Final Report

AMPC
AUSTRALIAN MEAT PROCESSOR CORPORATION

Harvesting Extracellular Vesicles (EVs) from blood

Project code
2025-1073

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1.0 Abstract

Australian abattoir blood is worth far more than the blood meal it is rendered into, and this project set out to prove the higher-value route and establish what it takes to capture it. The route runs through extracellular vesicles (EVs), a premium functional ingredient recovered from blood plasma, and the project tested whether they can be recovered reliably and economically under real commercial conditions.

They can. Working at Australian abattoirs, the project recovered EVs from plasma at 92.5 per cent, reproducibly, and without depleting the plasma, so the residual stream remains available for further high-value protein fractions. The economics are decisive. Plasma separation returns value from the very first step, through better rendering efficiency for the cellular fraction and a cleaner waste stream, and adding EV recovery lifts the return to 305 per cent above current practice for modest additional capital, recovered in about a year.

What determines whether that value is captured is not the science or the downstream technology, both of which were demonstrated, but the way the blood is collected. For these coproducts, quality is built in at the point of collection, not recovered afterwards, the process is the product. Collecting blood to an improved hygiene standard is therefore the clear unlock, and it is a defined, buildable requirement rather than an open question.

With that in place, Australia is positioned to take market leadership in food-grade, claims-capable coproducts, establishing itself as the global leader of an emerging high-value category as demand shifts decisively toward differentiated, evidence-backed products.

2.0 Executive Summary

Australia's red-meat sector generates large, predictable volumes of abattoir blood, and at present almost all of it is rendered to feed-grade blood meal/meat meal or lost to the waste stream, the lowest use it can be put to. A smaller share is refined to analytical and reagent grade for laboratory markets by a few specialist operators. The highest-value route, food-grade product for human nutrition, has not been forged in Australia. The barrier has never been the science, which is well established; it has been the absence of the chain that connects raw blood to a food-grade coproduct. This project set out to establish whether that chain can be built, with extracellular vesicles, naturally occurring particles, far smaller than a cell, that carry biological cargo and command high value as a functional ingredient, as the catalyst that lifts the whole stream.

The project answered that question, and the answer is yes. All five milestone achievement criteria were met. EVs were recovered from abattoir-collected plasma at 92.5 per cent, reproducibly and under commercial conditions, without depleting the plasma, so the residual stream remains available for the higher-value protein fractions. The economics are compelling: separating plasma from blood returns value at the very first step, through improved rendering efficiency and a better waste stream, and adding EV recovery to a plasma operation returns a 305 per cent uplift on current practice for modest additional capital, recovering that capital in about a year. This is demonstrated recovery under Australian conditions, not a future prospect.

By approaching the question as one connected problem rather than three separate ones, the project was also able to map the full set of obstacles that stand between current practice and optimised coproduct recovery, and to move each from an open question to a defined position. The collection of blood to a higher standard of hygiene was identified as the binding constraint and its solution specified; the regulatory pathway was scoped and established as the key determinant of commercial practicality; the durable market position was defined, in differentiated, evidence-backed product rather than commodity supply; and the resource base was broadened beyond blood alone. None of these is an open scientific question. Each is a matter of infrastructure, procedure, and commercial development now within the industry's reach.

One finding sits beneath all of them, and it is the heart of this report, for blood and plasma coproducts, the process is the product. Quality is not an attribute that can be recovered downstream, it is built into the product through the chain of edible-grade collection, prompt separation, and controlled handling, or it is not captured at all. Where that process is disciplined, the value is preserved; where it is not, no downstream capability recovers it. Every part of the opportunity, the economics, the recovery, the higher-value fractions, the food-grade position, depends on this single principle. It is the foundation on which the entire pathway is built.

The timing favours the move. Market demand is shifting from commodity supplements toward differentiated, evidence-backed products, and durable advantage accrues to those who can demonstrate what their product does, the food-grade, claim-capable position that no red-meat coproduct operator yet holds. The project's three objectives, to recover viable EVs from blood, to determine the processing and stabilisation parameters, and to establish product quality, coproduct availability, and business models, were each addressed at the feasibility level the project was scoped to. The work supports a staged, low-risk move from commodity rendering toward food-grade coproducts, with value captured at each step. The recommended next stage is to establish the pathway under live commercial conditions at one or two operating sites, where the process can become the product in practice rather than principle.

3.0 Introduction

3.1 Industry Context

The Australian red meat processing industry generates a large and predictable blood stream, in the order of 11 tonnes of recoverable raw blood per 1,000 head of cattle processed each day and comparable volumes from smallstock (recoverable basis; the larger total blood volume is reduced by losses at collection). At the project's reference volume of 1,000 head per day across 250 operational days per year, this is a sustained coproduct stream of national scale.
The dominant current practice is collection of whole blood at the slaughter floor and rendering to blood meal, a feed-grade output, and the lowest-value use of the stream. This sits within a wider pattern in red-meat coproduct recovery, in which blood-derived value is realised at two grades and no higher.

The first is feed-grade, blood meal and spray-dried plasma for animal feed, the established bulk market. The second is analytical and reagent-grade, purified proteins such as serum albumin and immunoglobulins sold in small volumes to laboratory and reagent markets. Both are real and both have value, but between the low-value bulk floor and the small-volume specialty ceiling lies the opportunity that has not been forged: food-grade bioactive coproducts, recovered at scale for human nutritional and functional use (Glenn 2015; Occum Enterprises 2012).

Industry analyses commissioned by AMPC and Meat & Livestock Australia (MLA) have repeatedly identified blood as one of the highest-potential underutilised coproduct streams in the Australian red meat processing industry (MLA A.BIO.0036; MLA A.BIM.0040; MLA A.BIO.0045; MLA P.PSH.0415; AMPC 2021-1055). Despite that recognition, the transition of blood from a rendered commodity to a recovered plasma- and EV-derived food-grade coproduct has not previously been demonstrated under Australian processor conditions.

Australian blood utilisation has been approached in two ways; bulk rendering to blood meal, or the isolated recovery of a single high-value component. In both, the economic, technical, and operational questions have been treated separately. This project treats them as one problem. It sets out to establish whether processor-relevant coproduct recovery is, at the same time, economically justified, technically validated, and operationally achievable under Australian conditions.

3.2 The Recovery Platform: Extracellular Vesicles and the Coproduct Base

Plasma carries a defined set of commercially relevant components. These include bovine serum albumin, immunoglobulins, transferrin, and other plasma proteins recovered through fractionation in the international plasma industry, together with extracellular vesicles.

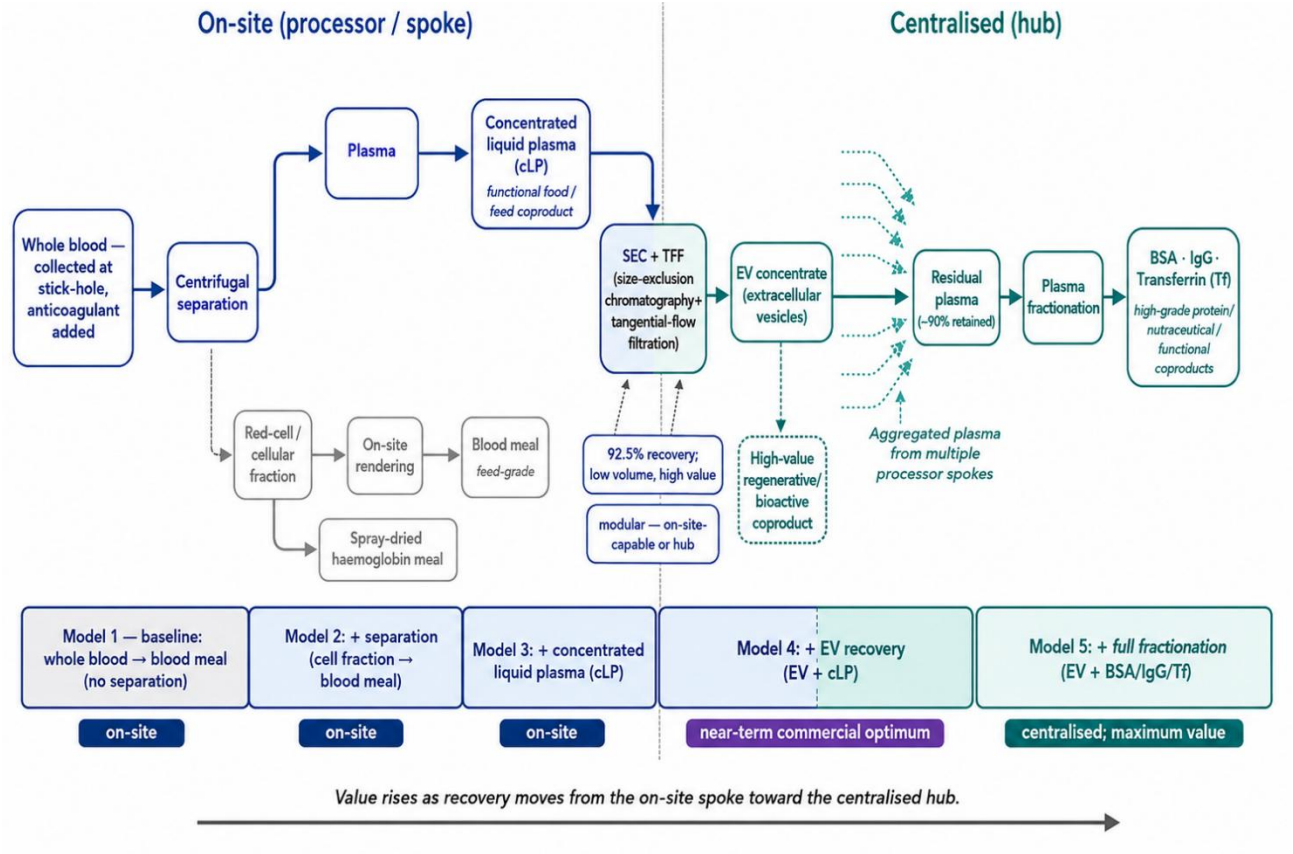
Extracellular vesicles (EVs) are nanoscale, membrane-bound particles released by cells that carry biological cargo. They have emerged as a distinct and high-value class within the broader plasma coproduct opportunity, and they are the central focus of this project: they sit at the top of the plasma value stack, and recovering and characterising them is the technical core of the work reported here. EV recovery is the catalyst in the coproduct model — the step that lifts a plasma operation from a modest coproduct margin to a high-value one. EV recovery and characterisation in this project are aligned to the Minimal Information for Studies of Extracellular Vesicles (MISEV2018) guidelines (Théry et al. 2018), which define the analytical standards for credible EV recovery and reporting.

Extracellular vesicles are present in plasma at characterised particle concentrations, not as a fixed share of plasma volume; the literature reviewing blood EV concentration notes that reported estimates vary widely and require careful analytical control (Johnsen 2018). The economic modelling applied an EV-concentrate yield of 11.5 per cent of processed plasma as a stated project assumption, drawn from the project's own

bench data and current literature rather than from a single published volumetric figure; the basis is set out in the Milestone 1 cost-benefit analysis.

While blood and plasma are the focus of this project, the recovery approach is a platform spanning more than one coproduct stream: Exomed's underlying intellectual property covers food-derived EVs from both plasma and adipose (fat) tissue (Exomed Patent WO2024108263A1). During the project, a parallel program required a supply of EVs, and because adipose is already classified as food-grade, a dedicated method was engineered to recover them from it. That work, using a different process suited to the tissue, the specifics of which sit outside this report , successfully recovered EVs from adipose in quantities sufficient at the scale and quality required to supply an external development program. Adipose therefore stands as a second, proven coproduct source, broadening the resource base beyond blood alone, though blood and plasma remain the subject of this report.

Figure. 3.2.1 Blood value-recovery streams – hub and spoke model.



Blood value-recovery streams across the hub-and-spoke architecture. Whole blood collected at the stick-hole with anticoagulant is separated on-site into a red-cell fraction and plasma. The red-cell fraction is rendered to blood meal (feed-grade, lowest value); the plasma carries the higher-value streams. On-site, plasma is recovered as concentrated liquid plasma (cLP). EV recovery by size-exclusion chromatography and tangential-flow filtration (92.5 per cent recovery) is a modular step that can sit on-site or at a hub, and it retains around 90 per cent of the plasma for further use. Full fractionation of the residual plasma into bovine serum albumin (BSA), immunoglobulin G (IgG), and transferrin (Tf) requires centralised volume aggregated from multiple processor spokes. The five models (lower panel) represent progressive depths of recovery: Models 1–3 are achievable on-site, Model 4 (EV + cLP) is the near-term commercial optimum spanning spoke

and hub, and Model 5 (full fractionation) is the centralised hub configuration. Value rises as recovery moves from the on-site spoke toward the centralised hub. Source: AMPC Project 2025-1073, Milestones 1–3.

3.3 The Australian Knowledge Gap

Prior Australian work has addressed parts of this problem in isolation. Earlier MLA blood-processing capability analysis (MLA A.BIO.0036) mapped Australian collection and processing systems and documented the principal impediments to blood collection and value-adding, the same upstream constraints this project re-examines under current operating conditions. CSIRO technical reports between 2005 and 2018 documented plasma fractionation pathways and reference yield data for bovine plasma proteins. MLA-funded work on Halal slaughter, blood collection, and welfare (P.PIP.0197; A.BIT.0014; MRR.576) characterised the operational reality of Australian collection practice, including the effect of widespread Halal adoption on the practical availability of contained blood collection. MLA-funded utilisation work (MLA P.PSH.0415) had already identified concentrated liquid plasma (cLP) as a lower-cost alternative to spray-dried plasma, the value step on which Models 3 and 4 of this project build. MLA-funded work has also documented industry-level plasma value-chain analysis (2023) and coproduct market positioning (2024).

What has not previously been produced is an integrated framework that brings together economic feasibility modelling, processor-relevant technical validation of EV recovery, and operational feasibility assessment under commercial Australian conditions. The knowledge gap is not in the science of any single step; it is in the enabling chain that connects them, hygienic collection, primary separation, and a demonstrated route from raw blood to a recovered, higher-value coproduct under real processor conditions. Most prior work also predates the widespread adoption of Halal processing across both large and small stock, which has materially changed the practical constraints on contained collection at the point of slaughter. AMPC Project 2025-1073 was undertaken to close this gap.

Underlying this is a strategic question that prior work has not addressed; not merely whether blood can be value-added, but to what end-point the value chain should be built. Recovering a food-grade coproduct is only the first step. Where a coproduct enters the market as an undifferentiated commodity ingredient, its value erodes over time, supply competes on price, the product is absorbed into the bulk market, and margin compresses toward the cost of production. The durable opportunity lies at the other end of the chain: in high-value, claim-supported nutraceutical ingredients, where value rests on demonstrated function rather than volume, and where evidence of what the product does sustains a premium that commodity supply cannot. For the food-grade opportunity to be worth pursuing, and to remain defensible as others enter, the value chain must be built through to that claimable end-point, not stopped at a higher-grade commodity. This is the strategic logic behind the project's focus on EVs as the highest-value, most differentiable component of the stream, and it shapes the forward pathway set out in §7 and §9.

3.4 Project Rationale and Structure

The project was structured in two phases, delivered across the project's milestones. Phase 1 established the foundation; the economic case through cost-benefit modelling of five processing configurations (from current rendering practice through to full plasma fractionation), followed by industry engagement, blood sampling, contamination assessment, and proof of concept for scalable recovery. Phase 2 built on that foundation to validate and characterise EV recovery under representative commercial conditions, with characterisation aligned to MISEV2018, and to confirm that the residual plasma remained available for further coproduct use. Together these phases delivered the economic case (Milestone 1), the technical validation of EV recovery (Milestone 2), a feasibility-level Minimum Viable Product (Milestone 3), and confirmation of residual plasma suitability (Milestone 5).

The project was scoped to address feasibility and industry readiness, not commercial execution. The intended outcomes are an evidence base sufficient to support processor investment and infrastructure decisions, a staged adoption framework that allows processors to enter at the level appropriate to their scale, and a defined forward research agenda required to progress the Australian red meat processing industry from commodity rendering to higher-value coproduct utilisation.

3.5 Target Audience and Intended Use

The primary audience for this report is AMPC and Australian red-meat processors of all scales evaluating investment, infrastructure, and capability options in blood coproduct development. The secondary audience comprises levy payers, industry implementation partners, and adjacent industry stakeholders working in plasma and bioactive coproduct development. The intended use is investment and infrastructure decision-making, staged adoption planning, and provision of an evidence-based foundation for further coproduct development within the Australian red meat processing industry.

4.0 Project Objectives

AMPC Project 2025-1073, *Harvesting Extracellular Vesicles (EVs) from Blood*, set out to establish whether higher-value coproducts, principally an EV concentrate, alongside plasma and its protein fractions, can be recovered from abattoir blood under commercial Australian processor conditions, while maintaining plasma integrity and preserving co-product availability.

The objectives specified in the Research Agreement are:

1. Develop and implement methods for the efficient extraction of viable EVs from the blood of young animals (lambs and yearlings) processed for meat production.
2. Investigate and determine optimal processing options and parameters to maximise EV yield and functionality, transforming raw materials into a stabilised oral therapeutic.
3. Ensure Product Quality and Efficacy:
    a. Develop Product Specifications.
    b. Maximise Co-product Availability.
    c. Identify Optimal Business Models.

All five milestone achievement criteria were met, and each of the objectives above was addressed by the project. The economic, technical, and operational work delivered against these objectives is reported in §6 to §8, and a summary of achievement against each objective is provided in §8. Consistent with the project's feasibility-and-readiness scope, elements relating to product optimisation, functional verification, formal specification, and regulatory or market pathways were advanced to feasibility level and are identified as forward work (§9.3).

5.0 Methodology

5.1 Overall Project Design

The project was designed to answer a single integrated question; whether processor-relevant recovery of higher-value blood coproducts is, at the same time, economically justified, technically validated, and operationally achievable under commercial Australian conditions.

Because those three dimensions are interdependent, economics depend on technical yield, technical yield depends on collection and separation conditions, and operational feasibility determines whether either can be realised at processor level, the project addressed them as one problem rather than three separate studies.

The work was structured into two methodological phases, delivered across the milestones.

Phase 1 — Foundation. Established the economic case, industry engagement, blood sampling, contamination assessment, and proof of concept for scalable recovery.

Phase 2 — Validation. Built on that foundation to validate and characterise the recovery process, and to confirm that residual plasma remained available for further coproduct use.

These phases were delivered across four milestones:

- **Milestone 1** — economic and pathway modelling
- **Milestone 2** — blood sampling and EV quantification
- **Milestone 3** — Minimum Viable Product
- **Milestone 4** — residual plasma suitability, reported in this Final Report

The work followed a deliberate sequence, each step de-risking the next. The economic modelling established whether the opportunity was worth pursuing and set the parameters the rest of the project was measured against; the technical validation tested whether recovery could be achieved at those parameters under commercial conditions; and the industry-feasibility assessment tested whether the proven process was compatible with how processors actually operate. Each step answered a question the next depended on, is it worth doing, can it be done, and can it be done in a working plant. The methodology for each phase is set out below.

5.2 Phase 1 - Industry Engagement and Sample Collection

Phase 1 established the foundation on which the rest of the project was built. It began with a substantial piece of analytical work, an ex-ante cost-benefit analysis that modelled the economics of staged coproduct recovery from first principles and set the parameters against which all subsequent technical and operational work would be assessed. With that economic case established, the phase moved to the practical work; engaging processors, collecting blood under commercial conditions, assessing contamination, and separating and preparing plasma, with the objective of confirming the feasibility of the proposed processing system without compromising plasma integrity or the availability of further coproducts.

5.2.1 Economic modelling - five-model cost-benefit analysis

The project opened with a detailed ex-ante cost-benefit analysis *(Output: ex-ante CBA; Milestone 1)*. This was the analytical foundation for everything that followed; it characterised the current baseline, modelled five progressively advanced processing configurations, assembled the cost, yield, and market-price data that underpin them, and evaluated each against a common set of economic and broader-value criteria. Its purpose was not only to estimate returns, but to establish which recovery configurations were worth pursuing and to fix the reference parameters, processing volume, yields, and coproduct values, against which the collection, separation, and recovery work would be measured.

Baseline characterisation.

Current practice, the collection and rendering of whole blood to feed-grade blood meal, was characterised as Model 1, the technical and commercial baseline; minimal infrastructure, low-value end product, high organic-waste potential, and no value recovered from plasma or EVs. Every advanced model was assessed as an uplift on this baseline.

Five-model framework.

Five processing models were developed to represent a progression from that baseline through to advanced plasma fractionation. The models were designed deliberately as a modular transition: once a processor commits to blood separation, each higher model is reachable by adding capability rather than rebuilding, so the framework supports staged investment sequencing across the sector rather than a single all-or-nothing decision.

- **Model 1** — Whole blood rendered to blood meal (baseline current practice)
- **Model 2** — Blood separated into plasma and cell fractions, with the cell fraction rendered
- **Model 3** — Concentrated Liquid Plasma (cLP) recovered and sold as a higher-value coproduct alongside cell-fraction blood meal
- **Model 4** — EV extraction integrated with cLP — a low-complexity, high-margin value stack
- **Model 5** — EV extraction followed by full plasma fractionation into bovine serum albumin (BSA), immunoglobulin G (IgG), and transferrin (Tf)

Data and assumptions.

Modelling was conducted at a reference volume of 1,000 head per day, equivalent to 11 tonnes of raw blood per day, processed across 250 operational days per year.

Plasma yield was modelled at 55 per cent of raw blood volume and EV-concentrate yield at 11.5 per cent of plasma processed, a stated project modelling assumption drawn from the project's bench data and current literature rather than a single published volumetric figure.

Protein-fraction yields for the Model 5 pathway used CSIRO (2012) reference data. Cost inputs were drawn from CSIRO (2012), Beston Global Foods (2021), the ACCC (2024), and peer-reviewed literature; market pricing was derived from commercial and industry sources, including MLA's Co-Product Market Report, adjusted using established margin converters (Sood and Van Nuys 2017).

Equipment overlap was modelled explicitly, with EV extraction in Model 4 treated as a membrane-based adaptation of the cLP infrastructure required for Model 3 rather than a separate capital programme, the basis on which a Model 3 processor can reach Model 4 incrementally.

Evaluation criteria.

Each model was evaluated for daily and annualised gross profit, net processing margin where input and downstream pricing were available, capital investment requirement and infrastructure crossover, and return on infrastructure. Outputs were structured around value-per-tonne-of-blood, providing a common metric for comparing return on investment across models and for building processor-level business cases.

Triple Bottom Line.

To align the analysis with AMPC's value drivers and MLA's evaluation principles, each model was assessed against a Triple Bottom Line framework spanning economic (profitability, return on investment, scalability), environmental (avoided rendering, waste and resource impact), and social (rural value-add, industry capability and innovation positioning) dimensions, mapped to MLA-aligned indicators. The environmental and social dimensions were assessed qualitatively at this stage; quantitative life-cycle analysis was outside the project's scope and is identified as forward work.

Collection-context assumptions.

The modelling assumes collection under conditions representative of current Australian practice, in which Halal processing predominates across both large and small stock. Non-Halal processing permits thoracic stick after hoisting, supporting cleaner, more contained collection and higher recovered volumes; Halal processing, by neck incision, gives wider variation in recovered volume and higher exposure to macro-contamination. These differences are carried through the five models as collection-context assumptions rather than fixed single values.

5.2.2 Industry collaboration and site visits

With the economic case established, the project engaged representative red-meat processing facilities covering large stock (cattle) and small stock (sheep and goat), under both Halal and non-Halal processing. Halal processing is the standard across the great majority of Australian plants and was treated as the practical baseline; a small number of non-Halal beef plants were engaged as reference points. Engagement also included collaboration with Sonac, an established Australian commercial blood processor, providing access to plasma collected and separated under mature commercial operating conditions.

A consistent observation across these visits was the substantial variation in collection hygiene and handling practice between facilities, in stick-hole technique, water and foreign-material exposure, and blood-flow management, and the apparent effect of that variation on the quality of the blood recovered. This observation shaped the contamination assessment and separation work that followed, and it is examined in §6.5 and §7.

5.2.3 Manual collection trials

Blood was collected manually at the stick-hole during commercial production, using a range of collection techniques and anticoagulant options to establish the conditions under which clean, usable plasma could be recovered. Variables documented at each site included stun method, stun-to-stick interval, animal positioning during bleeding, electrical immobilisation or stimulation where applied, and blood-flow path management, the factors that influence both recovered volume and contamination at the point of collection.

5.2.4 Contaminant assessment

Collected blood was screened for both macro- and micro-contamination, and interventions to minimise contamination at the point of collection were trialled. The assessment was designed to characterise the contamination introduced at collection, the variable identified during site visits as the most consequential for plasma quality, and to establish whether disciplined collection could bring it within acceptable limits. Macro-contamination screening assessed the incidence of wool and hair, fat and tissue from the neck incision,

blood clots formed before anticoagulant addition, and foreign material, against a threshold of less than 5 per cent incidence. Micro-contamination testing, conducted by an external reference laboratory, covered Total Plate Count, coliforms, Escherichia coli, total bioburden, and endotoxin, assessed against published reference values for biological coproduct streams. These were applied as indicative thresholds for a biological coproduct stream and do not constitute a formal food-grade compliance assessment, which would require validated, specification-linked testing against the applicable standard.

5.2.5 Plasma separation and preparation

Plasma was separated and prepared under conditions designed to preserve its integrity for EV recovery and downstream coproduct use.

- **Separation.** Blood was separated into plasma and a red-cell fraction by two methods; batch centrifugation for small-volume samples from direct site visits, and continuous disk-stack centrifugation for commercial-scale samples accessed through the commercial-processor collaboration. All samples were processed within same-day timeframes to minimise haemolysis, since delays between collection and separation raise plasma haemoglobin.
- **Haemolysis and plasma quality.** Plasma haemoglobin was measured using validated colour charts cross-checked by spectrophotometry, and assessed as an indicator of plasma quality. In the absence of a published threshold for raw abattoir-derived plasma, results were referenced against the haemoglobin standard for pharmaceutical-grade plasma.
- **Handling and storage.** Plasma handling and storage conditions, time and temperature between collection, separation, and processing, were managed to preserve EV integrity and plasma proteins through to recovery.

5.2.6 Proof of concept for scalable production

Phase 1 concluded by demonstrating that EV recovery from abattoir-collected plasma is achievable at a scale and standard relevant to industry *(Output: proof of concept for scalable production)*.

- **Recovery standards.** The project demonstrated recovery of blood to the standard required for EV extraction and further downstream processing, with EV recovery of 92.5 per cent through the workflow (§6.4).
- **Equipment verification.** The equipment selected for EV recovery was confirmed to extract and concentrate EVs from processed plasma at the required yield and particle characteristics, with reproducible results across independent runs (§6.4).
- **Feasibility review**. Shortlisted EV extraction methods were reviewed for their effectiveness and their impact on the use of the residual plasma, confirming that the recovery approach selected preserves the residual plasma for further coproduct recovery (§6.6).

5.3 Phase 2 Optimising Scalable Production

Phase 2 built on the Phase 1 foundation, moving from confirming that EVs can be recovered to optimising and validating the recovery process, stabilising the product, and confirming that co-product availability was maximised. Consistent with the project's feasibility-and-readiness scope, the optimisation, regulatory, and market-preparation activities below were taken to the level appropriate to a feasibility project; some were completed in full, some were demonstrated at feasibility scale, and some were scoped and progressed within the project's broader development workflow, with the remainder identified as forward work (§9.3). Each is addressed in turn..

5.3.1 Process optimisation and validation

Extraction parameters.

EV recovery was configured and refined using membrane-based concentration (tangential-flow filtration) combined with size-exclusion chromatography, to maximise EV recovery without compromising downstream plasma quality. This is the approach modelled in the Phase 1 economics as a membrane-based adaptation of the concentrated-liquid-plasma infrastructure rather than a separate processing line. Recovery and characterisation were validated on plasma collected during Phase 1 *(Milestone 2)*, establishing, at the particle level, the concentration, size distribution, and proportion recovered. Recovery averaged 92.5 per cent through the workflow, with a reproducible particle size distribution (median diameter 79 nm; coefficient of variation below 10 per cent) across three independent runs. Instrumentation was commercially available (Izon Science), operated within the manufacturer's recommended range, and recovery and characterisation were aligned to MISEV2018 (Théry et al. 2018). The results are reported in §6.4.

Refrigeration and transport.

Plasma and EV handling and storage conditions, time and temperature between collection, separation, and processing, were managed to preserve EV integrity through to recovery, and cryoprotectant-based stabilisation was developed as part of the Minimum Viable Product work (§5.3.3). Optimisation of refrigeration and transport conditions for a finished EV product at commercial scale is identified as forward work (§9.3).

Regulatory compliance.

The conditions required for food-grade coproduct use were assessed at a feasibility level, principally through the contamination and collection-standard work undertaken against AS 4696 and the establishment's HACCP-based food-safety program (§5.3.4). Regulatory compliance for a finished EV product, including any product classification and labelling, was not undertaken at full scale within this feasibility project; it is the central work package of the successor program (§9.3).

Figure. 5.3.1 EV analysis equipment – Exoid and size exclusion device.

5.3.2 EV yield and functionality verification

EV yield was verified at the particle level, concentration, size distribution, and recovery proportion, as the quantification the contracted feasibility scope required (§5.3.1; §6.4). Deeper functionality and bioactivity verification, including subtype identification, cargo profiling, and in-vitro bioactivity, was beyond the feasibility scope of this project. This deeper biological characterisation was undertaken within the project's broader development workflow and is identified as a forward research priority (§9.3); it is not reported here.

5.3.3 Drying trials and product stabilisation

A plasma-derived Minimum Viable Product was physically produced to enable final product analysis and evaluation *(Output: Minimum Viable Product; Milestone 3)*, demonstrating the feasibility of plasma handling, concentration, and stabilisation under representative conditions rather than commissioning a permanent processing system. Dedicated plasma-separation equipment was delivered later than planned within the milestone period; to meet the objective without compromising scope, temporary feasibility-level configurations were used, selected to replicate the functional outcomes of commercial plasma separation at batch scale. Plasma was separated from red cells using an adapted milk separator and large-volume batch centrifugation, clarified by centrifugal filtration, concentrated by cryoconcentration, and stabilised by the addition of cryo- and lyoprotectants to allow controlled freezing and an extended shelf life suitable for downstream analysis. The result was a stabilised plasma-derived MVP, representative of the intended coproduct stream, with plasma integrity preserved. The MVP results are reported in §6.5.

Drying trials were undertaken to address product stabilisation, and the project drew on both of its coproduct streams to ensure the drying deliverable was fully covered. Freeze-drying of the plasma-derived material was demonstrated at small scale, confirming the approach for the plasma stream. The parallel development program required a sizable quantity of stabilised, dried EV material, beyond what the small-scale plasma work produced and the adipose coproduct stream, which was available at that scale and already handled within food-grade workflows, was used to carry the at-scale freeze-drying. The majority of the drying work was therefore conducted on the adipose material, where freeze-drying was demonstrated successfully at scale. This division ensured the drying and stabilisation deliverable was fully addressed across the program: the plasma stream proven at feasibility scale, and at-scale drying demonstrated on the adipose material. Spray-drying and low-temperature spray-drying, already established for blood products at larger scale, remain options for higher-volume plasma drying.

5.3.4 Final product testing and market preparation

Quality assurance.

Process-control and contamination quality control were established through the collection and contamination work (§5.2.4) and the feasibility assessment below. The collection arrangements at the participating sites were assessed against AS 4696, the Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption, and the establishment's HACCP-based food-safety program. The assessment examined the conditions under which abattoir blood can be collected as edible material, including hygienic capture at the stick and the correlation of each collection to its carcass through post-mortem inspection, and the infrastructure and handling that food-grade collection would require. The proximity of collection to separation, the control of time and temperature after collection, and the physical layout of the collection environment were assessed as the factors determining whether plasma quality could be preserved to a food-grade standard. The findings are interpreted in §7. Efficacy testing protocols for a finished product are identified as forward work (§9.3).

Industry feasibility and benchmarking.

Workflow compatibility was assessed through direct site visits and operational audits at representative facilities *(Milestone 3)*, observing collection practice, hygiene controls, workflow constraints, and physical layout. The workflow was benchmarked against established commercial blood processing, through engagement with Sonac, as a best-practice reference. Benchmarking confirmed that scaled, high-value plasma processing is achievable in the Australian environment, and highlighted the dependence of highly centralised processing on a constrained upstream supply chain, informing the project's conclusion on the most resilient architecture for industry adoption (§7).

Regulatory documentation.

The documentation required to support a food-grade EV product was identified, as the schedule required. This involved reviewing the relevant regulatory and food-safety frameworks, including the Food Standards Australia New Zealand (FSANZ) food regulations, the applicable Therapeutic Goods Administration (TGA) considerations, HACCP-based food-safety requirements, and AS 4696, to establish the documentation and compliance requirements that a food-grade EV product pathway would entail. Preparing that documentation, and navigating the pathway itself, is the work of the successor program (§9.3).

Market strategy.

Market identification and positioning were undertaken as part of the project's value-pathway work, guided by a clear strategic principle; that the durable value of a food-grade coproduct lies not in commodity supply but in differentiated, evidence-backed ingredients. The analysis therefore targeted the higher-value end of the market, functional-nutrition and nutraceutical ingredient applications, where value rests on demonstrated function rather than volume, rather than the commodity feed and bulk-protein markets the existing blood stream already serves. The work assessed the positioning of an EV-based coproduct against this market, the basis on which such an ingredient commands and sustains a premium, and the contrast with commoditised ingredient categories where margin erodes toward the cost of production over time. This established the market rationale that underpins the economic case (§6.1) and the commercial pathway, including the durability of evidence-backed positioning and the demand shift toward science-backed products, which is set out in full in §7 and §9.4. Detailed market-entry strategy and the supporting market evidence base are identified as forward work (§9.4).

5.3.5 Maximising co-product availability

Residual plasma utilisation.

A defining requirement of the project was that recovering EVs must not deplete the plasma or reduce the availability of further coproducts. Analyses confirmed this directly *(Milestone 5, reported in this Final Report)*:

EV recovery is non-depleting, leaving the residual plasma intact and suitable for downstream processing into additional coproducts such as spray-dried plasma and protein or peptide fractions. The supporting evidence and the residual-plasma quality measures recommended for specification are set out in §6.6.

Value pathway quantification.

A central output of the project was the quantification of the additional value pathways that enhanced recovery opens up, delivered through the five-model framework (§5.2.1; §6.1). This established, for each step from current rendering practice through to full plasma fractionation, the specific value uplift available and the capital required to capture it, quantifying not only the headline returns but the *structure* of the opportunity that makes it adoptable.

Crucially, the higher-value stages were quantified against the pricing of the differentiated, food-grade and nutraceutical ingredient market they are intended to serve, rather than the commodity feed and bulk-protein pricing the existing blood stream attracts, anchoring the value uplift in the market segment where the recovered EV and plasma coproducts would actually compete.

The framework quantified the staged return; the efficiency and waste-stream gains banked at the separation step itself, before any high-value product; the uplift from concentrated liquid plasma; the step-change from integrating EV recovery onto that same infrastructure; and the upper bound available through full fractionation. It expressed these on a value-per-tonne-of-blood basis, providing a common metric for comparing returns across models and for building processor-level business cases, and it modelled the capital overlap between stages, establishing that each higher model is reachable by incremental addition rather than wholesale rebuild.

The quantification therefore captured both the magnitude of the value available at each stage and the staged, low-risk pathway by which a processor can capture it, anchored in food-grade market pricing.

6.0 Results

6.1 Economic Modelling Results (Five-Model CBA)

The Five-Model framework returns substantial economic uplift from current rendering practice across all advanced configurations. Annualised gross profit at the project's 1,000 head per day, 250 operational day per year reference volume is summarised in Table 6.1.

Table 6.1 — Five-Model Annualised Gross Profit and Capital Investment Summary

Model	Description	Capital Investment	Annual Gross Profit	Uplift Vs Baseline
Model 2	Blood meal from cell fraction	$0	$474,250	+50 per cent
Model 3	cLP + cell-fraction blood meal	$1.2 million	$574,515	+82 per cent
Model 4	EV recovery + cLP + blood meal	$1.3 million	$1,277,765	+305 per cent
Model 5	EV + full plasma fractionation (BSA, IgG, Tf)	$8.24 million	$4,387,250 (Year 2 at 50 per cent output)	+1,292 per cent

Source: AMPC Project 2025-1073, Milestone 1 Report §7.2 (Table 7.2); full supporting assumptions in Milestone 1 Appendix 2 (Tables A2.1–A2.5).

Model 1. The baseline, returns $315,250 in annualised gross profit through rendering of whole blood to blood meal. Model 2 returns a 50 per cent uplift through separation of plasma and cell fractions with rendering of the cell fraction only, requiring no additional capital. Model 3 introduces concentrated liquid plasma as a higher-value coproduct alongside cell-fraction blood meal, returning $574,515 against $1.2 million in capital for plasma processing equipment.

Model 4. Returns $1,277,765, a 305 per cent uplift against baseline, for only a marginal increase in capital to $1.3 million. The $1.3 million is the Model 3 plasma base (centrifuge and ultrafiltration separation, refrigerated tanks, filters, and pumps) plus the marginal EV-specific addition of ultrafiltration and chromatography hardware; EV recovery is modelled as a membrane-based adaptation of the cLP infrastructure rather than a separate plant (Milestone 1 Appendix 2, Table A2.4). The return combines three coproduct streams.

Table 6.1.1 Model 4 Annual Gross Profit by Coproduct Stream

Model 4 Gross Profit by Stream	Annual
EV recovery	$713,000
Concentrated liquid plasma (cLP)	$90,515
Cell-fraction blood meal	$474,250
Total	$1,277,765

Source: AMPC Project 2025-1073, Milestone 1 Appendix 2, Table A2.4. Figures are annualised gross profit at the 1,000 head per day reference volume.

Model 5. Returns $4,387,250 in projected annual gross profit (Year 2 at 50 per cent fractionation output), a 1,292 per cent uplift against baseline, for $8.24 million in capital, the $1.3 million Model 4 base plus $6.94 million in plasma-fractionation equipment (Milestone 1 Appendix 2, Table A2.5). This return is contingent on scale; the capital intensity and full-fractionation throughput are realisable only at centralised volume aggregating plasma from multiple processor spokes, positioning Model 5 as the hub tier of the hub-and-spoke architecture (§7.6) rather than a near-term, processor-ready configuration.

Table 6.1.2 Indicative Investment Metrics by Model (Models 3–5)

Model	Capital	NPV	IRR	Simple Payback
Model 3	$1.2M	$2,835,153	47%	2.09 years
Model 4	$1.3M	$7,674,487	98%	1.02 years
Model 5	$8.24M	$20,524,091	44%	2.38 years

Source: AMPC Project 2025-1073, Milestone 1 §7.4.3 and Appendix 2, Table A2.7. NPV and IRR are indicative estimates for capital-bearing models only; Models 1 and 2 require no additional capital and are therefore not assessed.

Model 4 returns the highest near-term capital efficiency, the strongest IRR (98 per cent) and shortest payback at 1.02 years, while Model 5 carries the largest absolute NPV on a longer horizon, consistent with its role as a centralised hub investment.

6.2 Triple Bottom Line Evaluation

Each model was assessed against the three pillars of the Triple Bottom Line, economic, environmental, and social, to capture value beyond gross profit alone. The pattern across the three is consistent; the gains begin at the first processing step and compound as recovery deepens.

Economic.

The economic pillar tracks the model uplift profile set out in §6.1, a staged progression in which value rises with each step, the first return is captured at separation, and Model 4 delivers the strongest near-term capital efficiency.

Environmental.

The decisive change is separation. Drawing the plasma fraction off the blood reduces the volume of material going to rendering and increases the solids content of the residual cell fraction, improving rendering efficiency and the quality of the residual waste stream, not merely reducing its volume (Milestone 1 Table 7.3). These are immediate operational and environmental gains, captured at the separation step (Model 2) before any higher-value coproduct is recovered. From there the pattern compounds; Model 3 diverts plasma to higher-value coproduct streams, reducing rendered waste volume further; Model 4 maximises material use without expanding the Model 3 processing footprint; and Model 5 increases overall recovery, though it adds processing steps with their own resource requirements. Across the ladder the consistent direction is improved resource use and a shift toward circular-economy outcomes through better coproduct recovery (Milestone 1 §7.4.4). These findings are directional and qualitative at this stage. Meaningful quantification of waste-stream and resource impacts is inherently site-specific, it depends on each processor's existing rendering load, utilities, effluent profile, and plant configuration, and is therefore most appropriately determined at the individual-site level by the processor, against its own operating baseline, rather than generalised from a single reference case. No quantitative environmental claim is made here.

Social.

The social pillar identifies the participation of Models 4 and 5 in functional, nutritional, and emerging bioactive coproduct applications as a contribution to rural value-add, industry capability building, and the innovation positioning of the Australian red meat processing industry. As with the environmental dimension, the realised social and economic impact will vary by site and region and is best quantified by individual processors against their own circumstances.

Across all three pillars, the evaluation at this stage is qualitative and directional, consistent with the project's feasibility scope; the economic pillar is quantified in §6.1, while the environmental and social pillars are framed for quantification at the individual-site level as the model is adopted.

6.3 Blood Collection and Quality Results

Blood collection quality and yield varied substantially across processor environments. Halal processing is the standard across the great majority of Australian plants, for both large and small stock, so it is the practical baseline for collection. At large-stock (cattle) plants, yields were variable but fell within the published literature range of 8 to 15 litres per head. Yield varied widely between plants and between individual carcases, the main factors being the interval between throat-cut and thoracic stick and slaughterman proficiency, alongside stun method, animal positioning during bleeding, and the use of electrical immobilisation and stimulation. At small-stock (sheep and goat) plants, recovered volumes of 1.5 to 2.5 litres per head were achievable. A small number of non-Halal beef plants were sampled as reference points, where thoracic stick after hoisting allowed cleaner and more consistent collection.

The collection method itself affected contamination, and the results point clearly to where quality is determined. Macro-contamination screening identified blood clots formed before anticoagulant addition, wool and hair, ingesta, saliva and fat tissue from the neck incision and added water as the primary contaminants. The clearest finding was that collection technique governed contamination load, blood from thoracic-stick collection in cattle (both on-cradle and hoisted) contained minimal contamination where regurgitation was avoided, while neck-incision collection introduced more wool, hair, and stick-wound tissue, reducible by a cleaner, single-cut incision which was heavily influenced by operator competency and class of stock being processed. This is a direct demonstration that contamination is set at the point and manner of collection, not downstream. Minimising macro-contaminants at the point of collection is essential to ensure final product specifications for micro-contamination can be achieved. Across all samples, macro-contaminant incidence remained below the 5 per cent significance threshold.

Micro-contamination assessment evaluated Total Plate Count, coliforms, Escherichia coli, total bioburden, and endotoxin against published reference values for biological coproduct streams. Results remained within those values.

Table 6.3 Plasma Haemoglobin Range

Measure	Value (mg/dl)	Comment	Reference
Lowest measured	29	Below all applicable reference thresholds	Milestone 2 Appendix C
Highest measured	78	Below the 90 mg/dL pharmaceutical-grade plasma threshold	Milestone 2 Appendix C

Source: Milestone 2 Appendix C.

All samples remained below the 90 mg/dL pharmaceutical-grade plasma threshold, and all but one remained below the 50 mg/dL maximum cited for serum and plasma in regulated downstream applications. Haemoglobin levels in plasma collected and separated under representative commercial conditions are within acceptable reference levels.

6.4 EV quantification and Characterisation

Extracellular vesicles (EVs) are nanoscale, membrane-bound particles released by cells, far smaller than a cell, typically less than 200 nanometres across and they are the high-value fraction this project set out to recover from plasma. Three things establish that recovery is real and reliable: how big the particles are (size distribution), how many there are (concentration), and what proportion survives the process (recovery efficiency). The results below report each.

The particle size distribution confirms the recovered particles are in the expected EV size range. Size distribution metrics for EV-enriched plasma are reported in Table 6.4.1.

Table 6.4.1 Particle Size Distribution

Metric	Value
Mean diameter	86 nm
Mode diameter	70 nm
D_{10}	69 nm
D_{50} (median)	79 nm
D_{90}	108 nm
D_{90}/D_{10} ratio	1.56
Span	0.49

Source: Milestone 2 Appendix C.

The median diameter of 79 nm sits squarely in the established size range for plasma EVs, and the narrow span (0.49) indicates a consistent, well-defined particle population rather than a broad mix of sizes.

Table 6.4.2 Particle Concentration

Metric	Value
Measured mean concentration	9.61×10^{9} particles/mL
Raw mean concentration	1.92×10^{11} particles/mL

Source: Milestone 2 Appendix A, Table A1.2.

Particle concentrations and size distributions are consistent with published data on plasma-derived EVs (Johnsen 2018; Théry et al. 2018). The coefficient of variation across three independent runs was below 10 per cent (Milestone 2 §8), meaning the result repeated closely each time the process was run, the consistency needed before a process can be scaled.

Recovery efficiency measures how much of the EV population is retained through the recovery process, the proportion captured rather than lost. Recovery performance is reported in Table 6.4.3.

Table 6.4.3 TFF + SEC Recovery Performance

Parameter	Pre-TFF	Post-TFF
Loaded volume (mL)	900	130
Concentration (particles/mL)	1.75×10^{9}	1.12×10^{10}
Total particles (entire fraction)	1.575×10^{12}	1.456×10^{12}
Overall recovery	—	92.5 per cent

Source: Milestone 2 Appendix B, Table B1.1.

The two-step process first separates the EVs from the rest of the plasma and then concentrates them, the loaded volume falls from 900 mL to 130 mL while the particles are retained, raising the concentration roughly tenfold. Recovery of 92.5 per cent shows that EVs are concentrated from abattoir-derived plasma without substantial loss, at a level consistent with bench-scale literature for plasma EVs.

Taken together, these three measures, consistent size, expected concentration, and high recovery, establish the foundational particle-level quantification this project set out to demonstrate; that EVs can be reliably recovered from Australian abattoir-derived plasma under feasibility-level conditions.

6.5 Industry Feasibility and Edible-collection Results

Site-based operational assessment identified substantial variability in blood collection practices across Australian red-meat processors. The variability spanned stick-hole technique, anticoagulant control, exposure of the blood stream to water and foreign material during collection, blood-flow path management, and the physical layout of the bleed area relative to wash-down and cleaning zones. Additional considerations included odour management, blood disposal infrastructure, and the residential and environmental adjacency of specific facilities. This pattern is consistent with the impediments to blood collection and value-adding previously documented in MLA reviews of Australian collection practice (MLA A.BIO.0036; MLA A.BIT.0014).

The most consequential feasibility finding concerns the eligibility of the blood for food-grade use. Assessed against AS 4696 and the establishments' HACCP-based food-safety programs, the participating sites were not configured for edible-grade blood collection. Blood drawn at the stick is, by default, inedible unless it is

collected through a dedicated edible system that maintains hygienic collection and correlates each collection to its carcass through post-mortem inspection. The sites had neither the edible-blood collection system nor the carcass-correlation mechanism in place at the point of collection, so the blood available was not eligible for release as edible material, not because it was rejected at inspection, but because the system to collect it as food-grade was not present. This is a defined, infrastructure-and-procedure finding rather than a limitation of the blood itself, and its implications for the path to commercial scale are interpreted in §7.

A clear pattern emerged alongside this. Where collection and hygiene practices were disciplined, plasma integrity was preserved and downstream coproduct pathways remained viable using standard processing. Where these upstream controls were inconsistent, downstream options were constrained, not because the downstream technology was unavailable, but because the input material needed more intensive intervention to reach a usable specification. The determinant of coproduct value is the front-end work, collection and primary separation, performed at the processor to a consistent standard. Where that front-end role is well bounded and standardised, it can be repeated reliably across sites, which is the basis for industry-scale adoption.

Benchmarking against Sonac showed that high-value plasma coproducts are operationally achievable at commercial scale in Australia where appropriate infrastructure, quality controls, and operating discipline are applied. Sonac's systems use contained blood collection with anticoagulant addition at the point of collection, a reference for commercial-scale operating standards. The benchmarking also showed the sensitivity of centralised processing to upstream supply-chain conditions: collection variability and hygiene practice at the processor level constrain downstream flexibility regardless of the capability installed at the central site. This reinforces the same division, strengthening and standardising the upstream front end at processor level is what allows centralised downstream processing to operate reliably, rather than concentrating all quality risk at the central facility and creates the opportunity for higher value end products.

Production of the plasma-derived MVP confirmed end-to-end workflow feasibility under representative commercial handling conditions. The MVP used an adapted milk separator and large-volume batch centrifugation for plasma and red-cell separation, centrifugal filtration for clarification, cryoconcentration, and addition of cryo- and lyoprotectants for stabilisation. The output was a stabilised plasma-derived MVP representative of the intended coproduct stream, with plasma integrity preserved through the workflow and suitable for analytical characterisation. The stabilisation step is significant for adoption: preserving plasma integrity after separation is what allows the residual plasma to be held and moved for further downstream recovery, supporting the staged pathway in which higher-value fractions are captured as that capability comes online. The MVP was produced at feasibility level and is not intended to represent commissioned pilot-scale, GMP, or routine commercial operation.

6.6 Residual Plasma Suitability

Stabilisation was demonstrated across both the project's coproduct streams, ensuring the drying and stabilisation deliverable was fully addressed. The plasma-derived MVP was stabilised by cryoconcentration and cryo-/lyoprotectant addition with controlled freezing (§6.5), preserving plasma integrity for downstream analysis. Freeze-drying of the plasma-derived material was demonstrated at small scale, confirming the drying approach for the plasma stream.

The at-scale freeze-drying was carried out on the adipose coproduct stream (§6.7), where the larger quantities required by the parallel development program were available and where the material is handled within established food-grade workflows. Freeze-drying was demonstrated successfully on the adipose material at scale. Across the two streams, the drying and stabilisation deliverable was therefore covered in full: the plasma stream proven at feasibility scale, and at-scale drying demonstrated on the adipose material. Spray-drying and low-temperature spray-drying, already established for blood products at larger scale,

remain the options for higher-volume plasma drying, and formal stability and shelf-life testing of a finished dried product is identified as forward work (§9.3).

6.7 Adipose Coproduct Results

In parallel with the blood and plasma work, and to meet the EV supply requirement of the concurrent development program, EV recovery was applied to adipose tissue as a second coproduct stream (§3.2; §5.3.3). Adipose is recovered downstream of post-mortem inspection from carcasses that have passed, and is therefore handled as compliant edible material, and it is less sensitive than blood to the time-and-temperature degradation that affects blood quality after collection.

The adipose work successfully recovered EVs using a process suited to the tissue, distinct from the plasma workflow, and produced material at the scale required to supply the parallel program's external development work. The at-scale freeze-drying reported in §6.6 was carried out on this material. These results confirm that the recovery platform extends beyond plasma to a second, proven red-meat coproduct source, broadening the resource base available for EV recovery. Consistent with the project's focus, the detailed adipose process and characterisation data sit outside this report; blood and plasma remain its subject.

6.8 Residual Plasma Suitability

A defining requirement of the project, confirmed at Milestone 5, is that recovering EVs must not deplete the plasma or reduce the availability of further coproducts. The project addresses this requirement at a system-feasibility level through the integrated evidence developed across Milestones 2 and 3.

Five elements support this position. First, plasma integrity has been confirmed by haemoglobin assessment, with all samples within acceptable reference levels (§6.3; Milestone 2 Appendix C). Second, contamination control has been demonstrated, with macro-contaminant incidence below the 5 per cent significance threshold across all samples and micro-contamination within published reference values (§6.3; Milestone 2 §4.2). Third, workflow compatibility has been established through site-based assessment confirming that residual plasma quality is preserved where upstream collection, hygiene, and primary separation are appropriately controlled (§6.5; Milestone 3 §7). Fourth, preservation-focused collection and separation conditions established across Milestones 2 and 3 maintain plasma integrity through the EV recovery step. Fifth, operational validation through MVP production confirmed end-to-end workflow feasibility (§6.5; Milestone 3 §4.5.1).

This is what underwrites the staged pathway: because EV recovery does not deplete the plasma, the same upstream work that preserves integrity for EV recovery also preserves the residual plasma stream for the higher-value protein fractions, to be captured as that downstream capability comes online.

Direct residual-plasma quality measures recommended for specification at the validation stage include total protein and solids (Brix by refractometer), a haemolysis index, and the haemoglobin and contamination assays applied in this project. As a limitation, pre-slaughter water withdrawal or dehydration may affect plasma concentration and solids content and should be controlled and measured in future validation work.

On the integrated evidence presented, the project confirms that residual plasma collected and processed under the conditions defined in this project is suitable for downstream processing into additional coproducts, consistent with the contracted achievement criterion.

7.0 Discussion

7.1 The Opportunity: A More Profitable Coproduct Model

This project set out to test a single proposition: whether a red-meat processor can move from commodity blood rendering to a more profitable coproduct model, with EV recovery as the catalyst that lifts the whole stream's value. The results, taken together, show that it can, and that the move is attractive on its own economics before any external factor is considered.

The case rests on how the returns are structured. They are staged, and the first one arrives early, before any high-value product is involved. Simply separating plasma from the blood rather than rendering it whole improves rendering efficiency and the quality of the residual waste stream, a gain banked at the separation step itself, independent of anything downstream. From that base the value builds in proportion to commitment: concentrated liquid plasma as a saleable coproduct, then EV recovery added to that same plasma infrastructure, then full fractionation. EV recovery is the catalyst in this progression, it is the step that lifts a plasma operation from a modest coproduct margin to a high-value one, and it does so as a membrane-based addition to infrastructure the processor has already installed, not a second build.

For a processor weighing the investment, the figures are favourable and, importantly, the risk is front-loaded out of the decision. Model 4, EV recovery integrated with concentrated liquid plasma, returns a 305 per cent uplift on the rendering baseline, and the modelling indicates it recovers its capital in approximately one year, with the residual plasma left intact for the higher-value protein fractions as that capability comes online (§6.1, §6.7). A payback of that order, reached from a Model 3 position the processor has already established, means the processor is not asked to make a single large speculative bet: the early steps pay their own way and de-risk the capital before the high-value EV step is taken, and the high-value step itself returns quickly. Model 5 defines the upper bound of value, a longer-term target requiring centralised, higher-capital processing and greater market development. The structure rewards starting at the scale that suits the business and advancing as each step proves itself.

The recovery that underpins this is technically robust. EVs were recovered from abattoir-collected plasma at 92.5 per cent through the workflow, with a reproducible particle size distribution (median diameter 79 nm; coefficient of variation below 10 per cent) across independent runs (§6.4), at parameters consistent with the published literature. The workflow is also operationally compatible with existing processing environments: site assessment and benchmarking against established commercial blood processing confirmed that plasma and EV recovery can be integrated into current operations without major disruption (§6.5).

The recovery platform proved adaptable beyond plasma, the same approach recovered EVs from adipose tissue, confirming that the method is not specific to a single coproduct stream and that the resource base available to a processor is broader than blood alone.

So the core feasibility questions are answered: the value is real and well-structured for staged investment, the EVs can be recovered reliably, and the process fits a working plant.

7.2 What Stands in the Way

The project also met a clear constraint, and identifying its cause precisely is one of the most useful outcomes of the work, because for a processor deciding whether to invest, the real barrier needs to be named honestly. The constraint was not biological, and it was not a limitation of the recovery technology. It was the availability of suitable raw material at scale, and it resolves into three linked layers.

The first is regulatory, and it is specific. Australian abattoirs operate under AS 4696, the Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption, together with each plant's HACCP-based food-safety program. Within that framework, blood drawn at the stick is by default inedible unless it is collected through a dedicated edible-grade system, one that maintains hygienic collection and correlates each collection to its carcass through post-mortem inspection, so that blood from any carcass later condemned can be identified and withdrawn. The trial sites were not configured for this, so the blood available could not be released as edible material — not because it failed inspection, but because the system to collect it hygenically was not in place at the point of collection.

The second layer is physical. None of the sites had processing capability near the point of collection. Blood had to be moved away from the stick area before it could be separated and chilled, and at one site the only access to the collection area would not admit refrigeration equipment. These are the ordinary realities of plants never built for this process, and they meant that time and temperature, the two factors that most affect blood quality after collection, were difficult to control.

The third layer follows directly. Most of the material that limits downstream recovery is not present when blood is collected; it forms afterwards, as the blood before separation stands and stays warm, with cells rupturing, proteins aggregating, and microbial load rising, all of it accelerating with time and temperature. The project did process blood at larger scale, but because the site conditions and equipment used forced delay and warmth before separation, the material degraded and recovery throughput fell sharply, the process could be run, but only slowly. This is consistent with the well-documented behaviour of membrane recovery on complex biological feeds, where throughput is governed by the condition of the incoming material (§6.5).

Faced with this constraint, and with a parallel program requiring EV material, the recovery platform was applied to adipose tissue as the practical response, a stream recovered downstream of inspection from passed carcasses, and far less sensitive to time-and-temperature degradation. That response kept the work moving and confirmed the platform's reach beyond plasma.

7.3 Why the Constraint is Bounded

For a processor, the significance of the constraint is that it is bounded and understood. It is not an open scientific question, and it does not sit in the recovery step or the product. It sits at collection, and collection is something the industry already knows how to control, through the standards and systems it operates under every day.

This is the project's central operational conclusion: for blood and plasma coproducts, quality is built in at collection and primary separation, not recovered downstream. The attributes that decide whether plasma reaches a usable specification, contaminant load, haemolysis, clotting before anticoagulant addition, and the degradation that time and temperature drive, are set at the point of capture, and no downstream processing fully retrieves quality that collection failed to preserve. For blood and plasma coproducts, the process is the product. That principle is not a limitation; it is the design brief.

It is worth being clear about why this showed up as a constraint in the project rather than being solved within it. The work was experimental, conducted inside operating plants and around live production. It could not interrupt day-to-day operations, and it was never within scope to modify a plant's collection arrangements or install dedicated infrastructure at the stick. The project therefore worked with blood collected under the arrangements that existed, which were built for rendering, not for edible coproduct recovery. The constraint we met is not evidence that the problem is hard to solve, it is evidence of what a purpose-designed system needs to include, learned from working without one.

Addressing it is a defined body of design, infrastructure, and compliance work, not a research problem. In concrete terms it involves:

- **A hygienic edible-blood collection standard.** A documented collection method that meets AS 4696 and the plant's HACCP program control contamination, covering hygienic capture at the stick, anticoagulant addition, contamination control, and the correlation of each collection to its carcass through post-mortem inspection, so the final blood products are eligible for release as food-grade material. This is the regulatory core, and it is built on frameworks the industry already operates.
- **Collection and primary-separation infrastructure** designed into the collection area: contained capture, immediate chilling, and separation close to the point of collection, the controls that hold blood inside the quality window, designed in rather than retrofitted.
- **A processing system designed against the constraints this project identified**. short time-to-separation, controlled temperature from the outset, and a feed-quality specification that keeps downstream recovery efficient and predictable.
- **Training and operating procedures** that embed the collection standard into routine practice, so quality is maintained by the people running the line, not by exception.
- **A commitment to hygienic handling** for the blood stream, the operational decision to treat blood as a food coproduct from the point of collection, which is what unlocks the entire value pathway.

None of these is novel science. Each is an application of standards, infrastructure, and disciplines the red-meat industry already understands. What the project has done is define precisely what they must achieve.

7.4 What a Processor Must Do, and How it Rolls Out

The path forward is clear, and the requirement is straightforward in concept. A commercial operation needs a purpose-built, hygienic collection-and-separation capability at the front of the process; hygienic collection that meets AS 4696 and maintains carcass correlation through inspection, so the blood is eligible as food-grade material; separation close to the point of collection; and chilling from the outset. Designed in from the start, these controls keep the blood within the quality window the recovery process needs. They cannot be retrofitted around an existing layout, which is the clearest lesson the trial sites taught, and a factor a processor should plan for at the design stage rather than discover later.

What remains to be determined is not whether this works, but its operating parameters, the maximum time from collection to separation, the holding temperature, and the measurable feed-quality window. These are a defined body of work, established through a controlled study on representative blood, rather than an open investigation.

The adoption model that follows is staged and low-risk by design. A processor enters at the level suited to its scale and builds capability progressively, Model 2 from existing infrastructure, Model 3 through targeted plasma processing, Model 4 through the marginal addition of EV recovery, and Model 5 through participation in centralised fractionation. The first investment priority is the upstream collection and separation capability. A hub-and-spoke architecture, the processor owning collection and primary separation to a defined standard, with centralised higher-capital processing where scale justifies it, lets processors of all sizes participate while preserving the economies that justify the centralised downstream investment. It is the most practical adoption model identified, not a fixed prescription, and it means an individual processor need not carry the full capital of advanced fractionation to benefit from the model.

Two further matters define the forward program, and they are linked. The first is that the recovery platform extends beyond plasma: the same approach recovered EVs from adipose, a stream that carries an edible classification by virtue of being taken from carcasses past inspection. The second is the regulatory pathway

for a food-derived EV coproduct, which is the key determinant of whether the opportunity is practical to commercialise.

These two work together. The adipose work has established a workable route for taking a food-derived EV product forward once a coproduct holds an edible classification, the platform has shown the pathway can be navigated. The blood stream follows the same logic: with an edible classification achieved at collection, through the AS 4696 and HACCP-based system described above, it moves onto a pathway the platform has already begun to define. Establishing that pathway for blood is the central work package of the successor program, which is already underway.

7.5 The Full Value: Efficiency, Environmental, Social, and Why Now

The economic return is the most direct case for a processor, but it is not the whole of the value, and the wider gains strengthen the rationale for moving.

The efficiency and environmental gains begin at the first step and accrue regardless of how far a processor progresses. Separating plasma from blood rather than rendering it whole reduces rendering volumes, improves the quality and reduces the load of the residual waste stream, and uses the blood resource more completely. These are operational and environmental improvements banked at the separation step, before any high-value product, and they align the processor with the circular-economy direction the sector is moving toward. The project's assessment of these outcomes was qualitative; a quantitative life-cycle analysis was outside the contracted scope and is identified as a clear opportunity for the next stage (§9.3).

The social and industry value is in what the model lets the Australian red-meat sector produce. EV recovery turns a low-value waste stream into a high-value functional ingredient — the kind of science-backed bioactive that the nutraceutical and functional-nutrition markets increasingly demand. That participation supports regional processing capability, industry innovation, and a route from commodity rendering toward differentiated, higher-value product, keeping more of the value chain onshore.

The timing is the final part of the case, and it is favourable. Demand is shifting from commodity supplements toward differentiated, science-backed products, and durable advantage increasingly accrues to producers who can demonstrate what their product does rather than compete on price alone. (Market analyses, including McKinsey's 2025 wellness research, point to sustained growth in this direction and to science-backed differentiation as the durable basis for premium value. For a processor, this means the high-value coproduct model is not a bet on a speculative future market but a position in a demand shift already under way. The processor that establishes the upstream capability now is positioned to supply that demand as the regulatory pathway opens, and to lead, rather than follow, the transition from commodity blood rendering to higher-value coproduct utilisation.

8.0 Conclusions

AMPC Project 2025-1073 was a feasibility study. Its purpose was to determine whether higher-value coproducts can be recovered from abattoir blood under commercial Australian conditions, and to establish what that would require. It has done so. All five milestone achievement criteria were met. Milestone 1 established the economic case through cost-benefit modelling of five processing configurations. Milestone 2 validated EV recovery from abattoir-collected blood, with characterisation aligned to MISEV2018. Milestone 3 delivered the industry feasibility assessment, benchmarking against an established Australian commercial blood processor, and a feasibility-level plasma-derived Minimum Viable Product. Milestone 4, financial reconciliation, was satisfied through the contracted update mechanism. This Final Report satisfies Milestone 5, confirming that residual plasma remains suitable for downstream processing.

The study's most useful outcome is not any single measurement but an understanding of where the opportunity is actually decided. By treating the economic, technical, and operational questions as one connected problem rather than three separate ones, the project was able to look past the individual difficulties of blood recovery and identify the small number of obstacles that determine whether coproduct optimisation is possible at all. Four were identified. Each was carried from an open question to a defined position.

The first is hygienic collection, and it is the binding one. Assessed against AS 4696 and the establishments' HACCP-based food-safety programs, the sites engaged were not configured to collect blood hygienically. Blood drawn at the stick is inedible by default unless it is collected through a dedicated system that maintains hygienic capture and correlates each collection to its carcass through post-mortem inspection. The sites had neither, so the blood available could not be released as food-grade. This is a defined requirement of infrastructure and procedure, not a limitation of the blood, the recovery, or the product, and the study has established what a compliant collection system must achieve. Because the attributes that decide plasma quality, haemolysis, contamination, and the degradation driven by time and temperature, are all set at collection, resolving collection also resolves the feed condition on which downstream recovery depends.

The second is the regulatory pathway. The documentation and compliance requirements for a food-grade EV product were identified through review of the relevant frameworks, including the Food Standards Code, applicable therapeutic-goods considerations, HACCP, and AS 4696. Beyond that, the study established that navigating the regulatory pathway is the principal determinant of whether the opportunity is practical to commercialise, more so than any remaining technical question. That pathway is a substantial body of work, and it belongs to the program that follows. The obstacle has been scoped and its significance established; it is not claimed as resolved.

The third is market positioning. The study established where durable value lies. A coproduct sold as an undifferentiated commodity competes on price, and its margin erodes over time toward the cost of production. The durable position is at the other end of the chain, in differentiated, claim-supported nutraceutical ingredients, where value rests on demonstrated function. The economic case was therefore quantified against that food-grade market, not against commodity pricing, and EVs were identified as the most differentiable component on which to anchor that position. The strategic position is set; the detailed market strategy is work for the next stage.

The fourth is the resource base, and it is the obstacle the study advanced furthest in practice. The constraints on blood collection raised a fair question about the reliability of supply. In addressing a parallel requirement for EV material, the project demonstrated that the recovery platform extends beyond plasma to adipose, a second coproduct source, recovered as compliant edible material and produced at the scale required to

supply a concurrent development program. The resource base for EV recovery is therefore broader than blood alone.

Against this understanding, the substantive results are clear. The economics are sound. The five-model framework shows staged recovery to be viable across a range of investment levels, and the returns are sequenced so that each step pays its own way before the next. The first return arrives at separation itself, before any high-value product: drawing plasma off the blood improves rendering efficiency and the residual waste stream. Model 4, which adds EV recovery to a concentrated-liquid-plasma operation, returns $1,277,765 in annual gross profit against the $315,250 baseline at the reference volume, a 305 per cent uplift, recovering its capital in approximately one year, for marginal capital beyond Model 3. Model 5 marks the upper bound of value at $4,387,250, a longer-term position requiring greater investment, complexity, and market development. The technical result is equally clear. EVs were recovered from abattoir-collected plasma at 92.5 per cent, with a reproducible particle size distribution, median diameter 79 nm, coefficient of variation below 10 per cent, across three independent runs, at parameters consistent with the published literature. Plasma haemoglobin remained within acceptable reference levels, and recovery concentrates the EVs without depleting the plasma, leaving the residual stream intact for the higher-value protein fractions as that capability comes online.

These results support a single operational conclusion. For blood and plasma coproducts, the process is the product. Final quality is not an attribute that can be recovered downstream; it is built through the chain of edible-grade collection, prompt separation, and controlled handling. Where that chain is disciplined, the value is preserved; where it is not, no downstream capability fully recovers it. This is the organising principle for everything that follows.

What the study has settled, it has settled firmly: edible-grade collection at the processor is the enabling foundation of the pathway, and the recovery, the economics, and the availability of the residual plasma that build upon it are demonstrated. How the steps downstream of collection, separation, EV recovery, stabilisation, and higher-value processing, are best organised and divided is not settled here, and is better not prescribed in advance. That question turns on commercial and technical factors that can only be resolved in an operating environment, and it is left open for the next stage to determine on its merits.

This is the proper boundary of a feasibility study. The project has taken the question as far as observational work within operating plants allows, and in doing so has defined the core constraint and the shape of its solution rather than leaving them open. The elements that remain, the operating parameters of an edible-grade collection system, and the commercial configuration of the downstream steps, cannot be resolved by observation alone. They require the pathway to be established and run under live conditions at a working site. That is the task the recommendations set out.

The project gives the Australian red meat processing industry a sound basis for a staged transition from commodity blood rendering to higher-value coproduct recovery, with each stage preserving existing value and creating the option of the next. The timing is favourable. Demand is moving from commodity supplements toward differentiated, evidence-backed products, and the durable advantage accrues to those who can show what their product does. In forging the first link in the chain from commodity coproduct to claim-capable ingredient, the project positions the Australian red meat industry to take a leading place in food-grade bioactives.

9.0 Recommendations

9.1 Recommendations for Industry (processors)

The clearest near-term action for a processor is to treat blood as a coproduct from the point of collection, and to get the collection right. The study's central finding is that the value of everything downstream is determined by the discipline applied at the stick.

Processors should prioritise hygienic, well-controlled blood collection, disciplined stick-hole technique, anticoagulant addition at the point of collection, physical containment, and contamination control. This is the single most consequential variable identified in the project, and it is the part of the chain only the processor can own.

Processors should approach coproduct development as incremental capability, not a single large investment. The five-model framework allows entry at the level suited to a plant's scale, with value captured at each step and the next step taken only when the previous one has paid for itself. The first return is available at separation itself, before any high-value product, through improved rendering efficiency and a better residual waste stream.

Where collection discipline is established, it transfers more readily between comparable plants than capital does. Sharing that practice across the industry is a low-cost way to raise the quality of the available blood stream as a whole.

9.2 Recommendations for AMPC

AMPC should continue to support an infrastructure-first, staged approach to plasma and EV coproduct development, in which investment is sequenced to de-risk adoption progressively rather than committed in a single step. The cumulative return on AMPC's investment is best served by stage-appropriate funding that carries the work from feasibility, through site-based validation, to commercial readiness.

AMPC should support the next stage of this work, the establishment of the pathway under live commercial conditions at one or two operating sites (§9.3), as the logical continuation of the feasibility work reported here. This is the step that converts a defined feasibility result into a validated, adoptable model.

AMPC should continue to invest in communication and knowledge translation around two outputs in particular; the staged five-model framework, which processors can use directly for investment planning, and the finding that the quality of a blood coproduct is set at collection. Both are immediately actionable by processors of any scale and are the highest-leverage extension activities available.

9.3 Recommendations for Future RD&E

The feasibility work has taken the question as far as observation within operating plants can take it. The defining recommendation of this report is that the next stage move from observation to operation: that the pathway be established and run under live commercial conditions at one or two processing sites. The constraints this project identified, and the questions it could not resolve by working around live production, can only be settled by building and operating the front end of the process in a real plant, against real throughput, on commercial terms. This site-based program is the central forward recommendation, and the priorities below define the work it should carry.

Establish an edible-grade collection-and-separation capability at site.

The first task is to design, build, and operate a purpose-built, hygienic blood collection capability that meets AS 4696 and maintains carcass correlation through post-mortem inspection, so the blood products are eligible as food-grade material. Operating it at site is what allows the remaining unknowns to be fixed: the maximum time from collection to separation, the holding temperature, and the measurable feed-quality window that keeps recovery efficient. These are a defined, specifiable body of work, not an open research question.

Determine the commercial configuration of the downstream steps.

How the steps downstream of collection, primary separation, EV recovery, stabilisation, and higher-value processing, are best organised and divided is a commercial and technical question that can only be answered in an operating environment. The next stage should establish, under real terms, which steps are best performed at the processor, by a specialist operator, or at a centralised facility. The hub-and-spoke model is one configuration to be evaluated in that work, not a settled prescription.

Advance the regulatory pathway as the central determinant of commercial practicality.

This project identified the documentation and compliance requirements for a food-grade EV product. Navigating the regulatory pathway itself is the principal determinant of whether the opportunity is commercially practical, and it is a substantial, defined body of work for the successor program. The demonstrated extension of the platform to adipose, recovered as compliant edible material, begins to establish that route and helps de-risk the pathway for the blood-derived stream that follows.

Develop the adipose coproduct stream alongside blood.

Adipose has been shown to be a second, viable source of recoverable EVs. The next stage should develop it as a parallel coproduct stream, broadening the resource base while blood and plasma remain the primary focus.

Develop the plasma-protein pathway.

Because EV recovery does not deplete the plasma, the residual stream confirmed suitable in this project (§6.8) is available for protein recovery and fractionation, bovine serum albumin, immunoglobulin G, and transferrin. The next stage should establish a validated process and assess the market for these fractions, converting confirmed suitability into a defined protein-coproduct pathway.

Advance EV characterisation.

The particle-level quantification established here, concentration, size distribution, recovery, reproducibility, is the platform for deeper biological characterisation subtype identification, cargo profiling, source-tissue verification, and dose-relevant functional delinition. This is the work that translates demonstrated recovery into a functionally defined coproduct.

Quantified environmental and resource impacts are best determined at the individual site, against each processor's own operating baseline, as part of the site-based program above rather than as a separate generalised study.

9.4 Recommendations for Adoption and Extension

The project's outputs support positioning higher-value coproduct recovery as a durable competitive advantage for the Australian red meat industry. The commercial logic is straightforward, and the timing is favourable.

Market demand is moving toward differentiated, evidence-backed products, and the durable advantage accrues to those who can substantiate what their product does. This premium is structural, not a passing preference, and the regulatory record shows why. Where a product's value rests on an authorised, evidence-backed claim, the category sustains its premium: the plant-sterol and plant-stanol cholesterol-lowering claim, supported by more than eighty clinical trials, has been authorised by EFSA and underpins a durable functional-food category (EFSA 2012). Where substantiation cannot be established, the category commoditises and margin erodes — the position collagen occupies, after EFSA rejected the collagen-hydrolysate joint-health and skin-function claims on the grounds that a cause-and-effect relationship had not been demonstrated (EFSA 2011; EFSA 2013). Higher-value coproduct recovery, anchored on EVs as the most differentiable component of the stream, positions the Australian red meat industry on the durable side of that divide.

There is a clear gap in the market, and a position above it. Australia's established blood- and plasma-derived specialists operate at serum, reagent, and purified-protein grade, Bovogen Biologicals and Moregate Biotech both manufacture fetal bovine serum, bovine serum albumin, and related proteins from inspection-passed Australian plasma, supplying cell-culture, diagnostic, pharmaceutical, and research markets. None bridges Australian red-meat coproducts through to a claim-eligible consumer-health product. That position, a claim-capable, durable-premium coproduct, remains unoccupied by red-meat derivatives. Reaching it depends on the regulatory pathway identified as the central forward work package (§9.3). This report does not assess the project's coproducts against that pathway, nor argue any claim on their behalf; that is the work of the successor program.

Two of the project's outputs are ready for immediate extension. The five-model framework should be used as a decision and communication tool for processors, supporting investment planning across scales. And the finding that coproduct value is set at collection should be carried across the industry as directly actionable practice.

10 Project outputs

10.1 Reports and Documentation

- **Milestone 1 Report:** *EV Extraction and Plasma Fractionation Pathway Strategy*, submitted 31 March 2025. Cost-benefit analysis, Five-Model framework, Triple Bottom Line evaluation.
- **Milestone 2 Report:** *Extracellular Vesicle (EV) Recovery from Abattoir-Recovered Blood, Blood Sampling, Quality Control and EV Quantification Workflow* , submitted 23 June 2025. Technical validation of EV recovery, contamination characterisation, EV quantification aligned to MISEV2018.
- **Milestone 3 Report:** *Extracellular Vesicle (EV) Recovery from Abattoir-Recovered Blood, Industry Engagement, Plasma Handling and Feasibility Assessment*, submitted 17 December 2025. Industry feasibility assessment, Sonac benchmarking, MVP production.
- **This Final Report:** Submitted 29 June 2026.

10.2 Tools and Frameworks

- Five-Model Cost-Benefit Analysis framework for staged blood coproduct valorisation, including capital investment, annualised return, and indicative NPV and IRR analysis at standardised processing volume.
- Triple Bottom Line evaluation matrix aligned to MLA framework.
- EV recovery and characterisation workflow aligned to MISEV2018 (Théry et al. 2018), using EXOID, size-exclusion chromatography, and tunable resistive pulse sensing.
- Site-based operational assessment framework for blood collection variability and hygiene discipline across Australian red-meat processor environments.

10.3 Materials Produced

- Plasma-derived Minimum Viable Product produced under representative commercial conditions, satisfying the contracted deliverable "Proof of Concept for Scalable Production".

Bibliography

1. ACCC 2024, *Beef and Cattle Market Study Final Report*, Australian Competition and Consumer Commission, Canberra.
2. Australian Meat Processor Corporation 2021, *AMPC Project 2021-1055 — Bioactive Processing Options*, prepared by Greenleaf Enterprises Pty Ltd and Management for Technology Pty Ltd, AMPC, North Sydney.
3. Beston Global Foods 2021, *Beston Global Food Company MST Access Report*, MST Access, Sydney.
4. Commonwealth Scientific and Industrial Research Organisation 2005, *Plasma Fractionation and Bovine Blood Coproducts — Technical Report*, CSIRO, Canberra.
5. Commonwealth Scientific and Industrial Research Organisation 2012, *Bovine Plasma Protein Yields and Fractionation Reference Data*, CSIRO, Canberra.
6. Commonwealth Scientific and Industrial Research Organisation 2015, *Plasma Fractionation Technologies for Australian Red Meat Coproducts*, CSIRO, Canberra.
7. Commonwealth Scientific and Industrial Research Organisation 2018, *Updated Plasma Fractionation Pathway Analysis*, CSIRO, Canberra.
8. Johnsen, K.B., Gudbergsson, J.M., Andresen, T.L. & Simonsen, J.B. 2018, 'What is the blood concentration of extracellular vesicles? Implications for the use of extracellular vesicles as blood-borne biomarkers of cancer', *Biochimica et Biophysica Acta — Reviews on Cancer*, vol. 1871, no. 1, pp. 109–116.
9. Meat & Livestock Australia 2011, *MLA Project A.BIO.0036 — Blood Processing Capability Analysis*, prepared by B. Spooncer, MLA, North Sydney.
10. Meat & Livestock Australia 2012, *MLA Project A.BIT.0014 — Halal Blood Collection*, prepared by B. Spooncer, Kurrajong Meat Technology Pty Ltd, MLA, North Sydney.
11. Meat & Livestock Australia 2013, *MLA Project P.PSH.0415 — Utilisation of Blood and Blood Components: Adding Value to Blood by Separating and Removing it from Slaughterhouse Waste*, MLA, North Sydney.
12. Meat & Livestock Australia 2014, *MLA Project A.BIO.0045 — Bioactives and Co-Products from Animal Blood*, prepared by N. Solomon, Thomson Reuters IP Analytics, MLA, North Sydney.
13. Meat & Livestock Australia 2015, *MLA Project A.BIM.0040 — Blood-Based Proteins: A Market Review*, prepared by D. Glenn, Corelli Consulting, MLA, North Sydney.
14. Meat & Livestock Australia 2023, *Plasma Processing Value Chain Analysis*, MLA, North Sydney.
15. Meat & Livestock Australia 2024, *Co-Product Market Report December 2024*, MLA, North Sydney.
16. Meat & Livestock Australia n.d., *MLA Project MRR.576 — Electrical Stimulation and Bleeding*, MLA, North Sydney.

17. Meat & Livestock Australia n.d., *MLA Project P.PIP.0197 — Halal Slaughter Welfare and Meat Quality*, MLA, North Sydney.
18. Meat & Livestock Australia n.d., *MLA Project P.PSH.1387 — Collagen Processing for Australian Red Meat Coproducts*, MLA, North Sydney.
19. Proliant Health and Biologicals 2025, *Immunolin Product Specification and Commercial Pricing*, Proliant Health and Biologicals, Ankeny.
20. Rion Health n.d., *Regenerative formulation — product and commercial pricing information*, Rion, Rochester, MN. （**CONFIRM: full citation detail — cited in §5.2 as the EV product-value pricing reference; confirm year/format or substitute the exact source used in Milestone 1**）
21. Sood, N. & Van Nuys, K. 2017, *The Flow of Money Through the Pharmaceutical Distribution System*, Schaeffer Center for Health Policy and Economics, University of Southern California, Los Angeles.
22. Standards Australia 2023, *AS 4696:2023 — Australian Standard for the Hygienic Production and Transportation of Meat and Meat Products for Human Consumption*, Standards Australia, Sydney.
23. Théry, C., Witwer, K.W., Aikawa, E., Alcaraz, M.J., Anderson, J.D., Andriantsitohaina, R., et al. 2018, 'Minimal information for studies of extracellular vesicles 2018 (MISEV2018): a position statement of the International Society for Extracellular Vesicles and update of the MISEV2014 guidelines', *Journal of Extracellular Vesicles*, vol. 7, no. 1.