Australian Government
Rural Industries Research and Development Corporation

New Animal Products

New uses and markets for by-products and co-products of crocodile, emu, goat, kangaroo and rabbit.

A report for the Rural Industries Research and Development Corporation

by
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Foreword

Recent Rural Industries Research and Development Corporation (RIRDC) research has found that prospective animal industries currently derive an income from only a few products, primarily meat and skin.

Traditional livestock industries in Australia, such as the cattle and sheep industries, have developed markets for co-/by-products that generate additional income for producers and improve the production viability of these species.

Finding new uses and markets for co-/by-products in prospective animal industries will offer producers the potential to increase returns and to accelerate industry growth.

This report identifies current and potential uses for co-/by-products of the crocodile, emu, goat, kangaroo and rabbit industries in Australia and examines aspects of their production, supply and demand as well as potential barriers to their viable commercialisation.

Existing and potential co-/by-products in each of the five researched industries offer good economic opportunities. Currently, the emu and goat industries commercialise their oil and offal respectively. In the medium- to long-term, viable opportunities may exist for other co-/by-products such as crocodile bones, emu feathers, goat blood, rabbit blood and rabbit manure.

This project was funded by RIRDC Core Funds provided by the Australian Government.

This report, an addition to RIRDC's diverse range of over 1600 research publications, forms part of our new animal products R&D program which aims to accelerate the development of viable new animal industries.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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In addition, the authors express their gratitude to representatives of the industry associations, representatives from state and federal agencies and CITES for providing information, statistics and advice on the regulations for each particular industry. Those include Arthur Pederick, Emu Industry Federation Association; Steve Peucker and Paul Kent, Queensland's Department of Primary Industries and Fisheries; Permit Officers, Department of Environment and Heritage; and John Caldwell, CITES in the United Kingdom.

Abbreviations

AAA	Anti-angiogenic agent
ABS	Australian Bureau of Statistics
ARTG	Australian Register of Therapeutic Goods
CITES	Convention of International Trade in Endangered Species of Wild Fauna and Flora
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEH	Department of Environment and Heritage
DPI&F	Department of Primary Industries and Fisheries, Queensland
DPIV	Department of Primary Industries, Victoria
EIFA	Emu Industry Federation Association
FSANZ	Food Standards Australia New Zealand
HACCP	Hazard Analysis and Critical Control Points
MLA	Meat and Livestock Australia
NSW	New South Wales
NT	Northern Territory
QLD	Queensland
RIRDC	Rural Industries Research and Development Corporation
SA	South Australia
TGA	Therapeutic Goods Administration
TAS	Tasmania
TGA	Therapeutic Goods Administration
UK	United Kingdom
USA	United States of America
VIC	Victoria
WA	Western Australia

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Executive summary

Who is the report targeted at?

The report is principally for meat producers, processors and marketers to add financial returns to Australian investors in new animal industries. This report identifies existing and potential uses of co-/by-products of the crocodile, emu, goat, kangaroo and rabbit industries. It examines identified co-/by-products and addresses aspects of market demand, supply, scientific validation and trade-related regulations as well as impediments to commercialisation in order to aid priority setting by industries.

Background

Traditional livestock industries in Australia and around the world have based their income on premium high yield cuts. However, in pursuit of additional income sources processors have been endeavouring to develop markets for co-/by-products. This effort has improved the viability of production from these species.

Australia's prospective animal industries—such as crocodile, emu, goat, kangaroo and rabbit—are small in comparison to traditional livestock industries. Prospective animal industries are focused largely on the production or harvesting of their primary products, for instance meat or skins. Industry focus on developing viable co-/by-products has been limited.

In Australia, little research has been undertaken into the uses of co-/by-products for these industries. It is largely international research findings that are scarce that point to the potential uses of co-/by-products.

Objectives

The aim of this project was to identify potential income sources for co-/by-products of prospective animal industries. These included crocodile, emu, goat, kangaroo and rabbit industries. The project was directed by the following objectives.

- Identify the current and potential uses for co-/by-products from the selected prospective animal industries.
- Identify potential market opportunities for co-/by-products from the selected prospective animal industries.
- Initiate supply chain linkages for co-/by-products of the selected prospective animal industries for which potential market opportunities were identified.

Methodology

The methodology for this project involved four stages.

Stage 1

- Identification and research of co-/by-products from traditional livestock industries.
- Identification of current and potential uses for co-/by-products from the selected five prospective animal industries by undertaking secondary market research and retail store audits.
- Development of a co-/by-product questionnaire based on the initial findings from the secondary market research and retail store audits.

Stage 2

- Collection of primary information from members of each industry along the supply chain as well as industry associations. Information was collected using face-to-face and phone interviews, mail or email.

Stage 3

- Compilation and analysis of the primary information collected.
- Collection of regulatory information from authorities.
- Preparation of a final report documenting key findings, issues and strategic recommendations.

Stage 4

- Communication of the project findings through industry channels.

Key findings

The research undertaken in each of the five industries found the following in relation to their co-/by-products:

Crocodiles

The crocodile industry in Australia is based largely on the production of skins —being the most lucrative crocodile-derived product. Meat and offal are considered a by-product of skin production. Currently, meat is recovered and commercialised, while offal and other co-/by-products are generally discarded. Key co-/by-products identified from the research include blood, bones, cartilage, head, claws, teeth, tail tips, gall bladder, oil, penis, tongue, liver, brain and innards.

Basic scientific research points to the potential health and medical properties of crocodile blood in antibiotics and artificial blood products, and cartilage as a substitute for shark cartilage. However, commercialisation of blood and cartilage would require further and conclusive research and clinical testing are needed that require a significant investment in time and money. In addition, for cartilage, the domestic demand is unknown and an appropriate and effective processing method is still to be developed.

Head, skulls, feet, claw, teeth and tail tips are processed and sold mainly to the tourist souvenir market which is likely to remain static for short- to medium-term. Crocodile tongue, brains, innards, liver, penis, gall bladder and oil are perceived by some Asian countries to have health properties mainly related to aiding respiratory ailments. Current demands for these products are small and sporadic and more scientific and market research is required to determine the commercial potential of these products.

Among identified co-/by-products, bones offer the most commercial promise. Crocodile bones cooked in soup are thought to assist asthma and other respiratory conditions in the Chinese community. Industry states that both the collection and processing of bones is simple compared to other co-/by-products. Thailand exports bones and canned crocodile soup to a few Asian countries and this may indicate some market opportunities for processed bone products derived from ‘clean and green’ Australian crocodiles that were fed on Avian Influenza-free chicken. However, further research is necessary to determine the market size and potential for crocodile bones.

Emus
The main emu products currently commercialised are meat, oil and skins. Co-/by-products of the industry include eggshells, feathers, cartilage, bones and liver.

Basic scientific research has been conducted to identify the health properties of eggshells, cartilage and oil. However, for eggshells large scale research and testing are required to verify the medicinal properties. Besides testing of shell would need to be carried out on each egg from every farm because not all eggshells possess therapeutic properties. This makes the collection and commercialisation of emu eggshells inviable for use as a health or medicinal product at this stage. As for cartilage, the presence of anti-angiogenic agents (AAA) was found with a potential to substitute shark cartilage. But, like eggshells, large scale research is required by research organisations or pharmaceutical companies before commercialisation.

On the other hand, oil has been being widely commercialised since TGA registration was obtained to take advantage of the oil's anti-inflammatory properties. Oil currently offers the best commercial potential for the industry. It has a growing market both domestically and internationally and industry considers it viable to collect emu oil. Further research into other claims of medicinal properties may expand their uses and markets.

Emu eggs, bones and feathers have been used in art as egg-crafts, souvenirs and fashion items such as garment and hat decorations. Emu eggs and bones have also been used in fertiliser, feathers as dusters for the computer and camera industries, and liver for occasional orders from restaurants for use in pâté. However limited markets exist for these products.

Goats
The goat industry in Australia has been focused largely on the production of meat, dairy and fibre. Currently the main activity of the industry is the production of meat, which is mainly exported. The research identified three main goat co-/by-products: offal, blood and colostrum.

The collection process for goat offal has already been established. Growing overseas markets are making goat offal the co-/by-product with the most commercial opportunities in the industry. Collection of goat blood is currently being trialled. The results of this trial will determine the commercial opportunities for this product. Colostrum offers many opportunities to producers in countries such as New Zealand where the industry is large and technically advanced. However, the Australian industry has limited opportunities because of the small size of the dairy goat industry and the lack of infrastructure to further process the colostrum.

Kangaroos
Kangaroos are mainly harvested for meat and skins. The research identified that co-/by-products from this industry have limited uses. Harvesting and the initial processing of the animals in the wild have limited the identification of potential uses of co-/by-products for value-adding. It was identified that the use of kangaroo parts such as pericardium, valves and cartilage may have some medical applications. However, research in these areas is at an early stage so further studies are required to evaluate such applications. Kangaroos were also identified as a possible source of collagen, but more research is necessary to evaluate these opportunities also.

Rabbits
Rabbit farming in Australia is focused on meat production. Co-/by-products generated include offal, blood, manure, head, ears, feet, tail and skins. The research identified that co-/by-products with the most potential in Australia are rabbit blood, manure and offal. A biotechnology

company has shown interest in collecting rabbit blood. However issues relating to collection and consolidation of supply need to be addressed before blood can be commercially viable.

Rabbit manure is another co-/by-product that, according to producers, could offer opportunities for commercialisation. However, industry has said that it would require investment from a third party to develop this opportunity as the current production commitments of producers do not allow them to pursue commercialisation of manure.

There is potential for rabbit offal in pet food manufacturing. Although demand for offal in this market is inconsistent, processors continue to look for opportunities in the pet food market. They are also focusing on developing supply links to penetrate this market.

Implications

The research found that emu oil and goat offal are currently being successfully commercialised and that opportunities may exist for crocodile bones, rabbit manure, rabbit blood and rabbit offal. However, in general, further research and testing into the reported health and/or medicinal benefits, product development and into processing methods is required for most of the co-/by-products identified prior to viable commercialisation. This needs to be accompanied by detailed research of viable markets and market development efforts. Impediments to processing and collection also need to be addressed. Achieving viable volumes is acknowledged by industries as the major challenge in the production of these co-/by-products across the selected prospective animal industries.

It should be noted also that the production and use of co-/by- products by animal industries depends on the development of the established products of those industries. The size and growth of primary products such as meat, skins and milk will be the critical factor influencing the realisable potential of most animal co-/by-products.

Recommendations

New animal industries need to continue to explore opportunities to better use co-/by-products. This includes efforts into the scientific and market research and development of markets, processing methods and marketable products. In addition, monitoring traditional animal industries would prove to be helpful for benchmarking their co-/by-product commercialisation and marketing practices. Current uses of co-/by-products in traditional animal industries are well developed, and offer experience, ideas and knowledge that can be effectively leveraged by the new animal industries. There is also scope for monitoring the way other countries produce and commercialise crocodile, emu, goat and rabbit co-/by-products.

1 Introduction

1.1 Background

There are more than 30 prospective animal industries in Australia, which include native, feral and domesticated animals. Most of these industries are relatively small alongside traditional animal industries. Various research studies have found that prospective animal industries rely on only a few products for their income, primarily meat and skin (Bodger & Goulding 2003; McNamara et al. 2003). Traditional livestock industries in Australia, such as cattle and sheep, have developed markets for co-/by-products which have generated additional income for producers and improved the viability of producing these species. For instance, a report by the Meat and Livestock Australia (MLA 1993) estimated that co-/by-products such as hides, edible offal, tallow and meal contribute approximately 14 per cent to the total value obtained from the carcass of cattle.

In the report 'Distribution of meat products from prospective Australian animal industries' (Bodger & Goulding 2003) a number of opportunities were identified for co-/by-products. 'Cartilage co-products' (Harper et al. 2000) also investigated the potency of cartilage across a number of species along with the potential for its commercialisation. One of the recommendations from this report was the need for research into the market acceptability of cartilage from alternative species.

For the purpose of this report, five of these industries have been selected for research: crocodile, emu, goat, kangaroo and rabbit. These five industries have shown continuous growth over the last few years owing to an increasing demand for their main products. These industries are expected to continue their growth in the short- to medium-term.

The aim of this research is to further explore opportunities for commercialising new and existing co-/by-products that will improve the economic viability of the new animal industries. This report builds on the previous research findings of Bodger & Goulding (2003), which identified potential opportunities in these industries for co-/by-products, including crocodile cartilage, crocodile blood, rabbit blood and emu oil.

Furthermore, increased demand for game meats in Australia and overseas has triggered strong demand for crocodile and kangaroo meats. The rabbit industry is also growing to meet increased domestic demand for meat, and a strong export demand for goat meat also exists. The slaughtering of emus for their oil has also increased as demand for emu oil products has risen. This increase in demand is due largely to the reported health benefits of emu oil, which have been recognised by the Therapeutic Goods Administration (TGA) since 2002.

By finding new uses and markets for co-/by-products of prospective animal industries, potential exists to increase returns and expand the income streams for producers of these products. This expansion offers stronger economic development of rural communities and new employment opportunities in those communities.

1.2 Objectives

The aim of this project was to identify potential alternative income sources derived from co-/by-products of prospective animal industries. These industries included crocodile, emu, goat, kangaroo and rabbit industries.

The objectives of the project are specified below.

- Identify the current and potential uses for co-/by-products from the selected prospective animal industries.
- Identify potential market opportunities for co-/by-products from the selected prospective animal industries.
- Initiate supply chain linkages for co-/by-products of the selected prospective animal industries for which potential market opportunities were identified.

1.3 Methodology

This project was supported by a methodology involving four stages outlined below.

Stage 1

- Identification and research of co-/by-products from traditional livestock industries.
- Identification of current and potential uses for co-/by-products from the selected five prospective animal industries by undertaking secondary market research and retail store audits.
- Development of a co-/by-product questionnaire based on the initial findings from the secondary market research and retail store audits.

Stage 2

- Collection of primary information from industry members of each industry along the supply chain as well as industry associations. Information was collected through face-to-face interviews, phone calls, mail or email.

Table 1: Companies interviewed by industry and activity

Industry	Company	Breeder	Processor	Wholesaler	Retailer/ vendor	Exporter
Crocodile	1	√	√	√		
	2	√	√	√	√	
	3	√	√	√	√	√
	4	√	√	√	√	√
Emu	1	√		√	√	
	2	√		√	√	
	3	√	√	√	√	
	4		√	√	√	√
	5	√	√	√	√	√
	6	√	√	√	√	
	7	√				
Goat	1		√	√		√
	2		√	√		√
	3					√
	4		√			
Kangaroo	1	√*				
	2		√	√		
	3		√	√		
	4	√**				
Rabbit	1	√	√	√		
	2	√	√	√		
	3	√	√	√		
	4	√	√	√		
	5		√			

* Harvester
** Industry association

Stage 3

- Compilation and analysis of the primary information collected.
- Collection of regulatory information from authorities.
- Preparation of a final report documenting key findings, issues and strategic recommendations.

Stage 4

- Communication of the project findings through industry channels.

1.4 Scope and limitations of research

The research focus of this project is on co-/by-products from prospective animal industries. For the purpose of this research, co-/by-products are considered as everything from an animal except dress meat. This includes the blood, bones, cartilage, feet, head, offal and so on. In this report the terms co-products, by-products and co-/by-products will be used interchangeably.

Meat and skins have been excluded as part of this definition, even though some of the nominated industries consider these two products as co-/by-products. Research on meat and skins has already been conducted for many of these prospective animal species. This project mainly focuses on co-/by-products which have received no or little research attention in the past.

Emu oil was included in the research despite being considered by industry as the main product. This is due to the oil's future potential for more health or medicinal properties to be verified for larger markets, and to the high expectations held by industry in obtaining good returns from the oil.

The information presented in this report has been collected from secondary research, retail audits conducted in Brisbane and the Gold Coast and personal interviews with industry members. Nevertheless, findings presented in this report were mainly drawn from the information collected during the industry interviews, as very limited information on animal co-/by-products was available from secondary sources or retail audits. The interview process was completed over a five-month period, between October 2004 and February 2005, and therefore may represent a cross-section of the industry situation at that particular time.

A minimum of three interviews were conducted per industry, involving members at different levels of the supply chain. Participant acceptance was largely influenced by the willingness of the industry members to participate in the research.

Individual company names have been omitted for confidentiality and all collected information has been consolidated.

Statistical data from the industries and the markets for the co-/by-products identified were difficult to obtain. The markets are usually small, and in most cases there were no data reported. Where it was not possible to obtain statistical data from recognised bodies, estimates were presented based on the information collected through the industry interview.

2 Overview of co-/by-products from traditional animal industries

This section defines the main co-/by-products obtained from traditional animal industries such as beef, pig and chicken and how they are collected, along with the main forms of use including the food, pharmaceutical and textile industries. Key issues that affect the adequate and viable collection and processing of co-/by-products are also discussed. This will offer a benchmark and sound basis on which to understand current uses as well as possible opportunities for the five prospective animal industries that are the focus of this report.

Traditional animal processing industries based their incomes on premium, high yielding cuts. However, in pursuit of additional income sources processors have been endeavouring to develop markets for co-/by-products. This effort has improved the viability of producing these species. A study developed by MLA in 1993 recognised that in a significant number of processing plants in Australia, profit generated from harvesting co-/by-products offset the cost of processing.

Animal co-/by-products are known to have been used since animals were first used as a source of meat for human consumption. However, only in the last century, as slaughter rates have increase, have co-/by-products become more and more important, directly increasing the amount of co-/by-products available after the slaughter process (Ockerman & Hansen 2000).

Large production of co-/by-products has made it necessary to identify and use these products in a more efficient way. Meat industries are now obliged to reduce waste by recovering and using as much as possible, and adequate use of co-/by-products has become economically important for processing plants, as they have found the benefits of collecting and processing them an extra source of income (Ockerman & Hansen 2000).

Non-use of animal co-/by-products increases the cost of disposal of these products for the industry, which in turn creates a public health problem (Ockerman & Hansen 2000).

The use of co-/by-products has evolved to form a large number of products ranging from ingredients for food to medicines (e.g. insulin, heparin, glucagon), household items (e.g. cosmetics, plastics, toothpaste) and other for uses (e.g. explosives, lubricants, cement) (Ockerman & Hansen 2000).

Without the use of co-/by-products, a valuable source of potential revenue is lost. The experience from the traditional animal industries may offer an excellent benchmark for new animal industries that are far less developed.

2.1 Definition

Traditional animal industries have been developed to provide a source of meat for human consumption. However, throughout the slaughter process there are other remaining products that are recognised as animal co- or by-products which may account for up to 50 per cent of the animal (Ockerman & Hansen 2000). This includes hides, skins, pelts, hair, feathers, hoofs, horns, feet, heads, bones, toenails, blood, organs, glands, intestines, fatty tissues and shells. Animal by-products serve as a source of material for a wide range of industries including food, pharmaceutical, chemical, agricultural and textile industries.

While edible meat, poultry and fish are the primary products of the livestock, poultry and fishery industries—and represent most of the value—the key to improved profitability is to earn higher profits on co-/by-products (Pearson & Dutson 1992).

Production of animal co-/by-products varies widely depending on species, sex, live weight, and methods of recovery (Ockerman & Hansen 2000). The amount of co-/by-products varies from animal to animal; for example, approximately 50 per cent of the live weight of cattle, 42 per cent of the live weight of pigs, 28 per cent of the live weight of broilers and 57 per cent of the live weight of cod fish (Pearson & Dutson 1992). Table 2 illustrates the approximate composition of cattle, pigs and sheep.

Table 2.1: Approximate composition of cattle, pigs and sheep

Component	Cattle (%)	Pigs (%)	Sheep (%)
Carcass meat	34	52	32
Bones	16	17	18
Organs	16	7	10
Skin and attached fat	6	6	15
Blood	3	3	4
Fatty tissues	4	3	3
Horns, hoofs, feet and skull	5	6	7
Abdominal and intestinal contents	16	6	11

Source: Pearson & Dutson (1988).

2.2 Products

Animal co-/by-products are mainly classified into two categories: ‘edible’ and ‘inedible’.

Edible co-/by-products are those products that with appropriate cleaning, handling and processing under sanitary conditions are destined for:

- human consumption
- further processing into ingredients for food preparations.

Edible co-/by-products destined for human consumption are those that can be consumed directly or require little further processing. In general, edible co-/by-products are collected in the dressing floor and then removed to a place where they are washed, trimmed, chilled, packed and frozen. Edible co-/by-products that can be consumed directly include organs (e.g. liver, hearts, stomachs, tongues, brains, tripe), meat trimmings from carcass, head, neck and viscera (e.g. carcass trimmings, cheek meat, head meat, salivary glands) and others (e.g. testicles, oxtails, pork skins). Edibility of co-/by-products is determined by consumer acceptance, regulatory requirements, economics, hygiene, legislation, tradition and religion (Pearson & Dutson 1988).

Australia is in general a country with low per capita consumption of offal. According to the Australian Bureau of Statistics (ABS), consumption of offal products in Australia was estimated to be around three kilograms in 1990. It is estimated that current consumption of offal in Australia is less than three kilograms per capita.

There is a perception among consumers that food items derived from co-/by-products are poor in quality. The wide availability of the meat and high capacity to pay are seen as two of the main reasons why consumption of edible co-/by-products in Australia is low.

Co-/by-products can also be processed into ingredients which are part of different food preparations. Processing techniques depend on the co-/by-product processed and the final ingredient that is expected to be extracted or produced. An example of a co-/by-product as a food ingredient is the use of blood as a colorant. Blood is collected in the killing area as edible product and processed with the addition of an anticoagulant. Other products, such as nitrite and salt, are added to provide microbial stability. The cured blood is then chilled and used in the preparation of other products such as sausages and pies (Pearson & Dutson 1988).

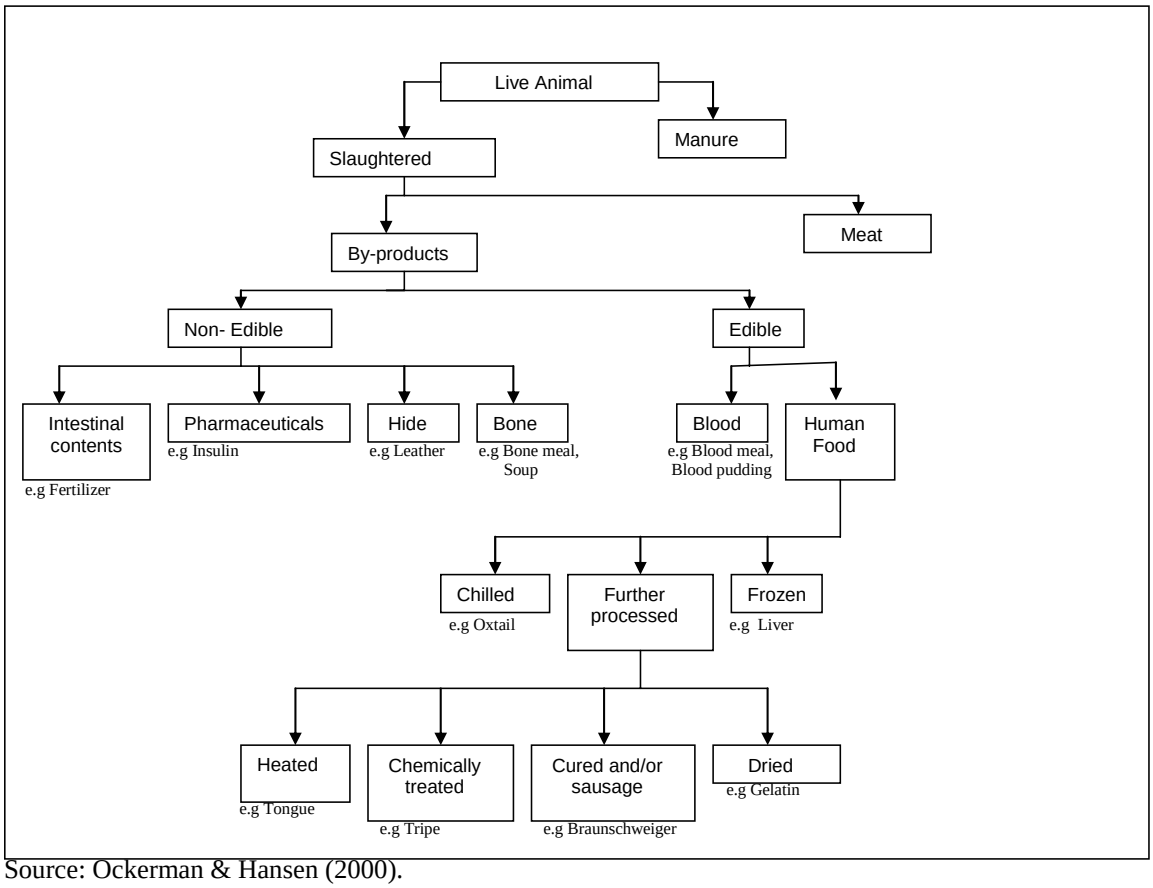
As with blood, there is a wide range of uses of co-/by-products as food ingredients. Co-/by-products are ingredients for soup bases, sausages, gelatine, margarine, mayonnaise, candies, ice cream, marshmallows, etc. (Pearson & Dutson 1988).

A detailed description of the main edible co-/by-products from traditional meat industries such as beef, pig, lamb, chicken and fish and their main uses can be found in Appendix A.

Inedible co-/by-products are defined as being all the portions of the slaughtered animal that are not used for human consumption. Importantly, inedible by-products provide raw material for many industries, such as: medical (e.g. blood fractions used in medical diagnosis); pharmaceutical (e.g. gall, splenic fluid and insulin used in pharmaceuticals); textile (e.g. skins and hides used in the production of leather); industrial (e.g. feet used in the production of industrial gelatine and industrial lubricant); and animal pet food or animal feed in livestock industries (Pearson & Dutson 1988). A list of the main inedible co-/by-products and their utilisation is presented in Appendix B.

Figure 2.1 flow chart shows the utilisation of edible and inedible by-products from a process perspective.

Figure 2.1: Edible and inedible co-/by-products originating from meat processing



Source: Ockerman & Hansen (2000).

2.3 Products chain analysis

The majority of co-/by-products produced are generated in the slaughter-house. However, co-/by-products can also be generated at the farmgate (e.g. manure), processing and rendering plants. The type of co-/by-products collected for edible and inedible uses is highly dependent on the species of livestock being processed and the infrastructure of the different slaughter-houses.

In traditional animal industries collection of co-/by-products occurs as follows. Livestock ready for slaughter are transported from the farm to the abattoir. Once the animal enters the killing area it is initially stunned and bled, and it is at this point where the first co-/by-product—the blood—is collected. The blood can be processed on site or refrigerated and further transported to a processing facility.

Once the animal leaves the killing area it enters the dressing floor. All co-/by-products are removed from the carcass during the dressing and evisceration. Co-/by-products obtained during this process are washed and sent to the offal room where they are further divided into edible and inedible products. Edible products are washed, trimmed, graded, packaged and refrigerated or frozen ready for distribution or further processing.

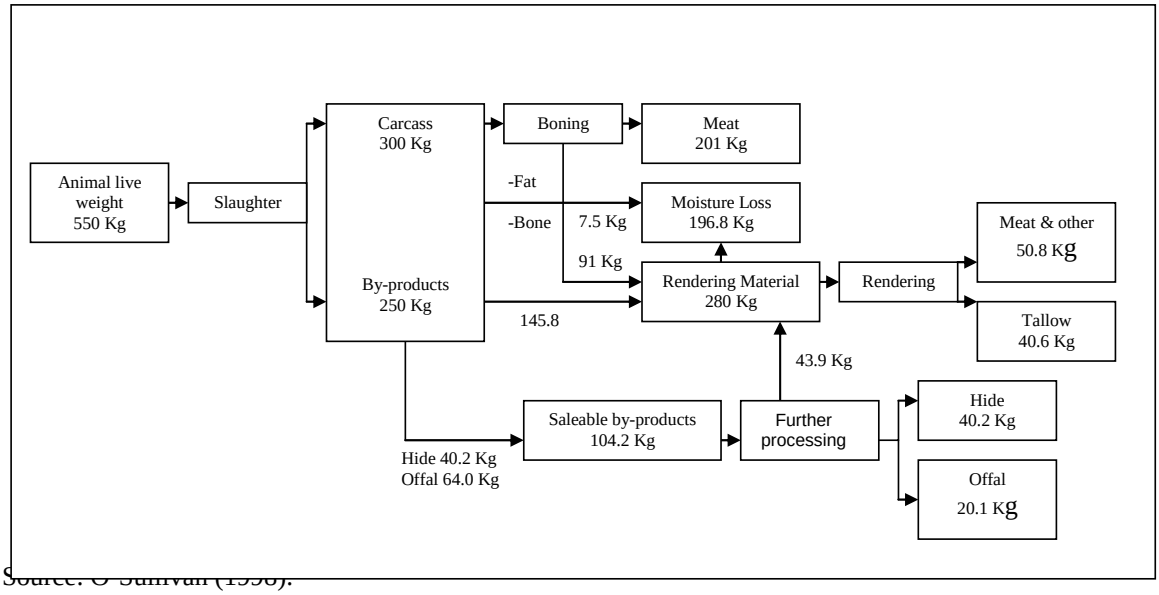
Products such as organs and glands that are not saved for edible uses may be frozen or sold fresh for pharmaceutical, pet food, animal feed, textile, industrial or medical uses. Processing of

inedible co-/by-products involves a wide range of technologies that vary from the simple (such as salting for preservation or freezing) to the extremely complex chemical engineering processes (such as extraction, centrifugation, filtration, deionisation and evaporation).

Collection of co-/by-products in abattoirs depends on the processing capabilities of each plant in relation to the raw materials that are produced. Recovery of co-/by-products is influenced by the size and the killing capacity of the facility, as these dictate the availability of skills, resources, and dedicated plant and equipment for co-/by-product collection.

Figure 2.2 illustrates the product flow deriving from meat processing and average quantity of co-/by-products obtained from cattle with a live weight of 550 kilograms.

Figure 2.2: Meat processing product flow



Source: O'Sullivan (1998).

2.4 Industry key issues

Ockerman & Hansen (2000) stated that adequate and effective utilisation of co-/by-products can be viable only if several requirements are met. The requirements are:

1. There must be a practical commercial process for converting the animal co-/by-product into a usable commodity.
2. There must be an actual or potential market for the commodity that has been produced.
3. There must be significant volume, at a viable price, of animal co-/by-product material in one location for processing and processing should be supplied within a reasonable distance.
4. There must be some method of storing the perishable product before processing and to store the manufactured product after processing.
5. There is often a critical need for highly trained technical operators.

The capacity of the industries to meet all these requirements together at one time in one place is not always an easy task to achieve. Thus, animal co-/by-products are not often effectively utilised.

Australian prospective animal industries of crocodile, emu, goat, kangaroo and farmed rabbit are small compared with traditional animal industries. These industries are usually highly fragmented and encountered with significant challenges toward accumulating high volumes of co-/by-products in any one location.

These industries are mainly focused on the production or harvesting of their primary products, for instance meat or skin. This situation is primarily responsible for the lack of product development and marketing of co-/by-products. The lack of product development for co-/by-products has restricted the need for the development of systems and expertise associated with processing, storing and distribution of co-/by-products to the market.

Research into the uses for co-/by-products in Australia has been limited and only occasional overseas research findings offer some indication of possible uses of co-/by-products. The following chapters examine animal co-/by-products of five Australian prospective animal industries - crocodile, emu, goat, kangaroo and rabbit.

3 Crocodile industry

3.1 Industry overview

Australia has two species of crocodiles, both of which are native to the tropics. These species are the freshwater crocodile (*Crocodylus johnstoni*) and the Estuarine or saltwater crocodile (*Crocodylus porosus*) (Peucker 2005; Britton 2005). The saltwater crocodile is the main species farmed in Australia, primarily for skin products. They are probably the largest living species of crocodile in the world (The EMBL Reptile Database 2005). The skin of saltwater crocodiles is reputed to produce the finest quality leather of the world's crocodilian species (Peucker 1997) due to their relatively small scales of even distribution and larger area of skin that contains no bony deposits (The University of Sydney News 2001). Because of insufficient domestic and international demand for the skins and meat products from this species, freshwater crocodiles are not farmed on a commercial basis in Australia (Peucker 2005; Camargo & Goodwin unpublished 2004).

Crocodile farming in Australia began in the late 1960s in Queensland, later expanding to the Northern Territory and Western Australia (Bodger & Goulding 2003). Commercial scale crocodile farming began in the 1980s (Peucker 1997). The lucrative potential in the export markets for crocodile leather products was the major contributor to industry development in this period (MacNamara et al. 2003) and the industry was able to benefit from the 1985 permission which allowed saltwater crocodiles to be harvested from the wild for commercial gain under controlled management programs (The University of Sydney News 2001). Crocodiles are currently produced in Queensland, Northern Territory and Western Australia.

Crocodile production in the Northern Territory and Western Australia is based on captive breeding supplemented with wild harvesting. However, production in Queensland relies solely on breeding in captivity as harvesting of wild crocodiles is restricted to special circumstances granted under the *Nature Conservation Act 1992*. As a result, farmers in Queensland either buy young juveniles or hatchlings from breeders, while Northern Territory and Western Australian farmers are allowed to collect eggs from the wild. Restrictions on securing a sufficient supply of hatchlings and breeding stock is viewed as a major impediment to business growth by Queensland farmers (DPI&F unpublished 2004b).

The crocodile industry in Australia is based largely on the production of hides or skins, with meat and offal considered co-/by-products of skin production (Bodger & Goulding 2003). Industry revenue is mainly generated from the production of skins and represents between 80 per cent and 90 per cent of the value of the crocodile if it is a first-grade skin (Camargo & Goodwin unpublished 2004). Hence skin prices and the proportion of skins sold as first grade are often determinants of profitability (Wondu Holdings 2002).

In November 2004 the industry estimated there were about 60 000 crocodiles farmed (DPI&F 2004a), of which Queensland accounted for 27 000 (DPI&F unpublished 2004b) or 45 per cent, with 16 000 processed each year in Australia (DPI&F 2004a). Average farmgate price per skin in 2004 was estimated at $380 and $12 per kg for meat (DPI&F unpublished 2004b). Adopting 8816, the projected skin production for 2003-04 (Foster 2005), and assuming each animal yielded 6 kg of meat, and no co-/by-products were traded, this sets the total Australian industry production yield at approximately $4 million.
In 2004 a few major players and a number of small operators were noted in the Australian crocodile industry. There were 13 crocodile operations in Australia that mainly focused on the

production of skins and meat. Seven of these crocodile operations had approved processing plants, and five of these were export-accredited (Camargo & Goodwin unpublished 2004). Six operations are located in Queensland, five are in Northern Territory and two are in Western Australia. Tourism is an additional income source for many crocodile farms. Little communication and cooperation among producers and poor integration along the value chain are often cited as characteristics of the industry (Bodger & Goulding 2003; MacNamara et al. 2003).

3.2 Legislation

As the crocodile is an endangered species, the production and trade of live crocodiles and any crocodile product, such as skins, skin products and meat, are controlled and traced by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Australia is one of over 166 signatory countries to the treaty (DEH 2004a).

The export of live Australian native crocodiles for private and commercial purposes is prohibited (DEH 2005b, 2004b). The collection, processing, domestic trading and exporting of all crocodile products are allowed, providing the product was sourced legally under required permits and licences. State regulations apply for domestic trading of crocodile products, and usually require the proof of compliance to the regulations on farming, processing, storage and transport (DEH 2005a).

For commercial exports of all crocodile parts, products and substances derived from crocodiles, permits are granted and issued by the Department of Environment and Heritage (DEH) (DEH 2005a, 2005b). Apart from the permit from DEH, clearance from the Australian Quarantine and Inspection Service (AQIS) needs to be obtained for exports. Effective from 1 July 2005, this not only requires the abattoir to be export-registered by AQIS but also requires the implementation of a Quality Assurance program in processing and packaging processes (AQIS 2005a). Crocodile co-/by-products and meat are classified as fish and fish products (AQIS 2005a, 2005b); therefore food safety regulations governing seafood have to be met for processing, storage and transport if the product is intended for human consumption. Export documents required by importing countries, such as health certificates, may also need to be prepared.

3.3 Product overview

The two products widely commercialised by the industry are skin and meat. Of the two, skin is regarded as the main product and generates 80 to 90 per cent of the industry value. As a result, supply of meat is dependent on demand for the skin (Peucker 1997) although demand for the meat is on the increase both in domestic and export markets (DPI&F 2004a).

A significant proportion of Australian crocodile skins are exported raw or salted for use in processing and manufacturing high quality leather goods (MacNamara et al. 2003; Peucker 1997). The average skin size of the saltwater crocodile is 1.3 m–2 m in length and 31 cm–42 cm wide across the belly, although the size varies depending on the age at slaughter (Peucker 1999 in MacNamara et al. 2003). Prices of the first-grade skins are estimated at more than double those of second grade skins according to a survey of producers in Australia and South Africa (Wondu Holdings 2002).

Meat yield varies between 5 kg and 9 kg per animal depending on the size of the crocodile, processor and processing method (DPI&F unpublished 2004b; Camargo & Goodwin unpublished 2004). The key domestic market for crocodile meat is the food service sector,

including restaurants and hotels targeting tourists from China and other Asian countries (Bodger & Goulding 2003).

Assuming all crocodile products were exported based on the number of permits granted, in 2004 Australia exported approximately 13.3 tonnes of raw or frozen meat and 13 520 pieces of raw, salted or tanned skins or belly skins (DEH 2005a). In 2004 the main export destinations for meat for which the permits were granted were Taiwan followed by Malaysia (DEH 2005a). For the same period, a total of about 2925 permits for export were issued for co-/by-products such as head, skulls, teeth, accessories with tooth/teeth, feet, treated eggs and backscratchers (DEH 2005a). These figures may include a small number of personal items that were sent via post or courier, as permits are also required for these items. It was also noted that permits were issued for about 195 000 crocodile pills or capsules for export to China. While the content of these pills and capsules is unknown, they are likely to contain crocodile gall bladder or oil which is commercialised in China, Mexico and South American and African countries.

Although the crocodile industry in Australia and around the world is focused on the production of skins and meat, many body parts have been used in a number of ways, including medicinal uses. Crocodile blood, oil, bile and gall bladder are reported to have been used by the Chinese community for conditions such as bronchitis, coughing, allergy, skin problems, high blood pressure and cancer (DPI&F 2004a; Sackton 2001). The use of co-/by-products such as oil is also reported in Latin America, the Caribbean and Africa for similar purposes (Cocodrilos Mexicanos 2004; e-xoticmeat.com 2002). In Mexico, crocodile oil is sold for illnesses such as asthma, emphysema, influenza and for a constant cough that produces phlegm. In Madagascar, oil is prescribed to assist burns, skin ulcers and cancer (Cocodrilos Mexicanos 2004; e-xoticmeat.com 2002). In Zambia, crocodile fat is used for medicinal purposes (e-xoticmeat.com 2002).

The industry believes that crocodile meat and edible parts are recognised in China as medicinal products rather than as food items, hence some potential may exist in the Chinese medicinal market (DPI&F 2004c). In recent years, research was conducted on potential medicinal properties of crocodile blood and cartilage. Apart from blood and cartilage, none of these medicinal properties are endorsed by the authorities in either western or Chinese medicine. The China Medical University and the Association of Chinese Medicine Merchants in Taiwan state that no Chinese medicine scripts record medicinal or health benefits of crocodile by-products (QGTIO Taipei 2005).

Thailand supplies China with crocodile meat and parts such as blood, lungs, genitals and stomach (The University of Sydney News 2001). With its competitive prices and geographical proximity to China and other Asian countries, Thailand may be a strong competitor to Australia for co-/by-products (DPI&F 2004c). Between 1999 and 2003 Thailand has been exporting annually an average of 35 tonnes of ‘meat’ and ‘meat and bone’ (Caldwell 2005). The main destinations were China, Hong Kong, Korea and Taiwan. Between 2000 and 2004 Thailand exported 114 skulls, 240 eggs, 1 skeleton, 120 kg of bones, 15 kg of tails and 42 360 cans of crocodile soup (UNEP-WCMC CITES Trade Database 2005). The bones were exported to Korea, 42 000 cans of soup were exported to Hong Kong and the remainder to China. Globally, Papua New Guinea and African crocodile products can also be supplied much cheaper than Australian products due to lower production, labour and distribution costs. A competitive selling point would need to be established for Australian crocodile by-products to succeed in the global marketplace.

The world commercial exports of crocodile co-/by-products recorded by CITES in 2004 were 806 skulls, 412 tails and 2 teeth (UNEP-WCMC CITES Trade Database 2005). The global commercial exports of crocodile by-products that may provide an estimate for the current market size are shown in Table 3.1.

Table 3.1: World commercial exports of crocodile by-products

Co-/by-product	Average annual export volume (2000–2004)	Major exporting country (in order of significant volume)	Major importing country (in order of significant volume)
Teeth	64 505	Singapore, Papua New Guinea, Malaysia, Australia	Australia, Singapore, Papua New Guinea, Indonesia
Soup	8472 cans	Thailand	Hong Kong, China
Tails	4941	Singapore, Zambia	USA, Mexico, China
Skulls	1303	Madagascar, South Africa	Italy, Netherland
Feet	306	Australia	Thailand
Eggs	51	Thailand	Netherland
Bones	24 kg	Thailand	Korea
Heads	16	Mauritius, Australia, Zimbabwe	USA, France
Skeletons	1	Australia, Thailand	USA, Korea

Source: UNEP-WCMC CITES Trade Database (2005).
Note: The average annual export figures have been rounded.

Crocodile farmers report receiving inquiries or small, sporadic orders for co-/by-products such as bones, gall bladder, penis and innards. An industry source states that current inconsistent demand has been a major deterrent to the collection of co-/by-products by farmers. Apart from the small and inconsistent demand, incidents are reported where processors were unable to supply these products to the specifications requested by the markets or buyers (DPI&F 2004a).

While crocodile meat is being recovered and commercialised to meet increasing demand, the offal and other co-/by-products are generally discarded by processors. Unlike Australia, some countries commercialise the by-products. In Thailand, for example, value-added by-products—including meat—can account for up to 50 per cent of the animals' worth in comparison to 20 per cent in Australia (University of Sydney News 2001). If the meat sold domestically covers the cost of breeding and growing out of an animal as suggested by a farmer (DPI&F unpublished 2004b), commercialisation of co-/by-products will be able to increase the value of the Australian crocodile industry.

Key co-/by-products identified from the crocodile industry through secondary research and industry interviews include blood, bones, cartilage, heads, skulls, claws, teeth, tail tips, gall bladder, oil, penis, tongue, liver, brain and innards.

3.4 Blood

Crocodile blood has been the focus of scientific research in recent years and this research has been divided into two main areas.

The first area of research has been the identification of unique types of haemoglobin in crocodile blood, which allows the crocodile to stay submerged for long periods of time. The capacity of the haemoglobin to bond with a waste product of respiration called bicarbonate ions allows the liberation of extra oxygen to the tissue (Blood Weekly 1995; Komiyama et al. 1995).

This discovery has been the basis for developing newly engineered haemoglobin, which uses elements of the crocodile haemoglobin cell. This novel human/crocodile haemoglobin has been initially called 'Hb Scuba' and is expected to improve the ability of artificial blood products to transmit oxygen to tissues (Blood Weekly 1995; Komiyama et al. 1995). Despite the early stage of the research, the possibility to engineer the use of Hb Scuba in humans may create some debate on ethical grounds (Blood Weekly 1995).

The second area of research has been the study of crocodile blood as a possible derivative of antibiotic drugs. Crocodiles are recognised as highly resistant to diseases and they heal rapidly without infection after losing their limbs, despite living in water filled with bacteria and fungi. Based on this and speculation that crocodiles have healing powers (Briggs 2003), studies of the crocodile immune system were initiated in 1998. These studies discovered that several antibody proteins in the reptile's blood kill bacteria that are resistant to penicillin (Reuters 2005). Recently, scientists from Crocodylus Park in the Northern Territory and McNeese State University in USA have been focusing on the isolation of antibiotic proteins and detailed study of the immune system. The studies have not progressed beyond the research stage, but it is expected that these studies may be able to create a new generation of antibiotics for human use which can be used for a wide range of bacteria, viruses including HIV, fungi and topical application on wounds (Britton 2005; Reuters 2005; Briggs 2003).

The total collectable quantity of blood is estimated at approximately 10 tonnes to 20 tonnes a year, assuming 0.6 kg–1.25 kg of blood per animal (DPI&F 2004a; Wondu Business and Technology Services 2004) can be recovered from 16 000 slaughtered crocodiles per year. Industry members cite that collection of blood at the farm or processor level would be viable without requiring additional capital expenditure should a market be developed (DPI&F 2004a).

Given the early stage of scientific research into the potential for oxygen transmitter and antibiotic products derived from crocodile blood, it is not possible to determine the potential market demand. Currently only a small demand exists domestically for crocodile blood for medicinal research purposes (DPI&F 2004a). In Thailand, crocodile blood is dried and placed into capsules for export to China (The University of Sydney News 2001). Further research on the current supply chain and uses for crocodile blood products in China and Chinese communities in Asian countries may be beneficial to determine if market opportunities for Australia exist.

3.5 Bones

Although no scientific research on the health or medicinal properties of crocodile bones was found in western medicine and no medicinal properties are endorsed by authorities in Chinese medicine, crocodile bones cooked in soup are thought to assist asthma and other respiratory conditions in the Chinese community. An industry source cited that the Chinese community also perceives crocodile bones as a potential anti-cancer agent.

Currently some demand exists domestically from the Chinese community. Several farmers have been approached by buyers from the Chinese community for bones to use in soup. Bones are sold directly to restaurants and the quantity sold varies from 12 kg to 8 tonnes a year (DPI&F 2004a). It is possible that much larger markets for bones exist in Asian countries where there are larger Chinese populations. Thailand has been exporting crocodile bones and soup to Korea, Hong Kong and China (UNEP-WCMC CITES Trade Database 2005). Crocodile bone soup may present further value-adding opportunities for Australia for export to Asian countries.

The collectable quantity of bones is estimated at 1.3 kg–4 kg per reptile depending on the animal's age and size (DPI&F 2004a; Wondu Business and Technology Services 2004; Hoffman et al. 2000). This sets the current potential annual supply of bones from 16 000 slaughtered animals at approximately 20 tonnes–64 tonnes. As bones are being sold raw to middlemen or restaurants, no processing is required except boning and freezing. Industry agrees that it is highly viable to collect and sell bones.

3.6 Cartilage

Although its effectiveness is yet to be clinically proven, shark cartilage has been known for its anti-angiogenic and anti-inflammatory properties as well as its ability to stimulate the immune system and repair soft tissue damage (Goding 2001). As shark cartilage becomes increasingly scarce, research of new sources of cartilage has discovered that anti-angiogenic agents (AAA) present in shark cartilage are also found in crocodile, emu, ostrich, camel, kangaroo and deer (Harper et al. 2000). Shark and cattle are the two species that have been receiving the most attention as sources of AAA in their cartilages.

A recent study released by RIRDC (Harper et al. 2000) highlights that the level of AAA harboured in crocodile cartilage is the highest among all six species tested, similar to that of shark cartilage, and in the cartilage obtained from ischium, the hip joints had the highest level of AAA. These findings make crocodile a potential substitute for shark cartilage. This is especially so when the discovery of mercury in shark cartilage has been reported by the media.

Given the embryonic stage of scientific research into AAA, it is difficult to determine the potential market demand for crocodile cartilage. If conclusive research and testing prove that crocodile cartilage is acceptable as a substitute for shark cartilage, it would seem there is potential for this product in both domestic and overseas markets. As shark species are depleted, crocodile cartilage may be able to replace a portion of the shark cartilage market as a highly efficacious substitute. Nevertheless, major scale research is required to commercialise crocodile cartilage products, which will demand a substantial investment by research organisations or pharmaceutical companies.

Retrieval of cartilage by producers is also a challenge. The supply of medicinal and pharmaceutical markets would require the employment of highly trained staff who can perform the task of retrieving cartilage, a complicated task compared to meat or organs (DPI&F 2004a). No industry member has collected cartilage for this potential market because no current demand

exists. An appropriate processing method needs to be determined by research and experimentation. An industry source suggests that an easy and less costly way of processing cartilage would be encapsulating dried cartilage concentrate.

If pharmaceutical companies successfully developed medicine using crocodile cartilage, all collectable cartilage in the industry may be able to be utilised. The volume of recoverable cartilage from an animal is very limited. An industry source estimates there is approximately 0.2 kg per reptile (DPI&F 2004a). This suggests that the collectable annual quantity at the industry level from 16 000 slaughtered animals may be 3.2 tonnes.

3.7 Head, skulls, feet, claw, teeth and tail tips

Heads, skulls, feet, claws, teeth and tail tips, for which no health or medicinal properties are reported, are usually thrown away, go to taxidermists for processing, or are sold to the tourist market as decorative artefacts and souvenirs. For exports, the DEH issues CITES personal effects permits for manufacturers of crocodile products, which are usually attached to manufactured souvenir products such as handbags, wallets, belts and backscratchers (DEH 2004a).

Between 2000 and 2004 Australia exported 26 heads, 184 skulls, 1503 feet and 28 173 teeth (UNEP-WCMC CITES Trade Database 2005). However, during the same period Australia imported a total of 177 980 teeth. The 2000–2004 CITES trade data (2005) on teeth indicate that Australia exported to Indonesia and Papua New Guinea, Indonesia re-exported, and Australia imported from Papua New Guinea and Singapore. This may indicate that Australia processes crocodile teeth products overseas for re-export or to meet domestic demand. Australia has been known as the most important buyer of crocodile teeth in the world, importing about 265 000 teeth between 1999 and 2003 (Caldwell 2005).

For food purposes, only a small quantity of feet and tail tips are sold to the Asian food market domestically (DPI&F 2004a). Associated with longevity and good health among Asian communities, the industry reports of inquiries for feet and tail tips receiving from Asian countries. An industry member has also sold a small amount of feet and tail tips to a Chinese restaurant for use in shark's fin soup. The restaurant reported that gelatine in crocodile feet and tail tips has similar qualities to shark's fin.

The industry views it is viable to produce these co-/by-products as no major add-on processes in the abattoir are required. With 16 000 animals slaughtered each year, 16 000 heads and tail tips and 64 000 feet and claws are potentially collectable.

3.8 Gall bladder

In some countries crocodile bile is used as an ingredient in the production of medicines for the treatment of diseases of the lungs such as asthmatic bronchitis, chronic bronchitis and emphysema. *Crocodile Gall Bladder Expectorant Pill* is a product currently manufactured in China and sold around the world to Chinese communities. The main ingredient of this product is bile from crocodile and snake with other herbal and natural ingredients. According to the label, the product claims to be effective in assisting with severe coughing, sputum, sore throats, laryngitis and chronic and acute bronchitis (Crocodile Specialist Group Newsletter 2003).

The industry cites occasional inquiries from Asian countries and domestic Chinese communities. Despite some interest, the processing method preferred by the potential buyer, i.e. sundried, was not permitted by AQIS regulations. Sundrying is not permitted for exports of crocodile products

due to food safety concern (AQIS 2005a). A small volume of gall bladder is sold to the domestic Chinese medicine market. A large producer reported selling about 100 gall bladders a year (DPI&F 2004a).

The retrieval of gall bladder without spilling the bile is not an easy process. Nevertheless, the industry cites that it is viable to collect the gall bladder as no major add-on processes are required in the abattoir. Assuming a gall bladder weighs approximately 0.1 kg (Wondu Business and Technology Services 2004), the collectable quantity potentially available each year is estimated at 1.6 tonnes.

3.9 Oil

Crocodile oil has been used in Asia for the treatment of asthma (DPI&F 2004a) and as massage oil and topical ointment for bruises and burns (WWFT 2001) although no scientific verification of crocodile oil's health properties is found. It was also noted that in Mexico crocodile oil has been commercialised as a food complement and for medicinal purposes for asthma, emphysema, flu and constant cough with phlegm (Cocodrilos Mexicanos 2004). In Madagascar, oil is prescribed to assist burns, skin ulcers and cancer (e-xoticmeat.com 2002). Similar uses have been noted in South America, Dominican Republic, Haiti and Zambia.

The industry cites that crocodile oil can be used for lubricants, cosmetics and as a waterproof leather dressing. For these uses, crocodile oil competes with oils from emu or ostrich and other consumer products providing similar benefits. An industry member who experimented with crocodile oil reports that adding stabilisers to the oil to develop into a saleable consumer product such as soft soap or lotion was a major challenge. Without the stabiliser, the oil products cannot be made shelf-stable for consumers.

Another industry member who has explored this opportunity encountered problems relating to the minimum quantity required for the rendering machine they sourced. Upon learning that the machine required about 500 kg of fat to initiate, the producer could not proceed with rendering as they did not have the market to sell this quantity. In order to collect 500 kg of crocodile fat, more than 250 animals would be required (DPI&F 2004a). The rendering process to produce oil of consistent quality is still to be researched and developed.

Collectable fat from a crocodile is estimated at between 0.13 kg (Wondu Business and Technology Services 2004) and 2 kg (DPI&F 2004a). Approximately 2 tonnes to 3 tonnes of fat may be available for collection each year from 16 000 slaughtered crocodiles.

3.10 Penis

According to the Chinese community, crocodile penis is believed to cure medical problems such as high blood pressure, heart disease, asthma and arthritic pains, while also being recognised as an aphrodisiac (Crocodile Specialist Group Newsletter 2000). However, no verification on crocodile penis' health properties is found in either western or Chinese medicine. The industry reports that crocodile penes are sundried, semi-dried or machine-dried and cryovaced, and sold widely in Asian markets. They are also sold in the domestic market. The industry views it is viable to collect and process this product (DPI&F 2004a).

Inquiries for crocodile penis have been received by the industry from the domestic Chinese community for use as aphrodisiacs. In 1998 a continued increase in the demand for natural aphrodisiacs was noted in Asian markets. At this time, export potential for the crocodile penis to

Japan and South East Asia was cited by a north Queensland crocodile farmer as worth $2000 per kilogram (ABC Online News 1998).

Only a small quantity of less than 10 g to 30 g is collectable per reptile (DPI&F 2004a, 2004c). With 16 000 animals processed, of which male animals are roughly assumed to be 75 per cent (DPI&F 2004a), the total collectable quantity is thought to be up to 360 kg.

3.11 Tongue, liver, brain and innards

No scientific verification of health properties of crocodile tongue, liver, brain or innards was discovered. Industry has reported receiving occasional inquiries from Asian countries for tongue, liver, brain and innards. Recently an industry member received inquiries from restaurants to use liver and spleen for crocodile pâté. Another industry member reported selling these to universities and schools for training purposes for veterinary students.

The industry cites that it is viable to collect these parts. No major add-on processes are required in the abattoir for retrieval of these parts. The collectable quantity of innards recoverable from a crocodile is approximately 1.1 kg (Wondu Business and Technology Services 2004). Collectable innards in total from 16 000 crocodiles are estimated to be about 17 tonnes a year.

3.12 Conclusion

The crocodile industry in Australia is based largely on the production of hides or skins, with meat and offal considered to be co-/by-products of skin production (Bodger & Goulding 2003). While crocodile meat is being recovered and commercialised to meet increasing demand, the offal and other co-/by-products are usually discarded. If the meat sold domestically covers the cost of breeding and growing out of an animal, as suggested by one farmer (DPI&F unpublished 2004b), commercialisation of co-/by-products will be able to increase the value and productivity of the Australian crocodile industry.

Key co-/by-products identified from the crocodile industry through secondary research and industry interviews include blood, bones, cartilage, heads, skulls, claws, teeth, tail tips, gall bladder, oil, penis, tongue, liver, brain and innards.

Basic scientific research has been conducted on the health and medicinal properties of crocodile blood and cartilage: crocodile blood for potential human antibiotics and artificial blood products that transmit oxygen to tissues, and cartilage as a substitute for shark cartilage. However, commercialisation of blood and cartilage requires further and conclusive research and clinical testing are needed that require a significant investment in time and money. In addition, for cartilage, an appropriate and effective processing method is still to be developed. The domestic demand for cartilage is unknown. The market size and characteristics of shark cartilage may provide an indication of the potential for crocodile cartilage should the scientific research prove its suitability as a substitute. Currently, small demand exists for crocodile blood for use in medicinal research.

Heads, skulls, feet, claw, teeth and tail tips are sold to taxidermists for processing and to the tourist souvenir market. These parts can be exported with CITES permits and the industry states that it is viable to produce these products. The tourist market for these co-/by-products is likely to be influenced by the growth in crocodile tourism, but no major change in market demand for these products is expected, at least in the short- to medium-term. A small additional market may exist for feet and tail tips in domestic and overseas Asian communities due to the association with longevity and good health, and as a perceived substitute for shark fin gelatine. However,

demand for feet and tail tips in Asian communities is expected to be sporadic, and true demand for shark fin gelatine substitute would require more trials by the food service sector.

For crocodile tongue, liver, brain or innards, small demand may exist in Asian countries. In the domestic market, small potential demand is noted for liver and spleen as a novelty food item and for training purposes at universities and schools. Demand is expected to remain small.

Although unproven by western and Chinese medicine, health benefits of crocodile bones, gall bladder, oil and penis are accepted as folk remedies among Chinese communities around the world. Bones, gall bladder and oil are used as medicinal supplements for various respiratory ailments and penis is also used as a medicinal supplement to assist with high blood pressure, heart disease, asthma and arthritic pains, and as a potential aphrodisiac. In terms of market demand, bones, gall bladder, oil and penis present some opportunities although the size and consistency of demand are uncertain. A few industry members cited sale of bones for the domestic market, and gall bladder, oil and penis are already being commercialised in international markets. With the exception of oil, which is not viable to manufacture, detailed international market research can determine the potential for bones, gall bladder and penis, which were cited as viable to collect and process by the industry. However, bones appear to present a better opportunity using existing processing abilities. This is due to the simplicity involved in collecting and processing bones compared to gall bladder and penis.

To conclude, of the identified co-/by-products of the crocodile industry, bones appear to present the best opportunity for the industry. Chinese communities around the world, including those in Australia, believe bones cooked in soup assist with various respiratory ailments. Existing processing capabilities can be used and collection of bones is considered by industry as simple compared to other co-/by-products. Thailand's export of bones and canned crocodile soup to a few Asian countries may indicate the existence of some market opportunities for processed bone products derived from 'clean and green' Australian crocodiles that were fed on Avian Influenza-free chicken. However, the consistency of demand and accurate market potential are uncertain. Detailed international market research of current export destinations, such as Hong Kong, China and Korea as well as other potential markets, may determine the market size and potential for bones.

4 Emu industry

4.1 Industry overview

The emu (*dromaius novaebollandie*) is a flightless Australian native bird found throughout Australia (Ramsay 1994). Like crocodiles, the *Nature Conservation Act 1992* (Commonwealth) protects wild emus from being captured or killed (Bodger & Goulding 2003). Emu farming commenced in Western Australia in 1976 with the breeding of stock captured from the wild by the Ngangganawili aboriginal community (APL 1997). Western Australia became the first state to legalise emu farming (Bodger & Goulding 2003). The first commercial scale emu farming to produce meat, leather and oil began in 1987 (O'Malley 1997) and by the end of 1988 there were more than 17 licensed farms located in WA (Parliament of NSW 1993). The industry then progressed slowly until the early 1990s (DPIV 2002a).

After the early 1990s, the industry grew rapidly as a result of optimistic predictions of high prices for meat, oil, skins, feathers and eggs, as well as perceived investment opportunities (Bodger & Goulding 2003). The fact that all other states passed legislation to allow emu farming by 1994 (O'Malley 1997) also contributed to this rapid growth. In 1995 the estimated number of farmed emus reached 110 000 throughout Australia (O'Malley 1997).

However, between 1996 and 1997 the industry suffered a major downturn. The industry and investors had focused on the short-term profits, from selling and producing breeding stock, without developing sustainable long-term markets for emu products (APL 1997). As a result, the supply exceeded demand from existing markets (O'Malley 1997) and the prices originally expected by the growers failed to materialise (Bodger & Goulding 2003). While the Emu Producers Association of Victoria described it as the typical boom and bust cycle experienced by most emerging industries, large reductions in farmed bird numbers occurred nationwide in 1998 (MacNamara et al. 2003). The total number of farmed birds reduced to 44 000 and 463 farms in 1998, from 103 700 birds and 1330 farms in 1996 (Bodger & Goulding 2003; EIFA in MacNamara et al. 2003).

Since the downturn emu farming has been going through an adjustment phase. The stock and farm numbers have been decreasing since 1999 (MacNamara et al. 2003). An estimate states that in 2001 there were about 45 000 farmed emus in Australia (Bodger & Goulding 2003). In March 2005 the number of birds recorded by the Emu Industry Federation Association (EIFA) was 17 500, a sharp fall from 2001. There were about 75 farms in 2002, 60 in 2003, and 40 in 2005 (EIFA 2005). Meanwhile the slaughter figure showed an overall increase, from about 2000 in 1999 to 4000 in 2004 (EIFA 2005). This adjustment may be attributed to the industry rationalisation with increased focus on high value products such as oil. Bird numbers and slaughter figures are shown in Table 4.1. The kills between April 2005 and March 2006 projected by EIFA are expected to be 4550 based on the current abattoir capacity.

Table 4.1: The number of emus and slaughtered emus (1999–2004)

Year	Apr 1999–Mar 2000	Apr 2000–Mar 2001	Apr 2001–Mar 2002	Apr 2002–Mar 2003	Apr 2003–Mar 2004	Apr 2004–Mar 2005
Number of emus	52 500	51 300	45 600	46 600	30 650	17 500
Slaughtered emus	*2012	*2146	*7351	unavailable	unavailable	4000

Source: Emu Industry Federation Association (EIFA).
* Figures are from financial year, not calendar year: AFFA Meat Levy Division 2002 in Bodger & Goulding (2003).

In March 2004 New South Wales was the largest producer of emus in Australia, producing 14 000 birds or more than 45 per cent of the national stock. Western Australia was second, accounting for 5400 birds, followed by Victoria, Queensland, South Australia and Tasmania. The number of emus and farms in each state is shown in Table 4.2.

Table 4.2: The number of emus and emu farms (March 2004)

State	Number of emu farms	Percentage (farm)	Number of emus	Percentage (birds)
NSW	14	23.3%	14 000	45.7%
WA	15	25%	5400	17.6%
VIC	5	8.3%	4500	14.7%
QLD	6	10%	3500	11.4%
SA	14	23.3%	2500	8.2%
TAS	6	10%	750	2.4%
TOTAL	60	100%	30 650	100%

Source: Emu Industry Federation Association (EIFA) in DPI&F (2004a).

In states such as Victoria, most emu farms bred and raised their birds through to slaughter. As the industry matures, however, an increasing tendency toward specialisation may emerge in which individual farms engage in one aspect of production, according to the Department of Primary Industries, Victoria. These aspects of production include breeding and incubating, brooding, raising juveniles and growing out (DPIV 2002a). The capital expenditure required for incubating and brooding is known to far exceed that required on a grow-out farm. Sustainable development of the industry is considered to depend on a substantial commitment to market development, reduction in production costs and availability of abattoirs in the vicinity (DPIWE 2004).

Often the processing of new species such as emus is not compatible with traditional processing lines. In August 2005 there were two export-accredited abattoirs slaughtering or processing emus, located in Pyramid Hill and Myrtleford, Victoria (EIFA 2005). Another abattoir is located in Dalriada, South Australia, which is licensed to process for the domestic market only (DPI&F 2004a).

4.2 Legislation

Trade of emus and emu products is strictly regulated, and exports of live emus for private or commercial purposes are prohibited (DEH 2004c). The collection, processing, domestic trading and exporting of emu products are permitted providing they are sourced legally under required permits and licences. For domestic trading of emu products, state regulations apply that usually require the proof of compliance to the regulations on farming, processing, storage and transport (DEH 2005a).

Commercial exports of all emu products require export permits from DEH. These permits ensure the products were derived from animals bred in a captive breeding program approved by DEH (DEH 2004c). In applying for the permit, written confirmation by the relevant state or territory agency needs to be attached.

Apart from export permits, clearance from AQIS needs to be obtained for exports. This requires the animal to be slaughtered at an AQIS-registered abattoir (AQIS 2005a). As exports of emu co-/by-products are controlled under quarantine regulations and requirements specific to meat and meat products (AQIS 2005a), related food safety regulations governing meat have to be met for processing, storage and transport if the product is intended for human consumption.

For domestic trading and export of all emu products intended for therapeutic use, however, the product must be registered as a domestically suppliable or exportable therapeutic good in the Australian Register of Therapeutic Goods (ARTG) or listed as an active ingredient under the Therapeutic Goods Administration (TGA) (TGA 2005). The ARTG is a computer database established under the *Therapeutic Goods Act 1989*, which holds details of therapeutic goods supplied in, or exported from, Australia (TGA 2004, 2002b). The TGA policy (2002b) categorises medicinal products within the ARTG into three: listed medicines approved for supply in Australia, registered medicines, and medicines intended solely for export. Exporters of both listed and registered medicines may request TGA to issue Certificates of Pharmaceutical Product should this document be required by the authority in importing countries (TGA 2002b).

Medicines or therapeutic goods that include TGA-listed ingredients such as vitamin and mineral supplements, herbal medicines and emu oil may be exported without being registered in the ARTG (EIFA 2005). As such, for the therapeutic goods containing emu oil that are not registered in ARTG for export, a DEH export permit is sufficient. For example, an exporter of pure emu oil, which is listed as an active therapeutic ingredient under TGA but not required to be registered in ARTG, needs only to obtain the DEH export permit.

As for manufacturers of therapeutic goods, the Goods Manufacturing Practice (GMP) licence must be obtained from TGA. To be GMP-accredited, a manufacturer has to be inspected by TGA to ensure the compliance with the codes of GMP (TGA 2002b). This accreditation involves all parts of the process of producing goods or of bringing the goods to their final state to include processing, assembling, packaging, bottling and filling, closure, labelling, storage, sterilising, testing or releasing for supply of the goods or of any component or ingredient of goods (AGD 2005; DPI&F 2004a). At the state level, QA-related licences are also required. In Victoria to render emu fat into oil for export, for example, compliance with the Prime Safe Registration and Hazard Analysis, and Critical Control Points (HACCP) and GMP principles are required (DPI&F 2004a).

4.3 Product overview

The emu products currently commercialised and widely recognised are meat, oil and skins.

Emu meat is a low-fat meat with less than 0.05 per cent cholesterol content and is sold to restaurants as a novelty gourmet food. Emu oil is used in cosmetics, therapeutic products, as an anti-inflammatory, and as treatment for muscle and joint pain (APL 1997). If only half of the health or medicinal properties speculated by the industry are verified by research and testing, the uses and market for oil will be able to expand substantially (DPIV 2002a). Tanned emu skin is used in a variety of products, including fashion clothing, watchbands, wallets and other accessory goods (APL 1997), competing with ostrich and Rhea leather (DPIV 2002a).

Emus are generally slaughtered at around 12 to 18 months of age, with the average return of 10 to 15 kg meat, six litres of oil, 0.8 m^2 of skin for leather, two leg skins, and 0.7 kg of feathers (Ramsay 1994). Although meat and oil together contribute 80 per cent of the total return from a bird (Stubbs 1998), the industry views oil as the main product, and meat and skins as co-/by-products. This is because the production costs are often not commercially viable for meat and skin products, especially when the cost for abattoir processing and transportation is added. It costs more than $150 to raise a bird to slaughter (DPIV 2002a), and between $55 and $100 per bird for meat processing (EIFA 2005). A bird would produce about 8 kg of saleable meat with a value of between $10 and $15 per kilogram and the average return for the skin is approximately $50 (DPIV 2002a), whereas the wholesale price for oil is $30–$40 per litre (EIFA 2005). This means it is only viable to farm and process emu if the oil is sold. As such, the industry has high hopes and expectations for gaining high returns from the oil.

Emu producers have been operating and attempting to market their own products largely on an individual basis (MacNamara et al. 2003). Nevertheless, markets are being established throughout the world for oil products, in particular with Europe, Japan and the United States of America (USA) as main export destinations (DPIV 2002a). Emu co-/by-products that have smaller, irregular markets include eggshells, feathers, cartilage, bones and liver.

Hence oil, eggshells, feathers, cartilage, bones and liver are examined as co-/by-products of the emu industry.

4.4 Oil

Emu oil is produced from rendered fat of emus. Emu oil has been used for thousands of years in aboriginal medicine as a remedy for joint pain, arthritis, rheumatism, skin irritation, and burns and as an antiseptic for cuts (DPIV 2002a; Business Wire 1998a; Snowden et al. 1997). The oil had been considered suitable for use in cosmetics and effective in the treatment of muscle and joint pain (O'Malley 1997). Research to verify these and other properties of oil has been conducted since 1987 (Smith et al. 1994).

Notable findings on the properties of emu oil include the presence of linolenic acid, a substance known to temporarily ease the discomfort of muscle and joint pain and containing anti-inflammatory properties (Business Wire 1998a; Business Wire 1988b; Snowden & Whitehouse 1997; Whitehouse et al. 1998; Ghosh & Whitehouse 1993). It was also found that the oil contained essential fatty acids, linoleic acid (omega-6) and alpha-linolenic acid (omega-3), which are known to help skin problems and promote skin softness (Minaar 1997; Zemstov et al. 1994; Smith et al. 1994). Emu oil is non-comedogenic, i.e. non-pore clogging, which allows it to penetrate deeply and rapidly (Business Wire 1998a; Univeristy of Texas Medical School 1993).

The major fatty acid in emu oil, oleic acid is a known enhancer assisting in the transporting of bioactive compounds into the skin, working as a penetrating transmitter (Smith et al. 1994).

After years of scientific research and subsequent clinical trials, in July 2002 emu oil was approved as a substance that can be used as an active ingredient in listable therapeutic goods (TGA 2002a). Many emu oil products are now listed under the ARTG as an anti-inflammatory agent active in treating conditions such as arthritis and osteoporosis. The oil's essential fatty acid omega-3 and -6 content, supported and confirmed by many studies, was also recognised by the TGA (DPI&F 2004a).

Individual TGA approvals are required for each emu oil product as not all oils have identical therapeutic properties. The efficacy of the oil is subject to factors such as breed, feed, bird handling and nurturing, processing and rendering methods and subsequent preservation of extracted oil (Whitehouse et al. 1998).

Since February 2000 research has been progressing into standardising the oil's anti-inflammatory potency through the identification of active ingredients and responses by the immune system, led by Professor Ferrante at the Women's and Children's Hospital in Adelaide (ABC 2000). The research also intends to compare oral and external topical applications of the oil. Results of the research are yet to be released.

Complying with the TGA requirements and the Australian and New Zealand Food Authority (ANZFA) guidelines for edible fats, oils and dietary supplements (http://www.tjuringa.com.au 2004), the oil is being commercialised for three purposes: therapeutic applications, cosmetic applications and food intended for human consumption. Popular emu oil product lines include a range of health and cosmetic products such as oil capsules, pure oil, rubs, creams, lotions, cleanser, toner, soaps, body wash, lip balms, shampoo, hair conditioner, deodorants, pet soaps, oils for veterinary use, massage oils and liniments. Other commercialised products include leather dressing and leather and timber wax (DPI&F 2004a).

Apart from the TGA-approved, anti-inflammatory and cosmetic properties, many other properties of the oil have been researched or speculated on by researchers, medical practitioners and the industry. Emu oil's efficacy in wound healing and cellular regeneration, anti-viral, bacterial, microbial activity, and cholesterol-lowering cardiovascular effects (O'Malley 1999; Snowden et al. 1997) are among the many areas researched. Anecdotal evidence and trials reported by industry also suggest the oil assists with diabetes, bowel disease, Crones disease, immune diseases, asthma, osteoarthritis, female hormone problems and depression (DPI&F 2004a). Relying on personal trials and beliefs, several industry members have been endeavouring to extend oil's unregistered health and medicinal property claims through organising research and tests. An industry source stated that clinical testing on cholesterol-lowering cardiovascular effects through internal use is planned by a group of cardiologists in a major hospital as soon as the funds become available. The industry recognises the oil's prospective market potential and the need for conclusive research and clinical tests.

An industry member also suggested that various industrial applications of the oil also require research. As emu oil and petrol do not separate and emu oil is considered to be a natural lubricant, it is thought that it could be used as engine oil (DPI&F 2004a). However, this requires research.

Emu oil products are being sold in domestic as well as export markets. The industry reports they export retail products or oil in bulk to the UK, USA, Germany, Greece, Japan, Korea, China, Taiwan, Hong Kong and New Zealand through various channels, including wholesalers, retailers, online orders, manufacturers, laboratories, pharmacies and agents. In 2004, 620 litres of oil were granted permits in Australia for export, with the main destination being Thailand (DEH 2005a). Domestic channels for oil include manufacturers of cosmetic and pharmaceutical products, tourist outlets, souvenir shops, duty free shops, doctors, practitioners, pharmacies, health stores, saddlers, farmgate sales, trade shows, local markets and the Internet. The quantity of oil sold by the industry members interviewed varied between 1 tonne and 25 tonnes during January–November 2004, with export values reported to be between $28 000 and $1 million. It is estimated that the production would be able to be doubled or tripled within one to three years without difficulty (DPI&F 2004a).

Industry also estimated that approximately 90 per cent of Australian emu oil is rendered at a plant in Victoria, which was the only HACCP-accredited facility in Australia in November 2004 (DPI&F 2004a). The remaining 10 per cent is rendered on individual farms or private processing sites.

Achieving consistent quality oil has been the long-term issue for the industry. As with eggshells, fat deposits and oil quality are determined by multiple factors. These include weight, age and sex of birds, season, environment, temperature, diet, transportation and rendering process (White 2001). In addition, manufacturers and marketing companies collect oil from each farm and mix it together thus reducing the ability to identify and produce consistent quality oil. There is no objective means of measuring oil quality. It was noted that a processing company in Victoria endeavoured to research and find an answer to this issue. After commissioning research in Germany and undertaking individual testing and research, they concluded that genetics exert a major influence on the levels of bioactives present in the oil, and by using selected blood lines, consistent quality can be achieved (DPI&F 2004a). Related research also indicates that oil from more primitive birds with wild genes grazing on traditional feeds, rather than birds selected for farming, are more likely to yield more efficacious oil (Whitehouse et al. 1998). The research and testing by this processing company also found that the content of feed could influence the biological activities of oil by up to 20 per cent.

Emu oil capsules sold for internal use are registered as a food product under Food Standards Australia and New Zealand (FSANZ), as there is no ‘food supplement’ classification in the Australian system. In European countries, the ‘food supplement’ classification allows claims for potential health properties or medicinal benefits of products to be made without requiring extensive medical research and clinical tests. While the cost of medical research and testing is significant for a small industry, market opportunities are reduced without scientific endorsement of health and medicinal claims.

The recovery rate of oil from the fat, cited by industry, ranged between 80 per cent and 85 per cent. The amount of collectable oil was stated as 9–10 litres by those interviewed, which is higher than the estimated industry standard of 5 litres (DPI&F 2004a). This could be attributed to improved nutrition and genetics of birds and longer grow out periods. Old birds deposit more fat than young birds and, by lengthening grow-out periods, the amount of fat can be maximised. Assuming 9 litres or 10 kg of oil are collected from 4550 birds to be slaughtered by March 2006, the total annual collectable quantity of oil would be 45.5 tonnes.

The industry generally agrees that it is viable to collect and process emu oil. This is considered to be largely due to superior land utilisation and low labour required compared with cattle or sheep farming, as well as relatively high profit margins usually attachable to products with existing or potential medicinal. However, some industry members raised concern over the escalating fees and charges involved in exporting and for the transport costs to abattoirs. There is a shortage of abattoirs available for slaughtering emus. As of March 2004, more than 45 per cent of the national stock was farmed in New South Wales, but there is no abattoir in that state. Two abattoirs are located in Victoria and one in South Australia. One industry source said they have to transport birds 12 hours to reach the abattoir in Victoria. Emus are known to stress and fight while being transported in cages and this not only damages the skin (Frapple et al. 1997) but also influences fat deposits (DPI&F 2004a). The industry suggested a change in regulations to allow emus to be slaughtered at the farm, as are kangaroos. This would mean that slaughtered birds can be directly sent for processing without incurring the cost of transporting live birds.

4.5 Eggshells

Emu eggshells are collected from hatcheries, hatched eggs, and as whole eggshells with yolk and white removed from infertile or surplus eggs (White 2001). The whole eggshells are commonly referred to as 'blown eggs' by the industry, and sold to egg carvers, aboriginal buyers, and tourists at farms or souvenir shops. The size and different colours offer attractive opportunities for eggs to be displayed in their natural state, carved, etched or painted (Minnaar 1995). Whole eggshells are also used to produce art crafts, such as clocks, jewellery boxes and various ornaments (Minnaar 1995). An industry member suggested fresh emu eggs could be sold for cooking, for which a small market may exist (DPI&F 2004a). In 2004 export permits were issued by DEH for one ornamental egg and twelve blown eggs (DEH 2005a).

Pieces of eggshell from incubated eggs are usually used in the production of shell powder and sold in bulk for meat and bone meal. Only a small number of industry members reported selling eggshells or shell powder to overseas or pharmaceutical companies.

Emu eggshell is believed to contain chitosan, which is the substance found in the exoskeleton of marine shellfish such as shrimp and crab (Nutraceuticals World 2003). In addition to cholesterol-lowering function in tested animals (http://www.pdrhealth.com/drug_info/nmdrugprofiles/nutsupdrugs/chi_0067.shtml 2006), chitosan is known to block the absorption of vitamin K, which aids blood clotting, and contains antibacterial properties that may alleviate high blood pressure (Teel 2000). An industry source reported receiving an order from the USA for emu eggshells for use to manufacture pressure bandages (DPI&F 2004a).

Emu eggshells are reported to have aphrodisiac properties according to industry. Some industry members have attempted to sell emu eggshells using these claims. However, tablets and capsules sold for this use were withdrawn from the Australian market as they were not recognised by the TGA (White 2001).

According to White (2001), some researchers believe that emu eggshells contain some amino acid, which is thought to have anti-convulsant properties and triggers anti-inflammatory and analgesic activity with less tendency to cause gastric side effects. It is also said that several members of these classes of amino acid possess analgesic properties that are comparable to those of morphine. However, a major medical research program and tests are required to substantiate claims on medical potency.

When conclusive research and tests on speculated health and medicinal potencies are completed, emu eggshells may present much wider applications and thus greater market potential.

However, not all eggshells will possess a therapeutic substance. The composition of shells is known to vary in thickness, strength, weight and density and to be influenced by nesting conditions, season, temperature, diet, age of birds, etc. (White 2001). To ensure the presence and strength of the therapeutic properties of each shell, testing would need to be carried out on each egg from each individual farm. This is likely to pose a major challenge to the commercialisation of emu eggshells for use as health or medicinal product.

Nevertheless, damaged eggs may present some export potential. It is believed that blue and green eggs have been used as a dietary supplement in traditional medicine in China, Japan and Korea for many thousands of years (White 2001). One industry member cited selling 40 kg–50 kg of eggshell powder to Taiwan as a virility booster (DPI&F 2004a). Others cite selling 10 kg–20 kg of eggshells to Malaysia, and 200 kg to Germany at $100 per kg.

The regulations limit emu eggs to be sourced only from hatcheries or breeders—not from the wild—with the exception of Tasmania. Eggs can also be purchased from aboriginal people who have a licence to catch bird from the wild (DPI&F 2004a).

According to the industry, they produce and sell between 250 and 600 blown eggs a year, which are sold at $8–$20 per egg. An industry member cites he sold blown eggs worth $6000 to the tourist market. Industry estimated an average of four eggs per bird can be collected for this purpose. As there is no significant extra labour required to collect the eggs, it was considered viable to collect and sell blown eggs (DPI&F 2004a). Although there has been a resurgence in the art of egg carving, with some works selling for $500 or more (DPIV 2002a), the industry estimates the market for blown eggs will remain small and static. The total collectable eggs for this purpose is estimated to be 56 200 over the next laying season given that about 4550 birds to be slaughtered between April 2005 and March 2006 are excluded (EIFA 2005).

As for broken shells, it was estimated that about 50 grams would be collectable from an egg (DPI&F 2004a). Eggshell pieces are mostly dumped by the industry, especially when they are contaminated with blood or soil (DPI&F 2004a). An industry source estimates there is potential to recover 60 per cent of broken shells for sale.

4.6 Feathers

There is a limited market for emu feathers for garment and hat decorations, souvenirs, arts and crafts, aboriginal basket making, New Zealand Maori skirts, birds' nests for pet shops and the sex industry. Also a small number of emu feather dusters are reportedly sold to the computer and camera industries for their non-synthetic, non-static qualities (DPI&F 2004a; DPIV 2002a). Depending on the size and focus of their businesses, industry members report selling 6 to 400 kg of feathers at $30 –$50 per kg. As 0.5 to 0.75 kg of feathers would be collectable from a bird and sell for about $15 per kg (EIFA 2005; DPI&F 2004a), the total quantity available for annual collection from 4550 slaughtered birds is estimated at 2.3 tonnes–3.4 tonnes.

Feather collection from emus requires manual pulling and cleaning as feathers get wet or contaminated with blood during the slaughtering process. Hence, the majority of feathers are thrown away at the abattoir. Only those who sell substantive volumes on a regular basis find the collection cost viable. One industry member stated that demand and prices are increasing and other industry members reported receiving small orders from China and the USA.

4.7 Cartilage

As mentioned in the crocodile cartilage section, research has discovered the presence of anti-angiogenic agents (AAA) in emu cartilage that may indicate potential as a substitute for shark cartilage (Harper et al. 2000).

Currently, few in the industry collect or process cartilage due to the small demand (EIFA 2005). In order to generate demand, large-scale research is required from research organisations or pharmaceutical companies to clarify the potential of emu cartilage as a substitute for shark cartilage. Once conclusive research and testing are complete, a market may exist for this use. As shark species are depleted, emu cartilage may be able to replace a portion of the shark cartilage market.

As with crocodile, retrieval of emu cartilage would require highly trained labour as it requires complicated work compared to meat (DPI&F 2004a).

4.8 Bones

Unlike crocodile bones, emu bones are not considered to possess health or medicinal properties. Emu bones are mostly disposed, with a small proportion used in meat and bone meal for fertilisers. However, in recent years the industry has attracted the interest of artists working with bones and feathers (Minnaar 1995). Although the unique shape and quality of emu bones offer a wide range of opportunities for use by artists and designers, the current use is limited. An industry member said that once a minimum level demand is generated it would be viable to collect emu bones (DPI&F 2004a). Assuming that about 1 kg of bones can be collected from a ratite, the total annual quantity collected from 4550 slaughtered birds would be about 4.6 tonnes.

4.9 Liver

An industry member reported he had recently received orders from restaurants for emu livers to use for pâté. A liver weighs about 0.5 kg. The producer sold 200 kg of liver at $9 per kg in 2004. In his view it would be viable to collect livers at the abattoir. The total quantity potentially available for annual collection from 4550 slaughtered birds is estimated at 2.3 tonnes.

4.10 Conclusion

Since the downturn in 1996–97, emu farming has undergone an adjustment phase. While stock numbers have gradually decreased since 1999 (MacNamara et al. 2003), the slaughter number has in general increased.

Oil and meat contributes 80 per cent of the total return from a bird. Other identified co-/by-products from the emu industry include eggshells, feathers, cartilage, bones and liver.

For eggshells, the market for blown eggs will remain small and static although there has been a resurgence in the art of egg carving. Some broken eggshells are sold domestically in bulk in powder form for meat and bone meal. However, demand for broken eggshells for their health or medicinal properties is small. Only basic level scientific research has been conducted into

potential health or medicinal properties of emu eggshells. A major medical research program and tests are required to substantiate claims on eggshells aphrodisiac properties, anti-convulsant effects, anti-inflammatory and analgesic activity. Moreover, even if the research and testing verified eggshells' medicinal properties, testing of shell would need to be carried out on each egg from every farm because not all eggshells possess therapeutic benefits. This makes the collection and commercialisation of emu eggshells inviable for use as a health or medicinal product at this stage.

With emu cartilage, a RIRDC research project found the presence of anti-angiogenic agents (AAA), which may mean that emu could be a potential substitute for shark cartilage. However, like eggshells, large scale research is required by a research organisation or pharmaceutical company to clarify the potential of emu cartilage for use as a substitute for shark cartilage. Currently, few in the industry are collecting or processing cartilage, due the small demand. As with crocodile, retrieval of emu cartilage would require highly trained labour which will increase processing costs.

There is a limited market for emu feathers for both domestic and export markets. This includes garment and hat decorations, souvenirs, arts and crafts, aboriginal basket making, New Zealand Maori skirts, birds' nests for pet shops, the sex industry, and feather dusters for the computer and camera industries. Demand for feathers is small but is thought to be growing. However, as feather collection from emus requires manual pulling and cleaning, only those who sell substantial volumes on a regular basis find the collection viable.

Unlike crocodile bones, emu bones are not thought to have health or medicinal properties. Only a small portion of collectable emu bones is used in meat and bone meal for fertilisers and by artists working with bones and feathers. Most bones are disposed of and it is viewed viable to collect emu bones if a market is identified.

No health or medicinal properties are known for emu liver. Although it would be viable to collect livers at the abattoir, until more trials by the food service sector determine otherwise only a limited market is likely to exist, such as for occasional orders from restaurants for use in pâté.

Oil offers the most opportunities. Basic level scientific research has been conducted on emu oil, eggshells and cartilage for their health and medicinal properties. Among these three emu co-/by-products, progress in scientific research and testings for oil has advanced the most. Emu oil is being commercialised for its anti-inflammatory properties and essential fatty acids such as omega-3 and -6 after TGA approval. Markets are being established throughout the world, mainly in Europe, Japan and the USA as main export destinations (DPIV 2002a). Demand has been on the increase both domestically and from overseas markets. The industry considers it viable to collect emu oil. Further research into other medicinal properties of emu oil speculated by the industry may be able to expand the usage and markets.

To summarise, emu oil presents far better potential than eggshells, feathers, cartilage, bones and liver. The industry's focus on oil needs to be maintained to further develop markets and, through research, identify new uses and verify medicinal properties.

5 Goat industry

5.1 Industry overview

Goats (*Capra hircus L*) were introduced to Australia in 1788 by the first settlers as sources of meat, milk and fibre. From this introduction, goats have adapted well to native Australian conditions. During unprofitable seasons, such as times of drought, goat herds were abandoned and became 'feral', gradually spreading across the semi-arid pastoral regions of Australia (The University of Queensland 1998). Feral goats have been harvested for the following main uses: domesticated to establish farm breeding stock; as a source of meat for either export or domestic consumption; and for live export (Forsyth & Parkers 2004). It is estimated that the total feral goat population in Australia is 2.3 million, making it the most common goat type used to produce meat (MacNamara et al. 2003).

When feral goats are domesticated and carefully selected they provide an excellent base for the development of cashmere, leather and meat production programs. These animals are now known as Australian Goat.

All species of goat can be used as a source of meat. All have fibre, while milk produced by female goats feeds goat kids or is used for human consumption. The most common goat meat breeds used in Australia include: feral goats, Australian domesticated goats, boer and boer crosses. Dairy breeds include: toggenburg, anglo-nubian, saanen and British alpine, while the breeds for fibre are angora and cashmere (DPIV 2002b).

Australian goat farming can be divided into three main groups: farmers who focus on growing goats for meat production; farmers who focus on dairy goats; and those that focus on fibre production.

Traditionally goat meat has been sourced from feral goats and animals used in milk and fibre production systems. The introduction of the boer goat in 1992 saw the development of specialty goat meat enterprises (McGregor 2002).

5.2 Product overview

In 2004, 1 127 088 meat goats were slaughtered in Australia (ABS 2005a). Queensland accounted for 33.3 per cent of slaughtered goats in Australia, followed by Victoria (32.7 per cent), Western Australia (16.7 per cent), New South Wales (14.6 per cent) and South Australia 2.3 per cent (ABS 2005a). Approximately 90 per cent of animals were slaughtered in export-accredited abattoirs, while only 5–10 per cent were killed in domestic abattoirs for local markets (Athas 2005).

Most goats slaughtered for meat export are feral. It is estimated that between 70 per cent and 90 per cent of animals slaughtered between 1998 and 2003 were feral goats (Forsyth & Parkers 2004).

In 2004, there were 20 export-licensed abattoirs to process goat meat. However, only 14 of those abattoirs are currently processing: six in Western Australia, four in Queensland, three in New South Wales and one in Victoria (Forsyth & Parkers 2004). The main abattoirs are in Wodonga in Victoria, in Geraldton, Western Australia and Charleville, in Queensland.

Australia began exporting goat meat in 1952 and is currently one of the world's leading goat-meat exporters. It exported more than 6300 tonnes in 2003–2004, valued at $23 million. The majority of this export meat was feral goat. The main markets for Australian goat meat exports are the United States of America with 52.1 per cent market share and Taiwan with 29.3 per cent of the market. These markets are valued at $11.8 million and $7 million respectively. Other export destinations include Canada, the Caribbean, Singapore, Malaysia, South Korea and high-value markets in Europe (ABS 2005b).

The dairy goat industry in Australia has traditionally supplied fresh milk and cheese to the domestic market. The industry has grown significantly since the beginning of the nineties, currently producing around 4.8 millions litres of milk a year (Abud 2005). The industry is highly seasonal with many farmers not producing milk during the winter months.

There are approximately 50 000 milking goats in Australia. Victoria, the largest producer, has 14 commercial herds with an estimated annual production of 1.1 million litres for 2003–2004 (The Dairy Goat Society of Australia 2005). New South Wales, Queensland and Tasmania also have milk-processing facilities.

The dairy goat industry in Australia relies heavily on the processing of milk into products, including cheese, yoghurt, ice cream and UHT milk. There are approximately 30 milk-processing facilities in Australia, with distribution channels in Western Australia, South Australia, New South Wales, Victoria, Queensland and Tasmania. Victoria has the greatest number of specialty cheese manufacturers producing goat cheese (Abud 2005).

Fibre obtained from goats is classified as either cashmere (fine) or mohair (coarser). Cashmere is a fine, down-like fibre, under 18.5 microns. It can be obtained from a number of breeds, including feral goats. Good quality cashmere goats produce between 300 and 500 grams of fibre a year. Australia is a small producer of cashmere (1200 kg in 2004), of which the majority is exported in a raw state to the UK where the product is further processed for resale (Gould 2005). More recently most of the fibre is marketed and exported after dehairing

Mohair, a product of the Angora goat, is a coarser fibre with a micron range between 23–45. Considered a luxury fibre in the textile industry, Australia has been exporting mohair for more than 25 years. It was estimated that Australia produced between 250 000 and 300 000 kg of mohair in 2004. In general the fibre has been exported in a greasy state to India, UK, Europe and South Africa (Hall 2005).

Goat skins are a co-/by-product from the slaughter of goats produced for meat. Skins recovered during the slaughter process are exported for tanning and used in the manufacture of garments, footwear, luggage and bookbinding. In 2004, Australia exported 1 300 239 kg of raw goat hides and skins valued at $1.8 million (ABS 2005c).

5.3 Offal

Goat offal in Australia is recovered for human consumption. Some of the main co-/by-products recovered include heart, liver, lungs, kidneys, testicles, feet, stomach and intestines. Most of these products are directed into the export market where there is a significant and constant demand for them. Consumption of goat offal in Australia is very small.

According to Australian processors, offal such as kidneys, livers, heart, testes, penis and heads are used for food preparation by several countries in Eastern Europe, the Middle East, Asia and

the Caribbean. Runners and intestines are commonly used for sausage casing, gullets have been used in pharmaceutical research, while the trachea has been used in the production of pet food.

Australia exports approximately 173 tonnes of goat offal annually, with the majority destined for Asia. Other markets include the Middle East and Eastern Europe which imports mainly hearts, livers and kidneys (MLA 2003).

According to processors, one of the main destinations for offal is Europe, especially Bulgaria, which imports significant quantities of plucks (heart, lungs, liver cut together as one pack). In Bulgaria plucks are minced and placed inside the stomach of an animal in the preparation of a traditional dish. The average price received was $0.72 cents per kilogram of plucks. Kidneys have been sent to the USA valued at $1.20 per kilogram. Taiwan has imported testes valued at $5.50 per kilogram at certain periods of high demand and $3.50 per kilogram during low season. Hearts, together with other offal, have also been sent to South Africa and are currently priced at $1 per kilogram. China imports runners and skins. Gullets are exported to New Zealand, where they are used in the pharmaceutical industry. The price received is $6 per kilogram for gullets, although collection of sufficient quantities is difficult.

Processors said there were opportunities to export goat feet and heads to Mexico, USA and the Middle East. Although some goat feet are already being exported to these countries, producers feel that the market is at an early stage of development. Enquiries to export edible goat heads into the USA have also been received by processors. Currently there are processors of goat heads that can meet the USA edible product standards. However, current protocols in the USA do not allow the importation of goat heads from other countries, limiting the opportunities for processors in this market.

According to industry, there is strong demand for co-/by-products throughout the year. Although prices do fluctuate from time to time. For example, at the time of the interview in November 2004, there was a strong demand for plucks, while demand for kidneys was low.

Production and availability of co-/by-products is always driven by the demand for goat meat. If there is not enough demand for specific offal or the price offered by buyers is not profitable the offal is sent to rendering.

Processing plants have different levels of collection and this depends mainly on the individual capabilities of the processing plant. While some plants have the capability to recover all offal, others only have the infrastructure to recover main organs such as liver, kidneys and heart, while parts such as the head, intestines and penis are rendered or discarded.

Collection and commercialisation of offal does not have any restrictions. However, all processing plants involved in exporting offal require certification by AQIS. They are also required to hold an export licence. Furthermore, depending on the markets to which the company sells their products, they may require USA, EU or Halal certification.

5.4 Blood

A processing company interested in the collection of goat blood is currently conducting a trial in collecting foetal blood. If the results are positive the company will consider continued collection of blood. Blood collected will be used in pharmaceutical and genetic research. For privacy reasons more information in relation to this trial was not available.

The research also identified some dairy goat farmers involved in the collection of blood from goats. Blood is taken from the jugular vein of the animals every month. It is estimated that on average 500 ml of blood is obtained per animal. Currently 800 animals are bled per month. This represents a monthly production of 400 litres. Bleeding of the animals only happens eight months a year during the milking season. Once the blood is collected it is centrifuged to obtain the serum, which is used in the manufacture of veterinary diagnostic kits and animal vaccines. Europe is the main market for the veterinary diagnostic kits. The market for the products is very limited.

5.5 Colostrum

Goat colostrum—the milk produced by the mammary glands for the first 72 hours after giving birth—is known to contain immune and growth benefits, which include the killing of bacteria and viruses, balancing the immune system, controlling inflammation, improving nutrient uptake and balancing blood sugar levels. In countries such as the USA and New Zealand goat colostrum is used in the manufacture of colostrum tablets that are taken as a food supplement.

In Australia, colostrum tablets are widely found in duty free and health food outlets predominantly targeting Asian tourists. Colostrum tablets are imported from New Zealand where there is a large powdered goat milk industry.

According to industry representatives all colostrum currently produced is used by farmers to feed goat kids. Also, given the size of the Australian herd, there are insufficient numbers of farmers able to produce the quantities of colostrum required for further processing. Furthermore, there is no powdered goat milk industry in Australia, although feasibility studies have been undertaken in relation to its establishment. However, nothing has progressed due to lack of investment into the sector.

The establishment of a milk powder industry will not only offer the opportunity to produce goat milk powder but also provide the option to further process the colostrum into goat colostrum powder which can be further processed into colostrum tablets.

5.6 Conclusion

Historically, goats have been used predominately for the production of meat, dairy products and fibre. Production of goat meat for export markets is currently the main activity of the industry and export of goat offal is a co-/by-product of the meat industry.

Research has shown that there are three key goat co-/by-products produced: offal, blood and milk colostrum.

Of these three products, offal offers the best opportunity for future growth. The worldwide demand for goat meat and offal has provided processors with the opportunity to recover and sell a wide range of offal, including liver, kidneys, testicles, heart, lung and intestine. Goat offal is mainly exported to the Middle East, Eastern Europe, Asia and the Caribbean, where it is used for human consumption. The current demand for offal, together with demand for new products such as heads and feets, represent opportunities for continued growth of the market for goat co-/by-products.

Goat blood is a co-/by-product that offers opportunities for collection and commercialisation in the medium- to long-term. Currently commercial collection of goat blood is under trial. The

findings will help determine whether it is a viable commercial process, and what timeframe is needed to establish a permanent collection facility.

Colostrum is a co-/by-product with limited opportunities. The small size of the dairy goat industry significantly limits the ability of the industry to collect colostrum. Furthermore there is a lack of infrastructure to further process the colostrum into a commercial product.

In summary, of the three co-/by-products identified in the goat industry offal, currently offers the best opportunities to commercialise as there is an established collection process and a growing market. Goat blood may offer opportunities in the medium- to long-term while colostrum does not appear to have any commercial use in the medium- to long-term.

6 Kangaroo industry

6.1 Industry overview

Native to Australia, kangaroos are marsupials belonging to the *Macropodiade* family. There are 48 species of macropods in Australia, of which seven are commercially harvested (Kelly 2002). For centuries Australian aborigines have used kangaroos as a source of food and fibre. Today kangaroos are still hunted for food, while in some cases aborigines sell the carcass and skin into the commercial kangaroo industry (Ramsay 1994).

According to the federal government, in 2004, the estimated population of the four kangaroo species that are commercially harvested was 27.5 million (DEH 2004d). The kangaroo industry has developed into a large commercial industry generating over $200 million per year and employing more than 4000 people (Kelly 2003).

Kangaroo harvesting is permitted in Queensland, New South Wales, Western Australia and Tasmania. Of the seven species commercially harvested, the following three species represent up to 90 per cent of the commercial harvest in Australia: Red Kangaroo (*macropus rufus)*, Eastern Grey Kangaroo (*macropus giganteus)* and Western Grey Kangaroo (*macropus fuliginous)* (Braddick 2001).

Commercial harvesting of kangaroos is regulated under an Australian government-managed system that includes annual establishment of harvest quotas, humane methods of harvest, quality-assured meat handling and inspection and a low risk of deleterious side effects to the ecosystem (Pople 2004).

The 'off-take' quota is established annually in each state based on aerial and other surveys, which are generally based on 10–15 per cent of the total kangaroo population (Kelly 2002). The approved commercial harvesting quota for 2004 was around 4.4 million, representing 16 per cent of the estimated population of kangaroo species that could be commercially harvested.

Professional shooters who have successfully undertaken industry accredited training courses harvest all kangaroos in Australia. Those harvesting for human consumption must also undergo assessment for shooting accuracy (Kelly 2003).

The kangaroo industry is an extractive industry offering environmental and economic benefits to the arid rangelands of Australia. Despite this, the industry must still overcome constant attacks from animal welfare groups, which have the potential to hinder industry growth (Kelly 2004).

6.2 Product overview

Kangaroos are currently harvested as a source of meat and skins. Kangaroo meat is used as game meat and in the manufacture of pet food, while the skin is processed for the manufacture of high quality leather goods, including footwear. The pet food market currently uses 50 per cent of kangaroo meat harvested each year, while the other 50 per cent is used as game meat for human consumption (Kelly 2005).

Human consumption market

Traditionally, kangaroo meat has been a food source for aborigines, although since 1959 European buyers have shown interest in importing the meat for distribution into local game meat markets (Ramsay 1994). Because inadequate attention was given to hygiene during processing and packaging of the meat, this venture was initially unsuccessful. At this time no regulations were in place to govern the harvesting and processing of kangaroos. It was then that processors developed a domestic pet food market for kangaroo, which now represents the major use for kangaroo meat (Ramsay 1994).

Kangaroo meat is recognised as being a very lean red meat with a slightly 'gamey' flavour. It has very low fat levels and a high proportion of polyunsaturated fatty acids compared with other meat from many livestock species. The characteristics of kangaroo meat are believed to improve blood flow and reduce the tendency for clots to form, therefore reducing the risk of cardiovascular diseases. It is believed that the consumption of kangaroo meat in a well-balanced diet can reduce plasma cholesterol levels and metabolic abnormalities such as diabetes (O'Dea 1988 in Ramsay 1994).

These health benefits have resulted in the development of new market opportunities in the food supplement industry. Currently food supplements using kangaroo meat are available for sale in health stores and souvenir shops. Targeting the therapeutic food sector could enable the kangaroo industry to establish a niche market, differentiating the product from traditional red meats. However, further research will be needed into the therapeutical properties of kangaroo meat (Macarthur Consulting 1997).

Approximately 60 per cent of the kangaroo meat produced in Australia is exported, with the remainder being sold on the domestic market (Braddick 2001). Kangaroo meat accounted for more than 50 per cent of the game meat market in 1997, although this represented less than two per cent of the total Australian red meat production during the same year. Domestic sales of kangaroo meat predominantly target the domestic tourist market, fine restaurants and cafes, and a limited number of supermarkets.

Kangaroo meat is exported to more than 20 countries. The Russian Federation is the largest market, accounting for approximately 72 per cent of trade. The remaining 28 per cent is exported to other markets including Europe, the USA and parts of Asia (ABS 2005d).

Pet food market

In 2002, the pet food market accounted for approximately 75 per cent of kangaroo meat harvested, totalling between 20 000 and 30 000 tonnes per annum (PacALLIANCE 2002) with an estimated market value of $40 to $50 million in 1997 (Senate Rural Affairs and Regional Affairs and Transport Reference Committee 1998). However, the continued increase in demand for kangaroo meat for human consumption during the last couple of years has taken a share of the kangaroo meat used in pet food manufacturing. It is estimated that in 2004 approximately 38 000 tonnes of kangaroo meat was harvested, of which 50 per cent was used in the manufacturer of pet food and the other 50 per cent was sold as game meat (Kelly 2005). Kangaroo meat for pet food is mainly sold as dry product and is available in all states and territories in Australia.

Kangaroo meat has been exported as pet food since 1982. The volume of kangaroo pet meat exported between 1982 and 1992 fluctuated between 200 and 700 tonnes annually (Ramsay, 1994). During 2003–2004 exports totalled 337 tonnes, mainly to Macau, Indonesia and Vietnam. (ABS 2005d).

Leather market

Kangaroo skin is recognised for its unique properties of high tensile strength relative to its thickness, and is one of the strongest leathers. Lightweight and flexible, this product meets premium market requirements. Kangaroo leather is used for the manufacture of high-quality goods, including sporting footwear (Looney et al. 2002).

Kangaroo skins are graded on the basis of size and quality. The classifications of the sizes are small (0.27 m^2 to 0.45 m^2), medium (0.45 m^2 to 0.63m^2) and large (more than 0.63 m^2). The quality is affected by the habitat of the animal; for example, kangaroos living close to agricultural areas may have scarring of the hide due to scratches from wire fences, while animals in regions affected by cattle ticks may have damaged skins due to tick infestation (Ramsay 1994).

Most skins commercially harvested are destined for export markets for use in footwear. The export market for kangaroo skins over the past 20 years has seen continued growth from a base of approximately $10 million dollars during the 1980s. It is estimated that the value of kangaroo skins, including raw, tanned and leather, was valued at $60 million during the period 2003–2004 (ABS 2005e).

To date, kangaroo skin and meat are the only products used in commercial harvesting. Other products that originate from collection are left in the field, as no commercial opportunities have been identified. In the case of harvesting for human consumption, the heart, lungs and liver are retained for testing purposes to ensure meat quality standards are maintained. However, after this testing process has taken place the organs are sent to the rendering plant.

6.3 Offal

The kangaroo industry differs from most other animal industries because it is based on harvesting animals from the wild. Once the animals are shot they are initially dressed on site. Dressing is the process of removing the head, hide, skin, viscera, genital organs, urinary bladder and feet from the animals. The level of dressing will depend on the purpose for which the kangaroo was harvested.

Kangaroos harvested for human consumption are taken from the paddock to the abattoir with liver, heart, kidneys and lungs attached. These organs are required to be left in the animal for initial examination of disease by meat inspectors. Once the organs have been inspected they are removed from the carcass of the animal. In most cases offal is sold for rendering or disposed of, but in some instances it goes into pet food. According to an industry member, the price received for offal sold for rendering is around $0.10 a kilogram. Determination of an estimated amount of offal used in the manufacture of pet food is not possible as this is an irregular activity and no data in relation to this have been collected.

Kangaroos harvested for pet food are fully dressed in the field and the carcasses taken to the abattoir without the offal attached. Harvesters who focus on collecting skins only take the skin and leave the carcass and the offal in the field.

According to the Australian Standard for Hygienic Production of Game Meat for Human Consumption, collection of offal from kangaroo and other wild animals is not allowed for human consumption.

Interviews with industry members show that, in general, there is no knowledge of any medical research or uses for kangaroo co-/by-products. Although the industry is not aware of any alternative uses of kangaroo offal, several research programs were identified that were investigating kangaroo parts such as the pericardium, and aortic valves for use in medical research. The Department of Cardio-Thoracic Surgery at the Fremantle Heart institute in Western Australia has been studying the potential to use kangaroo pericardium as an alternative for other bioprosthetic materials in cardiac surgery. Bioprosthetic materials (human, bovine and porcine) are used in various cardio-thoracic repair and replacement procedures because of their excellent performance and low thrombogenicity. Nevertheless, these bioprosthetic substitutes have a tendency to fail due to degeneration and calcification. Initial results from the studies have shown potential to use kangaroo pericardium due to the collagen composition and lower calcification characteristics (Neethling et al. 2002).

Since the initial trials in 2002 several studies showing positive results have been made on kangaroo tissues at the Department of Cardio-Thoracic Surgery in Western Australia. Currently the team involved in the research is in the process of identifying potential investors or financers who might be interested in supporting the final stages of product development and commercialisation (Neethling 2005).

Research at the Department of Cardio-Thoracic Surgery at the University of the Free State in South Africa have been evaluating the use of kangaroo heart (aortic valves leaflets) in relation to porcine heart (aortic valve leaflets) to be used as bioprosthetic material in surgery. Initial results have shown that kangaroo valve leaflets are superior to porcine valve leaflets as far as calcification is concerned (Neethling et al. 2000).

6.4 Collagen

Collagen is a protein of animal origin extracted from the skin, hide, bone and tendons of traditional livestock industries such as cattle, pig and poultry. Collagen has a wide range of uses such as anti-cancer therapy, wound healing, body implants, manufacturing of contact lenses, cosmetics and so on.

An Australian researcher said that kangaroo co-/by-products such as skin, bones and tail may offer an alternative source of collagen and that they are considered disease free. The need to identify alternative sources of collagen has increased in recent years. The recent outbreak of diseases affecting traditional animal industries, such as Bovine Spongiform Encephalopathy (BSE) in the cattle industry, has increased the concern in relation to extracting collagen from cattle. Consequently companies are looking for alternative sources of collagen.

However, this possible opportunity needs further research to evaluate the potential uses of kangaroo collagen and to investigate the feasibility of commercial collection. Currently there are no regulations affecting the collection of kangaroo collagen but, depending on the final use, there may be certain regulations that need to be met. For example if the collagen is going to be used by the pharmaceutical or medical industries in Australia it will need to comply with the current TGA regulations applicable to animal tissue.

6.5 Head, arms and tail

A kangaroo harvester related that a couple of years ago he was collecting tails and testicular sacks for use in the manufacture of toys and pouches. Some processing companies requested the harvesters to keep the tail, but the harvester estimated this represented less than one per cent of

all kangaroos harvested. Demand for the tail mainly occurred during winter because the tail then has winter fur. There is no additional payment to the harvester for collecting the tail.

A processing company said that although at one point they were involved in producing souvenirs, they decided to stop as the process became too costly and the market was too small.

Heads are occasionally collected and sold to taxidermists who sell them as souvenirs, while hands are also occasionally collected and used in the production of back scratchers or bottle openers. The main market for these products is the tourist industry.

6.6 Cartilage

Kangaroo cartilage from the sternum and the ribs has been studied to identify bioactive properties as an anti-cancer or anti-arthritic (Harper et al. 2000). The study, which also included analysis of cartilage from ostrich, emu, kangaroo, deer, camel and crocodile, evaluated the potency, production efficiency and sustainability of the different species as an alternative source of cartilage. The study demonstrated that kangaroo cartilage, together with that of other mammals (deer and camel), had some level of bioactive agents. The study demonstrated that cartilage from all species has different levels of bioactive agents such as anti-angiogenic agents (AAA) or anti-cancer agents. This suggests that all studied species, including kangaroo, could be used as a possible alternative source of cartilage.

6.7 Conclusion

The industry harvests kangaroos from the wild for meat and skins. Kangaroo meat is utilised as a game meat and in the manufacture of pet food. Commercial harvesting of kangaroos is strictly regulated by the Australian Government, which establish an annual ‘off-take’ quota based on an estimate of the total kangaroo population.

The research has identified that kangaroo co-/by-products currently have limited uses. Wild harvesting and the initial processing of the animal in the field—where most of the co-/by-products are removed and left behind—have limited the need to identify possible uses of the co-/by-products for value adding.

The research has identified that the use of kangaroo parts such as pericardium, valves and cartilage may have some medical opportunities. However, research in these areas is at an early stage and therefore further studies are necessary to evaluate these opportunities.

It was also identified that kangaroo co-/by-products could be used as a source of collagen but, like the medical applications, more research, time and money are necessary before any potential opportunities are identified.

Offal recovered from animals harvested for human consumption is mainly used in rendering and occasionally sold for pet food manufacturing. Kangaroo parts such as head, tail and hands are currently being used in the production of souvenirs or decorative items that are mainly sold to the tourist market. Nevertheless, the market is very small and does not offer any significant potential for adding value to kangaroo co-/by-products

To sum up, utilisation of kangaroo co-/by-products is very limited and does not offer any potential opportunities in the short-term. However, research into the use of kangaroo parts by the medical industry may offer some potential in the long-term.

7 Rabbit industry

7.1 Industry overview

Rabbit farming started in Australia in 1987 and before this a wild rabbit industry was well-established. Harvesting of wild rabbits offered low production costs coupled with abundant supply, therefore reducing the economic viability of farmed rabbit businesses.

Wild rabbit has been a source of meat in Australia since 1859, when 12 pairs of wild rabbits were released in Victoria (Gordon & Garrett 2004). They rapidly expanded throughout Australia and grew continuously up to the early 1990s, when over 2.7 million wild rabbits were sold each year. However, the release of the biological control agents (calici virus), in 1996 dramatically reduced the population of wild rabbits by the end of the nineties (Foster 1999 in Eady 2003). As a consequence the value of the wild rabbit industry, which was estimated to be $9 million per year in 1996, decreased to be worth only $400 000 in 1998–99 (Gordon & Garrett 2004).

Rabbit farming in Australia is currently allowed in all states except Queensland and the Northern Territory. Western Australia was the first state to recently legalise rabbit farming operations in 1987. New South Wales and Victoria followed in 1995 and 1997 respectively and South Australia and Tasmania in 2000 (Bodger & Goulding 2003).

In 2002, there were 561 rabbit producers in Australia, of which 500 were located in New South Wales, 52 in Victoria, six in South Australia and three in Western Australia (Bodger & Goulding 2003). During this same year, 21 farmed rabbit processing facilities were operating, of which nine were located in New South Wales, six in South Australia, six in Victoria, and one in Western Australia (Bodger & Goulding 2003). From the 21 processing facilities, five have a slaughter capacity between 500 and 600 animals a week, while the remainder slaughter around 50 animals a week (McNeal 2005). The principal breeds used for commercial farming in Australia are the New Zealand white rabbit and the Californian rabbit (Crusader Team 2002).

During the last three years rabbit farmers have been facing increasing production costs, in particular feed and the financial cost of setting up efficient large-scale operations. The 2002 to 2004 drought significantly affected feed costs forcing many farmers to leave the industry. Furthermore, the low rate of profit return to industry is preventing new farmers from getting into the industry (Gordon & Garrett 2004).

During the last decade rabbit farming was considered to be one of the fastest growing new industries in Australia. Despite the problems that the industry is currently facing it is estimated that demand for rabbit meat has the potential to grow in the domestic market, specifically during the cooler months when there is a significant increase in rabbit meat consumption.

It is projected that the rabbit meat market will reach around 305 tonnes by 2008 and 594 tonnes by 2015, and this equates to a 13 per cent growth during the period 2004 to 2008 followed by 8 per cent up to 2015 (Gordon & Garrett 2004).

7.2 Product overview

The rabbit farming industry in Australia is primarily based on the production of meat, predominantly New Zealand whites. Particular breeds are bred for the production of fleece and pelts, but in most cases skins are considered a co-/by- product of the production of meat. Other co-/by-products originating from rabbit meat production include offal, blood and manure.

Gordon & Garret (2004) estimated the size of rabbit meat production at 157 tonnes (dressed weight) in 2003, which suggests a market of around 131 000 rabbits. Rabbit meat production grew an average of 10 per cent per annum over the period 1998 to 2003. It is estimated that around 250 000 rabbits were slaughtered for meat production in 2004 (McNeal 2005).

Animals are ready for slaughter when they reach a weight of around 2.4 kg. On average they dressed out at 50 per cent of live weight at slaughter, which represents an average carcass weight of 1.2 kg, although weight can range between 800 g to 1.8 kg. The average price for live animals is around $2.96 per kilogram, while the dressed price is around $7.40 per kilogram (Gordon & Garrett 2004).

Rabbit meat is predominantly sold on the domestic market, with small amounts exported. Rabbit meat is available at European-style butchers, restaurants and delicatessens, with small amounts also sold at meat and produce markets and supermarkets (Bodger & Goulding 2003).

Rabbit farming is focused on the production of meat and any other product recovered from the production is considered a co-/by-product. This includes skins, blood, head, feet, manure and offal.

The following sections describe some of the most common co-/by-products recovered from rabbit production, along with their uses.

7.3 Offal

Rabbit offal is recovered at the processing plant for sale in retail stores. The rabbit offal, which is mainly demanded, includes head, lung, heart, kidneys, liver and stomach. Some countries in Europe and Asia use offal in the preparation of foods; for example, liver is used in the preparation of liver pâté. Offal parts such as the intestine and the liver are also used in the fishing industry as berley, while the heads are used for crab fishing (Bodger & Goulding 2003). Offal is generally sold to the market through the same channels as the meat products.

Offal produced during the processing of meat is classified into two main groups: red offal which is in most demand liver, kidneys, heart and lungs, and green offal which includes all the parts of the digestive system.

Livers and kidneys are the only organs that have been used for human consumption in Australia. According to industry representatives the liver and kidneys are frequently left in the carcass and sold along with the meat. Traditionally rabbit consumers purchase and prepare rabbit meat with the liver and kidneys attached. Under these conditions, rabbit livers and kidneys are not considered a co-/by-product However, if the carcass is further processed, livers are collected and sold separately for the production of pâté.

Some industry representatives said that they prefer to sell the liver attached or as part of the carcass as the value received is higher than when the livers are sold separately. At the time of the interviews the wholesale price for a kilogram of livers was $3.00, while if they are sold together with the carcass the wholesale value is between $10.50 and $11.50.

The heart and lungs are generally discarded although there are occasional opportunities for these products to be sold for pet food. Despite the unstable demand, it was indicated that collection of the products is an easy process and can be achieve as long as there is demand for the products. Current demand for rabbit offal is low as co-/by-products from traditional industries offer the advantage of providing bigger volumes of offal at a better price. A processor said that $0.40 cents per kilogram of offal is the minimum price at which the offal can be sold for pet food. Any offer below this price does not cover the collection cost.

A rabbit processor who occasionally sells hearts and lungs to pet food manufacturers states that his current sales of these products only represent five per cent of what is currently available for collection. Should demand for these products increase there is opportunity to supply extra product without increasing rabbit production.

Currently, green offal is not used and is being disposed of in land fills. In most cases this represents an extra cost as processing plants need to pay for the disposal of the products. In 2004 the disposal price paid in Melbourne was at $0.15 cent per kilogram of offal. A processing plant processing 600 rabbits a week produce around 282 kilograms of green offal. This plant incurred disposal cost of $42 a week or $2200 a year.

Rabbit offal does not have any scientifically recognised health benefits. However, rabbit parts are frequently used in medical research. For example, an industry source cites that the back legs of the rabbit have been used for medical research in the study of bone growth problems in infants at the University of New South Wales.

There are no major regulatory restrictions specific to collecting, processing or trading rabbit offal apart from standard licences and permits required at animal abattoirs and processing plants.

7.4 Blood

Rabbit blood has been widely used in scientific research as a source of serum, immunoglobulins and other specific proteins and enzymes present only in rabbits.

In Australia, collection of rabbit blood has been irregular; in most cases the blood collected has been intended for research purposes at universities and hospitals. A processor who has collected blood said that processing of the blood was done according to the requirements of the buyers. For example, in some cases he had to add anticoagulants and in other cases he spun the blood to collect serum. Some of the blood collected was used in cholesterol research. The price received was between $50 and $100 per litre, which according to the processors is a good return.

An Australian company located in Brisbane is interested in commercially collecting rabbit blood. However, it is currently in the process of overcoming issues related to techniques of collection, logistics in consolidating supply and securing continuity of supply.

According to interviews conducted with industry only one processing abattoir has experience in collecting blood in Australia. Nevertheless, this was not for commercial purposes. The lack of

knowledge in the area of collecting and processing blood and the small size of the processors located around the country has been a limitation in establishing a commercial venture.

Industry estimates that 30 ml of blood can be collected from one rabbit. Australia's largest rabbit processing abattoir can collect 18 litres of blood a week from processing 600 animals. Based on the weekly processing of 4800 rabbits in Australia it is estimated that 144 litres of blood is potentially available for sale every week.

Collection of blood occurs during the initial stages of the slaughtering process and apart from the licences, permits and inspection required to process the animals no major regulatory restrictions were found specific to collecting, processing or trading rabbit blood.

7.5 Manure

Rabbit manure is widely used as a plant fertiliser due to its unique composition. The presence of low levels of nitrogen gives it a clear advantage in relation to other types of animal manure as it can be directly applied on plants without burning the roots.

It is estimated that a large doe and her four litters of about 28 to 32 young will produce approximately six to seven cubic feet of manure annually (Smith 2001). Unlike other animal manure, rabbit manure is relatively dry and pelleted. It is composed of approximately 3.7 per cent nitrogen, 1.3 per cent phosphorus, 3.5 per cent potassium, and also contains many trace elements such as calcium, magnesium, boron, zinc, manganese, sulphur, copper and cobalt (Smith 2001).

According to rabbit producers, most of the manure produced is used as fertiliser on their own farms. However, on some occasions it is sold in bulk to other farmers to fertilise their crops. Alternatively, it can be sold to nurseries, packed in 40 kg bags sold at the farm gate or in some instances used in earthworm farming.

A New South Wales (NSW) rabbit producer with 300 breeding does stated that he sells approximately 100 bags of manure from the farmgate at $4.00 per bag, representing 10 per cent of the manure produced on the farm. The remaining manure (up to 90 per cent of production) was used on his own farm. Similarly, a Victorian producer stated that he sold all the manure produced to a neighbouring olive farm, receiving $1000 a year for around 30 cubic metres of manure.

Rabbit manure is easily harvested and unlike other animal manures can be directly applied as a fertiliser as it does not transmit weeds, a feature of many other animal manures. Most producers used the manure on their own farms. However, it was identified that more and more farmers are interested in selling the manure to obtain an additional source of income. The main method of sale is at the farmgate, where 10 kg bags are sold for $4.00 to $8.00.

Interviewees agreed that rabbit manure is a co-/by-product providing a unique opportunity for the development of fertiliser products. Rabbit producers agreed that, due to current production commitments, no additional resources could be committed to the development of this market. Industry representatives suggested a third party would need to drive this activity.

7.6 Heads and ear

Rabbit brains have been used for medicinal purposes for people with coagulation problems. This process involves the extraction of acetone that is only present in rabbit brains. An industry representative said he had received a query from Adelaide to supply rabbit brains, but due to his low levels of production he was unable to supply the quantities required. Producers also indicated trade enquiries had been received for rabbit ears for research on skin grafting.

Generally, Australian processors discard rabbit heads together with all offal. However, opportunities exist for the use of rabbit heads in the manufacture of pet food and as bait for feral animals. Some producers said they have received up to $0.20 per head sold to the pet food market, but the main limitation is that there is no continuity of demand.

A South Australian processor recently installed a smoke house to add value to rabbit meat products. He is also planning to develop a new pet food product using rabbit ears. Another processor stated that smoked rabbit ears were incorporated into cat food. This market requires further investigation. Alternatively rabbit ears are tanned for use as novelties and tags on items such as key rings (Sandford 1996).

According to processors, collection of rabbit heads and ears is a simple process that does not require further investment because collection can be easily achieved. Based on an annual slaughter of 200 000 animals and average weight per head of 200 grams, approximately 40 tonnes of heads are produced in Australia every year.

7.7 Feet and tail

In many regions around the world preserved rabbit feet are seen as a lucky artefact. Rabbit feet contain no meat on them so they are normally discarded, but they are easy to preserve. Although they can be treated to improve durability, rabbit's feet do not require elaborate taxidermy. In Europe and the USA, millions of rabbit's feet are generated on farms every year. As a result, rabbit foot key chains are inexpensive to produce. They can be sold at a very low price and still be profitable. Rabbit tails have been used by plant breeders as an artificial pollinator, but this practice is limited and has no economic value to producers (Sandford 1996).

The research identified that producers and processors in Australia are currently discarding all the rabbit feet and tails produced. It was also stated that an Australian processor was approached by an American company seeking rabbit's feet for the manufacture of key rings. The enquiry was not successful because it proved to be uneconomical for producers; the price offered for the feet was below the cost of collection.

7.8 Rabbit skin glue

After the hair has been removed, rabbit skin is used for the production of a high grade glue used in traditional woodworking and paintwork. The high-quality grade means that it is the lightest in colour and the most translucent as well as the strongest glue available. To date no synthetic glue has been manufactured to replace the quality of rabbit skin glue (Sandford 1996). The research did not identify any producer or company involved in the manufacture of rabbit skin glue in Australia.

7.9 Skins

Rabbit skin and pelts have been used for many years as fur, in the manufacture of felt and for a variety of clothes, hats, toys and miscellaneous items. The skins and pelts vary widely in their quality and value. The different types of fur characteristics vary depending on the breed and age of the animal, and the time of the year of slaughter (Mississippi State University 2003).

Rabbits are often slaughtered at an age when their coats have not fully developed (usually at 10–12 weeks), when they still have an infant coat or are beginning the sub-adult moult, limiting the suitability of the coats for sale. The winter season, when the animals coat is firm and homogenous, is the best time of the year to collect coats. During the rest of the year the animals are moulting—making their coats uneven—and the hair is not firmly attached to the skin (FAO 2004).

According to industry representatives the amount of skin recovered from meat production is small in Australia. Some producers sell the skin to Akubra in Kempsey for the manufacture of hats, but this only represents a small percentage of the total skins produced.

A processor in Melbourne, currently slaughtering 600 rabbits each fortnight, mentioned that the company is currently recovering the skin for supply to a skin merchant for consolidation and export to China for tanning. The price received for the skins is between $0.20 and $0.40 each. According to the processor, these prices could encourage additional processors to enter the market.

7.10 Conclusion

Rabbit farming in Australia is a new animal industry with a focus on meat production. Despite growth, the rabbit meat industry is still small, supplying niche markets domestically. Besides the meat, rabbit production generates co-/by-products including: offal, blood, manure, head, ears, feet, tail and skins. Processors have built the capacity to collect co-/by-products, with the current abattoir structure allowing the collection of rabbit body parts. However, industry fragmentation and low levels of production are the major impediments to growth. These issues have limited collection of sufficient amounts of product, and the possibility of developing new markets.

The research has shown that the rabbit co-/by-products with the most potential include blood, manure and offal. The interest of a biotechnology company in rabbit blood has come to the notice of processors, but there are still some issues to overcome related to the collection and consolidation of supply. The collection of rabbit blood offers a significant opportunity for processors to add value to their operations.

Rabbit manure is another co-/by-product that, according to producers, could offer opportunity for commercialisation. The industry, however, will require investment from a third party to develop this opportunity because the current production commitments of producers do not allow them to develop this opportunity.

Rabbit offal may also offer some opportunities. Livers and kidneys are sold together with the carcass in most cases. Heart, lungs, heads and ears have been collected for pet food manufacturing, but demand for these products is inconsistent. The remaining co-/by-products are discarded. Processors continue to look for opportunities to develop the pet food market and develop continuous supply links.

Preliminary research indicated that the collection and commercialisation of rabbit skins could provide an attractive opportunity for producers to enter the market, although further research is required.

In summary, rabbit blood, rabbit manure and rabbit offal are co-/by-products that offer the most promising commercial opportunities for the industry in the medium- to long-term. Research currently being undertaking by processors and companies will further assist in identifying other opportunities for co-/by-products.

8 Implications and recommendations

A key issue in the production and use of co-/by- products is the industries' dependence on the development of the main products of the industry. Therefore, opportunities for most of the co-/by-products are likely to reach their full potential if they are based on the size and growth of the primary products of meat, milk and fibre.

The research identified that some industries are currently recovering and commercialising some of their co-/by-products such as emu oil and goat offal. These are providing an extra source of income to producers and processors. However, other co-/by-products such as crocodile blood and cartilage, emu eggshells, rabbit blood, rabbit manure and goat blood may have potential in the medium- to long-term. Development of opportunities for co-/by-products relies on the identification of markets and addressing impediments, and for certain products scientific verification of health or medicinal properties and improving the viability of processing and collecting.

8.1 Crocodile

The key co-/by-products of blood, bones, cartilage, heads, skulls, claws, teeth, tail tips, gall bladder, oil, penis, tongue, liver, brain and innards were identified and investigated for their uses, viability for collection and potential market opportunity.

Basic scientific research has been conducted on the medicinal properties of crocodile blood in transmitting oxygen to tissues and potential human antibiotics. However, further research and testing are required to develop blood into marketable medicinal products supported by an effective processing method. This may be achieved through collaborative efforts among research organisations, industry and the pharmaceutical industry. As countries such as Thailand commercialise and export dried crocodile blood in capsules to China, research into the current processing methods implemented by these countries may prove useful for the industry. In China and other Asian countries, crocodile parts are perceived to have health benefits. The identification of the current and potential supply chains and further uses for crocodile blood products in these countries would assist the industry to determine if potential exists to increase exports of blood or blood products.

A recent RIRDC study (Harper et al. 2000) discovered the level of anti-angionic agent (AAA) harboured in crocodile cartilage was similar to that of shark cartilage. However, large scale research is required to commercialise crocodile cartilage products as a substitute for shark cartilage. Apart from substantial investment by research organisations or pharmaceutical companies, an appropriate processing method also needs to be determined by research and experiments. Retrieval of cartilage by producers requires employment of highly trained staff. Future endeavours to develop cartilage products and markets would depend on further research into its potential as a substitute, and in developing a cost-effective processing method.

Heads, skulls, feet, claw, teeth and tail tips are sold to taxidermists for processing and to the tourist souvenir market. The tourist market for these souvenir products is likely to be influenced by the growth in crocodile tourism, although no major change in market demand for these products is expected in the short- to medium-term. Nevertheless, developing a wider variety of souvenir goods from these parts that will appeal to tourists may increase industry's profit. No major add-on processes are required at the abattoir to collect these co-/by-products. Research of

the tourism market and lines from crocodile and alligator produced in other countries may provide the industry with insights on potential new products.

A small additional market may exist for feet and tail tips in domestic and overseas Asian communities due to their association with longevity and good health, and as perceived substitutes for shark fin gelatine. Market research of these opportunities will determine the potential for these co-/by-products as a food item. Demand for a shark fin gelatine substitute requires more research by the food service sector.

In countries such as China, crocodile bile is used as an ingredient in the production of medicines for the treatment of diseases of the lungs such as asthmatic bronchitis, chronic bronchitis, emphysema, severe coughing, sputum, sore throat and laryngitis. Export potential to Asian countries, including China, needs to be explored through market research, along with the identification of viable processing methods.

The industry cites that crocodile oil can be used in lubricants, cosmetics and, because of its smooth properties, waterproof leather dressing. However, the development of effective processing methods, such as in the use of stabilisers, is required. The rendering process that enables the production of oil of consistent quality also needs to be researched and developed.

According to the Chinese community, crocodile penis is believed to cure medical problems such as high blood pressure, heart disease, asthma and arthritic pains, while also being recognised as an aphrodisiac. High margins are expected for crocodile penis used as an aphrodisiac, particularly in Asian markets. Research of potential markets and preferred specifications will be valuable. Also, research verifying medicinal properties of the penis may prove beneficial for the long-term marketability of the product as well as expansion of the market.

Small demand may exist in Asian countries for crocodile tongue, liver, brain or innards. Industry has reported receiving occasional inquiries about these products. Domestic demand for the products as novel food items and in veterinary training is expected to remain small and sporadic, so research of opportunities in Asian markets may provide some insight into the industry.

In Chinese communities around the world, bones cooked in soup are thought to assist asthma and other respiratory conditions and some current demand exists domestically from restaurants. In addition to this perception and current demand, industry views it is viable to collect bones using existing processing capabilities. Further opportunities to expand the market—not only for bones but also for processed bone products—need to be explored in countries where larger Chinese populations exist. Research identifying market size, competitors, supply chain dynamics and structure, and preferred specifications in current export destinations such as Hong Kong, China, Korea and other potential export markets will assist in determining the potential for bones. Also, research verifying medicinal properties of bones may prove beneficial for the long-term marketability of the product as well as for the expansion of the market.

Globally, Thailand, Papua New Guinea and African countries can supply crocodile co-/by-products much cheaper than Australia due to geographical proximity to the markets and lower production, labour and distribution costs. Australian crocodile co-/by-products need to establish a competitive advantage to compete in the global market for co-/by-products. Future investigation of these competitors will help to determine if Australia has competitive advantage.

8.2 Emu

The key co-/by-products of oil, eggshell, feathers, cartilage, liver and bones from the emu industry were identified and investigated for their uses, viability for collection and their potential market opportunity.

After years of scientific research and subsequent clinical trials, many emu oil products are now registered under TGA for their anti-inflammatory properties and fatty acids omega-3 and omega-6 content. Further research and testing of other health or medicinal properties of oil speculated by industry and scientists may trigger the development of more oil products for different uses and subsequent registration under the TGA. In addition to health and medicinal properties, the areas for further research could include industrial uses of emu oil such as for engine oil.

Industry estimates that approximately 90 per cent of Australian emu oil is rendered in a plant in Victoria, the only HACCP-accredited facility in Australia. The remaining 10 per cent is rendered by individual farms or private processing sites. It is believed that regulated, quality-controlled facilities and rendering processes will increase the consistency, quality and long-term competitiveness of emu oil products both in domestic and international markets.

Emu oil capsules sold for internal use are registered as a food product under Food Standards Australia New Zealand (FSANZ) as there is no 'food supplement' classification in the Australian system, which would more aptly describe the nature of the capsules. In European countries, the 'food supplement' classification allows claims for potential health properties or medical benefits of a product without requiring extensive medical research and clinical tests. The cost of extensive medical research and tests to be listed under TGA is significant for small industries such as the emu industry. A more flexible regulatory environment, such as the introduction of the 'food supplement' category, may assist the industry to commercialise a wider variety of emu co-/by-products for which conclusive research or testing has not yet been completed. Whereas this research is expected to be lengthy and require substantial investment, a flexible regulatory environment would be able to facilitate and accelerate the industry's growth and value-adding activities along with its economic growth.

The industry generally agrees that it is viable to collect and process emu oil. This is considered largely due to superior land use and the low labour required compared with cattle or sheep farming, as well as relatively high profit margins that are usually attached to products with medicinal properties. Nevertheless, the lack of slaughtering facilities close to production sites has often been raised by the industry as an impediment. For example, New South Wales, where more than 45 per cent of the national stock were farmed in March 2004, has no abattoir. One industry source mentioned that his birds have to be transported for 12 hours to the abattoir in Victoria. Emus are known to be stressed and fight when transported in cages and this not only damages the skin but also contributes to fat deposits. Transport to abattoirs also adds substantial cost to the industry. The change in regulations to allow emus to be slaughtered at farms in a similar way to kangaroos would reduce costs and improve the quality and quantity of fat collected.

Emu eggshells' potential health and medicinal substances require verification through further and conclusive research and testing. This research needs to cover perceived aphrodisiac properties and potent anti-convulsant effect, as well as its analgesic properties. The development of an efficient method of testing the presence and strength of the therapeutic properties of each shell is also required, as well as a method standardising these properties in each shell. The

composition of shells is known to vary in terms of thickness, strength, weight and density and to be impacted by nesting conditions, season, temperature, diet, age of birds, etc. (White 2001).

For feathers, efforts are needed to increase demand through identifying new uses from current markets. Successful efforts in these areas would improve the viability of collecting feathers. There are limited markets for emu feathers for decorating garments and hats, souvenirs, arts and crafts, and in the computer and camera industries.

For cartilage, large-scale research is required by a research organisation or pharmaceutical company to clarify the potential of emu cartilage as a substitute for shark cartilage.
Only limited demand exists for bones and liver. Efforts to increase the demand from the current markets of fertiliser, arts and novel food items, and to generate demand through identifying new uses are recommended. Most bones and livers are disposed.

8.3 Goat

The goat industry's main areas of production are meat, dairy and fibre. Currently, production of goat meat for export markets is the main focus of the industry. As part of the production of meat, significant amounts of offal are produced. Offal, like the meat, has high demand in overseas markets, making it the main co-/by-product in the industry. Goat offal is mainly exported to markets in Asia, the Middle East, Eastern Europe and the Caribbean, where it is used as a food. Other identified uses of goat offal in Australia include pharmaceutical research and as an ingredient in the manufacture of pet food.

Of the five industries covered in the research, the goat industry is the most efficient user of co-/by-products. This advantage is due mainly to the current size of the industry and the presence of established markets for offal products overseas. However, current commercialisation of goat co-/by-products has been based largely on the supply of fresh products with no significant value adding.

Production and availability of goat offal is driven by the demand for goat meat. If demand is limited for specific offal, or the price offered from the market is not profitable, the offal is rendered. For this reason it is recommended that processing companies work towards identifying and establishing markets that offer sustainable and profitable demand for offal products in the long term. Establishing sustainable and profitable markets should improve the use of co-/by-products obtained from goats and hence result in improved profit for processors.

Two other identified co-/by-products in the goat industry included goat blood and goat colostrum. Goat blood is a co-/by-product used in medical, pharmaceutical and genetic research. A processing plant in Australia is currently evaluating the commercial collection of foetal blood, while a medical manufacturer is collecting blood from dairy goats to manufacture veterinary diagnostic kits and animal vaccines. If the current trials on the collection of the blood show positive results this will offer the opportunity to develop new markets and explore further methods to add value. Furthermore, this can be used as a model for other processing plants that may be interested in collecting and adding value to blood.

Colostrum, which is a co-/by-product from dairy production, has been used in other countries—the USA and New Zealand, for example—to manufacture colostrum tablets. Colostrum does not appear to have any commercial opportunities in the short term as the small size of the dairy industry limits its availability; furthermore, there is a lack of infrastructure in Australia to further process the colostrum into a commercial product.

It is recommended that processors continue to be active in identifying new opportunities for co-/by-products and at the same time explore options for adding increased value to co-/by-products they are currently commercialising. Processors should also continue to work actively with organisations such as MLA, who are identifying new market opportunities for goat co-/by-products.

8.4 Kangaroo

Kangaroo co-/by-products currently have limited uses. Wild harvesting and the initial processing of the animal in the field, where most of the co-/by-products are removed and left behind, have limited the need to identify possible uses for co-/by-products.

The research identified some potential opportunities for kangaroo pericardium, valves and cartilage for use in medicine. However, research in this area is at an early stage and therefore further studies will be necessary to evaluate these uses. It was also identified that kangaroo co-/by-products could be used as a source of collagen but, like the medical application, more time and money for research are necessary before any potential opportunities are identified.

The offal recovered from animals harvested for human consumption is mainly used in rendering and occasionally sold for use in pet food. Other kangaroo parts, such as head, tail and hands, are occasionally used in the production of souvenirs and decorative items sold to the tourism market. The market for these products is small and does not offer a significant opportunity to add value to kangaroo co-/by-products.

There are no significant opportunities for co-/by-products in the short term. It is recommended that the industry continues to investigate markets and options for co-/by-products and that better use of the whole carcass is explored to reduce the amount of co-/by-products left in the field to waste. An initial starting point could be further researching the medical qualities of collagen and cartilage obtained from kangaroo.

8.5 Rabbit

The rabbit industry focuses mainly on meat production, but it is a small industry only supplying domestic niche markets. The main co-/by-products generated by the industry include offal, blood, manure, heads, ears, feet, tail and skins.

Although processors have been built with the capacity to recover some of the co-/by-products, the industry's fragmentation at the production level and low levels of production are the largest impediments to growth. These issues have limited collection of sufficient amounts of product, and the possibility of developing new markets. However, if the industry grows according to projections, adequate quantities of co-/by-products may be available for the commercialisation of products such as blood and manure. In the short term, the industry could look into opportunities to consolidate co-/by-products from different regions to create increased volumes, and to facilitate opportunities for commercialisation.

The research identified three co-/by-products with the most potential for the rabbit industry. These included rabbit blood, rabbit manure and rabbit offal. Rabbit blood offers a significant opportunity for processors to add value to their activities as there is interest from a biotechnology company in collecting and commercialising the blood produced from the main rabbit processing facilities.

It is recommended that processors with significant slaughter capability work with the biotechnology company to evaluate the opportunity to collect and commercialise rabbit blood and address issues such as collection techniques, consolidation and transportation.

Rabbit manure is a co-/by-product that, according to producers, offers significant opportunities for commercialisation. However, these same producers also identified that involvement of a third party was necessary to drive commercialisation. It is recommended that alternative business strategies for the commercialisation of rabbit manure be explored. These alternatives should offer better returns to producers and processors than existing practices.

Rabbit offal, such as heart, lungs, head and ears, have been used occasionally in the manufacture of pet food. However, as demand is inconsistent processors are continuing to look for opportunities to develop the market for rabbit offal as pet food.

Research could focus on the use of rabbit offal in the preparation of pet food. Some issues that could be addressed include identification of potential uses for different offal markets (e.g. lung, heart, livers, heads and ears), as well as identification of the costs and logistics involved in the collection, storage, transportation and processing of offal for the pet food market.

Individual producers and processors in the rabbit industry have been actively involved in identifying potential opportunities for co-/by-products. An opportunity exists for them to work as a group instead of as individuals to identify and develop markets for rabbit co-/by-products. Working collectively, industry may be able to increase the supply base and resources.

Overall, these five prospective animal industries show some promising market opportunities with selected co-/by-products. However, a common requirement is that all of these areas need more research to validate actual markets, and health or medicinal properties if any, then implement strategies to produce, collect and market co-/by-products efficiently and effectively.

New animal industries need to continue to monitor how traditional industries are commercialising and marketing co-/by-products. The current usage of animal co-/by-products in traditional animal industries is at a higher level of development and could offer significant experience, ideas and knowledge to new animal industries for bechmarking. Furthermore, examining the use of co-/by-products in industries such as crocodile, emu, goat and rabbit in other countries could also be a valuable source of knowledge to the industries in Australia.

9 Appendices

9.1 Appendix A—Edible co-/by-products

Table A.1: Edible meat products consumed directly or that require little processing

Origin	By-products	
Organs	Brains Hearts Stomachs Tongues Pancreas	Liver Tripe Spleens Sweetbreads
Meat trimming from carcasses, head, neck and viscera	Carcass trimmings Cheek meat Weasand meat Giblet meat	Head meat Salivary glands Diaphragm meat
Miscellaneous	Oxtails Pork skins Testicles	Pigs' tails Udders Bone marrow

Source: Pearson & Dutson (1988).

Table A.2: Co-/by-products requiring further processing into edible meat

Co-/by-product	Edible meat co-/by-product	Potential uses
Large intestines	Chitterlings	Direct consumption, canned
Small intestines, large intestines, caecums and weasands	Casings	Container for sausages, luncheon meats and meat specialities.
Pork carcasses, trimmings (internal and external fatty tissue)	Lard	Direct consumption of food ingredient for margarines and shortenings
Beef, lamb and mutton carcasses, trimmings (internal and external fatty tissues)	Tallow	Direct consumption, food ingredients, shortening ingredients
Beef and pork fatty tissues	Partially defatted beef or pork tissues	Sausage or processed meat ingredients
Beef and pork carcass trimmings	Partially defatted chopped beef or pork	Sausages or process ingredients
Pork or beef fatty tissues	Cracklings	Direct consumption, food ingredients
Liquid recovered from cooking meat	Meat extract	Bouillon, soup base, meat, flavourings
Beef, pork, lamb or veal bones	Mechanically separated beef, pork, lamb or veal	Sausage or processed meat ingredients
	Beef, pork, lamb or veal stocks	Soup base, flavouring, processed food ingredient
	Bonemeal	Mineral supplement
Defatted beef, pork or lamb supplements	Ossein	Raw material for gelatine manufacture
	Edible bone collagen	Processed for ingredient
	Soluble bone protein	Soup base, processed food ingredient
Blood	Whole	Sausage ingredient, meat, specialities
	Plasma	Sausage and processed meats
	Red cells	Sausage and processed meat ingredient
Beef hide splits	Collagen	Collagen casings, edible films, food ingredient
	Gelatine	Meat and food product ingredient
Pork	Gelatine	Meat and food product ingredient
	Puffed pork skin snack food	Direct consumption
Pigs' feet	Pickled pigs' feets	Direct consumption
Beef feet	Edible beef feet	Direct consumption

Source: Pearson and Dutson (1988).

9.2 Appendix B—Inedible co-/by-products

Table B.1: Inedible co-/by-products of the meat, poultry and fish industries and their uses

Raw by-product	Processed by-product	Uses
Cattle hides	Salted or fresh	Leather
	Hide splits	Industrial gelatin, sausage casings, pet food
	Trimmings and fleshing	Animal feed, glue
Sheep skins	Wool, sheepskins, trimmings	Clothing, animal feed, lanolin
Pig skins	Salted or fresh	Leather, industrial gelatin, burn dressings
Fish skins	Salted and fresh	Industrial gelatin, glue
Poultry feathers, down	Cleaned processed	Bedding, ornamental, clothing, sport goods.
	Hydrolysed	Animal feed
Cattle, pig, hair, cattle switches	Cleaned	Upholster, plaster, sporting goods
	Hydrolysed	Animal feed, fertiliser, cosmetics
Cattle hoof, horns, pig toe nails	Hydrolysed	Animal feed fertiliser
Cattle, calf, pig, sheep blood	Blood meal	Animal feed
	Fresh blood	Pet food, glue
	Blood albumen	Letter mordant
	Blood fractions	Medical diagnostic
	Foetal calf serum	Tissue culture
	Fibrin	Pharmaceutical
Cattle, pig, sheep raw materials, mixed, condemned materials and whole animals	Inedible tallow and grease	Animal feed, industrial, soap, pet food
	Meat and bone meal	Animal feed, pet food
Poultry inedible raw material	Poultry fat	Animal feed, industrial
	Poultry by-products meal	Animal feed, pet food
Whole fish, fish offals, cooking and canning wastes	Fish meal	Animal feed, fertiliser, pet food
	Dried and condensed fish solubles	Animal feed, fertiliser, pet food
	Fish oil	Pharmaceutical, industrial
Beef, pork, sheep bones	Defatted bone	Industrial
	Bonemeal	Animal feed, fertiliser
	Mechanically separated product	Pet food
	Bone charcoal	Industrial
	Bone ash	China
Cattle feet	Neatsfoot oil	Industrial lubricant
	Bone	Industrial gelatin
Cattle, calf, pig, sheep glands	Extracts	Pharmaceutical, enzymes
Cattle, calf, pig, sheep livers	Fresh or frozen	Pharmaceutical, pet food
	Meal	Animal
Fish livers	Oil	Nutritional supplement
Pig hearts	Heart valves	Medical

Raw by-product	Processed by-product	Uses
Cattle, sheep, pig brains	Cholesterol	Pharmaceutical, cosmetic
Cattle, sheep, pig lungs	Fresh or frozen	Pet food
	Heparin	Pharmaceutical
Cattle, sheep rumen, reticulum	Meat meal	Animal food
Suckling calf abomasum	Rennin	Cheese
Pig stomachs	Pyloric sections	Pharmaceutical
	Pepsin skins	Pharmaceutical
Cattle, sheep, pig spleens	Fresh or frozen	Pet food
	Splenic fluid	Pharmaceutical
Cattle, sheep, pig gall bladders	Gall	Pharmaceutical
	Gall stones	Ornamental, industrial
Cattle, sheep, pig intestines	Sutures	Medical
	Strings	Sporting goods
	Casings	Meat products
	Mucosa	Heparin
Poultry egg shells	Meal	Animal feed
Poultry hatchery waste	Dried	Fertiliser, animal feed
Fishery waste	Digest	Pet food
Crab, shrimp wastes	Meal	Animal food
Oyster, clam shells	Ground	Poultry feed
Fish swim bladders	Isinglass	Gelatin

Source: Pearson & Dutson (1992).

10 References

ABC 2000, *News in science: the good (emu) oil*, 6 October 2000, Australian Broadcasting Corporation, <http://www.abc.net.au/science/news/stories/s196013.htm>, accessed September 2005.

ABC Online News 1998, *Croc farmer to cash in on aphrodisiac demand*, 14 July 2003, <http://www.abc.net.au/science/news/stories/s14397>, accessed January 2004.

ABS 2005a, *Slaughtered goats: unpublished data 2004*, Australian Bureau of Statistics.

ABS 2005b, *Goat meat export destinations: unpublished data*, Australian Bureau of Statistics.

ABS 2005c, *Exports of goat skins by state: unpublished data*, Australian Bureau of Statistics.

ABS 2005d, *Kangaroo exports by state 1998–99 to 2003–04: unpublished data*, Australian Bureau of Statistics.

ABS 2005e, *Australian Exports of Kangaroo Skin 2001–02 to 2003–04: unpublished data*, Australian Bureau of Statistics.

Abud, G 2005, Herd Improvement and Producers Association (HIPA), Personal e-mail communication.

AGD 2005, *Therapeutic Goods Act 1989*: Act No. 21 of 1990 as amended 4 March 2005, Australian Government Attorney-General's Department, Canberra.

APL 1997, *Bills Digest 154 1996–97: National Residue Survey (Ratite Slaughter) Levy Bill 1997*, Australian Parliamentary Library, <http://www.aph.gov.au/library/pubs/bd/1996-97/97bd154.htm>, viewed Aug 2005.

AQIS 2005a, Phone and e-mail inquiries made in July, August and September 2005, Australia Quarantine and Inspection Service.

AQIS 2005b, *Exporting fish and fish products*, Australia Quarantine and Inspection Service, <http://www.affa.gov.au/content/output.cfm?ObjectID=352A779A-CA09-4B297C05AB1EE57CF9C>, viewed July 2005.

Athas, S 2005, Meat and Livestock Australia, Personal communication.

Blood Weekly 1995, *Blood substitutes: elements of crocodile haemoglobin used to engineer new molecule*, 6 March 1995: 2–3, <http://www.NewsRx.net>, viewed September 2003.

Bodger, J and Goulding, B 2003, *Distribution of meat products from prospective Australian animal industries: crocodiles, emus, game birds, rabbits, hares and snails*, RIRDC Publication no. 03/023, Rural Industries Research and Development Corporation, Canberra.

Braddick, L 2001, *Market place demand for kangaroo meat consumption in Western Australia: a sustainability issue*, Murdoch University, Perth.

Briggs, M 2003, *MSU Professor studies alligators*. 6 Nov 2003, KPLC TV, Los Angeles, USA, <http://kplctv.com/global/story.asp?s=1514376&ClientType=Printable>, viewed 23 September 2004.

Britton, A 2005, *Crocodilians: natural history and conservation: recent news*, <http://www.crocodilian.com/>, viewed September 2005.

Business Wire, 1998a, Emu oil proven to be medical wonder, *Business Wire*, 10 August 1998, <http://www.nexis.com/>, viewed July 2005.

Business Wire, 1998b, Emu oil proven found to relieve arthritis while reversing wrinkles and hair loss, *Business Wire*, 28 January 1998,<http://www.nexis.com/>, viewed July 2005.

Caldwell, J 2005, *World trade in crocodilian skins, 2001–2003*, United Nations Environment Programme–World Conservation Monitoring Centre [UNEP-WCMC], Cambridge, UK.

Camargo M and Goodwin M 2004, *Draft: distributions of meat products for prospective animal industries in export markets* (unpublished), RIRDC Project no. DAQ 314A, Rural Industries Research and Development Corporation, Canberra.

Cocodrilos Mexicanos 2004, <http://www.cocomex.com.mx/productos.html>, viewed October 2004.

Crocodile Specialist Group Newsletter 2003, 142B, <http://www.flmnh.ufl.edu/natsci/herpetology/newsletter/news142b.htm>, viewed 25 September 2003.

Crocodile Specialist Group Newsletter 2000, vol. 18, no. 3, July–Sept 2000 (WWW Edition), 5–7, <http://www.flmnh.ufl.edu/natsci/HERPETOLOGY/NEWSLETTER/news193p5-7.htm>, viewed 11 December 2003.

Crusader Team, 2002, *Meat rabbit farming—an introduction*, CSIRO Livestock Industries <www.csiro.gov.au/crusader>, viewed November 2004.

DEH 2005a, Phone and e-mail inquiries made in May, June, August and September 2005 and permit data received in September 2005, The Department of Environment and Heritage.

DEH 2005b, *Wildlife trade fact sheet*, The Department of Environment and Heritage, <http://www.deh.gov.au/biodiversity/trade-use/index.html>, viewed March 2005.

DEH 2004a, *How to obtain a permit to import and export wildlife or wildlife products*, The Department of Environment and Heritage, <http://www.deh.gov.au/biodiversity/,publications/trade-use/factsheet/>, updated 29 November 2004, viewed September 2005.

DEH 2004b, *Approved farming operations for crocodiles in Queensland*, The Department of Environment and Heritage, <http://www.deh.gov.au/biodiversity/trade-use/sources/captive/crocodile-farms.html>, updated 20 June 2004, viewed March 2005.

DEH 2004c, *Approved farming operations for emus*, The Department of Environment and Heritage, <http://www.deh.gov.au/biodiversity/trade-use/sources/captive/emu-farms.html>, updated 20 June 2004, viewed March 2005.

DEH 2004d, *Background information: 2004 commercial kangaroo harvest quotas*, The Department of Environment and Heritage, <http://www.deh.gov.au>, viewed 2004.

DPI&F 2004a, Industry interviews for crocodile, emu, goat, kangaroo and rabbit industries, October 2004 – February 2005, Department of Primary Industries and Fisheries, Queensland

DPI&F 2004b, *Draft: review of crocodile farming research, development and extension within the Department of Primary Industries and Fisheries* (unpublished), Department of Primary Industries and Fisheries, Queensland.

DPI&F 2004c, Crocodile Industry Meeting for RIRDC Game Meat Project DAQ 314A, May 2004,

DPIV 2002a, *Agricultural notes: emus*, Department of Primary Industries, Victoria, September 2002, <http://www.dpi.vic.gov.au/DPI/nreninf.nsf/>, viewed August 2004.

DPIV 2002b, *Farm diversification information service*: *agricultural notes: capretto (kid meat)*, Department of Primary Industries, Victoria, Bendigo.

DPIWE 2004, *Emerging and other animal industries*, Tasmanian Department of Primary Industries, Water and Environment, <http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/EGIL-5K63K8?open>, viewed August 2005.

Eady, S 2003, *Farmed rabbits in Australia*, RIRDC Publication no. 02/144, Canberra.

EIFA 2005, E-mail inquiries made to Arthur Pederick (Secretary/Treasurer) in September 2005, Emu Industry Federation Association.

FAO 2004, *Production of rabbit skins and angora wool*, Food Agricultural Organisation, <http://www.fao.org/docrep/x5082e/X5082E0h.htm>, viewed 6 October 2004.

Forsyth, D and Parkers, J 2004, *Maximising the conservation benefits of the commercial goat industry in Australia*, Department of the Environment and Heritage, Canberra.

Foster, M 2005, *Emerging animal and plant industries – their value to Australia*, RIRDC Publication no. 05/154, Canberra.

Frapple, P, O'Malley, P, Snowden, JM and Hagan, R 1997, *Emu processing and product Development*, RIRDC Research Paper Series no. 97/66, January 1997, Rural Industries Research and Development Corporation, Canberra.

Goding, D 2001, Jaws of life: can a natural supplement cure cancer? *Sunday Mail*, 27 May 2001.

Gordon, J and Garrett D 2004, Rabbit farming: an evolution of the crusader R&D Program, RIRDC Publication no. 03/144, Rural Industries Research and Development Corporation, Canberra.

Gosh, P and Whitehouse, MW 1993, Experimental study to determine the anti-arthritic activity of emu oil formulation (EMMP), *AEA News*, 1993.

Gould, C 2005, Australian Cashmere Growers Association, personal communication.

Hall, J 2005, Mohair Australia, Personal communication.

Harper, G, Allingham, PG and Qiu, X 2000, *Cartilage co-products: commercial development from alternative production species*, RIRDC Publication no. 00/35, March 2000, Rural Industries Research and Development Corporation, Canberra.

Hoffman, LC, Fisher, PP and Sales, J, 2000, Carcass and meat characteristics of the Nile crocodile (crocodylus niloticus), *Journal of the Science of Food and Agriculture*, vol. 80, no. 3, pp. 390–396.

Kelly, J 2005, Personal communication.

Kelly, J 2004, Selling the kangaroo industry to the world: assisting ongoing kangaroo market growth by facilitating public industry acceptance, RIRDC Publication no. W04/114, Rural Industries Research and Development Corporation, Canberra.

Kelly, J 2003, The kangaroo Industry: its image and market, RIRDC Publication no. 02/166, Rural Industries Research and Development Corporation. Canberra.

Kelly, J 2002, *Kangaroo industry background*. <http://www.kangaroo-industry.asn.au/moreinfo/BACKGRI.HTM>, viewed October 2004.

Komiyama N, Miyazaki G, Tame J and Nagai K 1995, Transplanting a unique allosteric effect from crocodile into human haemoglobin, *Nature*, 373, 19 January 1995, 244–246.

Looney, M, Kyratzis, L, Truong, Y and Wassenberg, J 2002, *Enhancing the unique properties of kangaroo leather*, RIRDC Publication no. 02/105, Rural Industries Research and Development Corporation, Canberra.

Macarthur Consulting Pty Ltd. 1997, *A review of the impact of government polices on kangaroo industry commercial practises*, RIRDC Publication, Rural Industries Research and Development Corporation, Canberra.

MacNamara, K, Nicholas P, Murphy D, Riedel E, Goulding, B, Horsburgh C, Whiting T and Warfield B 2003, *Markets for skins and leather from the goat, emu, ostrich, crocodile and camel industries*, RIRDC Publication no. 02/142, Rural Industries Research and Development Corporation, Canberra.

McGregor, B 2002, *Agricultural notes–The Boer goat*, State of Department of Primary Industries, Victoria, Attwood, Bendigo.

McNeal, G 2005, Quality Australian Farm Rabbits, Personal communication.

Minnaar, M 1997, *Emu farmers handbook: introduction to emu oil: fats and oils in human health*, <http://www.tjuringa.com.au>, viewed June 2004.

Minnaar, M 1995, *The Emu farmer's handbook*, Nyoni publishing Co., USA.

Mississippi State University 2003, *Rabbit production*, <http://msucares.com/livestock/small_animals/slaughter.html>, viewed 6 October 2004.

MLA 2003, *Australia's goat meat industry: fast facts*, Meat and Livestock Australia, North Sydney.

MLA 1993, *Edible offal market study*, Meat and Livestock Australia, North Sydney.

Neethling, WM 2005, Fremantle Heart Institute, Fremantle Hospital, Western Australia, Personal communication.

Neethling, WM, Cooper S, Van Den Heever JJ, Hough J and Hodge AJ 2002, Evaluation of Kangaroo pericardium as an alternative substitute for reconstructive cardiac surgery, *Journal of Cardiovascular Surgery*, Jun 43(3), 301–06: Torino.

Neethling ,WM, Papadimitriou, JM, Swarts, E and Hodge, AJ 2000, Kangaroo versus porcine aortic tissue—valve geometry morphology, tensile strength and calcification potential, *Journal of Cardiovascular Surgery*, June 41(3), 341–8, Torino.

Neutraceuticals World 2003, Under the sea: marine products continue to gain in popularity as they're being touted for a wide range of health benefits, *Neutraceuticals World*, vol. 6, no. 7, July 2003, pp. 42.

Ockerman, H and Hansen, C 2000, Animal by-products processing and utilization, Technomic publishing company, Lancaster.

O'Malley, P 1999, *Emu products: increasing production and profitability: Part C emu oil*. RIRDC Publication no. 99/143, Rural Industries Research and Development Corporation, Canberra.

O'Malley, P 1997, *A handbook for farmer: emu farming*, RIRDC, <http://www.rirdc.gov.au/pub/handbook/emu.html>, updated December 1997 and viewed April 2005.

O'Sullivan, M 1998, *Beef: Queensland value chain analysis series*, Department of Primary Industries, Queensland, Volume 1, Brisbane.

PacALLIANCE (Australia) Pty Ltd 2002, *Kangaroo pet meat survey*, RIRDC Publication no. 02/145, Rural Industries Research and Development Corporation, Canberra.

Pearson, AM and Dutson, TR 1992, Inedible meat by-products, *Advances in Meat Research*, Volume 8, Elsevier Applied Science, London.

Pearson, AM and Dutson, TR 1988, Edible meat by-products, *Advances in Meat Research*,

vol. 5, Elsevier Applied Science, London.

Peucker, S 2005, Personal review of the draft report, October 2005.

Peucker, S 1997, The crocodile industry. *The new rural industries: a handbook for farmers and investors*, <http://www.rirdc.gov.au/pub/handbook/croco.html>, viewed Oct 2004 and last updated 29 December 1997.

Pople, A 2004, *Commercial harvesting of kangaroo in Australia.* The University of Queensland, Brisbane.

QGTIO Taipei 2005, Phone and e-mail inquiries made in May 2005, Queensland Government Trade and Investment Office.

Ramsay, B 1994, Commercial use of wild animals in Australia. AGPS: Canberra.

Reuters 2005, Antibiotics from crocodile blood? *Wired News*, <http://www.wired.com/news/medtech/0,1286,68553,00.html?tw=wn_tophead_7>, viewed August 2005.

Sackton, J 2001, Crocodile meat in demand amid EU livestock crisis, *Kyodo News*, 12 April 2001, <http://www.seafood.com/news/current/39744.html>, viewed December 2002.

Sandford, J 1996, *The domestic rabbit*, Blackwell Science, Victoria.

Senate Rural Affairs and Regional Affairs and Transport Reference Committee 1998, Commercial utilization of Australian native wildlife, Parliament of the Commonwealth of Australia, Canberra.

Smith, K 2001, *Raising earthworms with rabbits*, <http://www.cyberstreet.com/kwfarm/wormsandrabbits.htm>, viewed 5 October 2004.

Smith, P, Craig-Schmidt, M and Brown, A 1994, Fatty acid analysis of emu oil, *AEA News*, September 1994.

Snowden, JM, Roberts, M and Cross, S 1997, *Determining the efficacy of emu oil in wound healing and cellular regeneration*, RIRDC Research Paper no. 97, Rural Industries Research and Development Corporation, Canberra.

Snowden, JM and Whitehouse, MW 1997, Anti-inflammatory activity of emu oils in rats, *Inflammophamacology*, vol. 5, no. 2, pp. 127–132.

Stubbs, A 1998, *Information systems for new animal industries*, RIRDC Publication no. 98/139, Rural Industries Research and Development Corporation, Canberra.

Teel, G 2000, Dietician disputes fat-busting promise: pill blocks absorption of vital vitamins, *Calgary Herald*, 12 June 2000, Alberta, Canada.

The Dairy Goat Society of Australia, 2005 email communication.

The EMBL Reptile Database 2005, Family Crocodylidae, <http://www.embl- heidelberg.de/%7Euetz/LivingReptiles.html>, last updated 1 January 2005, viewed February 2005.

The University of Queensland Gatton College 1998, *Goat meat production field day proceedings*, 22th November 1998.

The University of Sydney News 2001, *Crocodile farmers compare notes in search of perfection (20 April 2001),*<http://www.usyd.edu.au/publications/news/0104intNews/int04.crocs.html>, viewed 7 July 2003.

TGA 2005, telephone inquiries in September 2005, Therapeutic Goods Administration of the Department of Health and Aging 2005.

TGA 2004, *Australian Register of Therapeutic Goods* (ARTG), Therapeutic Goods Administration of the Department of Health and Aging 2004, <http://www.tga.health.gov.au/docs/html/artg.htm>, viewed August 2004.

TGA 2002a, *TGA News Issue 39*, November 2002, Therapeutic Goods Administration of the Department of Health and Aging, <http://www/tga.gov.au/docs/pdf/tganws/tganws39.pdf>, viewed October 2004.

TGA 2002b, *Policy for the export of medicines from Australia*, May 2002, Therapeutic Goods Administration of the Department of Health and Aging, <http://www.tga.gov.au/docs/pdf/exppol.pdf>, viewed September 2005.

UNEP-WCMC CITES Trade Database 2005, <http://sea.unep-wcmc.org/citestrade/index.cfm>, viewed September 2005.

University of Texas Medical School 1993, Emu oil: comedogenicity testing, Department of Dermatology, Houston.

White, D 2001, *Adding value to emu co-products*, RIRDC Publication no. 01/089, July 2001, Rural Industries Research and Development Corporation, Canberra.

Whitehouse, MW, Turner, AG, Davis, CK and Roberts, MS 1998, Emu oil(s): a source of non-toxic transdermal anti-inflammatory agent in aboriginal medicine, *Inflammopharmacology*, vol. 6, pp. 1–7.

Wondu Business and Technology Services 2004, *Adding value to new animal product Supply chains*, RIRDC Publication no. 04/166, December 2004.

Wondu Holdings 2002, *Benchmarks for new animal products: crocodile, squab and yabby*, RIRDC Publication no. 02/113, October 2002.

WWFT 2001, *Buyer beware: focal species: reptiles: crocodile*, World Wildlife Fund Thailand, <http://www.wwfthai/wwc/en/buyerbeware/focal/reptiles/crocodile2.asp>, viewed September 2004.

Zemstov, A, Gaddis, M and Montalvo-Lugo, V 1994, Moisturising and cosmetic properties of emu oil: a double blind study, *AEA News*, October/November 1994.

Websites:

< http://www.pdrhealth.com/drug_info/nmdrugprofiles/nutsupdrugs/chi_0067.shtml>, *PDRhealth* viewed May 2006.

<http://www.tjuringa.com.au>, *Tjuringa Emu Products* viewed June 2004.

<http://www.e-xoticmeat.com/news_07.html>, *What crocodile fat is good for…* viewed December 2002.