustainable even though it may have needed ammonia management.

Post Digestion

Recovery of nutrients

Samples drawn from the cone of the reactor indicated that digestion was almost complete (little odour) and the solids fraction remaining would be suitable for further processing into a saleable product. The digestate consisted of fine fibrous material in addition to bone fragments which would mill into a finer product.

European experience to date is that demand for nutrients produced as a by-product or anaerobic digestion is outstripping supply. A significant benefit of fertiliser produced in this manner is that the nitrogen content is solubilised meaning greater uptake by plants with lower application rates, reduced leaching into waterways and reduced volatilisation (loss to sunlight). Similarly, the phosphorous content is important, with the world rapidly approaching peak production.

A limited amount of work was undertaken during the study to remove nitrogen from the discharge water utilising an Anammox like process and this work is continuing along with the recovery of phosphorous. Please refer to attachment 7.

Conclusions & Next Steps

The trial has established that this particular type of AD technology has the capacity to treat the wastes tested. However, there are a number of aspects of the design that have not been tested or have not been proven at a larger scale. In addition, continuous operation has been limited. Active Research recommend an intermediate stage prior to full commercial-scale development, where a plant is built that is large enough to test untried components of the design and the effects of scaling up, but is sufficiently small that adjustments and improvements can be introduced economically.

Such a 'pilot plant' could be located at Somerville and continue to test the variety of waste types discussed here. However, if designed appropriately, then at the successful conclusion of such a trial, the balance tank and reactor vessel could be re-deployed to a small site such as the hatchery at Pakenham and used to treat just hatchery waste. Alternatively, they could remain at Somerville to treat just one waste stream such as DAF 1 sludge or centrifuged sludge, thereby recouping some greater value from this pilot-scale plant.

Commercial Scale Plant

Whilst the design and hence the cost of a full-scale plant is undeveloped, the decision to invest in a pilot-scale plant still needs to be based on a business case. To address this requirement, a commercial scale plant has been designed to concept stage, with associated costs and forecasts of digestion rates and gas yields with an associated business case.

substrate characteristics		**DoA**	**DAF 1**	**FoG**	**Hatchery**	**Morts**	**WAS**	
Total Solids (TS) content (% w/w)	% w/w	24.0%	9.0%	52%	26%	24%	15%	
Annual generation (tonnes ww)		313	868	200	437	1560	348	
Amount of dry solids - tonnes		75	78	104	66	374	52	749 tpa
Nitrogen content total (average)	w/w	2.4						18 tpa
Phosphorous	w/w	0.1						

Table 3: Comparative market value

- 1 tonne nitrogen as urea (46% N) $700 per tonne (farm gate)

2.4% x 749 tonnes x 700 = $12,600

- 1 tonne phosphorous as single super $400 per tonne

0.01 x 749 x $400 = = $2,996

Feed stock average nutrient (N&P) values

	May-01	May-02	Jun-11	Jun-24	Jun-25	Jun-26	Jun-27	Jul-09	Jul-20	Jul-22	Jul-31	Aug-12	AVE
	N mg/l												
discharge	290	260			1300	1400	1600	1900	2000				1,250
bottom	270	220			1300					25000			6,698
cone			760	5800								3400	3,320
composite	230	230									24000		8,153
	P mg/l												
discharge			8.8		36	58	78	38	36				42.5
bottom										1700			1700
cone				1300								23	662
composite											880		880

So what is the commercial potential for recovery of energy from poultry waste?

Example 1

Grower and transport mortalities:- (whole birds) per 100,000 birds lost, average weight 2 kg will produce 14,000m³ biogas with a methane content of 75% equivalent to 375,900 MJ energy – say 300,700 Mj allowing for a loss factor of 20% pa.

A GC 120 kW Detroit diesel co-generation plant with exhaust heat recovery will burn 61 m³/h biogas with a CH_4 content of 55% to give 218 hours running time. Electrical output would be 120 kW hours plus 160kWh thermal energy. Add to this recovered heat for re-use and reduced plus eliminated landfill charges and nutrient value to give an indication as to the value of a dead bird.

Example 2

Hatchery waste (yolks, chicks and embryos)

Energy value – 2.5 times that of dead birds if digested.

Example 3

DAF sludge from processing waste, fat etc.

Energy value 2.0 times that of dead birds.

specific energy of methane	MJ/m3	35.8
specific energy of biogas	MJ/m3	25.06
specific energy of biogas	kWh/m3	6.96
specific energy of methane	kWh/m3	9.94
density of methane (1 atm, 15 Deg C)	kg/m3	0.67
density of biogas	kg/m3	1.10
1.kWh = 3.5 MJ	1MWh = 3.6 GJ	
Forecast quality of biogas	CH_4 75% Volume CO_2 23%	
Other trace gas 2%		
COD 200kg/tonne birds		

Design

Design Assumptions

The design reflects the original brief and is scaled to treat all on-site organic waste streams and also accept hatchery waste and mortality birds from growers off-site. It contains the following key assumptions:

Design Outline

In outline the design comprises a common receiving, handling and maceration train to receive both DoA's and mortality birds. These components may be in an enclosed shed and discharge via pipe work to a single sealed balance tank outside which also receives DAF 1 sludge directly from the existing Inghams AWTP and potentially hatchery waste (with shells already removed using a separator based at the hatchery). The balance tank transfers at a controlled rate to the reactor.

The reactor discharges the treated liquid outflow in such a way as to pre-heat the inflow, and the methane is piped to the existing covered anaerobic lagoon. Using the covered lagoon exploits the spare capacity and sunk cost of this existing gas storage. From the lagoon the gas mixes with lagoon gas and the combined volumes use existing pipe work to transfer to a new gas scrubber located adjacent to the existing flare. This cleans the biogas prior to passing via a new short pipe run to the boiler room for combustion in a new dual-fuel boiler. The design and pricing assumes that Inghams will shortly replace one of the existing boilers through the lifecycle programme for the site and that the replacement can be specified to run both mains and cleaned biogas. The flare remains in place for use as required.

The forecast total biogas production volume represents 15.4 % of overall mains gas consumption by the Inghams site and even with fluctuations in biogas production and site heat demand, the lagoon storage makes it unlikely that there will be periods where all the biogas is not fully utilised. This direct combustion approach makes beneficial use of all the gas with the least capital expenditure.

In order to reduce bio-security risk, waste from off site can be added to the system without the need to enter the main site. The design also anticipates (and this is subject to transport arrangements) separating shell from the hatchery waste at the hatchery site using the Active Research shell separator and transporting only the yolk fraction to the Inghams site. The shell fraction would leave the hatchery directly for secondary use.

Caveats

A number of the design components have not been tested at large scale or for continuous operation and some components are untested improvements derived from earlier design iterations. Such design uncertainties also affect cost and performance but nonetheless the assessment above represents a reasonable and prudent indication of future opportunity which we believe should support the development of a pilot plant.

Business Case study

Background

Regulators have expressed a desire to limit or ban poultry waste to landfill. By eliminating landfill and transport charges, a significant cost of production will be realised.

The objective is to process all organic waste from the two sites to a condition where landfill and other non-sustainable disposal practices are extinguished.

This in-turn contributes to corporate environmental policy standards plus sustainable production. A summary of the combined waste volume, disposal costs and energy potential from both hatchery and processing waste is revealed as:-

Feed stock	***DoA***	***morts (est.)***	***DAF 1***	***WAS***[i]	***yolks***	***shells***	***Total pa***
Vol t/a	*313*	*1560*	*868*	*9100*	*437*	*156*	*12,434*
disposal $	***55,088***	***265,200***	***130,000***	***150,000***	***105,000***	***38,856***	***744,141***
% / total	*8.5*	*42.4*	*23.5*	*3.8*[2]	*11.9*	*4.2*	*100*
COD kg/t	*200*	*200*	*400*	*16*	*500*	*--*	
Methane m^3	*21,900*	*109,200*	*121,520*	*50,960*	*76,475*	*--*	*331,044*
Meth @ 80% m^3	*17520*	*87360*	*97216*	*40,700*	*61180*	*--*	*303,900*
Mj equivalent	***630,720***	***3,144,960***	***3,499,776***	***1,465,000***	***2, 202,480***	***--***	***10,901,000***

The technology proposed is high rate, fixed film anaerobic digestion supported with pre-digestion equipment to separate the various fractions and post digestion materials handling.

Investment to meet objective $1,478,357
Disposal costs avoided $744,100 per annum
Amortisation 24 months.

[2] volume of solids v volume of product to be treated, water is recycled

Site 1 Hatchery

Current waste disposal costs	$144,000
Current gas cost	32,800
	$176,800
Cost of projected plant	$190,468

Yield is estimated at

- shell production 600,000 eggs per week average at 6 grams per shell - 3.6 tonnes shell per week
- yolks – currently 2400 litres per week (figure supplied)
- embryos – 1 tonne per week (estimate)
- water for washing - 1 tonne per week

Total flow 8 tonnes per week.

Site 2 Processing

Current waste disposal costs	$600,100
Avoided charges (gas)	*(51,243)*
Cost of projected plant	1,287,889

Yield is estimated at

- **8,698,160** MJ – (242,720m³ methane) pa
- **1,237** tonnes biofert

current gas consumption 61,700 GJ/pa
potential energy recovery 8,700 GJ/pa (15.0% of annual usage)

Charges likely to reduce with volume

	$/GJ	Volume GJ	$ value
energy charge	4.624	8700	40,230
Energy Safe Vic	0.02583	8700	225
AEMO tariff D	0.05943	8700	517
Emissions charge	1.1806	8700	10,271
			$51,243

Site 1 Detail

The plan calls for the installation of equipment to:-

- Separate the waste stream into three fractions – liquid, shells and membrane
- Recover energy as biogas from the liquid fraction to fuel a water heater
- Produce nutrient rich fertiliser (digestate)
- Produce clean shell and membrane for further off-site processing and sale.

Cost base

The cost is to design, manufacture and commission, but excludes civil works which may be required. Amortisation is 13 months at current waste disposal and gas costs. The proceeds of on-sale products, whilst very important, have not been included in the calculations. The market for membrane and shell (calcium carbonate) is developing around the world and it may not be prudent at this time to project a plan which relies on a bankable price for the product.

Preliminary investigations reveal a potential opportunity for value added shell supply to the paint industry where it may be used as an extender for titanium oxide in white paint and sheen adjustment. Current cost of calcium carbonate is quoted at $200 / tonne.

The plant will consist of:-

- disintegrator for shells and embryos, balance tank
- screw conveyor to move separated shells to holding bins
- high rate fixed film anaerobic digester including pumps
- all controls and monitoring equipment
- gas hot water system
- membrane and shell collection.

Plant capacity

Plant capacity is based on 2000 litres per day over a four day per week, or 8 tonnes over a 7 day week. The reactor is to have a capacity of 6 tonnes or 3 hatching days.

The increase over current yolk production reflects an allowance for the shell washing process, delivering more recovered yolk and embryos than is currently the case. There is also a margin for future increased chick production.

Footprint will be approximately 4m x 5m and height 3.8m. Loaded weight approximately 9 tonnes.

Potential

Egg yolk from hatchery waste has a chemical oxygen demand (COD) of approximately 500kg/tonne of liquid digested. Translated to Site 1, this equates to an estimated annual gas production of **70,000m^3** of methane per annum based on a throughput of 400 tonnes of waste material. (8m^3 per hour continuous or 288 MJ/hour).

The volume of yolks produced has been increased to reflect the additional recovery of soft organics through the Active Research process. The tonnage of shells has been reduced accordingly.

(Current annual gas usage at Pakenham is $122m^3$ or 4,514 MJ).

Parasitic heat requirement (reactor) is 103 MJ/h. At 24kW output, the heater will bring the reactor temperature up to 42 ˚C from ambient in 3 hours.

<u>Running costs</u> are low.

Energy requirement is parasitic on the biogas produced and the plant operates at low pressures. Vessels are constructed of 316 stainless steel and the expected lifetime of the non-motile plant is 30 years. The reactor is insulated.

Active Research would be pleased to negotiate a management maintenance agreement service for a monthly service fee. The service would include call-outs in the case of emergency, routine servicing and replacement of consumables. Replacement of parts not under warranty will be charged at cost plus 10%. Service arrangements to be reviewed at the expiration of 5 years.

<u>How it works</u>

Hatchery waste is separated into two streams – liquid and shells. Each fraction is removed by separate contractors for disposal.

The separated yolks are progressively pumped into the reactor where the resident microbes convert the proteins, sugars, carbohydrates etc into acetic acid. A second set of microbes (methanogens) convert the acid into biogas which is rich in methane. The pH of the reactor is maintained at 7.3 and the temperature 40 – 42 ˚C.

Biogas is collected in the head of the reactor, dried and utilised to power the water heater. Surplus gas may be used for other purposes or simply flared to atmosphere. Digestate, the remnant material remaining in the bottom of the reactor, is rich in nutrients. Process water may be further treated fit for purpose.

<u>General discussion</u>

Within the plan it is proposed to include a common hot water storage unit with the hatchery. This will represent a small saving in gas usage for the hatchery.

Egg membrane is a unique product in that it has a triple helix, making it a very strong material. Collagen, which constitutes approximately of 10% of the mass of the membrane, has many uses, one of which is imminently suitable for surgical procedures.

Currently the bulk of the world's supply of medical grade collagen is from sources which, due to bovine spongiform disease, are difficult to trade internationally, and human allergic reactions to the product are not uncommon. Collagen derived from avian sources does not have either of these two problems. Active Research is working with Monash University to determine a commercially viable method of recovery of the product.

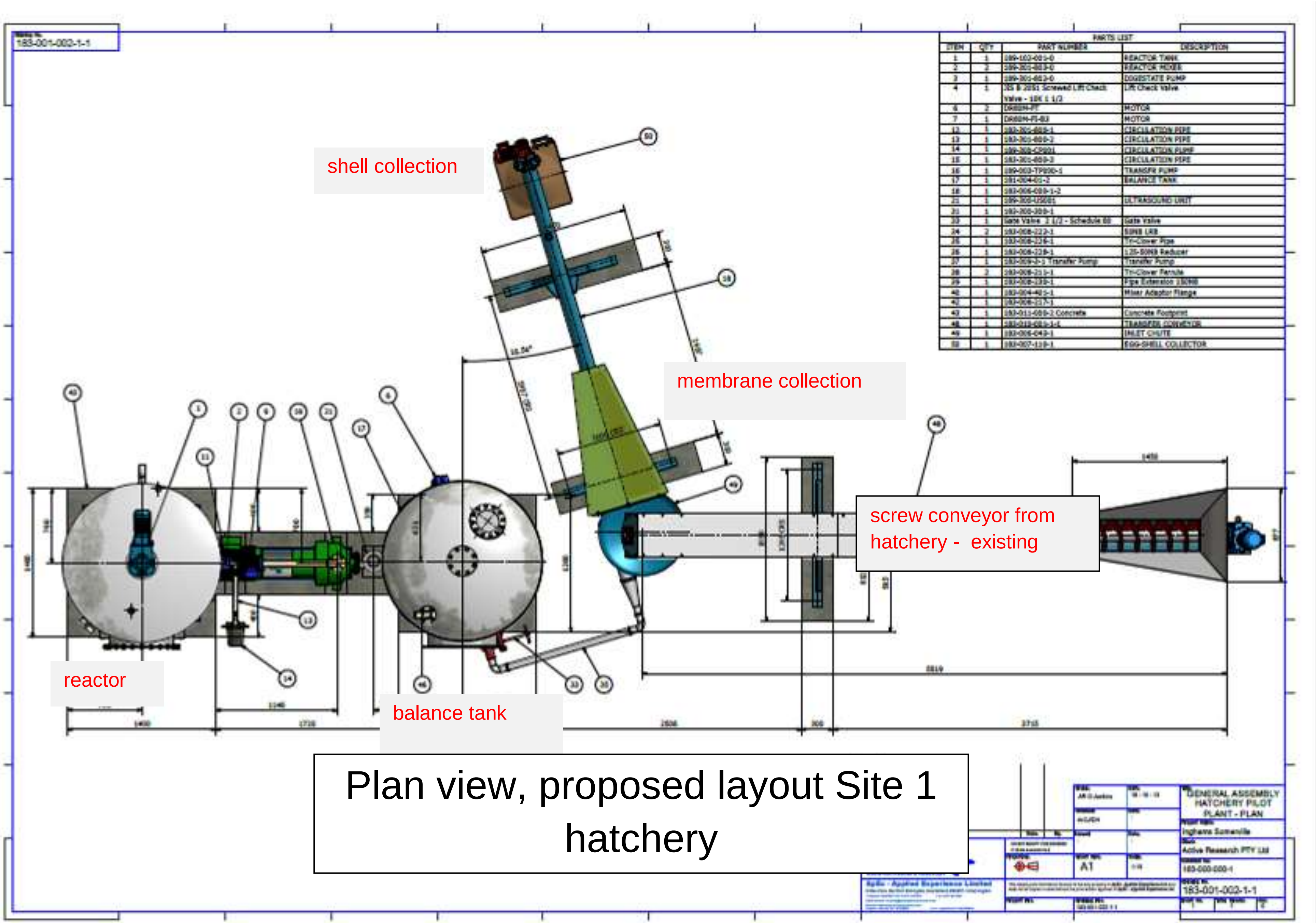
Membrane is high in protein and reportedly used as an ingredient in pet food manufacture.

Egg shell is 94% Calcium carbonate. Post the separation process, the shell will need to be dried and powdered to meet most market demands. The free water from the shells will be maintained in the system. A rotary dryer utilising the flu gas from the water heater may be able to achieve the desired degree of moisture removal.

Digestate as fertiliser. Total solids 35%

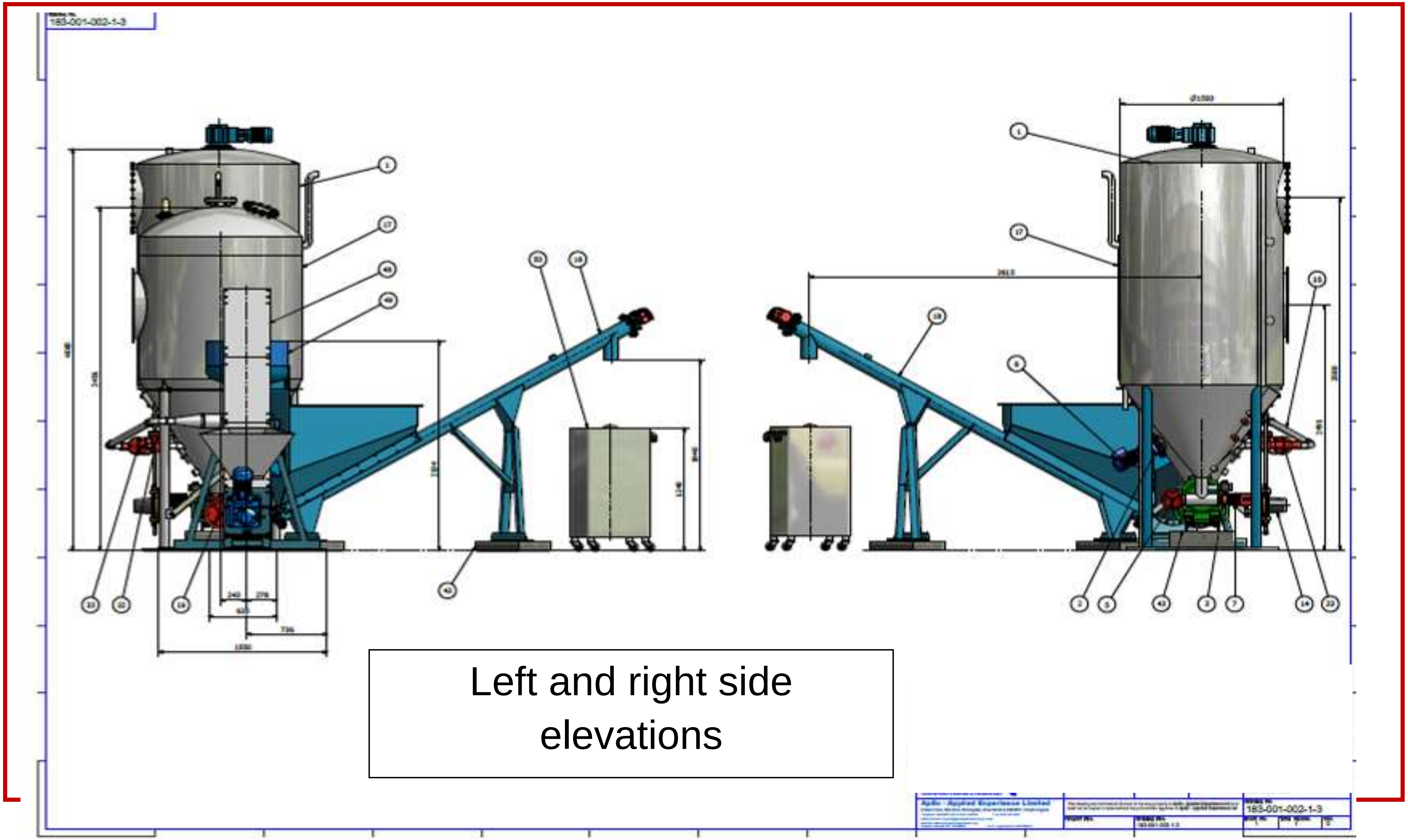
Dried samples of digestate from the reactor revealed 7.14% total nitrogen and 0.48% phosphorous. Annualised; the 125 tonnes of yolks treated will yield something in the region of 9 tonnes of bio-available nitrogen and 600 kilograms phosphorous.

To put the value of the nitrogen into perspective, the cost of Urea, (46% N) at the farm gate is in the region of $700 per tonne. This puts the value of the nitrogen recovered at $1,522 per tonne. Initially at least, or because of increased production, drying and processing of the digestate would be better handled off-site.

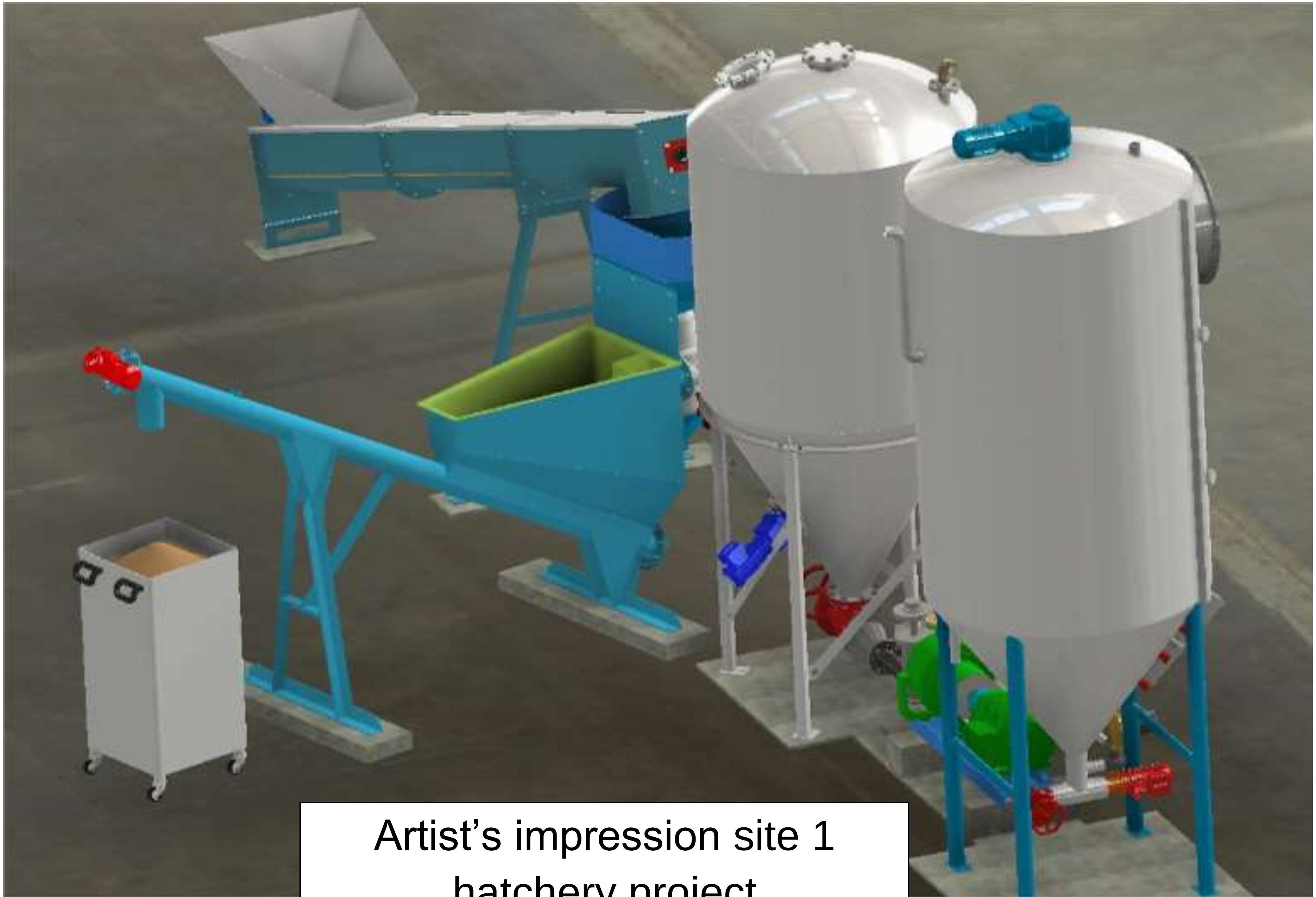


Plan view, proposed layout Site 1 hatchery

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	189-102-001-0	REACTOR TANK
2	2	189-301-003-0	REACTOR MIXER
3	1	189-301-002-0	DIGESTATE PUMP
4	1	JIS B 2051 Screwed Lift Check Valve - 10K 1 1/2	Lift Check Valve
6	2	DR80M4-FF	MOTOR
7	1	DR80M4-FI-B3	MOTOR
12	1	183-301-000-1	CIRCULATION PIPE
13	1	183-301-000-2	CIRCULATION PIPE
14	1	189-300-CP001	CIRCULATION PUMP
15	1	183-301-000-3	CIRCULATION PIPE
16	1	189-003-TP000-1	TRANSFR PUMP
17	1	181-004-01-2	BALANCE TANK
18	1	183-006-000-1-2	
21	1	189-300-US001	ULTRASOUND UNIT
31	1	183-200-300-1	
33	1	Gate Valve 2 1/2 - Schedule 80	Gate Valve
24	2	183-008-222-1	50NB LRB
25	1	183-008-226-1	Tri-Clover Pipe
26	1	183-008-228-1	125-50NB Reducer
27	1	183-009-2-1 Transfer Pump	Transfer Pump
28	2	183-008-211-1	Tri-Clover Ferrule
29	1	183-008-230-1	Pipe Extension 150NB
40	1	183-004-401-1	Mixer Adaptor Flange
42	1	183-008-217-1	
43	1	183-011-000-2 Concrete	Concrete Footprint
48	1	183-019-001-1-1	TRANSFER CONVEYOR
49	1	183-006-043-1	INLET CHUTE
50	1	183-007-110-1	EGG-SHELL COLLECTOR

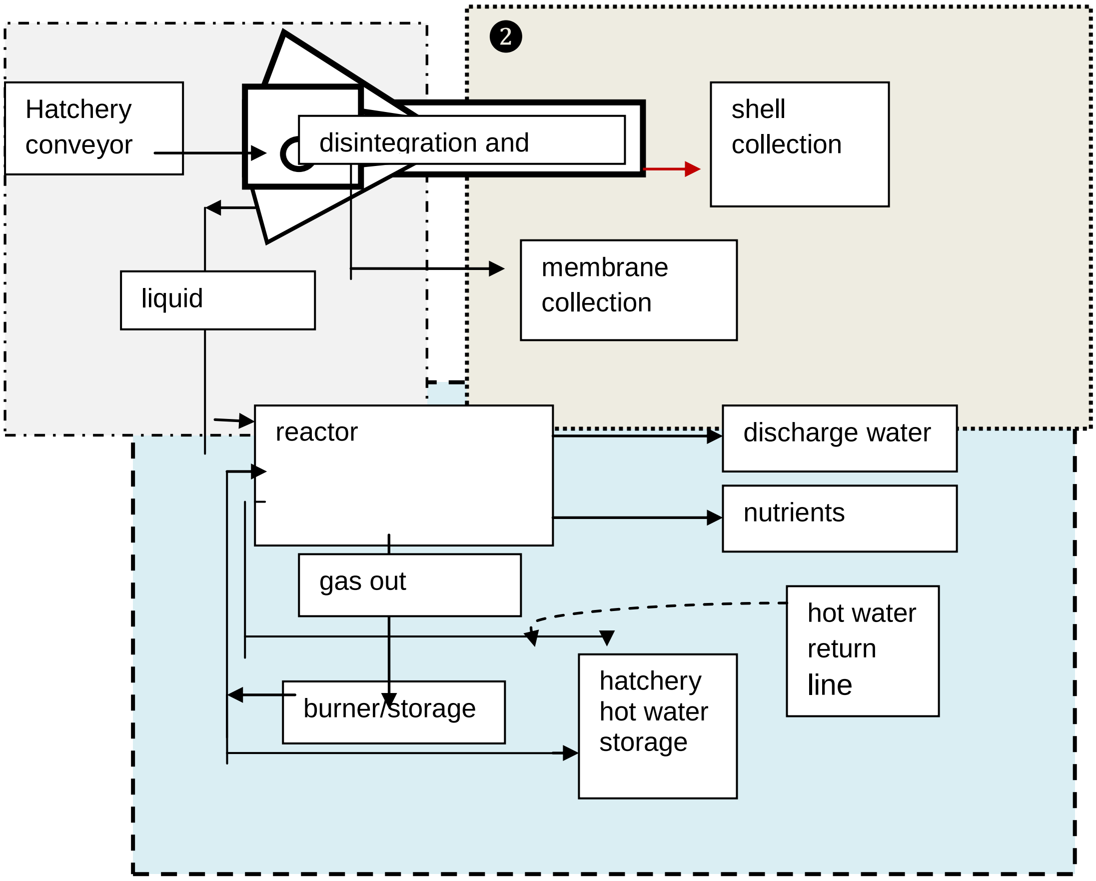


Left and right side elevations



Artist’s impression site 1
hatchery project

Site 1 flow chart



Site 2 Detail

Summary

Current waste disposal costs	$600,100
Avoided charges (gas)	*(51,243)*
Cost of projected plant	$1,287,889

Yield is estimated at

- **8,698,160** MJ – (242,720m³ methane) pa
- **1,237** tonnes biofert

current gas consumption 61,700 GJ/pa
potential energy recovery 8,700 GJ/pa (15.0% of annual usage)

Charges likely to reduce with volume

	$/GJ	Volume GJ	$ value
energy charge	4.624	8700	40,230
Energy Safe Vic	0.02583	8700	225
AEMO tariff D	0.05943	8700	517
Emissions charge	1.1806	8700	10,271
			$51,243

Background

The waste stream as evidenced at Site 2 is very diverse, very challenging and derived from a broad geographic area. The feedstock ranges across feathers, fat, blood, whole birds and sludge. Broadly, the material can be divided into two streams – liquid and solid. A significant amount of the processing may be undertaken with common equipment.

On the flip side, almost all of the waste will be high yielding in terms of energy and nutrients.

The site draws into focus some complexity relating to the delivery of material to the digester, for example, grower mortalities will be delivered by a yet to be decided collection and transport arrangement. DoA's and other factory waste may be delivered either in 1 tonne bins and forklift or pre-treated nearer the point of production and pumped to the balance tank.

It is expected 11,840 tonnes of material (liquids and solids) will be processed annually.

The plan calls for the installation of robust equipment to:-

- provide a materials handling function to ensure whole birds and disassociated parts are macerated to the smallest practicable portions pre-digestion
- bring liquids from current storage to the digestion facility for integration with the solids
- provide high rate fixed film anaerobic digestion
- recover energy as biogas from the substrate

- produce a supply of nutrient rich fertiliser (digestate)
- operate without supervision 24 hours per day.

The plant will consist of:-

- receiving hoppers, macerators, secondary cutter, pumps
- balance tank and high rate stainless steel reactor
- all management and control equipment
- high rate fixed film anaerobic digester including pumps
- all plumbing.

Cost

The cost to design, manufacture and commission the facility excludes civil works which may be required. The proceeds of on-sale products whilst very important have not been included in the calculations. The market for membrane and shell (calcium carbonate) is developing around the world and it may not be prudent at this time to project a plan which relies on a bankable price for the product.

Plant capacity

product	TPA	TS%	TPA	supply	holding	reactor capacity
WAS[3]	9100	6	546	25tpd/7 day week	2 days	50,000
DoA	313	30	94	1.2/ 5 day week	4 days	4,800
morts	1560[4]	30	470	6 tpd/ 5 day week	4 days	24,000
DAF	868	15	130	2.78 tpd /6 days	4 days	11,200
Total	**11,840**		**1240**	**35 t/day**		**90,000 litres**

Footprint

approximately 10 x 12 metres Full weight 138 tones.

Running costs of the plant are low running costs.

Energy requirement is parasitic on the biogas produced and the plant operates at low pressures. Vessels are constructed of 316 stainless steel and the expected lifetime of the non-motile plant is 30 years. The reactor is insulated.

Active Research would be pleased to negotiate a management maintenance agreement

[3] Waste Activated Sludge
[4] Morts and DoA's are the same. Morts originate from grower premises.

service for a monthly service fee. The service would include call-outs in the case of emergency, routine servicing and replacement of consumables. Replacement of parts not under warranty will be charged at cost plus 10%. Service arrangements to be reviewed at the expiration of 5 years.

Delivery considerations

Currently DoA's are delivered via fork lift to a commercial skip approximately 150 meters from the principle point of production, a round trip of possibly 3-4 minutes.

Option 1 (costed for) is to re-place the commercial skip with a hopper, macerator etc and pump the pulp to the balance tank. A fall of 1:200 has been included in the design.

Option 2 If the proposed site for the digestion facility is utilised as the point of reception the return journey for the forklift could well be 7-10 mins. The receiving point would be incorporated with the off loading point for imported feedstock.

How it works

The solid fraction must first be reduced to a particle size preferably less than 3mm. Water may be added to assist transfer. The macerated material is progressively transferred to the reactor where the resident microbes convert the proteins, sugars, carbohydrates etc into acetic acid. A second set of microbes (methanogens) convert the acid into biogas which is rich in methane. The pH of the reactor is maintained at 7.3 and the temperature 40 – 42 ˚C.

The biogas is collected in the head of the reactor, dried and utilised to power the water heater. Surplus gas may be used for other purposes or simply flared to atmosphere. Digestate, the remnant material remaining in the bottom of the reactor, is rich in nutrients. Process water can be further treated fit for purpose.

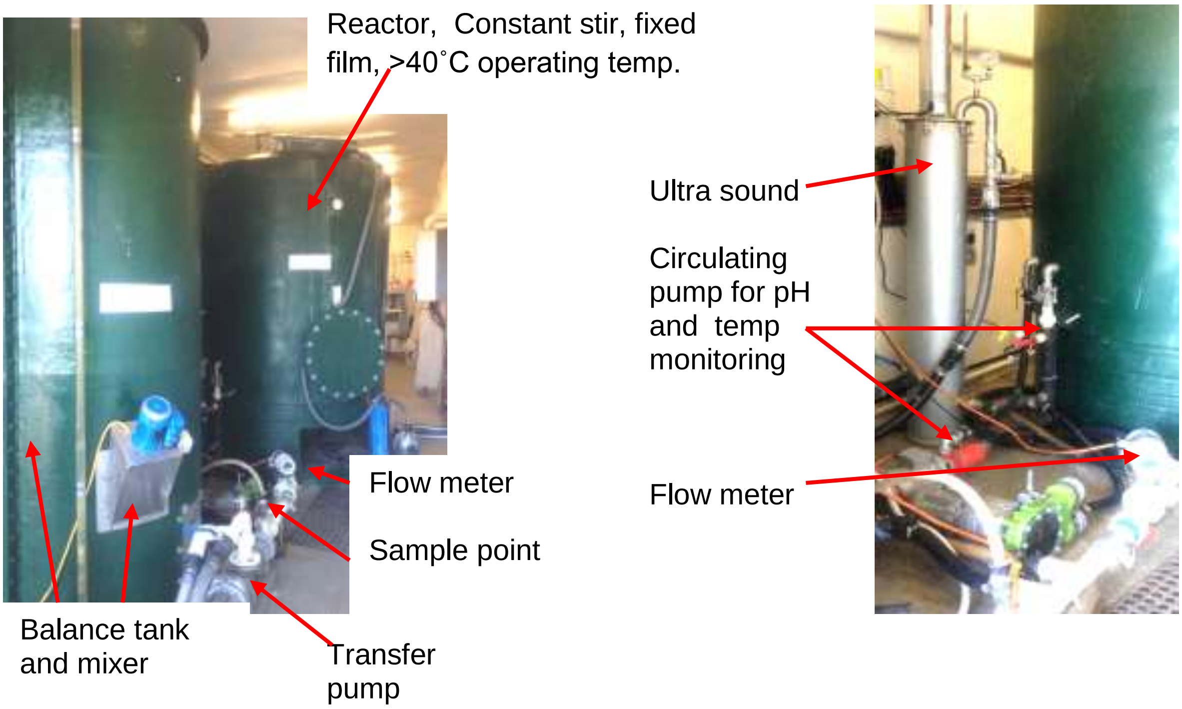
Acknowledgements

CRC, VFF, Alan Wilson, Hudson Cameron, Peter Banks and Mark Robinson at Inghams Somerville, Scott Lewis and Leon Stapley at Pakenham. Pat and Don Bingham (growers)

Appendix 1

Operating features of the mobile pilot plant utilised at Inghams for the feasibility study.

pilot plant



The mobile pilot is a unique piece of equipment designed to work between bench top and full scale commercial plants. The unit has proven to be essential when identifying and overcoming logistical/engineering issues such as reactor headspace foaming, gas production – volume and quality, ultra sound management, feather degradation and so on in difficult to handle waste streams.

Every waste stream is different in one way or another and the capacity to pre-empt possible process issues is a valuable asset potentially saving money and time.

Appendix 2

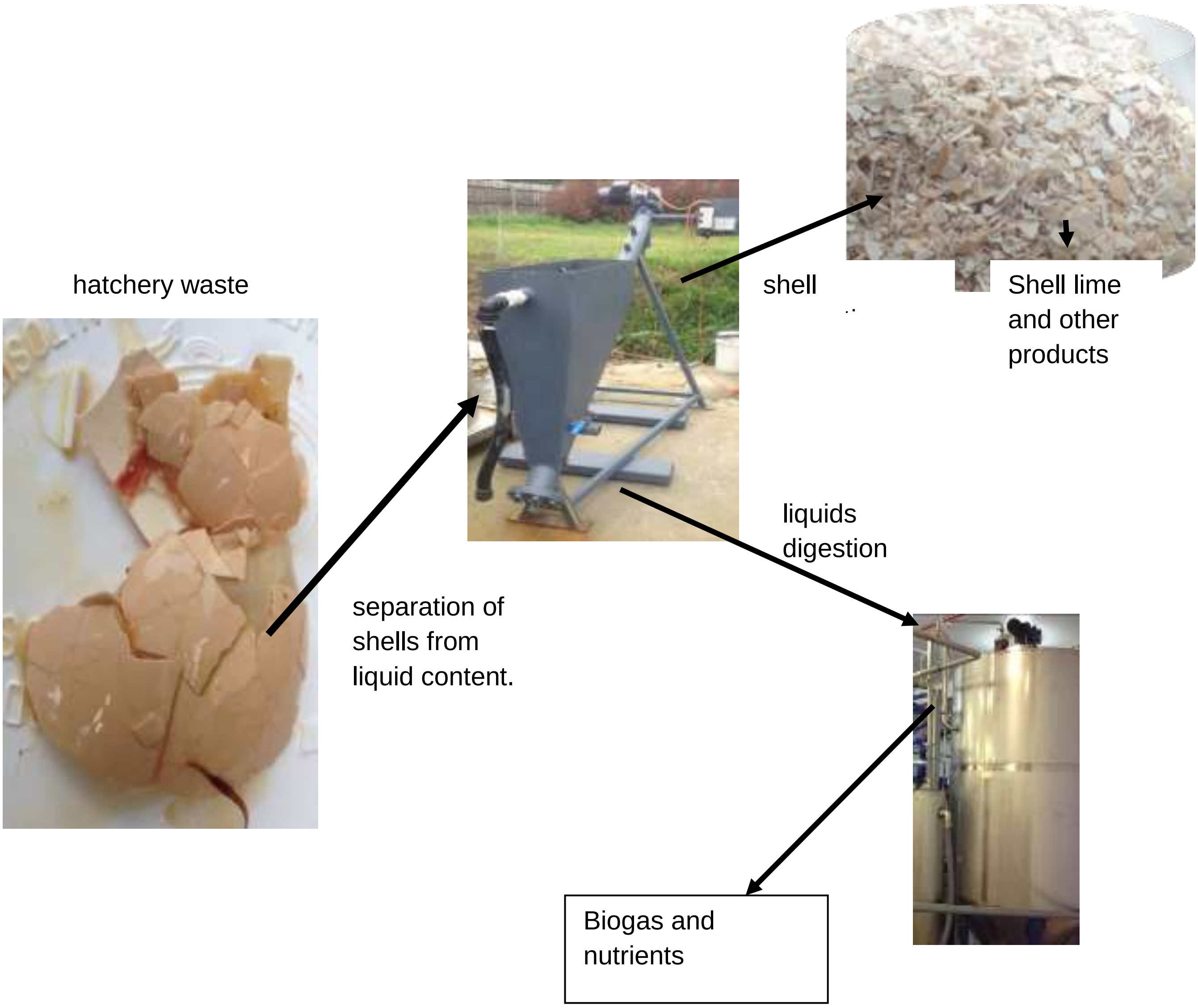
Pre-treatment of feedstock is a particularly important phase for the recovery of energy and nutrients in as much as the better the preparation the better the outcome of the process including reduction of digestate solids, reduced retention time, gas quality quantity and even a potentially smaller system (lower capex) and reduced running costs i.e. less power requirements to heat the system.

Appendix 3
Hatchery waste

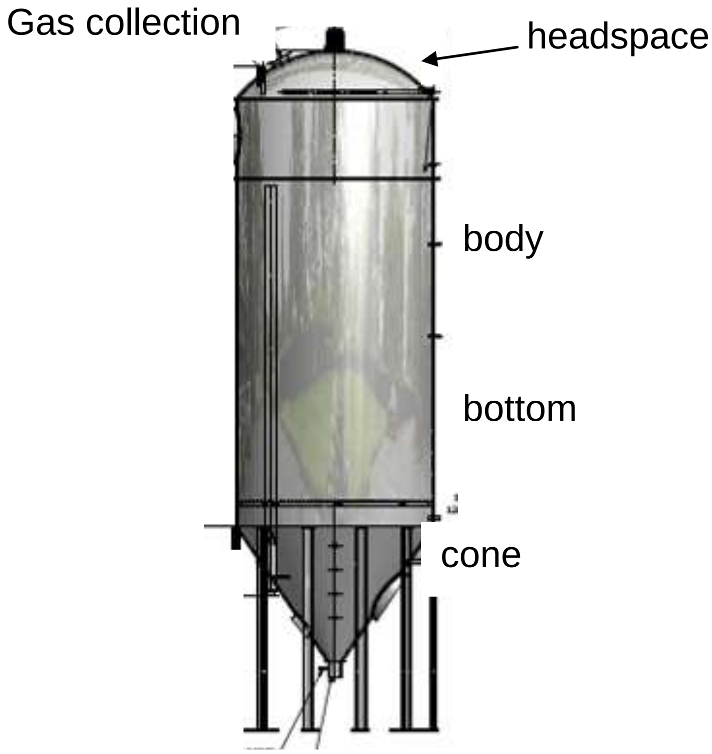
Hatchery waste

The recovery of energy and nutrients from hatchery waste is dependent on the efficient separation of the shells from the yolks and embryos. In the Active Research process the hatchery waste is macerated to reduce particle size followed by dissolved flotation. The shells are conveyed away from the liquid fraction, washed made ready, for example by further size reduction, to satisfy a market need.

The liquid fraction is pumped to a balance tank before transfer to the reactor for digestion and recovery of the biogas, nutrients and reduced landfill. Egg yolk has a total solids content of 24% dry weight. The residual solids had an N content of >8,000 mg/L

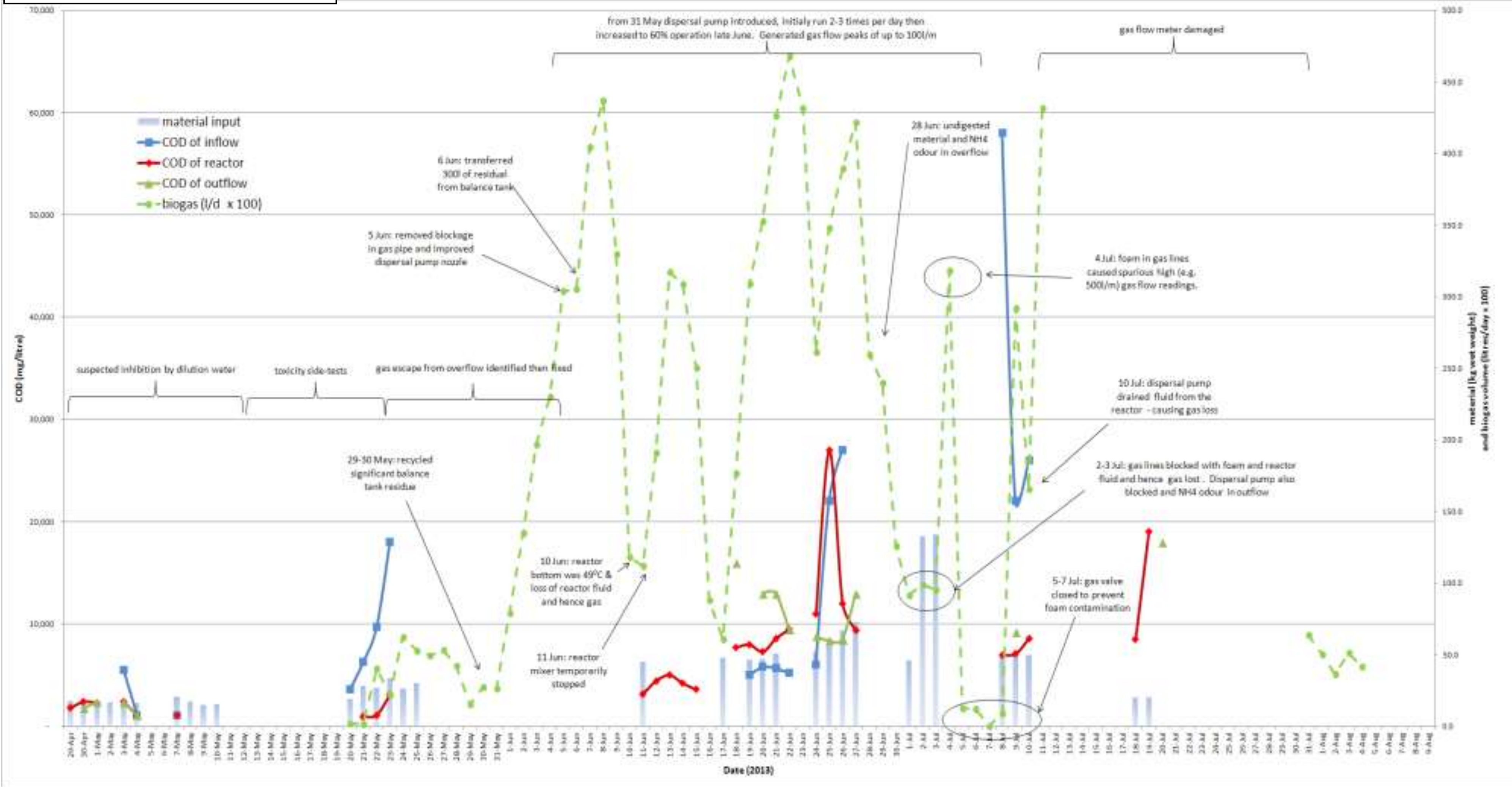


Appendix 4
Sample Points



Appendix 5

progressive graph



Consultants Report

Baseline®

Baseline (Australasia) Pty Ltd ACN 066 848 860 Trading as Baseline

[redacted]

Re: Perspectives upon future Microbiological aspects associated with production of Methane from Chicken mortality wastes processing of Poultry Wastes.

With such a broad and multifaceted project as this, much has been accomplished and yet the surface has barely been scratched. Cost- benefits have been variously calculated but one number which has not been measured though has been the cost of land disposal for dead birds which have been affected by disease (Freeman & Bevan 2007, Locke & Friend 1989). Potentially the passage of such carcasses through an anaerobic digestion process may not only "pasteurise" these biologically contaminated birds, it also reduces the total amount of waste and potentially circumvents issues of prime land being closed from further access without expensive rehabilitation.

The corollary to this pasteurisation issue is that it is likely to be more effective if thermophilic rather than mesophilic microbes are active in that thermophilic anaerobes are active at 55 °C and Mesophilic microbes those which are active at 37 °C . The second feature of thermophilic anaerobes is that much of the fatty material with the potential to remain viscous and confound processing at mesophilic temperature will have a greater potential to be completely emulsified at thermophilic temperature.

Clearly if the waste being treated is more homogeneous then the capacity of a bio-film adherent to the surface of the internal biomedia to have more intimate contact and so more vigorously degrade the waste is also a potential are for further development.

These observations inspire the matching of the chemical nature of waste substrates in the context of the biological optima of these different classes on anaerobes i.e. thermopile decomposition should be closely examined for carcasses while for egg waste when albumin proteins curdle and potentially become less tractable at elevated temperature it is clearly more practical to operate anaerobic digestion at mesophilic temperatures.

A feature of methanogenesis is that while it reduces Carbonaceous Oxygen Demand Nitrogenous Oxygen Demand persists. In conventionally operated sewage treatment processes solids were harvested to produce methane and the spent liquor was then treated aerobically to allow nitrification.

Under the Anammox® process (van der Graff *et al.* 1995) a specialized group of anaerobic budding bacteria can reduce Ammonium Ion to Nitrogen gas in the presence of equimolar portions of Nitrite ion. Potientially locally adapted and commercially unencumbered variations upon this then could provide a low energy alternative procedure for Nitrogen removal. Potentially under such a paired process waste processing could result in a net energy output compared to conventional aerobic treatment which has a net energy requirement. In this regard Baseline has independently constructed a prototype enrichment column as a prelude to evaluating anaerobic digestion and Anammox-like processes as a complimentary alternative combination which has the potential to allow sequential removal of Carbonaceous and Nitrogenous COD while at the same time harvesting energy. Our initial attempts at isolating these bacteria have been from sewage sludge but other more diverse are also to be commenced shortly. In this case the Baseline business model is to supply seed inocula to establish and maintain both Methanogenic and Anammox processes.

Photograph 1: Methanogenic Bacteria (Baseline 2013)
Photograph2: Acetoogenic Bacteria (Baseline 2013)

Photograph 1 is a MPN Tube which shows the presence of Biogas. Baseline has validated this method by a chromatographic technique. This assay indicated firstly that methane is a component of this biogas and the proportion i.e. quality is known. In the same tradition that plant breeders have used to Pollinate high yielding plant varieties Baseline is providing complimentary services to Active Research for the selection cultivation and supply of fast growing and high yielding methanogens.

Potentially as well as to provide different species of Heterotrophic and Autotrophic methanogens Baseline will also be able to supply Acetogens to start anaerobic digesters. Some work has also commenced on the cultivation and selective isolation of Acetogenic bacteria (Photograph 2) based on the method of (Harriot & Frazer, 1997).

Active Research brought it to our attention that the adequate maceration of feather waste was a major factor complicating the decomposition of this component of the waste stream. To this end another evaluation is underway to establish if there is an extant flora of anaerobic keratinolytic bacteria which can be included in this inoculum package.

SP Nearhos Ph.D. MASM
Steven Nearhos
Senior Scientist, Baseline.

References:
Freeman P. & Bevan P. (2007) Botulism in Cattle *NSW DPI Primefact* **596,** 1-3.

Harriot O.T. & Frazer AC (1997) Enumeration of Acetogens by a colorimetric Most Probable Number Assay. *Applied and Environmental Microbiology* **63,** 296-300.

Locke L.N. & Friend M. (1989) Avian Botulism: Geographic Expansion of a Historic Disease Chapter 13.2.4 *in* Friend M (ed) *Waterfowl Management Handbook: Field guide to wildlife diseases. U.S. Fish Wildlife Service, Resource Publication* **167.** 225 pp.

Van der Graff A.A., Mulder A. de Bruijn P. Jetten M.S. Robertson L.A. Kuenen J.G. (1995) Anaerobic oxidation of ammonium is a biologically mediated process. *Applied and Environmental Microbiology* **61,** 1246-1251.