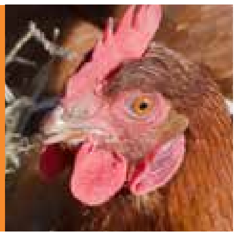
ANTIMICROBIAL STEWARDSHIP IN AUSTRALIAN LIVESTOCK INDUSTRIES

2ND EDITION



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Antimicrobial Stewardship in Australian Livestock Industries 2nd Edition.

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CONTENT

FOREWORD

The following report on Antimicrobial Stewardship (AMS) within Australian livestock industries is the result of a collaborative effort, which has been coordinated by the Animal Industries Antimicrobial Stewardship R,D & E Strategy (AIAS) and includes input from relevant AMS experts.

This report provides an overview of historical and current practises relevant to AMS in each of the contributing industries and is primarily intended for the stakeholders who are interested to know how livestock industries operate in Australia. Although some industries have not contributed to this report, it does not in any way imply a lack of dedication from those industries to AMS.

The volume of information supplied for each often reflects the intensity of production rather than their level of commitment to AMS. To an extent, the amount of information provided reflects the varying efforts required to manage diseases in different livestock systems. An important long-term goal is that this report will be updated to include contributions from other Australian livestock industries.

INDUSTRY CONTACTS

For enquiries on further information related to antimicrobial stewardship in the industries included in this report, please refer to the relevant contact below.

Industry	*Organisation*	*Contact Email*
Chicken meat	Australian Chicken Meat Federation	acmf@chicken.org.au
Dairy	Dairy Australia	enquiries@dairyaustralia.com.au
Duck meat	Australian Duck Meat Association	g.parkinson@iinet.net.au
Egg	Australian Eggs	contacts@australianeggs.org.au
Grain-fed beef / Grass-fed beef / Sheep-meat	Meat & Livestock Australia	info@mla.com.au
Pork	Australian Pork Limited	research@australianpork.com.au
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ABBREVIATIONS

ACMF	Australian Chicken Meat Federation
ACV	Australian Cattle Veterinarians
ALFA	Australian Lot Feeder's Association
AMR	Antimicrobial Resistance
AMS	Antimicrobial Stewardship
APL	Australian Pork Limited
APV	Australian Pig Veterinarians
APVMA	Australian Pesticides and Veterinary Medicines Authority
ARC	Australian Research Council
AVA	Australian Veterinary Association
AVPA	Australasian Veterinary Poultry Association
DAWR	Australian Government Department of Agriculture and Water Resources
ESA	Egg Standards of Australia
GVP	Gross Value of Production
IDF	International Dairy Federation
JETACAR	Joint Expert Technical Advisory Committee on Antibiotic Resistance
LPA	Livestock Production Assurance
MHU	Minor Human Use
MLA	Meat & Livestock Australia
NHMRC	National Health and Medical Research Council
NHU	No Human Use
QA	Quality Assurance
RDC	Research and Development Corporation
RD&E	Research, Development and Extension

INTRODUCTION

“Antimicrobial resistance (AMR) is one of the biggest threats to human and animal health today” is the opening statement of the Australian Government website devoted to AMR (https://www.amr.gov.au). This statement highlights the increasing national and international attention being given to the harmful consequences of antimicrobial resistance that may influence the health and welfare of current and future generations of animals and people. The Australian Government Department of Health and Department of Agriculture released “Australia’s National Antimicrobial Resistance Strategy - 2020 and Beyond” in March 2020, which followed Australia’s first National Antimicrobial Resistance Strategy “Responding to the Threat of Antimicrobial Resistance” (released in 2015).

The 2020 Strategy sets a 20-year vision to protect the health of humans, animals and the environment through minimising the development and spread of AMR while continuing to have effective antimicrobials available (Australian Government, 2020). The National AMR strategy describes seven objectives to successfully accomplish this goal, including the pivotal importance of implementing antimicrobial stewardship (AMS) practices across human health and animal care settings, to ensure appropriate and judicious prescription and administration of antimicrobials. This current document presents an overview of AMS initiatives already practiced across a variety of livestock operations in Australia. Objective 6 is “a strong collaborative research agenda across all sectors”.

In 2020, five major Australian livestock industries (Chicken meat, Dairy, Eggs, Pork and Red meat) came together to form the Animal Industries’ Antimicrobial Stewardship Research, Development and Extension Strategy (AIAS). This Strategy aims to ‘Create a collaborative mechanism for animal industries to identify common research, development and extension (RD&E) priorities for the effective monitoring of antimicrobial use (AMU) and surveillance of AMR to inform stewardship actions that meet Australia’s animal health and market access needs, without impacting food safety or human health.’ (https://aiasrdestrategy.com.au/)

What is Antimicrobial Stewardship?

‘Stewardship’ describes a situation where an individual takes responsibility for the care and management of something not owned by that individual. In the past, stewardship has applied to responsible care of forests, water, oceans, the environment in general (Darden, 1988) and to animal welfare. At the beginning of the 21st Century, the critical importance of the care and management of antimicrobials as precious, non-renewable resources has received heightened focus. The term ‘stewardship’ was applied to practises that minimise the need for antimicrobial use, as well as practises related to their use.

One of the most distinct descriptions of AMS was provided by two eminent researchers who are experts in appropriate antimicrobial use in animals, Luca Guardabassi from Denmark and John Prescott from Canada (Guardabassi and Prescott, 2015). They define AMS as, “the multifaceted and dynamic approaches required to sustain the clinical efficacy of antimicrobials by optimizing drug use, choice, dosing, duration, and route of administration, while minimizing the emergence of resistance and other adverse effects”. “Multifaceted and dynamic” indicates that AMS is complex, involves many elements, requires relevant knowledge, and reflects the fact that its practise is not static. The prevention of disease in animals and optimisation of drug use, choice, dosing, duration and route of administration when disease occurs is situation specific and each circumstance requires a tailored approach.

Before the development and publication of Australia’s first National AMR Strategy, various sections of the Australian animal health community, particularly those devoted to livestock, had been refining production systems to minimise disease challenge to animals. This was achieved through a collaborative relationship between farmers and veterinarians, and their efforts encompassed many of the elements of what is now described as AMS. The AMS elements have always been at the core of operations for livestock industries and their supporting veterinarians, due at least in part to the economic benefits of growing livestock that are free from disease. In many cases, the cost of treating or preventing disease with antimicrobials, and the resulting loss in productivity of a sick animal, outweighs the cost of improving biosecurity, hygiene practices and overall husbandry, which are key principles of good AMS. Therefore, no specific date can be ascribed as the ‘start’ of AMS in any livestock industry, as in many industries these principles have long been included and formalised as requirements under various quality assurance (QA) and accreditation programs.

The 5R framework for AMS

The 5R framework for AMS was developed to provide a systematic and comprehensive approach to AMS planning, implementation and monitoring, to allow a potentially complex process to be both practical and effective (Lloyd and Page, 2018; Page et al., 2014; Prescott and Boerlin, 2016; Scott Weese et al., 2013).

The AMS framework (Figure 1) includes five (5) essential components:

- Responsibility
- Review
- Reduce
- Refine
- Replace

which are described in detail in the relevant sections of this report.

'Good Stewardship Practice' describes the development, implementation and continual improvement of the AMS plan, the collaborative process between those responsible for the livestock and those responsible for supporting the health and welfare of the livestock. This includes tailoring approaches at the farm, business and enterprise levels.

The baseline and progress

The progressive introduction of biosecurity and infection prevention and control measures (including vaccination) in Australian livestock has significantly reduced the incidence of infections that require treatment. This proactive management, coupled with the limited number of antimicrobial agents available in Australia to treat bacterial disease in livestock, has resulted in the low incidence of AMR bacteria recovered from Australian pigs (Abraham et al., 2017; Kidsley et al., 2018; Obeng et al., 2014; Lee at al., 2021), meat chickens (Abraham et al., 2020; ACMF, 2018; Obeng et al., 2012a; Obeng et al., 2012b, 2014), laying chickens and their eggs (Obeng et al., 2014; O'Dea et al., 2019; Pande et al., 2015; Trott et al., 2019 Veltman et al 2021) and cattle (Barlow et al., 2015, 2017, 2020; Mellor, 2019 ;O'Dea et al 2020). The introduction of AMS programs across several of the livestock sectors provides a solid foundation for maintaining and improving the current baseline of low antimicrobial use, low incidence of antimicrobial resistance and high animal health and welfare.

Compared to most other countries, Australia has an enviable reputation for low use of antimicrobial agents and low frequency of AMR. However, there are only ad hoc systems in place to capture this information nationally, although there are efforts through the National AMR strategy to dramatically improve availability of data (Australian Government, 2020).

Figure 1. The 5R framework for good antimicrobial stewardship.

HISTORICAL AUSTRALIAN GOVERNMENT AMS EFFORTS

In 1997, Australia became one of the first nations to embark on a comprehensive process of reform aimed at protecting humans and animals from the harmful effects of AMR infections. The work of the Joint Expert Technical Advisory Committee on Antibiotic Resistance (JETACAR), which produced the JETACAR report in 1999 (JETACAR, 1999) set the scene for future efforts, and pointed out the significance of managing AMR in humans and animals as a single system. This 'One Health' concept encourages "healthy people, healthy animals and a healthy planet". In 2012, a renewed focus arose from a heightened collaboration between the Australian Government's human and animal health agencies, with improvements aimed towards aligning with the One Health approach. As a result, Australia's First National Antimicrobial Resistance Strategy 2015-2019 (2015 strategy) was released in June 2015 (Australian Government, 2015), which was followed by an Implementation Plan in November 2016 (Australian Government, 2016). The 2015 strategy recognised that, to successfully combat AMR, the community needs a broad-based effort on AMS to be simultaneously implemented across all sectors in the human healthcare and animal health systems. The 2015 strategy supports collaborative efforts to build on previous practices and implement new initiatives in the reduction of inappropriate antimicrobial usage (AMU) contributing to AMR in humans and animals.

The Australian livestock industries, and the Australian and State/Territory Governments were active participants in the implementation of the 2015 strategy, and related progress reports can be found on the Australian Government AMR website (www.amr.gov.au/resources). Subsequently, Australia released its second national AMR strategy (Australia's National Antimicrobial Resistance Strategy – 2020 and Beyond; Australian Government 2020) and a One Health Master Action Plan (OHMAP), which supports the implementation of the 2020 strategy (Australian Government, 2020). The 2020 strategy sets a 20-year vision to protect the health of humans, animals and the environment – a One Health approach. It aligns with the World Health Organization's Global Action Plan on AMR (WHO,2015), which is internationally recognised as the blueprint for addressing the global challenges of AMR. The Australian Government has historically implemented a suite of actions for supporting AMS in food-producing animals.

As Australia is a major global exporter of high-quality food products, governments and the animal health industry have a strong working partnership to manage issues of food integrity, including AMU in animals. A cornerstone of AMS involves the work of the Australian Pesticides and Veterinary Medicines Agency (APVMA) – the national agency that is responsible for registration of veterinary chemicals (including antimicrobials) for use in animals (APVMA, 2018). The APVMA strictly applies a process of scientific review for new antimicrobial products, which includes an antimicrobial resistance risk assessment to determine the possible impact of use on the health of Australians and sets risk management controls on use accordingly. This approach is uniquely conservative by global standards; wherein there are no antimicrobial products registered for use in food-producing animals in Australia that contain fluoroquinolones, carbapenems, colistin (a last-resort antibiotic for humans), or fourth generation cephalosporins. A comprehensive description of the APVMA's history and role in helping to coordinate Australia's human health and veterinary agencies to control AMR was released in 2017 (APVMA, 2017).

Complementing the national regulations are those directed at the 'control of use' of antimicrobials under state/territory legislation. These regulations govern all aspects of the supply and use of antimicrobials, including compliance with APVMA imposed restrictions. States/Territories also implement their own legislation aimed at maintaining high professional standards in animal health by ensuring only veterinarians with a current registration can prescribe scheduled substances, such as most antimicrobials. Prescription of antimicrobials by a veterinarian has been progressively implemented since the 1970s, with additional antimicrobials made prescription-only as risk assessments were undertaken over time. Historic AMS initiatives in Australia since the 1950s are outlined in Figure 2.

The commitment of the Australian and state/territory governments, along with food-producing animal industries, is demonstrated through the work of Animal Health Australia (AHA). AHA coordinates industry-government initiatives aimed at improving animal health, welfare and biosecurity. The Australian Government provides significant contributions to the annual Animal Health in Australia (AHiA) series of reports, which provide a comprehensive summary of Australia's animal health status and system (AHA, 2021). The AHiA System Report provides an overview of Australia's animal health system, the organisations involved, and key programs and arrangements in place to support disease surveillance and emergency preparedness. The AHiA Annual Report focuses on key achievements, disease investigations, surveillance activities and updates to policies and programs.

The state/territory and Australian governments are also active in supporting the Australian Veterinary Association's (AVA) efforts toward the implementation of good AMS principles for Australian veterinarians. Through various mechanisms, the AVA encourages adoption of the Guidelines for Prescribing, Authorising and Dispensing Veterinary Medicines (2013), which is overseen by the AVA (AVA, 2013). The combined effect of Australian and state/territory legislation ensures that antibiotics can only be administered to livestock when prescribed by a veterinarian and must be used according to label directions (APVMA, 2015). The use of antimicrobials, like all agricultural and veterinary chemicals, is controlled to ensure that residues do not exceed maximum residue limits in edible tissues of livestock at the time of slaughter. This requirement is monitored by the Australian Government's National Residue Survey, which was established by the Australian Government in the early 1960s (Australian Government, 1961).

Further, the Australian Strategic and Technical Advisory Group on AMR (ASTAG) was established in 2014 and is co-chaired by the Australian Government Chief Medical Officer and the Australian Chief Veterinary Officer. ASTAG is part of the broader AMR governance framework in Australia, and provides technical expert advice on AMR related issues, including the development and maintenance of the Importance Ratings and Summary of Antibacterial Uses in Human and Animal Health in Australia (Australia's importance ratings for antibacterials; ARSC, 2014; ASTAG, 2018).

The Australian Government sponsors a range of agricultural innovation initiatives aimed at improving the AMS in the food-producing animal sector. A major contribution is through financial support to the Rural Research and Development Corporations (RDCs; http://www.ruralrdc.com.au) servicing individual industries (details provided elsewhere in this document). The Australian Government has also directly funded several initiatives, including a pilot AMR survey in food-producing animals (Australian Government, 2007; Shaban et al., 2014), and proof-of-concept AMR surveys since 2015 (reports available on related industry websites). They have also supported the development of an online training program about AMS for veterinarians, which has been expanded and will be relaunched in 2021 (www.amrvetcollective.com).

Australian and state/territory governments continue to identify and prioritise opportunities for activities under the OHMAP related to improving veterinary AMS in Australia.

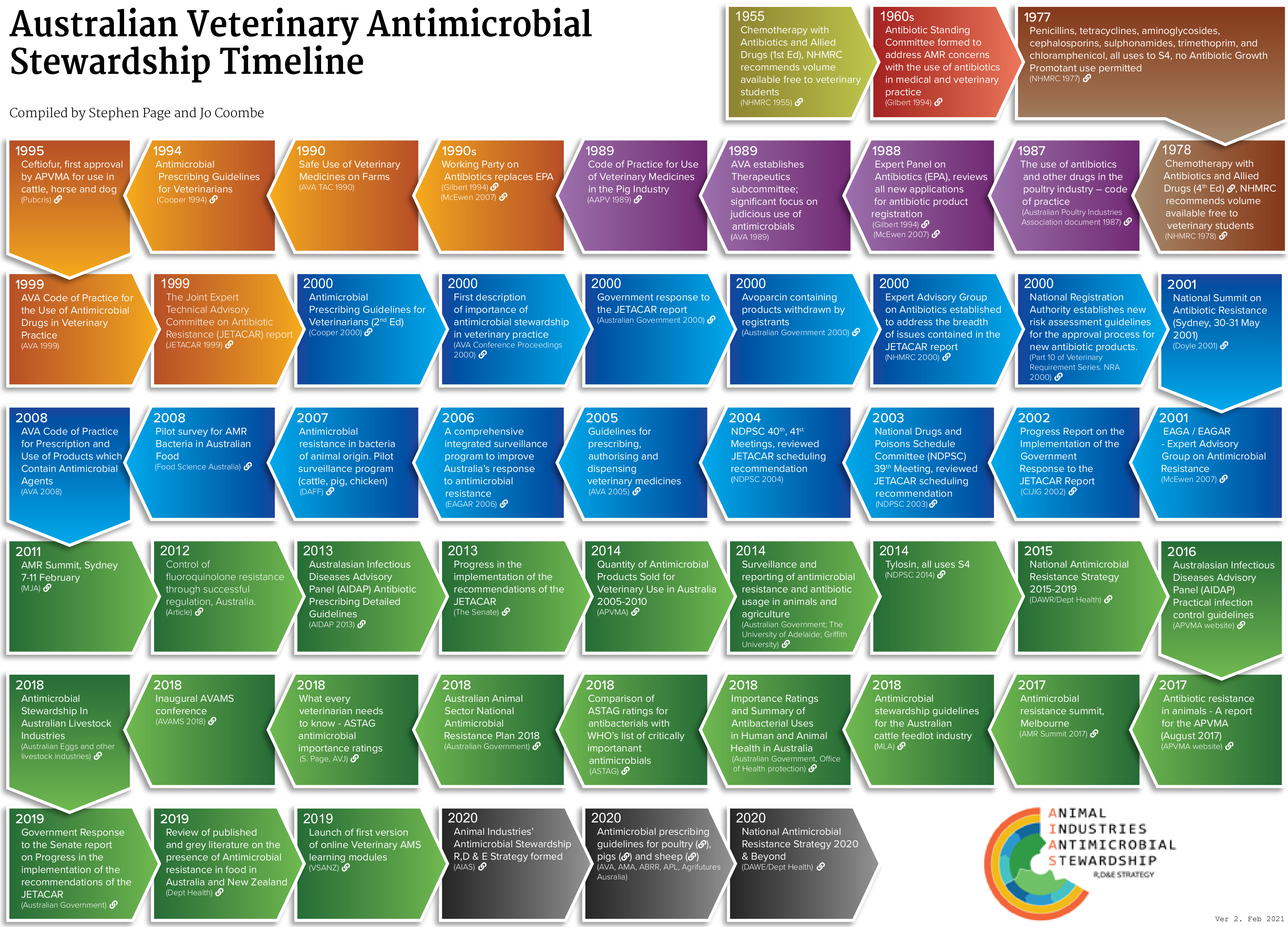

Figure 2. Key historical veterinary antimicrobial stewardship actions that have progressed veterinary antimicrobial stewardship in Australia.

THE AUSTRALIAN VETERINARY ASSOCIATION

For more than 30 years, the AVA has been actively involved in fighting the emergence of AMR through the development of factsheets and guidelines for veterinary professionals (all available, plus other resources from: https://www.ava.com.au/amr). Fighting AMR is one of the AVA's three strategic priorities. .

The AVA is an active participant in the national One Health initiatives and the implementation of the National AMR Strategy (Australian Government, 2015), and there are several aspects of the AVA's program to address AMR. The AVA's policies on the use of veterinary medicines and documents related to the management of livestock health and disease prevention can be accessed at: https://www.ava.com.au/about-us/policy-and-positions-1

Antibiotic prescribing guidelines

In 2017, the AVA embarked on a project in partnership with Animal Medicines Australia (AMA) to develop best- practice, evidence-based guidelines for the prescription of antibiotics to livestock species and horses. Thus far, guidelines for pigs, poultry and sheep have been completed (Cutler et al., 2020; Gray et al., 2021; https://www.ava.com.au/siteassets/resources/fighting-antimicrobial-resistance/antimicrobial-prescribing-guidelines-for-sheep.pdf). Guidelines for cattle (beef, dairy and feedlot) and for horses will follow.

Community awareness

The AVA has participated in Antibiotic Awareness Week since 2012 and has been represented on the national organising committee of this event since 2013. AVA's involvement will continue as a way of helping to increase understanding of antibiotic use and resistance in animals among animal owners and human health professionals.

One Health policy agenda

AVA supports the ASTAG and is part of the monitoring and implementation of the National AMR Strategy. The implementation plan includes several key projects that are managed by the AVA (Australian Government, 2016).


Australian Pork Limited

OVERVIEW OF THE CONTRIBUTING INDUSTRIES

This report provides an overview of historical and current practises relevant to AMS in each of the contributing industries and is primarily intended for the stakeholders who are interested to know how livestock industries operate in Australia. Although some industries have not contributed to this report, it does not in any way imply a lack of dedication from those industries to AMS.

Further, the volume of information supplied for each often reflects the intensity of production rather than their level of commitment to AMS. To an extent, the amount of information provided reflects the varying efforts required to manage diseases in different livestock systems.

A summary of key industry information is provided in Table 1. All details in this section have been obtained from a wide-range of resources from the relevant industry organisations.

Table 1: Key Annual statistics for the contributing industries.

Industry	*GVP ($billion)*[1]	*Livestock Slaughtered*[2] */ Litresmilk*[3] */ Eggs produced*[5] *(million)*	*Industry Representative Organisation*	*Industry RD&E Organisation*	*RD&E budget ($million)*	*Contact*
Chicken meat	2.83	666	Australian Chicken Meat Federation	AgriFutures Australia	6.1	chicken.org.au
Dairy	4.83	8.8[3]	Australian Dairy Farmers	Dairy Australia	56	dairyaustralia.com.au
Duck	0.12	10[4]	Australian Duck Meat Association	*In development*	N/A	N/A
Egg	0.88	507[5]	Egg Farmers of Australia	Australian Eggs	5.9	eggfarmersaustralia.org
Pork	1.52	5.4	Australian Pork Limited	Australian Pork Limited / High Integrity Pork CRC	9.1 / 20[7]	australianpork.com.au
Turkey	0.03	4.5[4]	Australasian Turkey Federation	N/A	N/A	turkeyfed.com.au
Beef (feedlot and pasture)	14.57	6.5	Australian Lot Feeders Association / Cattle Council of Australia	Meat & Livestock Australia	172	mla.com.au
Sheep meat	4.84	24.2	Sheep Producers Australia			

[1]ABS, May 2021 Value of Agricultural commodities produced https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/2019-20/75030DO001_201920.xlsx Duck and Turkey numbers from 2018. [2]ABS quarterly reports: number aggregated form March 2020 to March 2021 https://www.abs.gov.au/statistics/industry/agriculture/value-agricultural-commodities-produced-australia/2019-20. [3]Litres of milk; Australian Dairy Industry In Focus 2020. [4]2018 figures used. [5]Dozen Eggs produced; Australian Eggs Annual Report, 2020. [6]2020 annual reports - value of levied RD&E investment and does not include the value of RD&E undertaken within individual companies. [7] Most recent report 2018.

THE 5R'S FOR AUSTRALIAN LIVESTOCK AMS

This report highlights key efforts by each industry that contributed against each of the headings for the 5 R framework – Responsibility, Reduce, Refine, Replace, Review. This report is not designed to be comprehensive, but rather to provide avenues for obtaining further information as required by the reader of this report

Responsibility

A successful AMS plan requires a shared responsibility between the livestock producer, who is responsible for maintaining animals to high standards of health and welfare and following all directions for use and implementing associated management changes, and the prescribing veterinarian, who accepts responsibility for the decision to use an antimicrobial agent. Responsibility must also engender and promote the enthusiastic support from all levels of each organisation, including senior management, veterinarians and those working in practices, on farms and own animals (Cunha, 2018).

If producers believe that there may be a health issue on their site, they are responsible for alerting their company (if contractually obligated), their veterinarian or relevant flock/herd health management professional, and/or the relevant State Government Authority (in the case of a suspected emergency animal disease). The Model Codes of Practice for the Welfare of Animals has specific codes for each species (available from CSIRO publishing https://www.publish.csiro.au). There are provisions stating that those people responsible for livestock must take reasonable actions to ensure the welfare of the animals under their care, which includes the responsibility to understand and follow vaccination, chemical and medication treatment instructions. There are also several other obligations of producers, such as the development of livestock health plans. These Model Codes of Practice are in the process of being turned in to 'Standards and Guidelines', with 'Standards' eventually being incorporated into relevant legislation (further information available at: http://www.animalwelfarestandards.net.au/).

There is also responsibility for those that have relevant knowledge of appropriate AMS to improve the knowledge of others through various methods, such as provision of codes of practices, best practice manuals and training.

The AVA offers several further development and training opportunities for Australian veterinarians (further information available at: https://www.vetvoice.com.au/ec/veterinary-careers/continuing-professional-development).

Reduce

Wherever possible, means of reducing the use of antimicrobials should be implemented. Biosecurity measures underpin animal health and welfare and are supported by meticulous hygiene, precision nutrition, vaccination, and expert animal husbandry. The combination of these measures will ensure infectious disease incidence (and need for antimicrobials) is minimised. High order biosecurity measures and the continuing improvement of and use of vaccines provide enormous support for low use of antimicrobials (Hoelzer et al., 2018a, b).

Although reducing the use of antimicrobials is just one aspect of AMS, reducing their use is a key driver for all livestock industries. In many cases, the cost of treating or preventing disease with antimicrobials and the resulting loss in productivity of sick animals, outweighs the cost of improving biosecurity, hygiene practices and overall husbandry.

Industry specific biosecurity manuals have been developed in consultation with the Australian Government to outline the recommended minimum biosecurity practices that should be employed to prevent incursion of pathogens into the herd or flock (biosecurity manuals available at: http://www.farmbiosecurity.com.au/livestock). These biosecurity manuals require ratification by members of Animal Health Australia, which include state and Commonwealth Government representatives and representatives from many animal industries. Several, if not all, of these biosecurity recommendations are captured as requirements through various QA programs, accreditation programs and farm contracts (where farmers are contracted to supply livestock).

A greater understanding of the physiological, nutritional and behavioural requirements of all livestock species over time, coupled with the implementation of tighter biosecurity controls, has led to improvements in the prevention of disease incursion in Australian livestock, which subsequently minimises the use of antimicrobials.

Optimal genetic variation of stock is achieved through controlled breeding programs, which include consideration of the robustness and resilience of livestock to disease challenges simultaneously with quality production traits. Significant advances in assisted breeding technologies have resulted in livestock that are more resistant to illness than previous generations, and improvements in this area are continually progressing (Colditz and Hine, 2016; Hermesch and Dominik, 2014; Hu et al., 2020).

As there is no current standard measure for the quantity of antimicrobials that can be used for benchmarking, it is difficult to ascertain the extent of reduction over time resulting from the implementation of new technologies and practices. Through various legislative and commercial requirements, veterinarians (and in the instances of contract farming; the company) are required to maintain records of antimicrobial prescription and/or use. However, the completeness of this data its accessibility and the ability to consolidate it, is widely variable, as are the potential commercial-in-confidence considerations related to the data.

Refine

'Refinement' is defined as the right diagnosis and, if antimicrobials are required, the right drug, at the right time, at the right dose, through the right route, and for the right length of time. During the initial and ongoing reviews of an AMS plan, there are many elements of refinement that require attention. For example, improved detection of disease may allow earlier identification of animals for treatment, which can result in disease containment, improved animal health and potentially less ability for AMR to develop (Neethirajan, 2017; Richeson et al., 2018).

There are a limited number of antimicrobial agents with antibacterial activity that are approved for use in Australia. The agents approved for use in cattle, sheep, pigs and meat and egg laying poultry are presented in Appendix 2. Many approved agents are not used in human medicine and are not considered to present a risk of selecting AMR of significance to human health. There are very few agents approved for use in Australian livestock that are considered of importance to human health. All agents are appropriate candidates for a refinement strategy, and consideration of what constitutes appropriate use is of vital importance (Smith et al., 2018).

Australian livestock industries use diagnostic assays to detect and support confirmation of diseases in livestock. These assays are essential for evaluating whether an animal, herd or flock is suffering from viral, parasitic or bacterial diseases, and to appropriately direct antimicrobial use (i.e. not using an antibiotic to treat a viral infection). There are assays available to determine the resistance of bacteria, but they are expensive and, as such, are not often used by veterinarians to determine resistance profiles prior to prescribing or administering antimicrobials.

The growth-promoting effect of antimicrobials can arise when an antimicrobial agent is used at sub-therapeutic doses as a feed supplement in food animals. While the mode of action is not fully understood, it is theorised that by suppressing commensal bacteria (which divert nutrition from the animal), more nutrients are able to be utilised by the animal for growth/production and less energy is required for maintaining the integrity of the gastrointestinal tract (Gaskins et al., 2002).

Australian livestock industries have agreed to formalise a long-standing practice of not using antimicrobials of importance to human health for animal growth promotion purposes by progressing with the voluntary removal of growth promotion label claims from these antimicrobials (refer to the Office of the Australian Chief Veterinary Officer for more information). Antimicrobial manufacturers have removed (or are in the process of removing) all label claims for growth promotion from antimicrobials important for human health.

Application of antimicrobials is a key area for refinement of use and in most cases are administered via feed or drinking water. Antimicrobials are often administered through feed to allow mass medication of large numbers of animals and to achieve uniform distribution of medication throughout the herd/flock. It is also suitable for long-term medication, such as coccidiosis control.

Medicating via feed also removes the risk of error and omission when dispersal is dependent on a farm worker administering medication in the water on a frequent (once or twice daily) basis. Medicated feed does have its limitations; it cannot be implemented quickly enough to treat rapidly spreading, or fast onset diseases.

Implementation and cessation of medication can also be difficult to manage to avoid cross contamination when medicated and unmedicated feed may be stored sequentially in the same silo. Water medication is also very useful for administering antimicrobials to large groups of animals, and it allows for better refinement of the treatment than feed medication because the decision to medicate can be made and implemented quickly and terminated more rapidly. A disadvantage of water medication is that sick animals often reduce or stop water intake, therefore, there is the risk that sick animals do not receive adequate medication for successful treatment. Not all antimicrobials are able to be administered via the water.

The prescribing guidelines being developed by the AVA (described in later sections) will support livestock industries to further identify areas of possible refinement of antimicrobial use for disease prevention and treatment.

Replace

There is substantial national and global interest in finding non-antimicrobial approaches to support the continual health and welfare of animals. It is important that any measures taken to replace antimicrobials are based on sufficient evidence of effectiveness and safety in order to avoid unintended adverse consequences. Economic viability is an important consideration in livestock production where small profit margins are common.

A significant focus in Australian livestock is on the development of vaccines to reduce disease incidence, as vaccination and improved hygiene and biosecurity is more cost effective than managing disease, disease- related productivity declines and welfare issues. Apart from vaccines, other alternatives to antimicrobials that are the subject of active investigation are enzymes (Hassan et al., 2018; Rathnayake et al., 2021), phytochemicals (Lillehoj et al., 2018; Tedeschi et al., 2021), microbial products (Seal et al., 2018) various immunoglobulins and host defence peptides (van Dijk et al., 2018; Mookherjee et al., 2020), products containing essential oils and feed additives containing short and medium chain fatty acids. These alternative products, including those that aren't classified as medications, are regularly trialed on-farm to determine efficacy as a replacement for the prevention or treatment of livestock diseases. The extent of this type of trialing is dependent on the individual producer/company and is often not publicly reported.

Vaccines are the primary focus for livestock industries for limiting the impact of animal disease and are therefore central to livestock AMS. Vaccines can be 'live', 'inactivated' or 'attenuated', and may also be from strains of bacteria that are from the farm itself ('autogenous') that are then supplied back to animals on that farm only. Australian livestock often require vaccines specific to strains of pathogen present in Australia (due, in part, to Australia's geographic isolation). There is a relatively small market for those vaccines in Australia, and an inability to cost-effectively sell small volumes of vaccines (for smaller producers to access). Australia's strict quarantine requirements, designed in part to protect Australian livestock from diseases prevalent overseas, also limit the supply of vaccines to the Australian livestock sectors. Although RD&E funding organisations are continually investing in efforts to develop additional vaccines, it can be cost-prohibitive to commercialise vaccines that are effective in Australia only.

Industries work with the regulatory authorities to help reduce the time between development of a vaccine candidate and registration of a product available for use in industry and help to gain access to vaccines that may be available overseas. The PUBCRIS (Public Chemical Registration Information System; https://portal.apvma.gov.au/pubcris) database can be searched for current and historical information, including registration dates for vaccines available for Australian livestock. A comprehensive list of vaccines available is presented in Appendix 3. Autogenous vaccines may also be produced and administered under permit to prevent known local diseases (details available at https://portal.apvma.gov.au/permits). Vaccines are widely used where possible and recent technological advances may mean that more diseases can be controlled by vaccines in the future.


Australian Eggs

Review

'Review' involves recording and regularly reviewing effectiveness of AMS practices, including the quantity and quality of antimicrobial use when required, and using a selection of the most appropriate metrics or descriptors to ensure that antimicrobial use practises reflects best practice (Collineau et al., 2017; EMA and ESVAC, 2017; Harbarth and Hackett, 2018; Le Maréchal et al., 2018; Monnier et al., 2018; Versporten et al., 2018). In addition, an appropriate AMR surveillance program provides important guidance on progress and outcomes, and the relevance of AMS plan objectives (Jee et al., 2018; Simjee et al., 2018).

The AMS review process can take several different forms and includes the continual review and acknowledgement of improvements made through industry QA and other third-party QA accreditation programs, particularly components that relate to health, hygiene and husbandry. All livestock produced in Australia have state legislative requirements, as well as various requirements for QA depending on consumer and market requirements and, in most instances, there are industry-wide voluntary QA programs. All these approaches to QA and auditing require that accurate and detailed records are kept, including any medications administered to the livestock and production details; this provides numerous opportunities for review of antimicrobial use practises. There are currently no nationally adopted metrics for reporting quantity or quality of antimicrobial use in Australian livestock, and previous information available has been based on antimicrobial sales data (APVMA, 2014).

Surveillance for AMR in commensal bacteria supports AMS by providing information on the effectiveness, or otherwise, of various interventions. Several surveillance studies have been undertaken for various industries since the early 2000s and continue to be repeated, though usually with slight alterations as methodologies and economies for AMR testing improve. Some of these studies cover several livestock species (Australian Government, 2007), Australian pigs (Abraham et al., 2017; Kidsley et al., 2018; Obeng et al., 2012a), meat chickens (Abraham et al., 2020; Obeng et al., 2012a; Obeng et al., 2012b, 2014), laying chickens and their eggs (Obeng et al., 2014; O'Dea et al., 2019; Pande et al., 2015) and cattle (Barlow et al., 2015, 2017, 2020).

THE AUSTRALIAN PORK INDUSTRY

THE AUSTRALIAN PORK INDUSTRY

The size and geographic location of Australian pig farms vary due to a range of factors, including climate, the availability and price of feed, environmental permits/ licences, the demand and type of pork imports, currency fluctuations, and competition from other meat products. As of 2018, the Australian pork industry consists of approximately 400 producers that supply 90% of the total domestic production. A conservative estimate of pig holders outside of the commercial system is 1500-2000.

The size of pig farms vary from small, peri-urban operations to large, vertically integrated operations that can house tens of thousands of pigs on multiple farm sites linked by an overseeing company. Pigs may be reared indoors in conventional penned housing, or in deep-litter sheds. Outdoor pig units are where the animals are raised in paddocks or pens, operate in smaller areas, and generally supply niche markets. Semi-intensive piggeries keep dry sows (those with no piglets and not lactating) outside, and the mating and growing portions of the piggery are kept inside.

About 90% of the Australian sow herd is produced under the Australian Pork Industry Quality Assurance Program (APIQ✓®). To comply with APIQ✓®, each farm must have a herd health program and a consultant pig veterinarian that oversees all medical treatments.

Live pigs and any pig genetic material (e.g., semen for breeding purposes) are not allowed to be imported into Australia, however, approximately 300,000 tonnes of pork are imported annually from several countries, which has steadily increased as amended quarantine arrangements allow for imports to be sourced from more international suppliers. Under current arrangements, all imported pork must be cooked in Quarantine Approved Premises regulated by DAWE to comply with requirements of the Pork Import Risk Assessment and manufactured into processed meat products. Up to 70% of the ham, bacon and smallgoods produced in Australia are made from imported pork.

Responsibility

The frontline antimicrobial stewards for the Australian pork industry are the private and corporate veterinarians employed by, or working with, Australian pig producers. These veterinarians are required to be registered, and many are also members of the Australian Veterinary Association and the Australian Pig Veterinarians (APV), a special interest group of the AVA. Any use of antimicrobials in the Australian pig industry can only occur under the guidance and direction of the farm veterinarian. Pig production enterprises must have a consultant veterinarian and a herd health plan under the industry quality assurance program APIQ✓®, which underpins health management on most Australian pig farms.

Australian Pork Limited (APL) has developed a number of supporting documents for optimal pig husbandry in Australia, including the Companion Handbook to the Model Code to support the Model Code of Practice for the Welfare of pigs (APL, 2013b). APL has also produced the 'Care of the Compromised Pig' manual (APL, 2013a) to assist producers in the early identification and treatment of pig health issues in addition to training through various registered training organisations and APL initiatives, which include training (at various levels) in identification, management and reporting of exotic and endemic diseases to minimise the risk of disease spread.

In addition, supervisors and staff working as stock-people on piggeries hold a Certificate III in Agriculture – Pig Production, or equivalent, which includes training for competency in maintaining the health and welfare of the pigs in their care.

The publication in 2019 of the "Antimicrobial prescribing guidelines for pigs" funded in part by APL, Animal Medicines Australia and the Australian Government can be found on multiple websites including the APL site (Cutler et al., 2020). The guidelines, produced as an aid to veterinary prescribing practices, were the first amongst the animal industries to be produced but have now been joined by others.

Following these guidelines, APL sponsored the visit to Australia of Dr Mandy Nevel, leader of the UK AHDB antibiotic use group across cattle, sheep, and pigs. Dr Nevel presented papers on AMS at the APV AGM in 2019, and to groups of producers in each state. As a direct consequence of this, some Australian producers have tested the AHDB antimicrobial use recording software but have found that it needs adapting to the medications available locally.

SunPork Farms, a large integrated producer, has successfully used the number of daily doses per 100kg finisher pig as their unit of measurement. Others have access to farm recording systems that record individual treatments. In addition, an App, "Data Pig", has been developed by APIAM Pty Ltd, a listed animal health services company for the purpose of recording antimicrobial use. Pork producers are positive about the need to reduce antimicrobial usage.

Reduce

Many pig diseases are highly contagious and can be easily spread by a variety of vectors, and as most pig herds consist of pigs of varying ages, good biosecurity is critical. To this end, biosecurity is a stand-alone module in the industry's QA program, APIQ✓® (Module 4), and biosecurity performance indicators are also included in several other modules. New diseases or disease-causing agents of significant importance can be established in a herd through the introduction of new stock or semen to breed new stock, and biosecurity requirements also include management of these risks. The pork biosecurity manual, which was updated this year is available at: http://www.farmbiosecurity.com.au/ industry/pigs.

APL and its predecessor, the Pig Research and Development Corporation, invested considerable resources to gain a greater understanding of the risks to the Australian pig herds' biosecurity (information available from annual reports at: http://australianpork.com.au/library-resources/publications/annual-reports). APL have also established a micro-site specifically dedicated to consolidating information regarding biosecurity and the maintenance of a high-health-status pig herd in Australia (https://keepingourpigssafe.com.au). The Australian pig industry's biosecurity endeavours have been greatly enhanced by the formation of the APL Biosecurity Strategic Review Panel, whose members are authorities in this field within, and outside, of the industry.

There are a small number of commercial breeder organisations in Australia that specialise in the development and distribution of commercial pork genetics within Australia. The Pork Cooperative Research Centre had an entire sub-program devoted to developing and implementing robust pork genetics, with a focus on breeding healthy, resilient and robust pig herds (further information can be found at: sub-program 2B; http://porkcrc.com.au/research/program-2). To further manage health and biosecurity, semen is often brought onto a farm to inseminate the sows for breeding, as opposed to bringing in new animals to a herd, which has a high risk of directly introducing disease.

The Australasian Pig Research Institute LTD (APRIL) is co-funding a project to improve resilience in piglets through a nutritional strategy, with the aim of eliminating the need for antimicrobials (https://apri.com.au/research/current-projects/).

Refine

The Australian pork industry allocated resources through the High Integrity Australian Pork CRC and the APL to target specific areas focused on further refinement of antimicrobial use. Research outcomes have provided the platform for adoption of systems to improve management and, subsequently, the health and welfare of the pigs. The Pork CRC specifically invested in the development and refinement of diagnostic assays for Australian pigs and chickens (further information can be found at: http://porkcrc.com.au/research/program-2) and helped to implement these diagnostic assays in laboratories that support the pig industry and confirm disease treatment.

A recently completed APL project reviewed and standardised the efficacy of bacterial isolation and AMR methodologies in various laboratories that service the pig industry, to ensure that techniques and methodologies are consistent across the various labs so that comparisons can be made.

Many trading partners are either legislating, or have legislated, against the importation of pork products that have been produced with the use of growth promotants, however, their use has been phased out voluntarily in the Australian pig industry and antimicrobials are only used to prevent and treat disease. Generally, the conditions that commonly require antimicrobials in pigs are enteric and respiratory diseases, which can lead to considerable pig morbidity and mortalities.

Replace

Prior to the early 1980's, there were no vaccines available for some of the most common enteric and respiratory diseases in Australian pigs. Producers relied on antibiotic treatment and replacement fluids, and the efficacy of feed-back methods (a crude type of oral vaccination) was variable. Vaccine development for pigs was initiated in the early-mid 1980's and the impact on preventing disease was significant.

The Australian industry has access to commercial vaccines for many of the common pig diseases, including porcine circovirus associated disease, ileitis, parvovirus, leptospirosis, erysipelas, and the respiratory diseases enzootic pneumonia and pleuropneumonia. Despite access to a vaccine, pleuropneumonia has proven difficult to control, even with the use of autogenous vaccines, and as such, there have been ongoing investments to develop more effective pleuropneumonia vaccines and the identification of a vaccine candidate for swine dysentery. There are also ongoing investments in the development of more effective vaccines against bacterial and viral pathogens and the viability of alternative treatment options, such as the use of pre- and pro-biotics, bacteriophages, water/feed supplements, disinfectant fogging (to reduce bacterial loads in the environment) and organic acids that may not demonstrate antimicrobial action but improve gut health and function.

Different management systems have replaced traditional systems in an effort to better manage pig flow to reduce disease transmission between and within pig batches and housing cleanliness, and consequently, reduce antimicrobial use to treat bacterial diseases. These all-in/all-out systems of management can result in significant health improvements as they minimise transfer of pathogens from older to younger pigs, which assists in the maintenance of health status, however, these systems are not always economically viable and may not be adopted by all producers.

Review

The voluntary industry quality assurance program, APIQ✓®, was developed and implemented in the 1990s and is the vehicle for many practises that safeguard the health and biosecurity of Australian pig herds. APIQ✓®certification allows pork producers to demonstrate their compliance with state and federal laws relating to food safety, animal welfare, biosecurity and traceability, and includes many elements of pig health. APIQ✓®has annual minor and major reviews every four years and export abattoirs only accept pigs that are APIQ✓® certified. APIQ✓® has transitioned to independent, or third-party, auditing. For an APIQ✓® certification to remain current, a producer's site/s must have an annual APIQ✓® Compliance Audit prior to the expiry of their certification, to have their APIQ✓® Certification approved for renewal. A significant aspect of compliance is an internal audit or review, which must be conducted approximately every six months and includes the review of on-farm manuals and records to ensure their systems remain current and are compliant.

Surveillance projects for the detection of AMR in bacteria from Australian pigs have been ad hoc and are summarised in the review by Abraham et al (2017). While only some AMR bacteria of concern have been identified, the results are favourable when compared internationally, and the industry is actively taking steps to address issues identified. The elements of the pig industry's AMS program have already been voluntarily adopted by several producers and integrated into standard business operations.

An AMS resources package has been developed and is undergoing testing on farm before wider release to veterinarians to use with their customers in 2021.

A Murdoch University based team has recently published evidence that enterococci from Australian finisher pigs are not a source of resistance to critically important antimicrobials (ie vancomycin resistant enterococci VRE) and that E. faecium from pigs is not part of the current hospital adapted population (Lee at al., 2021). The increasing prevalence of antimicrobial resistance in hospital adapted VRE over the last three decades is often considered to originate from livestock. Enterococci are ubiquitous opportunistic pathogens and in hospital settings have become a major global public health issue. While acting as opportunistic pathogens, invasive infections range from mild to life threatening sepsis. Although international studies have observed some genetic similarities between enterococci of human and livestock origin and evaluated the possibility of zoonotic transmission, robust evidence of this occurring has been sparse. This study compared contemporary pig, poultry and human hospital derived enterococcal strains. Some antimicrobial resistance was observed in the pig strains, including to tetracycline, erythromycin, ampicillin and gentamycin, however, resistance to the critically important antimicrobials vancomycin, teicoplanin, and linezolid was not found in enterococci collected from Australian finisher pigs. The results indicate that Australian finisher pigs are not a source and reservoir of hospital-adapted E faecium in Australia and the Australian pig strains remain susceptible to important antimicrobials used to treat enterococci infections in humans.

THE AUSTRALIAN POULTRY INDUSTRIES

THE AUSTRALIAN POULTRY INDUSTRIES

The Australian chicken meat, duck, turkey and egg industries are separate from each other, with their own industry representative organisations and RD&E arrangements.

The poultry meat industry is vertically integrated, and the farmers are predominately contractors to the processing companies who own the poultry. This relationship means that the processing companies are directly responsible for the farm inputs that are related to the poultry, including the feed, animal health, management advice, animal welfare standards and chicken harvesting. Flock health in the poultry meat companies is always managed by at least one registered veterinarian with expertise in poultry, who oversees and manages disease surveillance and prevention through biosecurity, vaccination and other integrated disease preventative strategies. The registered veterinarian is also responsible for disease diagnosis and treatment, including the administration of antimicrobials, for all contract, company and breeder flocks.

The scale of production in the Australian egg industry is varied and ranges from large, integrated, multi-system producers, through to a large number of small to medium-sized operators, plus small niche producers. In Australia, there are cage, barn and free-range egg production systems. Organic egg production is a niche segment within the free-range farming sector. Hens can lay at approximately 18 weeks of age and are in production until 80 weeks of age. Some larger egg producers employ a registered veterinarian with specialist expertise in poultry, who oversees and manages disease surveillance and prevention.

Very few countries have been able to meet the strict protocols for importing poultry products into Australia, and as a result, few poultry products are approved for importation into Australia. No live poultry or shell eggs that are intended for human consumption are imported into Australia, and any egg products that are imported are either preserved, cooked, pulped or in powder form.

Apart from chicken products imported from NZ, the only other poultry meat products currently imported into Australia are small volumes of processed chicken, duck or turkey meat products that have been fully retorted (i.e. cooked to high temperature in their container), such as in some canned foods, soups or animal feed. Over the last few years there have been steady imports of retorted bone out duck meat, century duck eggs, and of recent times imports of duck blood, salted and cured duck egg yolks have begun to enter the Australian marketplace. Furthermore, it is anticipated that a “cooked rather than retorted” bone out duck meat will soon be imported for the ready to eat market. Undoubtedly the increasing demographic of Asian consumers is stimulating the demand for more diverse duck products, many of which were not traditionally available in significant volumes in the Australian market.

Poultry genetic stock for the chicken meat, egg, duck and turkey industries is imported as fertile hatching eggs that undergo strict quarantine protocols, which includes fumigation of the eggs and testing for various pathogens in the overseas donor flocks. The fertile eggs are hatched out in licensed, registered quarantine stations in Australia and the chicks hatched from them are subject to rigorous testing for key pathogens before being released to highly biosecure breeder farms.

The Australian chicken meat industry is dominated by six companies that supply the bulk (approximately 90%) of domestically produced chicken meat. Meat chickens reach processing age at between 5 – 7 weeks of age, in either barn or free-range production systems.

All meat chickens are grown on the floor of large barns that are either climate-controlled or naturally ventilated. The chicken meat production system is ‘all-in/all-out’, which means there is a period between flocks when the sheds are emptied, cleaned and sanitised. This breaks the pathogen cycle and minimises the proliferation of bacteria and transfer to subsequent flocks.

The two largest meat chicken processors also produce the bulk of Australian turkey meat, alongside several smaller turkey companies that breed, grow and process their own flocks. Turkeys reach processing age from eight weeks of age.

The Australian duck meat industry is dominated by two large companies and two smaller enterprises, which supply the majority of domestically produced duck meat. Ducks are raised to approximately 7 weeks of age on the floor of large barns that are usually naturally ventilated with some tunnel-ventilated.

Responsibility

Veterinarians

Antimicrobial stewards for the poultry industries are the veterinarians employed by, or working with, the poultry companies that operate in Australia. Australian registered veterinarians that have specialist expertise in poultry and are engaged in the management of the commercial poultry industries are members of the Australasian Veterinary Poultry Association (AVPA) and/or the Commercial Poultry Veterinarians (CPV), the latter being an AVA special-interest group. Australian poultry veterinarians have a long, documented history of embracing the principles for the appropriate use of antimicrobials.

Their most recent code of practice, 'AVPA Code of Practice for the Use of Antimicrobials in the Poultry Industry, 2021 Edition' has recently undergone a complete review, but the original version was produced in 1987 (APIA, 1987). The current version of this document has been revised to reflect changes in legislation, and incorporate the recommendations of the AVA Prescribing Guidelines for Poultry which were released in 2020 (Gray et al., 2021).

The poultry industries and the AVA jointly developed a "Code of Practice for the Use of Prescription Animal Remedies (Schedule 4 Substances) in the Poultry Industry" (further information can be found at: http://www.ava. com.au/policy/26-code-practice-use-prescription-animal-remedies-schedule-4-substances-poultry-industry), which was ratified by the AVA in 2005.

From 2018, the 'Model Code of Practice for the Welfare of Animals: Domestic Poultry' (PISC, 2002), is being revised and rewritten into Standards and Guidelines (expected to be released in June 2021), which includes requirements for adequate husbandry and disease prevention strategies to reduce the incidence of poultry diseases in Australian poultry flocks.

Poultry breeders

There is clear recognition that the use of antimicrobials in flocks and hatcheries at the top of the 'breeding pyramid' may affect the characteristics of the microbiological populations of subsequent, much larger, generations of poultry.

The operations involved in supplying poultry genetics to the commercial Australian market are either owned by, or directly associated with, international breeding companies. The primary poultry breeding operations in Australia employ veterinarians that are directly involved in the overall management of the breeding stock and who are responsible for prescribing and overseeing the administration of all antimicrobials used in poultry breeding operations. Veterinarians are given independence in decision-making related to antibiotic use and are supported by local and international company management.

Poultry meat industries (chicken, duck and turkey)

Due to similarities in the vertically integrated structure of the chicken meat, duck meat and turkey meat operations, there are a small number of skilled veterinarians responsible for the flock health programs and stewardship in the poultry meat industries. This has allowed, and continues to facilitate, prompt improvements made to poultry management when new evidence is supplied to support change in practices. As part of the contractual arrangements, poultry meat farmers are required to adhere to company specified practices (these are commercial-in-confidence) and there are often financial penalties to farmers whose flocks experience an increase in mortality or morbidity. Flock supervision and monitoring must adhere to company policies, procedures and industry manuals, with implementation and progress monitored by company representatives, including the veterinarians, during frequent farm visits. In-house training is provided for farmers and company service personnel and livestock managers on early disease identification and optimising husbandry and biosecurity for each farm.

In 2017, the chicken meat industry formalised an AMS plan that was implemented in the companies that produce approximately 90% of the chicken produced in Australia. This plan was tailored to operations within each of the companies and an independent review of these programs in 2019 found that the six major chicken companies have either a mature, robust animal health or AMS program in place that apply appropriate use and AMS principles and are subject to regular review.

The egg industry

There are a few large producers in Australia that supply the bulk of fresh egg products consumed domestically and as a result, there is only a small number of skilled poultry veterinarians responsible for the health and stewardship of antimicrobials in layer hens. These producers either employ or contract to skilled poultry veterinarians for veterinary and flock health management advice. Similar to the chicken meat industry, strict company policies and practices are developed to ensure flock health is monitored and optimized. Responsibility for antimicrobial stewardship remains with the veterinarian. However, for the niche and small-to-medium sized producers, access to a poultry veterinarian may not always be possible or affordable, which means they may access general practice veterinarians to manage the health of their flocks, even though only registered veterinarians can prescribe antibiotics.

Australian Eggs Ltd has developed the 'Antimicrobial Stewardship Framework (a guideline for veterinarians and the egg industry)', which was released and rolled out to key producer and veterinary stakeholders in early 2020.

Reduce

Prevention of disease in poultry flocks is paramount. Since the 1980s, there has been ongoing work to better understand poultry diseases, define biosecurity controls, improve precision of nutritional management and develop and implement extensive flock vaccination programs (Appendix 3). This has resulted in a significant reduction in the incidence of respiratory and gastrointestinal diseases that could otherwise require treatment or prevention with antimicrobials. As a consequence, there has been a reduction in the overall use of many antimicrobials in poultry production. The growth in free-range farming practices means that there is an increase in poultry with greater exposure to environments that may contain pathogens, which has resulted in the re-emergence of some diseases that sometimes require treatment with antimicrobials, when other preventative or treatment options fail or aren't available.

The National Farm Biosecurity Manual for Poultry Production outlines the minimum recommendations for biosecurity that capture risks relevant to all poultry operations (further information can be found at: http://www.farmbiosecurity.com.au/livestock/), and the chicken meat, egg and duck industries have each developed industry specific biosecurity manuals that were updated between 2018 and 2020.

Disease prevention, through biosecurity, optimum nutrition, vaccination and improved husbandry procedures have been, and continue to be, key to ensuring production of healthy poultry without being excessively cost prohibitive.

Primary poultry breeders and hatcheries

Whenever possible and viable, methods of reducing the use of antimicrobials have always been assessed and implemented by poultry breeders. There is an emphasis on stringent, audited biosecurity throughout the poultry primary breeding industry internationally, and particularly in Australia where all new poultry genetics is imported. This aims to prevent the introduction of exotic diseases and endemic agents that may cause disease within valuable genetic flocks, which can significantly impact on the availability of commercial poultry for production.

Access to primary breeding operations is strictly controlled and all material inputs undergo risk assessment before coming into contact with flocks. Through biosecurity and flock monitoring, the primary Australian breeding industries have become free of agents that had previously been controlled with antimicrobials, such as Mycoplasma species, which is considered a significant achievement.

Hygiene on farms and in hatcheries must be of a standard that can reduce the contamination and challenges encountered by newly hatched chicks. For example, hatching egg hygiene on-farm must include clean nest boxes, dry, friable litter, clean egg belts, hand washing, and clean and disinfected storage facilities to ensure the highest hygiene standards in the hatchery. Fumigation of eggs, cleaning and disinfection of hatchery equipment and personal hygiene of staff that handle newly hatched chicks are all standard in primary breeding hatcheries. In 2017/18, two of the largest primary breeding companies in Australia invested heavily in new hatchery buildings and technology, with the aim of improving hygiene and reducing early chick mortality.

Continual improvements in the genetics of poultry breeds are controlled and undertaken by international nucleus breeding companies, to produce an immunocompetent, robust hybrid bird at the commercial production level.

This is coupled with refined management practices to significantly reduce the incidence of disease and, therefore, the need for antimicrobials over time.

Poultry meat industries (chicken, duck and turkey)

Poultry meat farmers are required to adhere to the relevant National Biosecurity Manual as part of their contractual obligations with the processing companies and various auditing requirements.

Commercial operations have always continually assessed operations to identify areas for improvement in biosecurity and disease prevention, in order to ensure healthy and productive poultry. This has reduced the need for treating, or routine prevention of, illness in the poultry meat industries with the use of antimicrobials. This is particularly important as the structure of the industries changes to consolidate operations into fewer, larger farms.

The evolution of improved duck drinking systems (nipple drinkers) and the reduced use of troughs and surface water has had a profound impact on the incidence of bacterial disease in growing ducks, with similar impacts on fertile egg hygiene and embryonic survival. High standards of endemic disease control have reduced the number of significant disease incursions since 2012.

The egg industry

Improvements in husbandry and continual upgrades in housing have reduced the need for antimicrobials in egg production. However, the recent growth in free-range and cage-free farming has resulted in the re-emergence of some diseases, such as fowl cholera, colisepticaemia, erysipelas and spotty liver disease (SLD), which has been identified as caused by a new aetiological agent, Campylobacter hepaticus (Van et al., 2016). These diseases require treatment with antimicrobials where relevant, and when other preventative or treatment options are not available, or appropriate. Significant progress has been made towards the development of new and improved vaccines against these bacterial pathogens, ensuring that antimicrobial usage will be trending downwards against these diseases.

Refine

For most of the poultry meat and eggs produced in Australia, routine diagnostic testing is performed to inform veterinary treatment of flocks that are demonstrating clinical signs of bacterial disease. More than 25 molecular and/or diagnostic assays are available at private, in-house and public veterinary diagnostic laboratories to support the diagnosis of avian diseases present in Australia (an example list of diagnostics can be found at: https://fvas.unimelb.edu.au/__data/assets/pdf_file/0010/2860804/APCAH-Customer-Commercial-Price-List-PCR-and-Serology-FEB-2018-v.2.pdf). There is extensive collaboration across the poultry industries for on-going investments in research to provide rapid, effective typing for avian diseases.

As part of the commitment to judicious antimicrobial use, the Australian poultry industries reviewed the efficacy of AMR methodologies in the 1980s to ensure that AMR detection and surveillance approaches are consistent (Whithear et al., 1986). Since then, there has been greater alignment of techniques used by industry laboratories for detection and reporting of AMR, although improvements can still be made. As such, current RD&E investments aim to further align the bacterial isolation and characterisation methodologies across public and private laboratories that support the poultry industries.

A review of the testing capacity for AMR in laboratories servicing the Australian chicken meat industry was completed in 2020. The aim of this review was to determine if the possibility existed to develop a framework for future AMR surveillance and diagnostics using existing capabilities and to identify areas that require further support.

Primary poultry breeders

The use of antimicrobials in the Australian primary poultry breeding industry is tightly controlled and can only be administered after investigation and diagnosis by a registered veterinarian. When possible, medication will only be administered after a culture and sensitivity assay is performed to ensure the antimicrobial used will be effective. Records of all treatments are completed.

Poultry meat industries (chicken, duck and turkey)

The Australian Chicken Meat Federation (ACMF) established a policy in 2007 that antibiotics should not be used for growth promotion purposes, and has been actively working with the product registrants since then to have growth promotion claims for chickens removed from labels (ACMF, 2021). There are currently two products that remain registered for use in poultry that have growth promotion claims, however, neither of them are used in human medicine. One of them is not available for sale in Australia, and the other is occasionally used to treat enteritis when other preventative and treatment measures have failed to control disease.

The chicken meat and turkey meat industries generally use in-feed medication for the prevention of common diseases, such as coccidiosis and necrotic enteritis, which are highly likely to be present in a flock. Water medication is generally used for treatment of diseases post-diagnosis by a veterinarian. Due to the short production cycle, there are regular opportunities to trial refinement of preventative therapies, whether using antimicrobials or other products.

Almost three quarters of Australia's meat chickens are produced under veterinary health programs in which diagnostic tools are always used to confirm bacterial infection to inform veterinary treatment of flocks demonstrating clinical signs of bacterial disease. The majority of chickens produced in Australia are grown without the preventative use of categories of antibiotics that have a use in humans.

Disease prevention and refinement of antimicrobial usage are the predominant drivers to producing healthy turkeys without being excessively cost prohibitive. Focus on hygiene, management and biosecurity are key underlying measures to prevent disease in turkeys, and the industry continually refines the use of the few tools available to support health management in turkey flocks.

The availability of autogenous vaccines for Riemerella and Pasteurella, plus the adoption of dry production systems with good shed litter management, has enabled antimicrobial use to be almost eliminated in duck production in Australia. Treatments are generally only used in response to a disease outbreak and in these cases, the limited therapeutic treatments for ducks are conventionally provided by water medication. For most duck meat produced, routine diagnostic testing is performed to inform veterinary treatment of flocks displaying clinical signs of disease. Antimicrobial susceptibility testing is undertaken where available. The ongoing improvements in control of bacterial disease in duck production by improvements in the understanding of husbandry and nutritional triggers, has resulted in the proposals for some antimicrobial free production and marketing strategies, that seem likely to occur in the short to medium term.

The poultry meat industries endeavour to continuously assess gaps in disease prevention and determine areas where improvements in biosecurity can be made to reduce the introduction and spread of pathogens. These industries have made, and continue to make, investments into improving biosecurity with the aim of reducing the introduction of pathogens and therefore the need for treatment or preventive uses of antimicrobials to manage disease in meat poultry flocks.

The egg industry

There is a very limited range of antimicrobials registered for use in laying hens in Australia. There are different antimicrobials that can be used for prevention or treatment of disease depending on whether the hens are laying or are in the weeks prior to coming into lay (termed ‘pullets’). The reason for this is to prevent potential antimicrobial residues in the eggs, as only antimicrobials with a nil withholding period for eggs can be used on hens during lay.

Effective biosecurity, nutrition, vaccination and husbandry are crucial to ensuring a high health status for hens to reduce the number of preventative treatments required.

The egg industry supports projects in collaboration with the APVMA and other regulatory authorities, to allow the registration of antimicrobials that are widely used internationally but not currently registered for use in the Australian layer industry. This is to ensure the health and welfare of hens and help refine, or remove, the use of antimicrobials that are of importance to human medicine.

Replace

The Australian poultry industries have a long history of collaboratively identifying, developing and implementing alternatives to antimicrobials. There is increasing use of alternative therapeutic options, such as probiotics, prebiotics, organic acids and other feed supplements that aim to improve gut health by modifying the intestinal microbiota. However, the focus for disease prevention has historically been, and continues to be, high standards of biosecurity coupled with the use of vaccines.

Vaccines available in Australia for the prevention of poultry diseases are outlined in Appendix 3, along with Riemerella and Pasteurella vaccines in ducks. Autogenous vaccines are also used. Vaccine use is dependent on the risk of infection in the region where the poultry are raised, and in some cases, an industry may vaccinate every chick hatched nationally (e.g. Mareks Disease and Infectious Bronchitis in the egg industry). Vaccines are applied either directly to commercial poultry or to breeder stock, to build adequate early immunity and to break the cycle of infection. Many vaccines are used in the primary breeding stock due to the high nationally significant economic repercussions of disease in these flocks.

Prior to the development and implementation of many of the currently available poultry vaccines, chronic respiratory disease complexes were the greatest source of economic loss due to disease in poultry, along with the secondary bacterial infections that required treatment with antimicrobials (Delaplane and Stuart, 1943; Bagust, 1989; Miflin and Blackall, 1998). In response to this challenge, the Australian poultry industry funded the development of vaccines to prevent mycoplasma-associated diseases (Whithear et al., 1990), which has meant macrolide and pleuromutilin antibiotics are rarely indicated or required in Australian poultry industries. These vaccines are now used internationally. The Australian poultry industries have invested in the development and licencing of a vaccine candidate for necrotic enteritis (caused by Clostridium perfringens infection), which looks promising and, if it results in a commercially viable product, implementation would significantly reduce the need for some preventative antimicrobial use in Australia and internationally.

The poultry RD&E and industry representative organisations work with the vaccine supply companies through various industry and state government groups, to ensure there are viable and sustainable options available for preventing disease in poultry. There are also additional candidate vaccines currently going through the commercialisation and registration process, and continued investment from the R&D funding organisations and veterinary vaccine companies into improving the efficacy of current vaccines.

Poultry meat industries (chicken, duck and turkey)

Improved vaccination strategies have reduced antimicrobial use over time, as they help to protect more poultry more effectively, through the prevention of immunosuppressive diseases (such as Marek's disease, chicken anaemia virus and chicken infectious bursal disease) and the accompanying secondary bacterial infections or vertically transmitted diseases (e.g. Mycoplasmosis). Vaccines for the control of coccidiosis are also available and are being trialled widely in the chicken meat industry. Improvements in biosecurity and hygiene in these industries have not only reduced the use of antimicrobials, but in some instances, have also reduced on the need for vaccination.

Vaccination (particularly autogenous vaccines for Riemerella and Pasteurella) has been very successful in controlling almost all the important bacterial diseases that cause disease in Australian intensive duck systems, which is considered to have reduced the use of antimicrobials (particularly amoxicillin and oxytetracycline) to almost zero.

Implementation of tighter biosecurity controls, precise nutritional management and the development and use of Pasteurella and Erysipelas vaccines has resulted in a reduction in the need to use antimicrobials in the Australian turkey industry. Vaccination is widely applied where available, and new vaccines for meat chickens are often trialled for efficacy in turkeys, although this is not always successful. While there is significant R&D undertaken in turkey production (including vaccine development) in the USA and other countries, many of those advances cannot be adopted in Australia, usually due to import biosecurity restrictions. The Australian poultry industry also lacks the relevant infrastructure to undertake significant R&D for alternatives to antimicrobials for turkeys, and resources are limited as there is no R&D levy on turkeys (which means there is no formal R&D program). Despite this, progress is being made to develop an Australian-turkey specific Mycoplasma gallisepticum vaccine, and a haemorrhagic enteritis vaccine has been developed but there are delays with registration and commercialisation (Clements, 2015).

In the meantime, there is continuous assessment of other alternative treatment options, such as the use of pre- and pro-biotics and feed supplements that do not have direct antimicrobial action, but which may improve gut health and function and be effective replacements for antimicrobial use in turkeys.

The egg industry

The increase and expanding number of hens farmed under extensive conditions, such as free-range, has resulted in the re-emergence of diseases (such as parasitic infections and bacterial diseases). These diseases were better prevented in more intensive systems where the faecal oral cycle was limited (e.g. cage), however, the limited availability of antimicrobials to use in hens, particularly during lay (due to the concern of antimicrobial residues in eggs), means there is a greater reliance on disease prevention strategies.

Since 2016-17, the egg industry has heavily invested in the development of vaccine candidates to minimise the impact of Spotty Liver Disease (Van et al., 2017).

Review

Given the long history of interrelationships between veterinarians in the poultry industry through the AVPA, there is regular opportunity to review industry level practices and identify opportunities for improvement. This has resulted in harmonisation across the poultry sectors in relation to the adoption of AMS principles in practise.

Surveillance projects for the detection of AMR in bacteria from Australian poultry have been ad hoc, with most of the public information available for the chicken meat and egg industries, as they are the two predominant poultry industries in Australia. Routine antimicrobial susceptibility testing is considered commercially sensitive and, subsequently, is not reported outside the companies. Prior to the AMR surveillance studies funded by the Australian Government for the egg and chicken meat industries in 2016/17, the chicken meat industry funded RD&E to assess the levels of resistance in bacteria isolated from chickens in Australia in 2000/01 (Barton and Wilkins, 2001). Results to date indicate that the presence of AMR bacteria in Australian poultry is low in comparison to other countries; meat chickens (Abraham et al., 2020; ACMF, 2018; Obeng et al., 2012a; Obeng et al., 2012b, 2014; Pande et al., 2015; Trott et al., 2019).

Primary poultry breeders

The small and very valuable nature of the primary poultry breeding industry in Australia means there is tight managerial and veterinary oversight of all flocks. Health issues must be, and are, identified and addressed quickly. Efficacy of treatments is continually assessed and subsequently modified by a process of continual improvement. Despite no formal QA program for the poultry breeder industry, audits are conducted by the Australian Government of Agriculture and Water Resources to approve sites for export, and some are ISO and HACCP accredited. Due to the high value of primary breeding stocks, extensive records are kept of husbandry practices, including medications that may be administered, throughout the life of the flocks.

Poultry meat industries (chicken, duck and turkey)

There are no national QA Programs for the chicken meat, duck meat or turkey meat industries. This means that each company has different approaches and requirements based on their own situation and their customers' needs, including customer (e.g. Coles, Woolworths, McDonald's etc) programs and third-party QA accreditation schemes (e.g. FREPA [Free Range Egg and Poultry Australia];RSPCA). All these programs have strict requirements for keeping accurate and detailed production records, including details of medications provided. Records and industry practices are subject to separate audits for all required accreditations and programs on a regular basis.

As there is no formal industry-led method for auditing and practice verification, the industry-led AMS program that was adopted voluntarily and integrated into standard business operations for the chicken meat industry in 2016/17 and independently verified in 2019. This verification project also included the development and implementation of an industry self-assessment tool, so that companies can conduct formal reviews of their own programs on a more regular basis. Industry-level verification will also be repeated periodically.

Since 2018, the ACMF has coordinated an antimicrobial usage survey of the 6 Australian chicken companies that produce approximately 90% of Australian chicken. The purpose of this program is to provide companies with national data against which they can benchmark their own internal company usage, and as such, the results are not published. It has also helped to capture baseline data against which future usage patterns can be compared. Once a baseline of acceptable usage is achieved, variations above and below this baseline would be expected. 'How much' antimicrobials are used is meaningless without context to inform whether the usage was 'appropriate'. Therefore, in 2020 the ACMF developed a survey, to be conducted on an annual basis, to provide a measure of the appropriateness of use of antimicrobials across the industry using an exhaustive list of 'appropriate-use' elements (Monnier et al., 2016). The results help clarify national AMS practices and priorities in the meat chicken industry and captures many elements of AMS in place in the industry that are taken for granted and helps to identify gaps and opportunities for improvement.

The egg industry

The Australian egg industry has a voluntary industry QA program, Egg Standards of Australia (ESA), which was implemented in 2016 (superseding the Egg Corp Assured, which commenced in 2009) and provides a framework to demonstrate compliance against a set of standards for quality egg production in Australia. ESA has been developed to provide a compliance framework for egg farmers to meet the needs of regulators, retailers, farmers and egg buyers in areas including hen welfare, egg quality, biosecurity, food safety, work health and safety and environmental management. Audits are conducted at least once per year. The ESA program itself is regularly reviewed to ensure it is up to date with current knowledge on disease prevention, treatment and husbandry, and relevant supporting materials, including those for AMR/AMS, are available to support producers.

Under ESA, medications used must be recorded and the principles of AMS are currently being formally incorporated to assist vets and farmers in recording all details regarding the use of antimicrobials, including a record of script and use directions from a veterinarian. Given the wide variation in the size of egg businesses, not all are accredited under ESA, however, the companies that produce the bulk of eggs and egg products sold commercially are ESA accredited.

In 2019 the egg industry commissioned its first survey of antimicrobial resistance and plans to repeat this work within a 5-year timeframe. The findings of the survey reflect the low antimicrobial use and low disease status of Australian layer farms (Trott et al., 2019).

Justin Toohey

THE AUSTRALIAN RED MEAT INDUSTRIES

The Australian Red Meat Industries

The Australian sheep meat and grain-fed and pasture-fed cattle industries are separate from each other with their own industry representative organisations, although all R&D for these industries is coordinated through Meat & Livestock Australia (MLA) as their RDC. The Australian cattle and sheep meat industries focus on meeting consumer expectations, conducting research to ensure a sustainable future, and encompass scientific approaches to production and disease management. The industries have a broad geographic distribution across Australia, with a wide range of production sizes and thousands of producers.

In 2019, Australia was ranked as one of the world's most efficient producers of cattle and one of the largest exporters of beef. As of 2019, Australia is also the world's largest exporter of sheepmeat and goatmeat and is the world's second largest producer of lamb and mutton (MLA, 2020).

All cattle in Australia are born and spend most of their lives in extensive grazing systems. Sixty percent of beef produced in Australia is produced from livestock which spend some time in a feedlot to produce grain-fed bee. In the first quarter of 2021, 51% of domestically consumed beef came from feedlots. Grain fed cattle made up more than 50% of beef production for the first quarter of 2021. Grain-fed cattle spend 70 – 100+ days in a feedlot to improve body condition and enhance the quality of beef meat with a controlled environment.

Similarly, a small number of sheep may spend a short time in a feedlot to improve and standardise their meat quality or help when seasonal conditions dictate the need for this system. Some cattle may be kept in a feedlot for an extended period to produce meat of exceptional quality, such as highly marbled beef. Cattle and sheep reach slaughter age anywhere between 12 – 30 months, and potentially much earlier or much later as slaughter age is often based on maturity/production definitions rather than chronological age. Beef and lamb are only allowed to be imported from a very limited number of countries and very little product is imported; strict import protocols mean no live cattle or sheep are imported into Australia.

Veterinarians are often hired to aid with animal health management and are required for prescribing medications (including antimicrobials), and feedlot veterinarians and other staff inspect cattle every day to identify early signs of disease. Few cattle receive antibiotics at any time during their lives in Australian extensive agriculture. Anecdotally, it is considered that there would be, "far less than one course of antimicrobials used per animal per year" (MLA, 2014). Due to the low usage of antimicrobials, the presence of antibiotic resistant bacteria is also low (Barlow et al., 2015, 2017, 2020; Mellor, 2019).

Responsibility

The major antimicrobial stewards in the red meat industries are the prescribing veterinarians and the farm or feedlot team who are responsible for good animal care practices, including infection control and prevention. A significant proportion of veterinarians who practice in livestock support the red meat industries and many of them are members of special interest groups of the AVA (Australian Cattle Veterinarians [ACV] and the Sheep, Camelid and Goat Veterinarians [SCGV]), which provide opportunities for professional networking and discussion about current practice, and they are all supported by various AVA policies and guidelines. In 2014, MLA produced a factsheet that outlined the AMR status and AMS initiatives in the cattle industries in Australia to that date (further information can be found at: https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/ food-safety/pdfs/antimicrobials-and-the-cattle-industry- fact-sheet.pdf).

The Australian Lot Feeders Association (ALFA) and Meat & Livestock Australia launched the comprehensive 'Antimicrobial stewardship guidelines for the Australian cattle feedlot industry' in early 2018 (https://www.mla.com.au/research-and-development/animal-health-welfare-and-biosecurity/diseases/), which outlines the AMS plan for the industry. The report provides supporting tools, such as antimicrobial usage calculations, guidance on how to produce an AMS plan and recommendations for lot feed producers (MLA, 2018a). These guidelines provide a continuous improvement framework that will help feed-lot producers understand and ensure their appropriate use of antimicrobials. More than 62% of feedlots have an AMS plan (MLA, 2021). An extensive array of tools and training opportunities for cattle are also provided by MLA (further information can be found at: https://www.mla. com.au/extension-training-and-tools/).

The model code of practice for the welfare of cattle in Australia was converted to Standards and Guidelines in 2016, which has been embedded in the grain fed sector's quality assurance program, National Feedlot Accreditation Scheme (NFAS). Additionally, as of 2020 most states have either endorsed that standards and guidelines and can use them as evidence in legal disputes, or they have been adopted into state legislation. An update on the level of adoption of each state is monitored and reported (Cattle : Animal Welfare Standards).

Reduce

Commercial industries have always strived for continuous improvements in the understanding and management of biosecurity, husbandry, hygiene, cattle and sheep physiology and quality nutrition, as these issues are central to preventing disease, and the related productivity issues. The Livestock Production Assurance program has more than 190,000 participants and part of this program requires producers to have a Farm Biosecurity Plan and integrate best-practice biosecurity practises in their on-farm management. This program was relaunched with enhanced requirements in 2017 and further information can be found at: https://www.integritysystems.com.au/on-farm-assurance/livestock-product-assurance/ .

Animal Heath Australia (AHA) and Plant Heath Australia (PHA) provides a central point for biosecurity information regarding red meat and plant producers. This central website provides red meat producers with the necessary tools and useful information to manage disease (endemic and exotic), pest and weed events on their farms in consultation with industry and the Government. These specific tools and resources are provided for cattle (http://www.farmbiosecurity. com.au/industry/beef-cattle/) and sheep meat (http://www.farmbiosecurity.com.au/industry/sheep/) industries, while a specific Farm Biosecurity Manual has been provided for feedlots. farmbiosecurity. com.au/industry/lot-feeding/). In addition, biosecurity requirements are captured as part of the the National Feedlot Accreditation Scheme (NFAS) (https://www.ausmeat.com.au/services/list/livestock/nfas/ ; https://www.ausmeat.com. au/WebDocuments/NFAS_-_Rules_and_Standards_ of_Accreditation.pdf).

MLA invests up to $5 million a year in livestock genetics R&D under a standalone R&D program, to facilitate increased genetic gain and health robustness for cattle and sheepmeat industries. A number of resources and research reports have been developed to assist producers in genetic selection and breeding in cattle and sheep (further information can be found at: https://www.mla.com.au/research-and-development/Genetics-and-breeding/cattle/genetics/; http://mbfp.mla.com.au/Cattle-genetics; https://www.mla.com.au/research-and-development/Genetics-and-breeding/sheep/; http://www.sheepgenetics.org.au/Home).

Cattle in feedlots are considered more susceptible to ailments caused by seasonal influences that may require antimicrobial treatment. Several research studies are underway to support previous work related to reducing the use of antimicrobials in feedlot cattle and other red meat industries (further information can be found at: https://www.mla.com.au/research-and-development/animal-health-welfare-and-biosecurity/). These projects range from investigating better ways of preparing cattle to enter a feedlot (for example, becoming used to being in larger social groups), determining the best vaccination regimen for cattle prior to feedlot entry, and faster diagnosis of infection in cattle while in a feedlot.

The grazing cattle and sheepmeat industries have low rates of infectious disease because of inherently low stocking rates and the use of preventive measures, including vaccination, stock handling practices, insect control, biosecurity, herd management and infection control (Barnes, 2015; MLA, 2014), which has resulted in significant reductions in the use of antimicrobials in these industries over time and is reflected in the low frequency of AMR.

The sheepmeat industry is working to reduce the cost of endemic diseases, including internal and external parasites, by $69 million by 2030. This cost saving to the industry is expected to be predominately due to a reduction in illness, reduction in the need for antimicrobial treatments and the loss of productivity from sick animals.

Refine

The use of antimicrobials in red meat industries is guided by veterinary prescribing guidelines such as those issued and reviewed by the AVA (AVA, 2017). Evidence-based practice guidelines for antibiotic use in treating sheep diseases has been published (https://www.ava.com.au/siteassets/resources/fighting-antimicrobial-resistance/antimicrobial-prescribing-guidelines-for-sheep.pdf) and similar guidelines for grazing cattle and feedlot cattle are expected to be published in 2021-22. An extensive suite of diagnostics has been developed and are regularly used by veterinarians to diagnose disease and identify appropriate treatment (further information can be found at: https://www.dpi.nsw.gov.au/about-us/services/laboratory-services/veterinary/veterinary-test-list-by-species/cattle). MLA invests millions of dollars each year in improvements to diagnostics and disease control (further information can be found at: https://www.mla.com.au/research-and-development/animal-health-welfare-and-biosecurity/), which inform the industry's best practise manuals that underpin the various accreditation programs in place, such as the National Feedlot Accreditation Scheme and Livestock Production Assurance programs (further information can be found at: https://www.ausmeat.com.au/services/list/livestock/nfas/https://www.ausmeat.com.au/WebDocuments/NFAS_-_Rules_and_Standards_of_Accreditation.pdf; https://www.integritysystems.com.au/on-farm-assurance/livestock-product-assurance/).

Replace

Australia is fortunate to be free of all the major epidemic diseases in red meat livestock and is relatively free of other serious parasites and diseases (AHA, 2021). Of the endemic diseases that do affect these industries, parasitic diseases have the largest financial impact on farm productivity.

Vaccines that are available in Australia to help prevent common endemic diseases in red meat livestock are listed in Appendix 3. These include vaccines to help prevent Bovine respiratory disease, Clostridial diseases (including botulism), Cheesy gland, Johne's disease, Leptospirosis, Pestivirus, Pinkeye, Three-day sickness and Vibriosis.

These diseases can have a significant impact on the health, welfare and productivity of livestock. Vaccines are used at different times in the production cycle depending on the disease, the vaccine and the risk of infection in the region where the cattle or sheep are being produced.

The replacement of antimicrobials of importance to human medicine is considered whenever evidence becomes available that supports the efficacy and safety of an alternative. Adoption is carefully assessed to avoid unintended consequences of harm to the animals, or subsequent increased need for the use of antimicrobials of importance to human medicine if the vaccination fails.

Currently, there are few alternatives to antimicrobials for treating unwell red meat livestock, and the best options for reducing antibiotic use lie in the prevention of infection through the use of vaccines, good biosecurity and hygienic husbandry. Extensive resources to support the health and welfare of red-meat livestock are available from MLA, as well as the numerous other organisations that support the red-meat industries (further information can be found at: http://mbfp.mla.com.au/Herd-health-and-welfare).

The use of antimicrobials in beef, particularly pasture-fed, and sheepmeat has always been low, and often for practical reasons, a farmer will avoid calling upon a veterinarian for consultation and treatment unless necessary. As a result, preventative measures will always be preferable to treating disease.

Review

The Livestock Production Assurance (LPA) program was introduced in 2004 and is the Australian red meat industry's on-farm program covering food safety, animal welfare and biosecurity. It is part of the integrity system used requirements for domestic and export markets (further information can be found at: https://www.integritysystems.com.au/on-farm-assurance/livestock-product-assurance/).

More than 190,000 producers are part of the LPA, which covers requirements for safe and responsible animal treatments, stock foods, fodder crops, grain and pasture treatments, biosecurity and animal welfare, and includes numerous learning modules for accredited producers. It is a requirement of LPA that stringent records are kept of how the meat was produced, including detailed records of medications administered. This information is used for analysis of use and efficiency to guide future decisions on treatment protocols, antimicrobial use and to allow quality of use to be assessed. However, given the structure of the industry, this information is not easily captured at a national level.

Due to the significant reliance on export markets for the red meat produced in Australia, the industries maintain surveillance of developments in AMR and stewardship initiatives and conduct research to measure its performance against recommendations. MLA has funded several surveillance projects in the Australian red-meat industry (Barlow et al., 2015, 2017). The results of recent surveys (Barlow et al., 2020; Mellor, 2019) demonstrate very low levels of AMR in bacteria from cattle and sheep in Australia.

Grain-fed beef industry

The Australian Lot Feeders Association implemented the National Feedlot Accreditation Scheme in 1994, which was the first QA program implemented in Australian agriculture (further information can be found at: http://www.feedlots.com.au/industry/nfas). This QA program was comprehensively reviewed in 2015 and subsequently 2020 (Cudmore J.W., 2015). It requires every accredited feedlot to be independently audited on an annual basis, to ensure they comply with animal health, welfare, environmental and food safety legislation in addition to best practice guidelines.. As of 2021, 387 feedlot producers are accredited through NFAS, which is a voluntary industry self-regulatory, QA scheme, although accreditation is mandatory for feedlots that produce for export markets. To be accredited under the NFAS, feedlots must have procedures that meet the requirements of industry standards and maintain records to demonstrate that these procedures have been adhered to for all cattle prepared at the feedlot (MLA, 2018b). The procedures, records and feedlot facilities must then undergo a third-party audit and feedlots must have a specific number of QA officers at the feedlot (number on site is related to the size of the feedlot; further information can be found at: https://www.feedlots.com.au/nfas).

In what is believed to be a first for feedlot industries around the world, the Australian industry implemented the Antimicrobial Stewardship Guidelines (MLA, 2018a) in 2018, to help guide judicious use of antimicrobials without compromising animal health. The AMS program is designed to promote individual businesses reviewing internal processes in line with their AMS plan, encouraging continuous improvement. This will be used by individual businesses to evaluate compliance with the initiatives and ensure that if antimicrobials of importance to human health are required to be used, their use reflects contemporary best practice. The feedlot industry has announced that the AMS guidelines for the Australian cattle feedlot industry would become a mandatory component of the NFAS following a positive trend in its voluntary adoption.

Sheepmeat industry

In extensive agriculture, few sheep ever receive antibiotics at any time during their lives. Recent projects to enhance sheep health have included the development of a tool for the assessment of alternative endemic disease control measures, vaccines for nematodes, and diagnosis of ovine pneumonia. For sheep feedlots guidelines have been updated.

Assessment and review of these risks will enable the development of improved processes, to ensure a reduction in mismanagement of antibiotics used in the sheepmeat industry.


Sheep Producers Australia

iStock

THE AUSTRALIAN DAIRY INDUSTRY

THE AUSTRALIAN DAIRY INDUSTRY

In the 2019/2020 financial year, the Australian dairy industry had a farmgate value of approximately $4.8 billion and was Australia's fourth largest rural industry. There are approximately 5,000 dairy farms located in all states of Australia and the national dairy herd is 1.41 million cows. Whilst there is a long-term trend of numbers of dairy farms across Australia decreasing; the average herd size is increasing. Improved herd genetics, advances in pasture management and supplementary feeding have also seen milk yields per cow more than double over the last four decades.

Australia is a significant exporter of dairy products and ranks fourth in terms of world trade. Exports are concentrated in Asia, which accounts for around 88% of total export value. Cheese is consistently the major product stream, accounting for 39% of Australia's milk production. Drinking milk and skim milk powder/butter production were the two next largest users of milk in the 2019/2020 financial year, accounting for 32% and 22% of Australian milk.

The dairy industry has been significantly challenged over recent years by volatility in farmgate milk price and farm incomes as well as unfavorable seasonal conditions in some regions which has impacted farmer confidence and industry growth.

For more information please see the Australian Dairy Industry In Focus 2020 Report (https://www.dairyaustralia.com.au/industry-statistics/industry-reports/australian-dairy-industry-in-focus#.YJ39lqgzY2x).

Responsibility

The Australian Dairy Industry Sustainability Framework was launched in 2012 following extensive consultation with dairy farmers and manufacturers as well as stakeholders including government, retailers, customers, non-government organisations (NGOs) and interest groups. The framework outlines the Australian Dairy Industry's key sustainability commitments which includes a commitment to antimicrobial stewardship. The 2030 antimicrobial stewardship goals and targets include:

- The dairy industry uses antibiotics responsibly, as little as possible, as much as necessary, to protect the health and welfare of animals.
- All dairy farmers access antibiotics from a registered veterinarian.
- All dairy farmers use antibiotics responsibly under veterinary direction.
- Antibiotics of high importance to human AMR in Australia are only used to treat dairy livestock in exceptional circumstances where no other alternative exists.

The goals and targets for each commitment are tracked, measured, and publicly reported annually. The 2020 Australian Dairy Industry Sustainability Report can be accessed at https://www.sustainabledairyoz.com.au/.

A materiality assessment was undertaken during 2019 to determine the priority issues for both the development of the Framework and related performance reporting. This work refreshed previous materiality reviews undertaken in 2011-12 and 2016. Materiality was defined according to two dimensions:

1. Significance of the industry's economic, environmental, and social impact
2. Significance to and influence on stakeholder assessments and decisions

Antimicrobial stewardship was identified as one of the most material topics emerging from the assessment. The Dairy Sustainability Steering Committee is currently reviewing these highly material topics and recommend strategic responses for consideration by the Australian Dairy Industry Council.

Reduce

Disease prevention continues to be a key focus for the Australian dairy industry to support a reduction in antimicrobial use. As an example, mastitis is inflammation of the udder usually caused by a bacterial infection that has entered via the end of a cow's teat. It is the single most significant animal health problem affecting all Australian dairy farms. Most recent estimates suggest that mastitis costs the industry around $150 million annually, through reduced milk yield and reduced milk quality. In addition, antibiotic therapy used to treat and control mastitis accounts for more than two thirds of all antibiotic courses supplied to dairy farmers by veterinarians.

Since 2017, Dairy Australia, the Australian dairy industry's Research and Development Corporation has invested approximately $1.5 million in the national mastitis control program Countdown (Brightling et al., 2009). Specific outcomes of this investment included:

- Training of approximately 300 dairy farmers and farm employees each year via the Cups on Cups off training program. Cups on Cups off is a two-day training course designed by Dairy Australia and delivered by a Countdown trained expert in mastitis and milk quality to help farmers achieve best practice in milk harvesting, with the emphasis on the detection, treatment, and prevention of clinical mastitis.

- The development and national launch of a fully online training program, Milking and Mastitis Management (Fundamentals), covering the fundamental best practice in animal handling and milking procedures, and the prevention and identification of mastitis.

- Training of approximately 20 service providers per year via the Countdown MQ advisor training program. Countdown MQ is an intensive 10-month professional development program for milk quality advisors to improve their ability to provide problem solving and milk quality management services to dairy farmers.

- Updates to seven of the 27 Countdown Technotes. Each Technote summarises the experimental and observational data that underpins the key guidelines for mastitis control as well as the rationale, background information and bibliographic references for key research papers and articles for further reading. The Technotes are presented in a manual designed specifically for dairy service providers, including veterinarians, factory field officers, milk recording field personnel and milking machine technicians. Additionally, two advisor FAQ sheets were updated/created which included "What are the keys to the prevention and control of Mycoplasma in dairy herds?" and "What techniques can be used to identify bacteria other than traditional milk culture?".

Current, but not yet completed activities include the development of a decision support tool for farmers to appropriately implement selective (part-herd) rather than blanket (whole-herd) antibiotic dry cow therapy and a redevelopment of the mastitis focus report which enables farmers, their veterinarians, and advisors to monitor udder health of individual herd and assess the success of key mastitis management areas. Recently, a project was approved to develop a machine learning underpinned clinical mastitis treatment decision tool that will reduce antibiotics used to treat clinical mastitis and treatment failure rates and improve health and treatment event data capture to a level that enables industry, milk processors and farmers to monitor and benchmark clinical mastitis incidence and associated antimicrobial use.

Refine

To ensure the most appropriate use of antimicrobial agents, the Australian dairy industry has committed that all dairy farmers access antibiotics from a registered veterinarian, use antibiotics responsibly under veterinary direction and antibiotics of high importance to human AMR in Australia are only used to treat dairy livestock in exceptional circumstances where no other alternative exists. To support achieving these commitments, the Australian Dairy Industry has co-invested with Animal Medicines Australia in the development of evidence-based AVA Prescribing Guidelines for Dairy Cattle which are expected to be finalised in 2021.

Replace

As discussed earlier, antibiotic therapy used to treat and control mastitis accounts for most of the antibiotic courses supplied to dairy farmers by veterinarians. Australia is part of a global dairy industry trend to move away from blanket (whole-herd) antibiotic dry cow therapy and implement selective (part-herd antibiotic) dry cow therapy. The consideration to use selective antibiotic dry cow therapy is aimed at reducing both antimicrobial use on farm and treatment costs, whilst maintaining equivalent calving period clinical and subclinical mastitis rates. The literature indicates that farms using a selective antibiotic dry cow strategy can lower the new mastitis infection risk by incorporating internal teat sealants into the approach.

Internal teat sealant products contain no antibiotics, instead, a viscous material sinks to the lower teat sinus after infusion and remains there without hardening or setting until it is removed by suckling calves or by manually stripping the quarter. Their purpose is only to prevent new infections, especially during the initial dry period and the transition period just prior to calving. The replacement of antibiotic dry cow therapy teat sealants requires decisions about the likely infection status of individual cows and should only be considered by herds participating in milk recording (or an equivalent level of diagnostic testing). Attention to thorough disinfection of the teat end, in addition to proper hygiene of gloved hands and treatment tubes during handling and insertion, is also paramount.

The Australian dairy industry has produced several resources to assist farmers with moving to selective (part-herd) dry cow therapy strategies and is in the process of developing a herd decision support tool that will provide recommendations as to whether a farm should consider a selective (part-herd) dry cow strategy and which cows should be treated with antibiotic dry cow therapy or teat sealants alone.

Review

A working group was established in May 2020 to develop an agreed methodology and metrics for collating and monitoring antimicrobial use (AMU) data relevant to the Australian dairy industry. The group explored the range of existing methodologies for reporting AMU around the world and potential data sources available to the dairy industry in Australia. Two principals were agreed:

- the data must be reliable and efficient to collect and analyse; and
- the methodology must be clearly documented and repeatable to allow an assessment of AMU trends over time.

The working group identified that significantly more work is required on the dairy industry's Central Data Repository to enable farm/enterprise level AMU reporting. However, the group was able to describe industry level AMU in terms of milligrams per population corrected unit (mg/PCU) for ceftiofur, the macrolide antimicrobial class and for all antimicrobial classes (total) and number of lactating and dry cow intramammary courses per 100 milking cows using existing data on veterinary medicine sales to dairy farmers from a sample of key veterinary businesses. Importantly, the data available at the time did not include antimicrobials supplied by third parties (e.g., stockfeed manufacturers) under prescription of the veterinarians, or those antimicrobials that can be supplied without prescription (e.g., ionophores). This work will be used to inform an ongoing strategy for AMU monitoring in the Australian dairy industry.


DAIRY AUSTRALIA

CONCLUSION

This report cannot be considered comprehensive, as there is an abundance of resources available online and elsewhere that support the health, welfare, husbandry (including hygiene) and disease prevention in livestock through biosecurity. However, the purpose of this report is to provide an overview of the historical and current practises relevant to AMS in each of the contributing industries that are already in place and the information that is available to support AMS in Australian livestock. In particular, this report is directed at the stakeholders that currently lack a comprehensive understanding of how livestock industries operate in Australia. The implementation of the 2015 National AMR Strategy (Australian Government, 2015), and the process for developing and implementing the latest national strategy (Australian Government, 2020), have provided an impetus for each industry to assess its current activities under an AMS framework and identify opportunities for improvements and define barriers that align across all animal industries which can be addressed collaboratively. The formation of the Animal Industries' Antimicrobial Stewardship R, D & E Strategy (AIAS) and the Australian Veterinary Antimicrobial Stewardship (AVAMS) conference are both ways in which stakeholders in the Australian animal industries, including the livestock industries, will be assisted with their understanding of AMS and its principles, and highlight barriers and improvements required for successful AMS programmes. The aim is for this report to be updated biennially to capture updates on the initiatives from industries that were in a position to contribute to the first edition and this version. It is hoped that information from additional industries will be captured in subsequent editions.

While AMR is a significant human health issue, it should not be forgotten that it is also an animal health issue, as antimicrobials (including those not used in human medicine) are still required to manage disease in livestock, and animal pathogens with resistance to these antimicrobials can potentially cause significant issues to both humans and livestock. Ignoring AMR in animals may also result in the use of antimicrobials of importance, or of greater importance, to human medicine, which could perpetuate the development of further AMR. Despite this, the momentum is high in Australia, 2021 and has grown since the last edition of this report (2018), for adopting AMS principles, through capturing current efforts and identifying further areas for improvement. Continuation of this momentum through collaborative efforts will be essential to maintaining and improving Australia's positive track record for AMS, and generally low levels of AMR bacteria in livestock. The development and implementation of systems to capture the information needed to support this narrative at the national level is essential to minimising AMR into the future.

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ACMF

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APPENDIX 1

Agents registered for antibacterial use in livestock by Australian Pesticides and Veterinary Medicine Authority (APVMA, Information accessed June 2021)

		Importance[A]						
Antibacterial Agent	*Class*	*ASTAG 2018*	*WHO 2018*	*Cattle*	*Sheep*	*Pig*	*Meat Chicken*	*Egg-layer hen*
Novobiocin	Aminocoumarin	low nhu	5	X[D]				
Spectinomycin	Aminocyclitol	med	4			X	X	X[R]
Apramycin	Aminoglycoside	med	*2*	X		X	X	
Dihydrostreptomycin	Aminoglycoside	low hnu	2	X[DG]	X[G]	X[G]		
Framycetin	Aminoglycoside	low	2	X[J]	X[J]			
Neomycin	Aminoglycoside	low	2	X	X	X	X	X[R]
Streptomycin	Aminoglycoside	low	2	X				
Trimethoprim[S]	Diaminopyrimidine	med	3	X	X	X	X	X[R]
Flavophospholipol	Glycophospholipid	low nhu	5	X[K]		X[K]	X[K]	X[RK]
Lasalocid	Ionophore	low nhu	5	X[FK]	X[K]	X[K]	X[F]	X[RF]
Maduramicin	Ionophore	low nhu	5				X[F]	
Monensin	Ionophore	low nhu	5	X[FK]	X[K]	X[K]	X[F]	X[RF]
Narasin	Ionophore	low nhu	5	X[FK]	X[K]	X[K]	X[F]	
Salinomycin	Ionophore	low nhu	5	X[FK]	X[K]	X[K]	X[F]	X[RF]
Semduramicin	Ionophore	low nhu	5				X[F]	
Lincomycin	Lincosamide	med	3	X[D]		X	X	X[R]
Erythromycin	Macrolide	low	1	X	X	X	X	
Oleandomycin	Macrolide	low nhu	1	X[D]				
Tilmicosin	Macrolide	low nhu	1	X		X		
Tulathromycin	Macrolide	low nhu	1	X		X		
Tylosin	Macrolide	low nhu	1	X		X	X	X[R]
Avilamycin	Orthosomycin	low nhu	5				X	
Florfenicol	Phenicol	low nhu	3	X		X		
Tiamulin	Pleuromutilin	low mhu	4			X	X	
Bacitracin	Polypeptide i	low	4	X[J]	X[J]		X	X[R]
Polymyxin B	Polypeptide ii	high	1	X[J]	X[J]			
Olaquindox	Quinoxaline	low nhu	5			X		
Virginiamycin	Streptogramin	high nhu	3	X	X		X	
SulfadiazineT[+]	Folate pathway inhibitor	low nhu	3	X	X	X	X	
SulfadimidineT[+/-]	Folate pathway inhibitor	low nhu	3	X	X	X	X	X[R]
SulfadoxineT[+]	Folate pathway inhibitor	low nhu	3	X	X	X		
Sulfaquinoxaline	Sulfonamide	low					X	
Chlortetracycline	Tetracycline	low nhu	3	X		X	X	X[R]
Oxytetracycline	Tetracycline	low nhu	3	X	X	X	X	
Cephapirin	β lactam cephalosporin [1GC]	med	3	X[H]				
Cephalonium	β lactam cephalosporin [1GC]	med nhu	3	X[D]				
Cefuroxime	β lactam cephalosporin [2GC]	med	3	X[D]				
Ceftiofur	β lactam cephalosporin [3GC]	high nhu	1	X				
Amoxicillin	β lactam penicillin	low	2	X	X	X	X	X[R]
Ampicillin	β lactam penicillin	low	2	X[D]				
Cloxacillin	β lactam penicillin	med nhu	3	X[DJ]	X[J]			
Penethamate	β lactam penicillin	low nhu	2	X	X	X		
Penicillin (and salts)	β lactamase inhibitor	low	2	X	X	X		
Amoxicillin with Clavulanic acid	β lactamase inhibitor combination	med	2	X[D]				

[A] IMPORTANCE for human medicine: ASTAG, version 1.0 2018; nhu no human use; WHO, version 6 2018; 1 HPCIA (Highest Priority Critically Important Antimicrobials for human use); 2 CIA (Critically Important Antimicrobials for human use); 3 HIA (Highly Important Antimicrobials for human use); 4 IA (Important Antimicrobials for human use); 5 nhu (No Human Use), [S]combination with a sulfonamide; [T+/-] with or without trimethoprim, [D]active only available in an intramammary product, [R]pullet laying replacement, [F]Label claim for coccidiosis or [K]growth promotion [G](Dihydro)streptomycin/penicillin combination available under APVMA permits issued to veterinarians for control of leptospirosis in cattle, sheep and pigs, campylobacteriosis in bulls and for live cattle for export to countries which require (dihydro)streptomycin injection prior to shipment, [H]Intrauterine use [J]Topical and/or ocular and/or aural use

APPENDIX 2

Vaccines registered, or approved by permit, for use in cattle, sheep, pigs and poultry by APVMA (information accessed June2021)

Immunogen	*Type*	*Cattle*	*Sheep*	*Pig*	*Poultry*
Actinobacillus pleuropneumoniae	Bacteria			X	
Anaplasma centrale	Protozoa	X			
Avian encephalomyelitis virus	Virus				X
Avian influenza virus (H5N2, H5N9, H7N1)	Virus				X
Avibacterium paragallinarum	Bacteria				X[a]
Babesia bigemina	Protozoa	X			
Babesia bovis	Protozoa	X			
Bacillus anthracis (Sterne 34F2 strain)	Bacteria	X	X	X	
Bovine coronavirus	Virus	X			
Bovine ephemeral fever virus	Virus	X			
Bovine herpesvirus 1	Virus	X			
Bovine pestivirus	Virus	X			
Bovine rotavirus	Virus	X			
Campylobacter fetus subsp fetus	Bacteria	X	X		
Campylobacter fetus subsp venerealis	Bacteria	X			
Camplyobacter hepaticus	Bacteria				X[a]
Campylobacter jejuni subsp jejuni	Bacteria		X		
Chicken anaemia virus	Virus				X
Clostridium botulinum Type C	Bacteria	X	X		
Clostridium botulinum Type D	Bacteria	X	X		
Clostridium chauvoei	Bacteria	X	X		
Clostridium haemolyticum	Bacteria	X	X		
Clostridium novyi Type B	Bacteria	X	X		
Clostridium perfringens Type A	Bacteria				X[a]
Clostridium perfringens Type B	Bacteria	X	X		
Clostridium perfringens Type C	Bacteria	X	X		
Clostridium perfringens Type D	Bacteria	X	X		
Clostridium septicum	Bacteria	X	X		
Clostridium tetani	Bacteria	X	X		
Contagious pustular dermatitis virus (Orf virus)	Virus		X		
Corynebacterium pseudotuberculosis	Bacteria		X		
Dichelobacter nodosus	Bacteria		X		
Egg drop syndrome 76 virus	Virus				X
Eimeria acervulina	Protozoa				X
Eimeria brunetti	Protozoa				X
Eimeria maxima	Protozoa				X
Eimeria mitis	Protozoa				X
Eimeria necatrix	Protozoa				X
Eimeria praecox	Protozoa				X
Eimeria tenella	Protozoa				X
Erysipelothrix rhusiopathiae	Bacteria		X[a]	X	X
Escherichia coli (many types)	Bacteria	X		X	X
Foot and mouth disease virus (FMD)	Virus	X[a]	X[a]	X[a]	
Fowl adenovirus	Virus				X
Fowl pox virus	Virus				X

Haemophilus parasuis	Bacteria			X	
Herpes virus of turkeys (HVT)	Virus				X
Infectious bronchitis virus (IB)	Virus				X
Infectious bursal disease virus (IBD)	Virus				X
Infectious laryngotracheitis virus (ILT)	Virus				X
Klebsiella pneumoniaie	Bacteria			X[a]	
Lawsonia intracellularis	Bacteria			X	
Leptospira borgpetersenii serovar Hardjo	Bacteria	X	X		
Leptospira interrogans serovar Pomona	Bacteria	X	X	X	
Leptospira interrogans serovar Tarassovi	Bacteria			X	
Mannheimia haemolytica	Bacteria	X			
Marek's disease virus	Virus				X
Moraxella bovis	Bacteria	X			
Mycobacterium paratuberculosis	Bacteria	X	X		
Mycoplasma gallisepticum	Bacteria				X
Mycoplasma hyopneumoniae	Bacteria			X	
Mycoplasma synoviae	Bacteria				X
Newcastle disease virus	Virus				X
Ornithobacterium rhinotracheale (ORT)	Bacteria				X[a]
Papilloma virus	Virus	X[a]	X[a]	X[a]	
Pasteurella multocida	Bacteria	X[a]	X[a]	X	X
Porcine circovirus type 2	Virus			X	
Porcine parvovirus	Virus			X	
Salmonella Bovismorbificans, Uganda & Zanzibar	Bacteria	X			
Salmonella Dublin	Bacteria	X			
Salmonella Typhimurium	Bacteria	X			X
Staphylococcus hyicus	Bacteria			X[a]	
Staphylococcus spp (incl aureus, epidermidis, hyicus)	Bacteria	X[a]	X[a]	X[a]	X[a]
Streptococcus suis	Bacteria			X[a]	

[a] *vaccine only available under permit*