# INSECT MEAL FROM PORK-PROCESSING-DERIVED MATERIAL

## 5A-102

### Final Report prepared for the Australasian Pork Research Institute Limited (APRIL)


**By**

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# Executive Summary


**Rationale:**
Feed use and food wastage is an issue challenging animal production enterprise globally. Additionally, the supply of feed protein to animals is a large economic and environmental cost to producers. Alternate sources of protein for use as animal feed may reduce costs of production while reducing the environmental costs of the enterprise. In pork processing systems, while much of the waste is rendered and sold for meat and bone meal, the price received for such materials has been declining in recent years. One novel process recently developed is to use insects, such as black soldier flies (BSF), to 'bioconvert' processing waste into a high quality (high in protein and fat) insect product that can be utilized as an animal feed ingredient. This project aimed to examine the use of low-value waste from Australian pork processing systems as a rearing substrate for BSFL.

**Major outcomes of the project:**

- Pork waste cannot be used as a stand-alone substrate for rearing black soldier fly larvae (BSFL). While the waste was somewhat consumed by the larvae, growth was inefficient and larvae survival was low.
- While production was not optimal, the BSFL reared on pork waste that survived grew to a good size (0.12 g) with a modest nutritional profile (~24 MJ/kg ME, 26% CP, 66% fat).
- The BSFL did not totally consume and bioconvert the pork processing waste which resulted in no residual friable frass (fertilizer) being produced.
- High levels of bone in the pork waste were not an efficient rearing substrate and not efficiently bioconverted by the larvae.
- High levels of fat in the pork processing waste became liquid at the BSF rearing temperature (28°C) and resulted in an environment that was not favoured by the BSFL, leading to inefficient growth and high mortality.
- A lack of carbohydrate in the pork processing waste likely contributed to the stunted growth of the BSFL.
- The addition of a small amount of fibre (carbohydrate) to pork processing waste marginally improved the bioconversion and larvae growth, although this growth remained inefficient compared to solely plant-based rearing substrates in published studies.
- Bioconversion of pork processing waste into BSFL is predicted be improved with the addition of carbohydrate sources to the rearing feed. While this was not directly explored in this research project, published studies and commercial information from Hatch Biosystems demonstrates the importance of carbohydrate sources (such as vegetable matter) in BSFL rearing substrates.
- Additional waste streams that can be used as co-waste sources for rearing BSFL on low-value pork processing waste warrant exploration to improve larvae growth and bioconversion efficiency.

**Relevance of the project's outcomes to the Australasian Pig Industry.**

- With additional development and optimisation of rearing substrates, pork processing waste can be utilized as a contributing nutrient source for rearing BSFL.
- There is an opportunity to combine pork processing waste with other agricultural waste streams and develop an efficient closed loop system whereby waste produced is bioconverted into a high value insect protein, rather than ending up in landfill.

# Table of Contents

# 1. Introduction

Feed costs associated with pig production systems can account for 55-70% of the cost of production (COP). In recent years, due to drought, feed costs represented approximately 65-70% of COP, with feed cost >$520/tonne (in Southern Australia and >$560/tonne in Queensland). These prices see Australia having some of the highest pig feed costs in the world, and whilst the 2020/21 harvest has brought some relief to feed prices, there is a need to continuously explore lower-cost ingredient options to buffer higher feed prices.

Approximately 20% of the live pig processed is categorised as manufacturing /processing waste; ~85% of this waste is sent to rendering for manufacture of animal protein meals like meat and bone meal and tallow to contribute towards a 'nothing wasted' strategy and recoup some revenues. The SunPork Group processes approximately 22,000 pigs per week (average 105 kg liveweight) at Swickers abattoir, Kingaroy. The volume of material sent weekly for rendering is ~400 tonne/week. Restricted Animal Material (RAM) legislation and other commercial decisions around species segregation of porcine material has seen the value of porcine processing rendering material drop by ~50% in recent years. The devaluing of pig abattoir processing material for rendering is unlikely to be reversed given current legislation and volumes of material being rendered. The trend of rising feed costs and falling revenues from pork waste product has significant implications for the cost of pork production for the SunPork Group, and a scenario that is also magnified across other pork supply chains. Ultimately, profitability and sustainability of the Australasian pork industry is significantly impacted. Given this, there is significant urgency we must find ways to increase the value of pork processing waste and source competitively priced feed ingredients.

Our project seeks to address both these challenges in one solution. Insects, particularly Black Soldier Fly (BSF) larvae, are known to bioconvert organic waste into a protein and fat rich biomass suitable as an animal feed source. The large-scale bioconversion of organic waste streams by BSFL may provide a novel single solution to increasing the value of pork processing waste and reducing feed costs. With feed conversion ratios ranging from 1.4 to 2.7 (Oonincx et al. 2015), BSFL can be used to produce protein-rich feed sustainably and quickly – within 14 days. The BSFL can be used to recycle low value organic waste streams such as abattoir offal back into the food supply chain as a high value feed ingredient (Lalander et al. 2019). Through consuming processing waste streams, BSFL become a protein rich biomass that can then be rendered and safely fed back to livestock including pigs. Companies such as HATCH Biosystems are working on ways to do this at large scale and at low cost. Insect meal created from pork processing waste streams could be natural, low cost, high quality and sustainable future feed source. Further, BSF's are endemic to Australia, do not naturally carry pathogens, and have suspected antibiotic characteristics (currently being investigated overseas).

Our project aimed to identify any barriers to using BSFL to bioconvert pork abattoir waste into protein and fat-rich feedstuffs suitable for pig (and other) production industries. As no local and few international studies have assessed this opportunity, little is known about potential risks relating to any aggregation of microbiological and chemical contaminants of BSFL bioconversion of pig abattoir material into pig feed.

# 2. Methodology

***Pilot experiment***

A small pilot study was conducted to ensure that the BSFL would consume pork products. Rendered pork waste samples (n=2, trim and offal) were sourced from Diamond Valley Pork (VIC) and frozen samples sent to HATCH Biosystems. Samples (approx. 200 g) were subsequently minced in a domestic mincer and processed as per standard practices by HATCH Biosystems. Samples were maintained as two subset replicates of each waste sample (Trim vs Offal) and a third treatment as a mix (50% each waste sample, T&O) was created. Approx. 200 x six-day-old BSFL neonates were then added to each sample in individual tubs. After 12 days of BSFL growth samples were harvested and frozen for further analysis of general nutrient composition (DM%, CP% and fat%).

***Experiment 1) Optimising growth of BSFL reared on pork processing waste***

Two experiments were undertaken using pork waste sourced from SunPork Group (Swickers). Experiments A & B are described below.

**A)**

Two streams of pork processing waste (trim and bone; T&B) and offal (a mix of floor waste and other soft offal) was sourced from SunPork Group (Swickers) and sent as frozen samples to the HATCH processing facility in Melbourne (see images in appendix). The T&B (~30% bone, 70% trim) was defrosted and shredded in an industrial shredder creating particle size of approx. 1 cm cubed, then minced using a 0.5 cm commercial mincer plate and processed as per standard practices by HATCH Biosystems. The offal was defrosted and minced using a 0.5 cm commercial mincer plate and processed as per standard practices by HATCH Biosystems.

Three replicates of the 3 treatments containing 6.15 kg each of T&B, offal or a 50/50 mix of the offal and T&B wastes were weighed into individual tubs. Each replicate tub was then inoculated with ~7,000 six-day old BSF neonates, weighing ~0.009 g each. The tubs were then stored in a climate-controlled room (28° C and ~55% RH) for 12 days. Every second day for 12 days 3 samples of 5 larvae each were sourced from various locations across each replicate tub (n=15 larvae per tub) and weighed. Recorded weights were then presented as average weight per individual larvae per tub.

**B)**

Three pork processing waste samples: testes & skin, throat, and uncleaned large intestine, were sourced from SunPork Group (Swickers) and sent frozen to the HATCH processing facility in Melbourne (see images in appendix). Each waste type was defrosted and shredded in an industrial mincer using a 3 mm commercial mincer plate. The wastes were combined and the total pork waste mix (22 kg) was then mixed with 2.3 kg Gainesville Diet (for added carbohydrate and to reduce substrate moisture content). Three replicate tubs of the waste mix (7.5 kg total per tub) were then processed as per standard practices by HATCH Biosystems. The pork waste mix was then inoculated with ~6,600 six-day old larvae each weighing ~0.011 g. A sample of larvae from each tub was collected and weighed every 2 days until weight stagnated (approx. 10 days) at which time the experiment was ended. A sample of ~100 g of larvae was harvested from each tub and combined for further analysis. No frass was collectible as little of the substrate had been fully bioconverted by the larvae even though larval growth had stagnated.

**Experiment 2) Evaluation of nutrient, chemical and microbial composition of insect meal reared on pork processing waste**
After incubation, samples from Experiment 1 were consolidated from sub-samples from each tub and grouped by treatment diet, then frozen for further analysis. Samples were assessed for energy, nutrient and amino acid (AA) composition by Symbio labs (Eight Mile Plains, Qld, Australia). Concentrations of key bacteria related to food safety were measured by ACE laboratory Services (Bendigo East, Vic, Australia).

# 3. Outcomes

***Pilot experiment***
While the pilot experiment was not designed as a full experimental trial, it is pertinent to present the results here as they contribute to these findings. The pork waste samples from a commercial abattoir in Victoria were sourced from different waste streams to those supplied in later experiments, and likely included more nutritional portions of the gastrointestinal tract (such as stomach) that may have contained undigested carbohydrate including fibre. Samples from this waste stream were assessed for nutrient analysis (Table 1), and these samples were higher in fibre content (5% CF) than those used in later experiments which ranged from <0.1-1.6% CF (as discussed further later in this report and shown in Table 3). As shown in Table 1, a promising response and nutrient composition of larvae reared on the two samples (and mix) of pork waste was observed. These larvae averaged at 0.23 g per larvae, 46% CP and 48% fat when mixed, which is similar to BSF samples reared on different waste streams such as vegetable waste from supermarkets (i.e., 40-50% CP and 12-40% fat; DiGiacomo & Leury, 2019). However, as with Experiments 1&2 the waste was not completely bioconverted into friable frass and growth was not optimal.

**Table 1.** The BSFL reared on samples of mixed pork processing waste (pilot trial).

| | Pork waste sample (mix) | BSFL | | |
|---|---|---|---|---|
| | | Trim | Offal | Mix |
| DM % | 39.2 | 42.8 | 42.7 | 35.9 |
| CP % DM | 33.0 | 33.6 | 50.8 | 45.7 |
| Fat % DM | 45.2 | 55.6 | 40.0 | 48.2 |

DM: dry matter; CP: crude protein.

***Experiments 1 & 2***

Based on the success of the pilot trial, Experiment A was designed to measure the growth of BSFL reared on unrenderable waste sourced from SunPork Group (testes, bone, trim and stomachs). This waste was separated as trim, bone and offal. As bone alone would not be a complete source of nutrients for the larvae the bone was mixed with the trim waste. The final average larvae weight on day 7 from Experiments A and B are presented in Table 2. The BSFL are considered a good size when they reach 0.15 to 0.2 g. As demonstrated in Table 2, the larvae in Experiment A only reached adequate size when fed the offal diet, while those fed the diets containing T&B stagnated growth at approx. 0.04 g, well below appropriate size.

Experiment B was designed to test challenging pork processing waste samples that have no home apart from landfill, comprising some muscles and intestines (which may have had a small amount of fibre present). In Experiment B, the larvae grew to approx. 0.15 g by day 9. However, as the larvae were unable to consume (bioconvert) all the pork waste in every sample, there was no friable frass produced in Experiments A & B and thus frass nutrient content was unable to be determined in these experiments.

**Table 2**. Average weight of an individual black soldier fly larvae (BSFL) reared on a range of pork waste products.

| | | Ave. BSFL weight (g) |
|---|---|---|
| Experiment A | Offal | 0.140 |
| | Trim and bone | 0.042 |
| | Mix | 0.043 |
| Experiment B | Mix | 0.124 |
| | Mix day 12 | 0.147 |

*Samples are taken on day 7 unless otherwise indicated.

The nutrient compositions of pork waste sourced for Experiments A & B are presented in Tables 3 and 4 and compared in Figure 1. Table 3 also outlines the nutrient content of the BSFL reared on the offal waste. Unfortunately, the larvae reared on the T&B waste and the mix of T&B and offal failed to grow adequately so sufficient samples were unable to be collected for further analysis. The BSFL resulting from Experiment A were lower in energy and all major nutrients compared to previous experiments conducted by the research team (DiGiacomo et al. 2019) using different rearing substrates. For example, CP concentrations generally average above 40%, while they were only at 15% in Experiment A.

In Experiment B, a mixture of pork waste was successful in producing adequate BSFL able to be processed for energy and nutrient analysis. This is likely driven by the improved energy and nutritional content (ME, CP, CF and fat, no bone) of the waste stream. Although Experiment B saw improved BSFL growth, it was still sub-optimal compared to other growth substrates previously utilized (DiGiacomo et al. 2019). Compared to Experiment A, the larvae in Experiment B were approximately the same size (0.14 g), while the CP (15% vs 26%), ME (14% vs 24%) and fat (18% vs 66%) contents were all improved in Experiment B.

**Table 3**. Nutrient concentration of pork waste products used to rear BSFL in Experiment A.

| | Pork T&B Waste | Pork Offal Waste | Pork Offal BSFL |
|---|---|---|---|
| DM % | 56.0 | 27.8 | 36.0 |
| Moisture % | 44.0 | 72.2 | 64.0 |
| ME (MJ/kg) | 13.3 | 13.8 | 13.7 |
| CP% | 13.1 | 15.2 | 15.0 |
| Fat % | 37.7 | 10.3 | 17.5 |
| CF % | <0.1 | 0.5 | 1.6 |
| Ash % | 5.3 | 1.0 | 1.3 |
| Ca (mg/kg) | 19700 | 520 | 1750 |
| Mg (mg/kg) | 442 | 121 | 447 |
| P (mg/kg) | 10100 | 1780 | 2020 |
| K (mg/kg) | 1350 | 1950 | 3070 |
| Na (mg/kg) | 1390 | 1290 | 220 |

ME: metabolisable energy; CP: crude protein; CF: crude fibre.

**Table 4.** Nutrient concentration of pork waste products utilized in BSFL growth Experiment B.

| | Pork waste | BSFL |
|---|---|---|
| DM (%) | 41.6 | 36.4 |
| Moisture (%) | 58.4 | 63.6 |
| ME (MJ/kg) | 22.3 | 23.9 |
| CP (%) | 27.2 | 26.1 |
| Fat (%) | 54.2 | 65.5 |
| CF (%) | 3.4 | 4.6 |
| Ash (%) | 2.8 | 5.7 |
| Ca (mg/kg) | 2700 | 16000 |
| Mg (mg/kg) | 1270 | 2680 |
| P (mg/kg) | 4160 | 5190 |
| K (mg/kg) | 5880 | 8330 |
| Na (mg/kg) | 2750 | 490 |
| Iron (mg/kg) | | 63.5 |
| Zinc (mg/kg) | | 97.8 |
| Manganese (mg/kg) | | 112 |
| Aluminium (mg/kg) | | 3.66 |
| Cadmium (mg/kg) | | 0.1 |
| Cobalt (mg/kg) | | 0.05 |
| Chromium (mg/kg) | | 0.2 |
| Copper (mg/kg) | | 5.53 |
| Lead (mg/kg) | | 0.039 |
| Selenium (mg/kg) | | 0.15 |

ME: metabolisable energy; CP: crude protein; CF: crude fibre.

Various factors are likely to have contributed to this lack of larvae growth in Experiment A. Firstly, as highlighted in Figure 1, the diets fed in Experiment A were lower in ME, CP and had negligible CF, while the diet fed in Experiment B was still low in CF (~3%) but it was improved from the undetected fibre in T&B diet. Experiments A&B were both designed to provide approx. 1 g of diet substrate per larvae (which has been previously established as the average feed consumption required for BSFL). However, in both experiments most of the waste was not consumed (particularly in Exp. A) and only a small number of BSFL were harvestable, which suggests a high mortality rate (whereby only the strongest larvae survived; although this was not measured) in this substrate.

Further, as demonstrated in the photos provided in the appendix, the wastes used in Experiment A were high in liquid fat at rearing temperature, which was not conducive for the larvae to thrive or even survive in; many small larvae were seen trying to escape the tubs. While there was also liquid fat present in the diet used in Experiment B (and as demonstrated by the fat content of these diets presented in Table 4), this waste’s nutrient composition was more conducive to larvae growth. Optimal BSFL rearing temperatures are around 28°C, which results in liquid fat and creates a far too wet environment the for the larvae to live in and bioconvert (as shown in the photos in the appendix where the larvae were actively trying to get out of the tubs). While larvae do prefer a high moisture growth medium (~70%) which was provided in these experiments, the high liquid fat present was not conducive to efficient larval growth.

Pure pork waste (no additional ingredients were provided) resulted in larvae that failed to grow and did not reach adequate size, particularly in the diets containing bone, which the larvae could not consume at all despite the bone being minced. The mixed diet in Experiment A was an improvement, but still did not provide adequate nutrition for the larvae to grow sufficiently. The addition of a small amount of Gainseville diet (a standard diet fed to flies) combined with different pork waste sources improved larvae growth in Experiment B, yet was still not ideal as compared to vegetable wastes used in previous experiments (DiGiacomo et al., 2019). Other studies have also noted that an adequate CP and carbohydrate mix (a balance of nitrogen to carbon) is required for optimal BSFL growth and the lack of carbohydrate fed in the experiments presented here likely significantly inhibited larvae growth and increased mortality (Lalander et al., 2019; Meneguz et al., 2018; Spranghers et al., 2017). According to Palma et al. (2019), a lower N/C ratio (16-24) is preferred to maximise BSFL growth and AA content.

Lalander et al. (2019) compared various substrates for their suitability to rear BSFL, including vegetable waste, abattoir waste (sheep rumen contents, cattle blood, manure and organs such as lung and heart), various manures and sewage sludge. In their experiments, Lalander et al. (2019) showed improved larvae growth when fruit and vegetable waste was combined with the abattoir waste, which they concluded was due to the additional carbon provided by the diet which balanced the high N content. However, unlike the results presented in these experiments, their larvae reared on abattoir waste (that contained no fat, was mixed with manure and thus had a varied nutrient composition to the waste used in the experiments presented here) grew largest and demonstrated a decent biomass conversion ratio (Lalander et al. 2019), although their growth was slower (17 days). This is likely driven by the varied waste used between experiments, as Lalander et al. (2019) used sheep rumen contents that would have been high in fibre (data not shown).

The final chemical composition and size of larvae is determined by the insect species and the feed consumed during the rearing process. Thus, if the rearing substrate lacks carbohydrate then the resultant larvae are likely to be low in ME (and some nutrients). Spranghers et al. (2017) also concluded that BSFL were less efficient at growing when reared on substrates high in grease (although they did not use meat products as a rearing substrate). As shown in Figure 2, the larvae reared in experiment B (with a small amount of CF available) had improved ME, CP and fat contents.

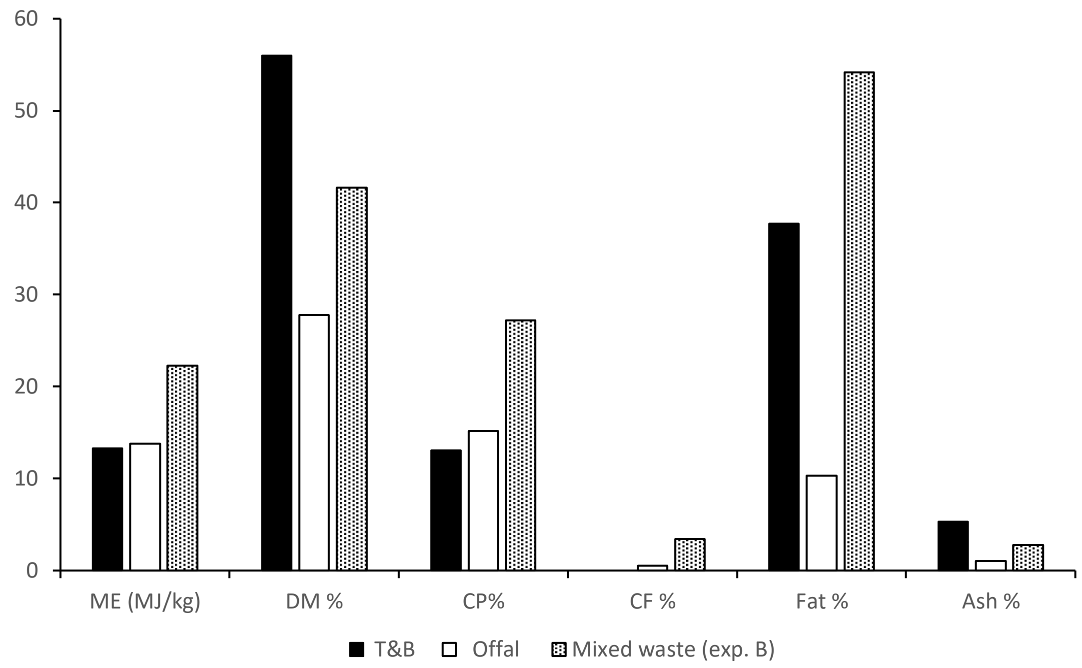


**Figure** 1. Comparison of pork waste sample energy and nutrient content used as BSFL rearing substrates in Experiment A (T&B and offal) and Experiment B (mixed waste).

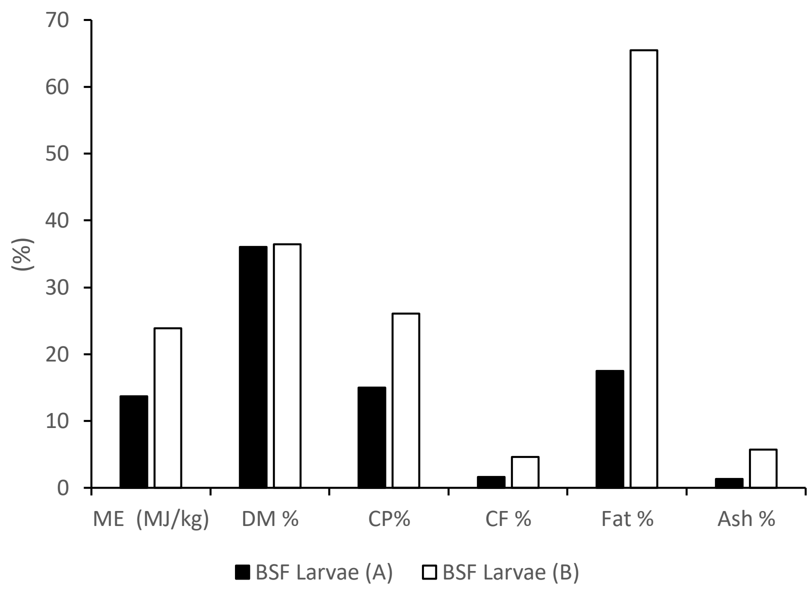


**Figure 2.** Comparison of energy and nutrient composition of BSFL reared in Experiments A and B.

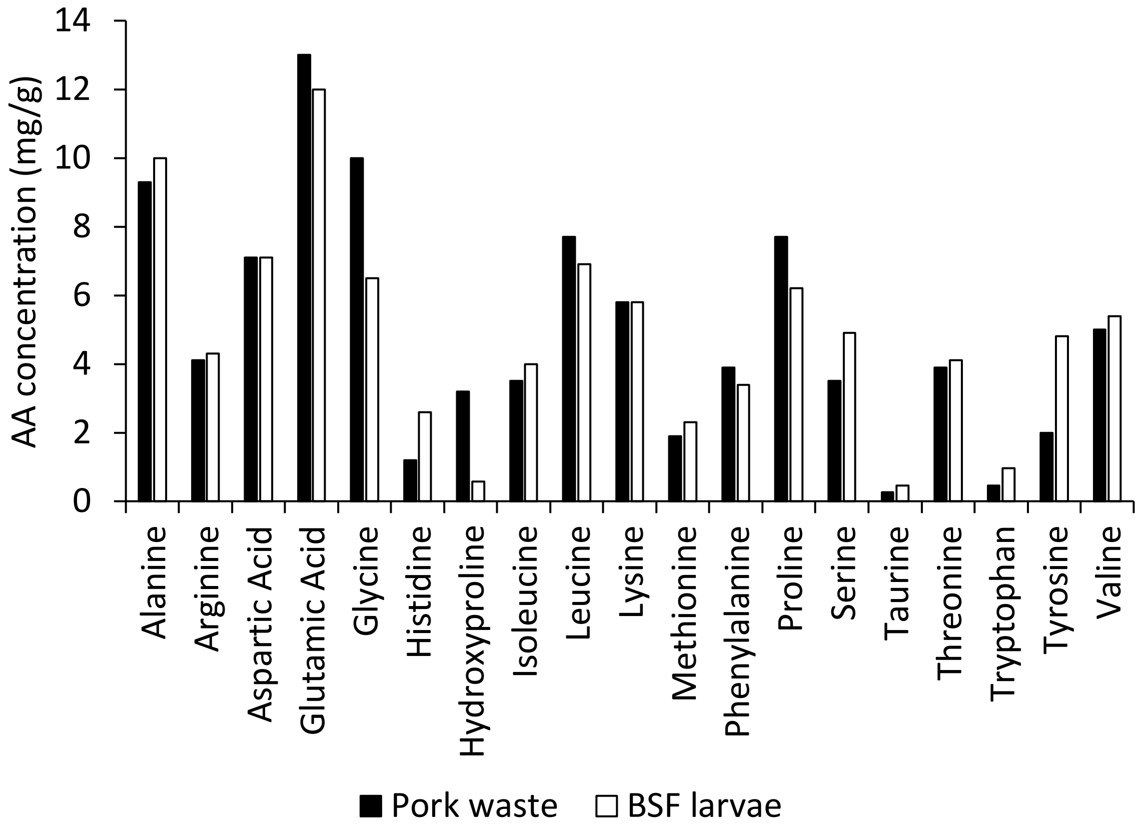


**Figure 3.** Amino acid concentration of pork waste and BSFL (Experiment A) reared on pork offal waste.

Samples of larvae produced from offal waste in Experiment A were subjected to further analysis for AA contents (Figure 3). The bioconversion of the pork waste into the BSFL resulted in an increase in the concentration of alanine, histidine, isoleucine, methionine, serine, taurine, threonine, tryptophan, tyrosine and valine compared to the rearing substrate. The contents of lysine, arginine, aspartic acid and threonine in both the waste and the BSFL were similar. The larvae had reduced concentrations of glutamic acid, glycine, hydroxyproline, leucine, phenylalanine, and proline compared to the pork waste. These results are promising as they do not demonstrate any major change or degradation to amino acids during the bioconversion process. In particular, the first four limiting AA's (for pork production): lysine, methionine, threonine and tryptophan, are all either equal to or increased from those measured in the pork waste material.

**Table 5**. Key bacterial concentrations of black soldier fly (BSF) larvae reared on pork processing waste.

| | Total Plate Count, (CFU/g) | Interpretation* |
|---|---|---|
| *Clostridium perfringens* | <100 | Satisfactory |
| Total Coliform Count | >15,000 | Unsatisfactory |
| Total *E. coli* Count | >15,000 | Unsatisfactory |
| *Bacillus cereus* | <100 | Satisfactory |
| Coagulase positive *Staphylococcus* | <10 | Satisfactory |
| *Salmonella* spp. Culture | Not detected in 25g | Satisfactory |
| *Listeria* spp. Culture | Not detected in 25g | Satisfactory |

*Interpreted according to the Food Standards Australia New Zealand (2018).

Food safety analysis (Table 5) of key biological hazards commonly found in food products indicated that the unprocessed raw BSFL were generally satisfactory even as a human food source. However, there were levels of coliform and E. coli detected that were above accepted food safety limits. This is likely driven by issues with shipping during the Covid-19 lockdown in Victoria whereby the larvae did not remain frozen prior to analysis. Nevertheless, BSFL will always be processed (heat, microwave etc.) prior to use as an animal feed and these processes would eliminate any potential contaminants. Encouragingly, BSFL can eliminate manure pathogen loads as demonstrated by reduced *E. coli* counts in dairy manure (Liu et al. 2008) and *E. coli* and *Salmonella enterica* in dairy and chicken manure (Erickson et al. 2004). These findings warrant further investigation to ensure the safety of the larvae as a potential animal feed source. While Table 4 demonstrated that lead was present in the BSFL, the levels observed were well below the 0.5 mg/kg required for human food (offal) in Australia. Similarly, cadmium was well below all tolerable limits (offal and vegetable products) for human consumption. The BSFL were also a valuable source of selenium, which has numerous growth and health benefits for pigs (and humans).

The results from all the experiments presented here conclude that pork waste alone, particularly waste that is high in bone and fat, is not suited as a rearing substrate for BSFL. Additional carbohydrate sources such as fibre are required to produce an adequate rearing substrate for BSFL. There are many potential sources of waste that could be utilised as a co-feed for rearing the larvae. These include manure (pork and other systems), and swine, ruminant, equine and poultry manure has been successfully used as a BSFL rearing substrate in numerous studies (e.g., Beskin et al., 2018; Elhag et al., 2018; Erickson et al., 2004; Liu et al., 2019; Liu et al., 2008; Moula et al., 2018; Newton et al., 2005; Oonincx et al., 2015). Additionally, external waste sources such as horticulture waste, grain processing waste and other fibre sources not used for food/feed systems could be utilized as co-substrates to provide carbohydrate for rearing the BSFL. Examining such combinations was outside the scope of this project but warrants further attention.

# 4. Application of Research

This research demonstrates that while there is potential for pork abattoir waste to be used as a portion of the rearing substrate to grow BSFL, it is clear that additional sources of carbohydrate sources including/such as fibre are required. Other published studies have concluded that the balance of carbon to nitrogen is important for BSFL growth, but an estimated range of CF between 5-10% would be more suited to maximise BSFL growth efficiency. There are various potential carbon sources that could be suited for use as a BSFL rearing substrate, although research will also be required to ensure the form of this carbon (i.e., structure/fibre content, particle size, particle form etc.) to ensure the carbon is accessible to the larvae. Additional waste streams from pork production systems (wasted feed grains, manure etc.) warrant further examination, as do waste sources from axillary production systems (such as food/feed waste, horticulture waste and processing waste from other industries).

Opportunities uncovered by the research:

- Further research into waste streams that can be used in conjunction with pork waste are warranted;
- Additional research into optimising the balance and type of pork waste utilized as a BSFL rearing co-substrate.

**Commercialization/Adoption Strategies**

• *Potential benefits to cost of production*

Any processes that will eliminate waste production and processing costs will be of benefit to the industry, especially wastes that are of low (or no) commercial value. This project demonstrated that there is potential for pork processing waste to be used as a portion of the diet for rearing BSFL as a? feed input.

• *Ease of adoption by producers*

The Australian BSFL industry is still in its infancy, but companies such as HATCH are aiming to be operating at commercial scale within the next few years. As this happens more information will become available about the cost/benefit opportunity pork producers like SunPork to process pork waste using BSFL bioconversion. At this stage, further development is required (as described previously) before these processes can be adopted by industry. This includes exploration of additional waste streams and further investigation into the processing and handling of BSFL (which was outside the scope of this research).

• *Impact of the research*

To our knowledge this is the first body of work examining the use of pork processing waste as a rearing substrate for insect production. While limitations and challenges have been outlined here, there were also promising results that indicate bioconversion to insects is a potential stream via which pork processing waste can be utilized. Even in non-ideal growth situations the pork waste used in these experiments produced larvae with a high fat (65%) and decent CP (26%) content. When defatted this could produce a high-quality feed for the pork industry. Considering the volume of pork waste not suitable for rendering and costing companies like SunPork to dispose of, this research suggests there are potentially both economic and environmental benefits for BSFL bioconversion of pork waste. This research sets a framework from which future experiments can build upon and develop a more efficient system.

# 5. Conclusion

While this project was successful in rearing BSFL from various sources of pork waste, none of the substrates measured were adequately able to produce larvae of a size and nutrient content observed in published trials conducted using different waste streams. This is driven by 1) the form of the waste which either had too much bone and/or was too fatty and 2) a lack of carbohydrate source such as fibre in the rearing substrate. Nevertheless, pork waste can be successfully used as a co-substrate for rearing BSFL. When larvae did grow, they were a good size had a decent nutritional (including amino acid) content which would be suited to use as animal feed. Further research is required to optimize the balance of pork waste used as a co-substrate for rearing BSFL.

# 6. Limitations/Risks

To the application of the research findings:

To our knowledge this was the first study in Australia examining the use of pork processing waste as a rearing substrate for BSFL. While the experiments presented here demonstrated a proof of concept that BSFLwill consume pork processing waste, further experiments are required to optimise the nutrient content of the rearing substrate to be more conducive to larvae growth and survival.

# 7. Recommendations

As a result of the outcomes in this study, the following recommendations have been made:

1. Further experiments are warranted to combine pork processing waste with additional agricultural waste streams and to process (e.g., defat) pork waste to then investigate their potential use as a BSFL rearing substrate.
2. Processing of larvae post-production (i.e., drying and handling methods) need to be adequately explored to ensure resultant feed products are of acceptable quality and safety for use as animal feed.

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**Appendix 1 - Notes**

### *Confidential Information*

If a Final Report contains Confidential Information:

- The Researcher must indicate on the cover of the Final Report that the Final Report contains Confidential Information.
- APRIL may request the Researcher to produce a non-confidential version of the Final Report in a form suitable for general distribution, and the Researcher must do so within 28 days of receiving the request.

### *Deficient Report*

If APRIL reasonably forms the view that the Final Report does not adequately set out matters referred to, it must notify the Researcher of the extent to which it believes the Final Report is deficient.

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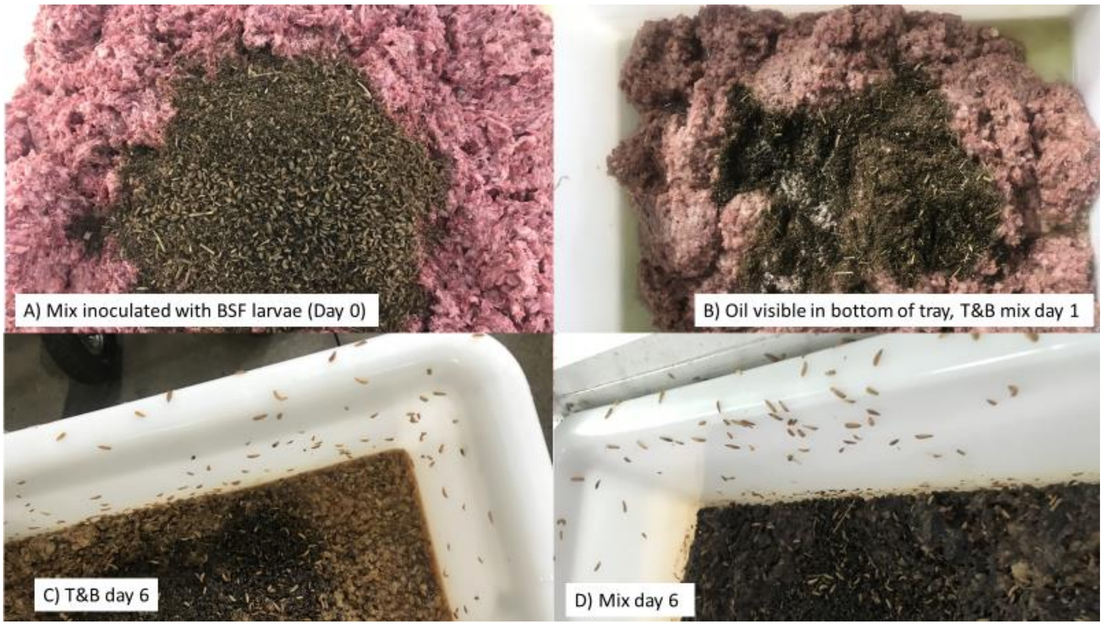
# Appendices

## *Appendix 1:*

### Experiment A larvae photos:

## Experiment B Larvae photos: