Final report

Enterprise level antimicrobial usage measurement - pilot

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Abstract

The rising threat of antimicrobial resistance globally is driving governments and multinational customers to increase their focus on the types and quantities of antimicrobial products being used in agricultural production systems. Even though Australia's red meat producers are considered low users of antimicrobial products compared to more intensive livestock industries, systems will soon be required to measure antimicrobial use (AMU), providing assurance to customers and a tool to drive improved antimicrobial stewardship on farms.

This project delivers a key dose-based metric (nADD/100 head/yr) for measuring AMU in Australian red meat enterprises and recommends different weight-based metrics for reporting industry level AMU.

This project has also delivered a relatively simple and robust on-line App (the *MyFarmAMU* App) that enables producers to generate their AMU results from data held at their farm and a bespoke database of veterinary product registration data (the AVAP data resource) created by the project team. Subject to permissions, data entered into the App by producers can be captured, de-identified, collated and then used to generate a range of industry level AMU statistics.

The project provides a practical option for capturing enterprise level data for AMU reporting purposes. However, at this point in time, the lack of a significant driver to encourage the uptake and use of the App is a significant barrier to its widespread adoption and use by producers.

The next step is to develop an industry-agreed plan for the monitoring and reporting of AMU in the red meat industry in consultation with industry stakeholders.

Executive summary

Countries report annually to the World Organisation for Animal Health (OIE) on the quantities of antimicrobials used (AMU) as a part of a global strategy to tackle antimicrobial resistance. The Australian Government uses data sourced from drug manufacturers to address this reporting requirement. However, it is impossible to determine the quantity of antimicrobial medicines used by each different livestock industry from these data.

Red meat producers are considered to have low AMU compared to other livestock industries such as pigs and poultry, but even so, are facing increasing scrutiny from Governments and customers seeking assurance that the antimicrobials being supplied to red meat producers are being used judiciously.

In the European Union (EU), methodologies have been developed and mandatory systems implemented to capture the quantity of antimicrobial medicines used by livestock enterprises for annual reporting. Enterprise (farm) level data is thought to provide the most accurate AMU data as only the chemical user/producer knows the class of animal that each antimicrobial treatment was administered to.

At this point in time, most Australian red meat producers keep their records of AMU (animal treatment records, drug purchases and stock numbers) in a variety of paper-based and electronic formats, and collating these records to analyse their farm's AMU is rarely attempted. These records are also not accessible to calculate industry level statistics.

This project aims to develop relevant AMU metrics and a practical system to measure AMU at the enterprise farm level.

Producers can benefit by becoming more informed about the quantity and type of antimicrobial active constituents being used on their livestock, potentially driving improvements in antimicrobial stewardship and lowering the risks of antimicrobial resistance on their farms.

Subject to permission, enterprise level data entered by producers can also be used to generate industry level AMU statistics. This data can be used by industry to demonstrate that antimicrobial products are being used judiciously by red meat producers and so support continued access to markets and the range of antimicrobial medicines used to preserve the health and welfare of livestock.

Objectives

The objectives of this project were to:

- develop and demonstrate reliable, practical, and meaningful measurement systems for antibiotic use in different kinds of red meat enterprises, being cattle, sheep and goats, in both extensive and intensive raising systems; and
- use the data captured during piloting of the system to compare with industry level AMU measurements.

The objectives were partially met. A simple and robust App has been developed to measure and report AMU in cattle, sheep and goat enterprises. The *MyFarmAMU* App also has the capability to capture data for industry-level reporting. However, there was insufficient AMU data collected from the producers piloting the App to generate any meaningful industry statistics.

Methodology

Desktop research including a review of the literature, public websites and discussions with different livestock industry representatives was used in developing the metrics recommended for measuring AMU.

A minimal viable product (MVP) version of the system developed to measure enterprise level AMU was constructed and tested in MS Excel®, before being built into an on-line application (*MyFarmAMU* App) in RShiny. In addition, a new data resource was created to house the veterinary antimicrobial product information required to calculate AMU metrics.

A range of MLA advisory groups and industry contacts were used to distribute the App to cattle, sheep and goat producers for piloting. Feedback from the producers involved in the pilot was collected via SurveyMonkey®, a BetterBeef discussion group and follow up telephone conversations.

Results/key findings

This project has developed a key dose-based metric, the number of animal daily doses per 100 head per year (nADD/100 head/yr), for measuring AMU in Australian red meat enterprises and recommends different weight-based metrics for reporting industry level AMU.

This project has also delivered a relatively simple and robust online application (the *MyFarmAMU* App) that enables producers to generate their AMU results and a report for their enterprise. The app can be accessed at www.amuapp.net

The data contained in PubCRIS is not suitable to calculate enterprise level AMU and so a bespoke database of veterinary product registration data (the AVAP data resource) was also created by the project team.

An online App is well suited to capturing AMU data and offers significant advantages compared to other tools, such as paper-based sheets and downloadable programs.

Currently, producers have no clear drivers to motivate them to collate their AMU data or use a tool to generate enterprise level or industry level AMU statistics. Assisting them to more easily meet compliance obligations (such as those of LPA) would provide one such driver.

A significant program of producer engagement (communications and education) would be required to support an industry-wide release of the *MyFarmAMU* App if it is being considered as a future tool to generate industry-wide AMU statistics.

Benefits to industry

This project delivers some practical tools that can be applied for measuring enterprise level AMU, as well as some valuable insights on how they might be received by red meat producers. This information will help industry evaluate different methodologies and options for capturing and reporting of AMU data in the future.

Future research and recommendations

The project has four key recommendations to help the red meat industry prepare for future AMU reporting requirements:

#1. In consultation with industry stakeholders, develop an agreed industry plan for monitoring and reporting AMU in the red meat industry. Key issues to address in the plan include:

- the current and future need for red meat industry AMU data;
- the most appropriate metrics to use at both the enterprise and industry level;

- the source/s of data and the methods used to collect it;
- the method/s used to collect and analyse the data; and
- the governance of the plan, data and reporting.

#2. Clear market signals, industry messaging and an improved 'value proposition' are needed to get the *MyFarmAMU* App used more widely by producers.

#3. The data resource created to house information about registered antimicrobial products (the AVAP data resource) should be maintained and made available to facilitate the calculation of AMU by interested parties.

#4. Education and veterinary advice should be provided to producers (and their advisors) to properly interpret enterprise AMU results and use them to drive improvements in antimicrobial stewardship in herds and flocks.

List of Acronyms

ADD	Animal daily doses
AMR	Antimicrobial resistance
AMS	Antimicrobial stewardship
AMU	Antimicrobial usage
APVMA	Australian Pesticides and Veterinary Medicines Authority
ASTAG	Australian Strategic and Technical Advisory Group
AVAP	Australian Veterinary Antimicrobial Products (data resource)
ECED	European Centre for Disease Prevention and Control
ESI	Export slaughter interval
ESVAC	European Surveillance of Veterinary Antimicrobial Consumption
EU	European Union
LPA	Livestock Production Assurance
MLA	Meat & Livestock Australia
MVP	Minimum viable product
NABRC	North Australia Beef Research Council
OIE	World Organization for Animal Health
PCU	Population-corrected unit
PubCRIS	Public Chemical Registration Information System
RDCs	Rural Research and Development Corporations
SALRC	Southern Australia Livestock Research Council
VCA	Vet Compass Australia
WALRC	Western Australian Livestock Research Council
WHO	World Health Organization
WHP	Withholding period

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1. Background

1.1 Measuring AMU

1.1.1 Why the interest in measuring AMU?

Australia reports the volume of antimicrobial medicines used in agriculture to the international community annually via the World Organisation for Animal Health (OIE), and uses data on the manufacture and importation of bulk antimicrobial actives to achieve this requirement. This data is high level, and the antimicrobials used by Australia's red meat industry cannot be separated from those used by other livestock industries, particularly those 'higher use' intensive industries such as pigs and poultry.

In 2020, the Australian Government launched Australia's National Antimicrobial Resistance Strategy (Australian Government 2020). The measurement of antimicrobial (specifically, antibiotic) usage is a priority (strategic priority 4.3) and is required to *support the development of targeted, timely and effective responses* to antimicrobial resistance (AMR). As a stakeholder in the strategy, the red meat industry needs an accurate estimate of the amount and type of antibiotics being used currently, so that risks can be identified, priorities set and improvements tracked over time.

European Union (EU) regulations (EU Regulation 2019/6 Veterinary Medicinal Products Regulation) coming into effect in January 2022 will require EU member countries to report antimicrobial usage (AMU) statistics to the European Medicines Agency on an annual basis. The new EU regulations will also place some new requirements on suppliers of meat products being imported into the EU (Article 118), although how AMU in primary production is to be measured and verified in supplier countries has yet to be specified by the EU.

Even though the EU's AMU reporting systems have not been compulsory to date, many European countries now report their AMU statistics annually (European Medicines Agency 2020) and this has resulted in non-European countries examining what data sources they can use to generate AMU statistics of their own.

International and domestic customers are also driving an increased awareness and scrutiny of AMU at the farm level. Although the demand for quantitative AMU data is mainly coming from governments, producers are also facing requests from customers on the types of antibiotics being used on their farms. In some instances, customers are seeking to differentiate their meat product based on their being no antibiotics used in its production, but some of the larger multinational customers have introduced procurement policies to remove antimicrobials of critical importance to human medicine from the food chain.

With the exception of lot feeding enterprises, the demand for enterprise level AMU data to drive antimicrobial stewardship (AMS) on farms has been very low. To date communications about the risks of AMR and the need for improvements in AMS have generally been directed at veterinary practitioners. Producers are already very aware about the risks of antibiotic residues in meat, so introducing messages about the need for good AMS on the farm to address AMR is a logical next step.

Clearly the need for accurate information about the use of antimicrobial agents in agriculture is growing and this project investigates practical options for generating enterprise level data for the Australian red meat industries.

1.1.2 Metrics

There is no international consensus on the metrics which should be used to measure AMU at either the national or enterprise level, although all quantify AMU in a similar way:

$$\text{AMU Indicator} = \frac{\text{Amount of antimicrobials}}{\text{Population at risk of being treated}}$$

(Sanders et.al 2020)

At the enterprise level, a variety of different metrics have been reported (Mills et al 2018; Sanders et al 2020), each having advantages and limitations. Typically, the 'amount of antimicrobials' is measured by either the number of treatments given (dose-based) or the amount of active ingredient given (weight-based).

Dose-based metrics are based on the number of antimicrobial treatments used, so seem to be the most useful for driving improvements in antimicrobial stewardship at the enterprise level. The number of doses administered is easier for farmers to comprehend and respond to than the total milligrams of antimicrobials administered.

Weight-based metrics are based on the quantity of antimicrobial active ingredient supplied or used, so seem to be most relevant for reporting the use of different types of antimicrobial actives and/or total AMU at the industry or country level.

Both dose- and weight-based metrics require an estimate of the population over which the antimicrobial medicines are used. This requires estimations of the average number and liveweight (total biomass) of different classes of livestock over time, which in turn requires detailed enterprise level data or a range of assumptions used on livestock population data already collected at the industry or country level.

The OIE requires countries to report AMU based on the weight of antimicrobial actives in milligrams, over an estimate of the animal biomass in kilograms (Gochez et al 2019). The data reported by countries is based on the weight of antimicrobial actives supplied (imported or manufactured) annually in their jurisdiction, so it is not possible to separate the amount of antimicrobials used in different species.

The EU has defined metrics to be used for reporting AMU by member countries (ESVAC 2019; ECED et al 2017) and these metrics are being used as 'default' metrics by other countries, despite the European metrics being based on a number of assumptions that have little relevance to non-European agricultural systems. Their primary reporting metric of milligrams antimicrobial active sold per kilogram of population corrected unit (mg/PCU) is problematic when applied at the enterprise level, as it is difficult to understand and can potentially lead to perverse outcomes if used to drive a change in the types of antimicrobials used. The EU's dose-based metrics, Defined Daily Dose – vet (DDDvet) and Defined Course Dose – vet (DCDvet) are based on European medicinal products and use patterns, so whilst having some use for international comparisons, are less useful for reporting AMU within non-European countries.

1.1.3 Practical systems to capture and analyse enterprise AMU data

Arguably, AMU data based on 'use' by the producer, rather than 'supply' (by vet, wholesaler, distributer or manufacturer), should provide the most accurate estimate of the amount and types of antimicrobials being used in individual livestock species. Several countries have now introduced

mandatory cloud-based animal treatment record keeping systems by regulation (e.g. Denmark and Netherlands) or through industry quality assurance programs (e.g. UK pig industry's e-MB / electronic medicine book, Red Tractor Assurance).

In Australia, although records of AMU are kept on farms for regulatory and quality assurance purposes, these records are kept in a wide variety of paper and electronic formats, limiting their potential use for generating aggregated AMU statistics.

The sophisticated stock treatment record keeping systems used on many feedlots in Australia are a rich source of AMU data but this data is closely guarded and only applicable to that type of production system. Extensive cattle, sheep and goat enterprises use minimal quantities of antimicrobials so do not have the infrastructure or inclination to adopt these types of electronic record keeping systems.

The capture of data regarding the quantity of antimicrobial medicines administered through stock feed is particularly problematic. Frequently the stock feed supplier will know the type, quantity and concentration of antimicrobial product being supplied in the feed, but not necessarily the number, class or liveweight of the stock being fed, nor the quantity of feed being fed daily. On the other hand, the feedlot manager will know the number, class, liveweight of the stock and the quantity of feed being fed daily, but perhaps not the exact type or concentration of antimicrobial medicines being used in the feed.

To date, no simple system has been developed in Australia to capture and collate enterprise level AMU data so it can be used to estimate industry-wide use.

This project seeks to develop and trial a system which enables red meat producers to measure their AMU, and so provide a platform for producers to monitor and improve their AMS over time. The system should also provide the means whereby enterprise level data can be organised and collated so industry-wide AMU statistics can be calculated.

2. Objectives

The objectives of this project were to:

- develop and demonstrate reliable, practical, and meaningful measurement systems for antibiotic use in different kinds of red meat enterprises, being cattle, sheep and goats, in both extensive and intensive raising systems; and
- use the data captured during piloting of the system to compare with industry level AMU measurements.

These objectives were partially met.

Practical and meaningful metrics have been developed for measuring AMU in red meat enterprises in Australia.

A reliable and simple on-line application (App) was also developed which is capable of calculating and reporting enterprise level AMU. The App uses data entered by the producer together with antimicrobial product registration information to calculate the enterprise's AMU results. A bespoke database of veterinary product registration data (the AVAP data resource) was created by the project team as the data held on the Public Chemical Registration Information System (PubCRIS) database is not sufficient to calculate enterprise level AMU statistics.

Both the metric and App were piloted over 3 months to demonstrate wider use, with cattle, sheep and goat producers invited to participate. However, the number of producers who provided feedback to the project team after completing the App was smaller than anticipated and so there was insufficient quantitative enterprise AMU data captured to adequately represent cattle, sheep and goat enterprises. In addition, industry-level AMU measurements are not currently available so comparisons with enterprise level AMU could not be made.

3. Methodology

3.1 Defining enterprise level AMU metrics

3.1.1 Enterprise level metrics

An investigation of the enterprise level metrics being used in different countries and livestock industries was undertaken via a search of the literature and through discussions with other Australian livestock RDCs and industry contacts. A useful review of the various farm level metrics being used internationally is provided by Sanders et al 2020.

3.1.2 Industry level metrics

A similar method was used to investigate industry level metrics, although most commonly the metrics were applied at the country rather than species level. Standard AMU metrics and calculation methodologies have been defined by the OIE for international reporting and by the EU (ESVAC) for EU member States. Several countries outside of the EU report country level data using a methodology similar to the European (ESVAC) methodology, with minor differences in the assumptions to allow for differences in product information and production systems.

3.2 Identifying source data

A desk-top study was undertaken to identify the type and quality of enterprise-level AMU data available. The study was based primarily on conversations with people involved with a range of livestock industries, government and research organisations, as well as semi-structured interviews with seven Livestock Production Assurance (LPA) auditors, two vets and three farmers involved in MLA reference groups.

LPA auditors were chosen as they examine treatment and other farm records from a range of enterprises as a part of their routine work. The auditors contacted worked with extensive beef and sheep enterprises across the country.

3.3 Building the *MyFarmAMU* App

The R Environment software was used to create an online App using R Shiny.

The advantages of an online Shiny App include: a single program and portal is required to be maintained, thereby ensuring consistency in data collection; Shiny provides advanced real-time look-up table filtering allowing for tailored and responsive data entry; user-friendly interfaces can be developed using the Shiny tools; access to other R libraries, such as the basic analytical tools and database libraries (including sqldf, dplyr) supports detailed analysis, and reporting libraries (such as

RMarkdown) bring detailed but tailored reporting capability; and output from individual users can be packaged into a common format to support industry-level aggregation and analysis.

Disadvantages of an using an online tool include: data can only be entered when the user has internet access; there is a risk of loss of data if internet connections are unstable; a stand-alone app has no or limited integration with existing farm and herd management software systems (so there is a requirement for double data entry); and the current version is not optimised for use on mobile phones, however there is potential to develop a mobile-phone optimised version of the App (using shinyMobile).

3.3.1 PubCRIS

The PubCRIS database contains information on every registered veterinary and agricultural chemical product (including antimicrobial treatments). The database contains information on each registration's: registrant details, product name, active constituents (actives), active concentrations, packaging and presentations, host (use) details and pest (target) details. PubCRIS also provides links to product labels, which contain use (dose rate and course) instructions, withholding periods and exclusion periods. The PubCRIS database is maintained by the Australian Pesticides and Veterinary Medicines Authority (APVMA) with an archive of PubCRIS being available from the data.gov.au site (Australian Government 2021). The data.gov.au site contains individual tables that can be recombined into a relational database using individual table keys.

PubCRIS is primarily used by the APVMA to maintain the registration of products. Although it can be used to query individual products (to find those with a given active, for example) or actives (to find those registered products that contain the active, for example) and to look up images of product labels, it does not contain all of the product information required to calculate AMU. A significant set of enhancements and extracts needs to be applied to the data available from PubCRIS in order to create a data source capable of providing the product information required to calculate AMU. The various measures taken to amend the extracted PubCRIS data are described below.

The majority of PubCRIS registered products are not antimicrobial products. A table of all antimicrobial active constituents was constructed, and this was used to find all registered products within PubCRIS that contained an antimicrobial active. The Australian Strategic and Technical Advisory Group (ASTAG) rating of the medical importance of each antimicrobial active (and therefore product) was recorded with the active. One challenge in extracting the products and registrations using this method was inconsistency in the spelling used to record an active in PubCRIS. For example, 'sulphonamide' and 'sulfonamide' and 'amoxicillin' and 'amoxycillin' were used interchangeably. A corpus of active names with every spelling variant was constructed and this was used within a string-matching algorithm to identify products that may contain antimicrobial actives. The final list was the result of a manual examination of the string-matching algorithm search.

Capability to determine the number of animal doses within a treatment course and within a supplied unit of a registered product (e.g. 100 mL bottle) was added to the PubCRIS extract by the construction of new fields within the tables. The most important additional fields recorded the method of dosing (unit-dosing versus rate-based dosing) and the dose rate (for rate-based dosing products) of each active for each species (cattle, sheep and goats) and age class. This information was obtained from examination of registered labels, literature review and reference to pharmacological literature. These fields were appended to the actives table.

A major hindrance encountered was, again, the inconsistency in use of terms for recording units and concentrations. For example, 'tube', 'syringe' (among others) were used interchangeably to describe products that were administered as a single dose of all contents (e.g., an eye ointment, a mastitis treatment tube) and concentrations were described in a form relevant to the pack size (e.g., mg/mL for most injectables and grams/kg for many feed additives). This required conversion of these fields to a standardised system.

PubCRIS also only includes registered products, so any product whose registration had lapsed is removed from PubCRIS. This works for the management of products currently sold in the market, but is not ideal for monitoring use of products still in the field. It is theoretically possible for a product whose registration has lapsed to still be present in residual units in stores on farms and therefore potentially used to treat animals.

For this reason, updates from PubCRIS were not used to wholly replace the existing (old) information extracted, but any new product registered since the old extract was obtained was instead added to the data to bring it up to date. In other words, the data held about registered products could only grow over time and not shrink.

In summary, a new data resource – the Australian Veterinary Antimicrobial Products data resource (AVAP data resource) has been developed, comprising linked antibiotic tables which contain all of the data fields and standardised data necessary to calculate AMU. The AVAP data resource contains:

- An extract of PubCRIS, containing only antimicrobial products registered for use in cattle, sheep and goats;
- Extra information (dose rate and therapeutic days) for every registered product to allow the calculation of the number of doses;
- All antimicrobial products that have been registered for use in cattle, sheep and goats in recent times; and
- Standardised and internally-consistent fields (that are extensively used in look-up queries).

A set of data cleaning and recoding functions have been developed that semi-automate the process of updating the AVAP data resource as and when a new PubCRIS archive is lodged at the national archives. However, the final extract still requires the oversight of a skilled operator who is familiar with the extraction process, relational database management and, most importantly, antimicrobial products and their use in animals.

3.3.2 App operability

The Shiny app was built around a set of key R algorithms (functions) that were developed to calculate antibiotic dosing, duration and quantities used, from data contained in the AVAP data resource using custom-built R functions. The software developed in the project is listed at Appendix **Error! Reference source not found.**.

3.3.2.1 Data sources

The key table and field relationships from the AVAP data resource are: **Actives, Products, ProdActives, PackSize** and **Additives** (feed).

The **Actives** table lists all antibiotic active ingredients and their antibiotic class and AMR ratings (ASTAG, WHO & OIE). This table included the (new) dose method and dose rate fields. Dose rate information was provided for cattle, sheep and goats and for adults and young animals respectively. Each active has a unique identifier.

The **Products** table lists all registered products that contain an antibiotic active and that are registered for use in cattle, sheep or goats. Each product has a unique identifier.

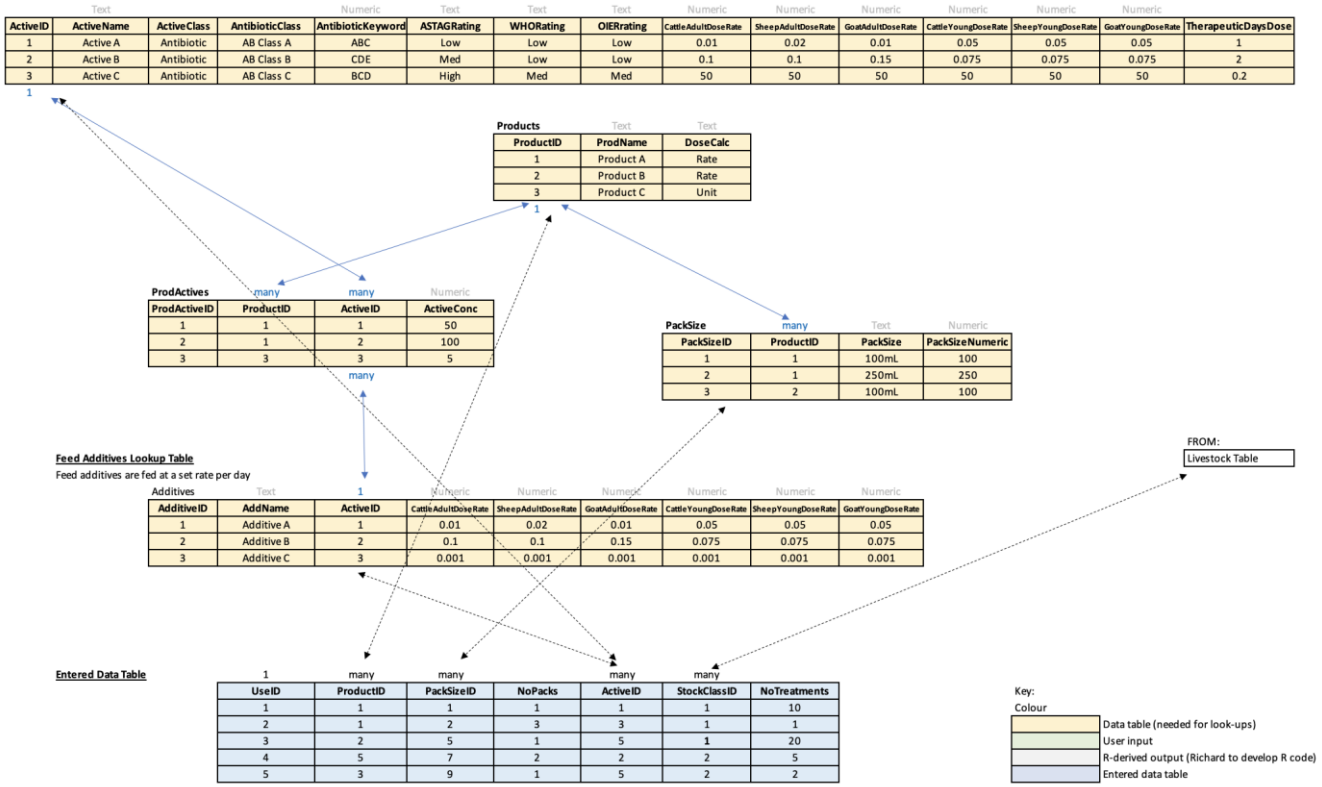
The **ProdActives** table lists each registered antibiotic, its constituent active/s and the active concentration within the product. Each entry has a unique identifier.

The **PackSize** table lists each pack size combination for every registered product within the **Products** table. Again, each entry has a unique identifier.

The **Additives** table is a stand-alone derivation of the **Products** table. It should be noted that the list of registered feed additives is very long (and confusing) so feed additive products were removed from the **Products** table and reduced from individual commercial brand names to actives for listing within the **Additives** table. Most farmers will find the list of registered feed product names large and confusing but as most know which additive they are feeding, then selecting on active ingredient will suffice for most users.

The links between these tables and to the entered data table is presented graphically in Fig. 1.

Figure 1: AVAP data resource - relationship between key data tables used in the App



3.3.2.2 R calculation functions

The buttons on the application call various R functions that perform necessary data manipulation, aggregation and processing to calculate AMU.

The primary data structure used by the App is an R list (called *SessionList*). This object holds all user-entered data, aggregations and tables of outputs (including calculated metrics). The current SessionList object is described in Table 1.

Table 1: SessionList object content description

List item	Data source	Description and use
SessionList[[1]]	Farm tab	User and farm details
SessionList[[2]]	Livestock tab	Details on stock held, species and class
SessionList[[3]]	Purchases tab	Antimicrobials usage entered from drug purchases
SessionList[[4]]	Treatments tab	Antimicrobial usage entered from animal treatments
SessionList[[5]]	Feed tab	Antimicrobial usage entered from medicated feed use
SessionList[[6]]	SessionList[[3]], SessionList[[4]] and SessionList[[5]]	Data from the three antimicrobial use entry options are aggregated into a standard format and stored here
SessionList[[7]]	SessionList[[2]] and SessionList[[6]]	The antimicrobial use metrics are calculated from the livestock details and aggregated (standardised) antimicrobial use data
SessionList[[8]]	A unique session identifier is stored here	The session identifier is generated that combines the user and farm name and a date/time stamp is generated when the report is requested to be emailed to the user. This is used to identify data from individual users and to help individual users keep records from multiple years (as separate files) on their local computer
SessionList[[9]]	Software, app and PubCRIS identifiers	An identifier listing the PubCRIS database extract version, the Shiny App engine version and the GUI version. This will help version management and data centralisation
SessionList[[10]]	A blank field	This is filled with a timestamp if centralised data is aggregated into an industry-wide database. Once the data from SessionList has been incorporated into the

central database, a time stamp denoting the time of importation is written to this slot

A key aspect to the data capture system is the capture of raw enterprise level data. Data on the number and class and weight of livestock and on each antimicrobial product, purchased or used or fed, is linked through the relational database structure to allow any AMU metric to be calculated. Currently, the App only presents the number of Animal Daily Doses per 100 head per year (nADD/100 hd/yr) metric to the user, but it also captures the data necessary to calculate other metrics (such as milligrams of active used, PCUs etc).

Different metrics can be calculated via a simple change to functions stored into SessionList[[7]]. The count of doses, duration of activity of treatments, weight of actives administered and the number and weight of animals that were at risk of treatment (and the subset that was treated) are contained within the data. This means that any metric can be calculated from the entered data — even retrospectively if required. This flexibility will allow the system to contribute effectively to Australia's antimicrobial reporting obligations now and into the future.

3.3.3 AMU calculations

Dose-based metrics appear to be the most useful for driving AMS at the enterprise level. This is because they enable both the amount of active ingredient and the duration of treatment to be monitored. A dose-based metric is easier to communicate to producers than total weight of antimicrobial actives used. Dose-based metrics also cater for differences in the potency (dose required) of different active ingredients, with some newer chemistries requiring much smaller doses than some of the older chemistries. Importantly, dose-based metrics can be used to selectively monitor the use of different antimicrobial actives and/or antimicrobial classes. Farmers can also use these metrics to calculate and track AMU for different cohorts in their herds.

The AMU metric recommended for use at the enterprise level for the red meat industry is the number of Animal Daily Doses per 100 head per year (nADD/100 head/year). This metric is a standardised antimicrobial drug usage rate. It is calculated as shown in Table 2.

Table 2: Method followed to calculate the standard AMU metric (nADD/100 head/ year)

Step	Method	Result
1.	Count the number of animal-days that had an antimicrobial concentration at or above therapeutic levels for the herd/flock in question across the period in question (year). *Note that if more than one antimicrobial active was administered to animals within the herd/flock, calculate and sum the number of animal-days across all administered actives.* *Specifics of calculating 'A' from records of the drugs purchased/dispensed, animal treatment records and in feed medications are given below.*	**A**
2.	Estimate the total number of animal-days at risk (of being treated with an antimicrobial) for the herd/flock in question and across the period of interest. *Note this can be estimated by the average of opening and closing stock numbers multiplied by 365.*	**B**
3.	Estimate the proportion of the animal days at risk that had an antimicrobial concentration at or above the therapeutic level for the herd/flock. i.e. A / B	**C**

4.	Convert the proportion (C) to a standardised rate by multiplying by a constant, being 100 animals held for a year. This is the number of days that a herd/flock of 100 animals will have an antibiotic concentration at or above therapeutic level over a year. i.e. C * 100 * 365	**D**

Specifics of calculation of the numerator (A) from prescribed medicines, treatments and administered in medicated feeds respectively is described below:

> **Estimated from drugs purchased (dispensed)** = number of antimicrobial product packs purchased per year X number of daily doses in each product pack X number of therapeutic days per dose (summed across all actives in products purchased)
>
> **Estimated from herd treatment records** = number of animals treated X number of therapeutic days per dose (summed across all actives used)
>
> **Estimated from in-feed medication records** = number of days that medicated feed was offered X number of animals in group (summed across all actives fed in the period)

Calculating how many 'daily doses' of an antimicrobial medicine are applied to a population over a defined period is an intuitive approach to measuring AMU on farms, as it estimates the rate of use of antimicrobials. This has been recently advocated for monitoring farm level AMU in the Australian dairy industry (S. McDougall 2019). This standardised AMU metric can be used in a number of different ways to highlight different aspects of a farm's AMU, by the number of animal daily doses of: total antimicrobials; antimicrobial class; route of administration; antimicrobial resistance (ASTAG/WHO) rating; total livestock; and/or by class of livestock. Standardised rates can be compared within farm, across years and between farms. Differences in the size of the herd/flock between comparison groups are also possible because of the standardisation of each rate to be compared to a constant herd/flock size and study period.

3.3.4 App appearance

Shiny is an R package used to build interactive web Apps from within R. The layout of the App is presented below. Each tabbed page contains instructions on how the App is to be used and the introductory page presents information on the role and purpose of calculating AMU on farms. A screen shot of each 'tab' is provided in Appendix 8.2.

The app can be accessed at www.amuapp.net

It should be noted that this version of the App was created for piloting only. Advice on branding, style guide, legal protections and the like need to be received and applied to the App (and report) before it is suitable for more general release (see Milestone Report #6).

3.3.5 Reporting

Users have the option to send a PDF report and an R object (file containing all session entered data) to their nominated email address, once they have completed their data entry. This action can also send a copy of the uniquely-named R data file to a central email address where it can be held. The RData object contains raw and calculated data in a form suitable for reconstituting (using the same R functions), and aggregation into an off-line database. Such a database allows industry-level analysis or exploration. Users may opt out of sharing their data this way.

An example of the PDF report is provided in Appendix 8.3. The report was generated using RMarkdown (an R library that generates a LaTeX file and PDF document within the App). The PDF report is tailored, using a series of logical tests to ensure that only relevant summary tables and statistics are presented to individual users.

3.4 Piloting the *MyFarmAMU* App

3.4.1 Beta-testing of the MVP Tool

The initial iteration of the App was a Minimum Viable Product (MVP) version created in Excel®. Creating the MVP facilitated the planning of the overall structure of the App and the testing of core functionality, such as the dropdown product lists drawing data from PubCRIS and calculation of the various usage metrics, prior to the more complex Shiny build.

The MVP Tool was tested extensively for bugs by the consultancy team using dummy data. It was then piloted in May-June 2020 with a small number of producers nominated by MLA. The aims of the pilot were to:

- Identify any bugs in the tool (e.g. dropdown lists not working);
- Assess the user-friendliness of the tool; and
- Gauge the value of outputs to the users, and potentially other producers.

Participants in the pilot were asked to populate the tool with 12 months of real data from their enterprise, print the report and send their completed spreadsheet to the consultants. They were also asked to complete a brief online survey describing their experiences of using the tool and specifically noting any bugs or other issues (for example, difficulties making livestock numbers fit the input options).

3.4.2 Piloting the on-line App with producers

The Shiny version of the App was extensively tested by the consultancy team for bugs and other issues. It was then piloted with cattle, sheep and goat producers between January and April 2021. The aims of this pilot were the same as that of the MVP Tool pilot, but with the additional hope of generating a preliminary (if not statistically significant) data set on actual AMU across the industry for comparison with industry data sets.

Participants for this pilot were asked to access the App via a browser and to populate it with 12 months of real data from their enterprise, as per the initial pilot. However, as the difficulty of recruiting participants became increasingly clear, and as it emerged that privacy concerns or lack of any AMU by the enterprise were prime drivers of this lack of willingness (see below), the team compromised on the requirement for real data to be used and allowed producers to enter dummy data. Participants were asked to send the generated data file and report to the consultancy team and to complete a short online survey capturing their experiences with the App. The survey was a slightly augmented version of the original survey, designed to capture some additional information about likely acceptance of the App among the broader producer community.

It was agreed in the project design that MLA would recruit at least 50 participants for the App pilot through its producer networks. Preferably, these participants were to be stratified by geography and production system (southern and northern beef, sheep, goats). MLA sought expressions of interest to participate in the pilot through its three research councils – the Southern Australia Livestock Research Council (SALRC), the North Australia Beef Research Council (NABRC) and the Western

Australian Livestock Research Council (WALRC) – as well as various other producer networks. Unfortunately, only a small number of people (around 12) responded positively to this approach.

With the agreement of MLA, the consultants sought to identify participants through their own networks. A large number of direct telephone calls were made to potential participants (including the ones provided by MLA) and producer network coordinators. These networks included:

- Nine BetterBeef groups in Victoria;
- BestWool / BestLamb in Victoria;
- SALRC and WALRC (follow-up and resend of article seeking expressions of interest);
- Several NSW DPI and Local Land Councils in NSW, accessed through the Department of Primary Industries at Wollongbar, NSW; and
- Various goat industry contacts.

This modified process was not much more successful, with only five 'formal' completions, despite requests being distributed to several hundred producers.

Due to the low uptake of the on-line format, the project team also presented the tool to a BetterBeef discussion group in Warragul (15 producers) and sought their comments and advice on the App and the report. This was not an ideal method either as only two of the participants had looked at the App prior to arriving at the meeting as they had been requested to do.

Another idea was to pilot the App face-to-face with a group of agriculture students (Certificate II) from Federation University TAFE in Ballarat. Despite some initial interest from Federation University, this was not able to be pursued.

4. Results

4.1 Availability of source data

The anecdotal evidence from the interviewees for this part of the project supported previous findings that AMU is very low among sheep, beef cattle and goat producers. Usage appears to vary between regions, being generally higher (among extensive systems) in more southern parts of Australia, as would be expected. In Tasmania, for example, the estimate was that 100% of sheep flocks would have at least one antibiotic treatment record during a given 12-month period, whilst for southern Queensland the estimate was <1%. Estimates for beef ranged from 0% (northern) to 40% (Victoria). Ionophores, primarily monensin, are used in licks in some regions but few producers would even know that they include an antimicrobial drug.

LPA auditors report that treatments are usually recorded (although of course LPA auditors are taking the producer's word that no record equates to no treatment). The quality of records varies. One auditor stated that most records of treatment (including drenches, dips etc) do not meet LPA requirements and that 75-80% would attract a corrective action request or observation. Records would most commonly provide the date, product name (although sometimes this will just say 'antibiotic') and dose, type of animal and mob (e.g. 'steer in back paddock'). Treated animals may be segregated or marked. WHP might be recorded and possibly batch number and expiry date. Some producers will rip off a label (e.g. a feed mix containing an ionophore) and stick it into a diary or notebook.

The form of the record varies, from calendar notes or diary entries to records in templates and electronic capture – most commonly spreadsheets but also using smartphone apps, stockbooks and

proprietary systems such as AgriWebb®. Hard copy predominates, perhaps representing 75% of records. Only a small number would use the LPA treatment template and those are often people who have been shown the template by an auditor. Not surprisingly, younger farmers are more likely to adopt electronic records. Systems such as AgriWebb® are good but mob-based, at least in the case of sheep. There is no facility yet to scan an animal's electronic identification tag and then the product barcode to obtain a complete, individual animal treatment record.

Producers supplying buyers such as JBS (through Farm Assurance) or Greenhams in Tasmania must keep more rigorous treatment records and are subject to more stringent audits than those of LPA. In fact, Farm Assurance and two of Greenhams' programs do not accept animals that have ever been treated with an antimicrobial. Animals falling into this category on supplier farms must be permanently identified with a red eartag.

Vet invoices will generally specify any antibiotic treatments administered, although sometimes the drug's name is not specified. There are times too when a vet may administer a treatment on-farm and the producer either forgets what has been given or loses any documentation provided to them by the vet.

No data was collected on the type of records farmers keep for the supply of medicated feeds. These are rarely used on extensive enterprises, perhaps with the exception of ionophores included in lick blocks or as supplements.

Producers generally have a good idea of the number of livestock on the property at any given time, even in extensive northern cattle systems. Only a minor proportion of producers would weigh animals and even then, this is only done with certain classes of stock at critical times of year, e.g. weaner sheep over summer.

4.2 Practical system to measure enterprise level AMU

The main output delivered from the project is a simple, robust tool that can be used to measure and report enterprise level AMU – the *MyFarmAMU* on-line App. A major focus of the developers was to make the tool as easy to use by farmers as possible. One feature developed to enable this was the use of smart lookup tables to identify the registered antimicrobial product administered. Most farmers do not know the name of chemical actives, but know products by the registered product name. The App includes a free-text entry box where the user may enter a few letters of the name of the product and subset of products that match this text string is immediately offered to the user for selection. Importantly, the string of text entered by the user can occur anywhere within the registered name of the product. This feature worked seamlessly in the App; there were no reports that a product could not be found by users. This tool has the capability to capture all the data required to generate a variety of enterprise level and industry level AMU statistics using a range of metrics.

The metrics for enterprise level reporting have been defined in Section 3.3.3.

The intellectual property developed during the project is presented in the Appendices (Section 8) and includes:

- The code for the key R functions used in the App;
- Screenshots of the appearance of the App;
- An example producer report; and
- The RMarkdown code used to produce the producer report.

The project team also developed the Australian Veterinary Antimicrobial Products data resource (AVAP data resource) providing the data required to calculate AMU metrics for every antimicrobial product registered for use in cattle, sheep and goats. This was a significant piece of work and is the first time this data has been collated in Australia.

In the initial pilot using the MVP tool (Excel version), seven individuals completed the pilot. The average rating for 'ease of use' among the group was 3.6/5, whilst the average rating on whether the report made sense was 3.3/5. The qualitative feedback received was very valuable, identifying a number of bugs and other issues, as well as suggestions for improved user-friendliness. These were taken into account as far as possible in the development of the Shiny App.

The pilot of the on-line Shiny App (*MyFarmAMU* App) in early 2021 provided the project team with a reasonable understanding of the likely appetite among producers for the App and its usability. Although only a small number of producers completed both the App and the survey, discussions with prospective and participating producers and at a producer workshop, provided a rich source of qualitative data for the project team. The main findings of the pilot were:

- The App is robust, easy to access and maintain. Any bugs or issues with App that were reported by users were quickly fixed with minimal down time, which is an advantage of having the application online and having combined domain and programmer skills in the (small) project team. This is the benefit of using an online application as opposed to producing a program that must be downloaded to each user's device (and updated periodically).
- The programming which enables the user to search and select a product from a drop-down list of APVMA-registered products was particularly successful. There were no reports of failure to find the right antimicrobial product, and periodic checking of ADDs as calculated from entered data proved to be correct every time. The manipulation required to convert the PubCRIS repository into a useable form — the linking of product names to drug active, active concentrations, animal dose rates and calculations of drug doses and therapeutic days — is significant. We have developed code to allow the five APVMA-derived tables used by the App to be updated as the PUBCRIS repository database is updated.
- There was some confusion about the benchmark measure of nADD/100 hd/yr among pilot participants. This was despite an explanation in the report of how the metric is calculated. This is perhaps not surprising, as a relatively simple antibiotic regime can result in a value for ADD/100 hd/yr that is not intuitive, particularly if it involves long-acting products and/or those containing more than one active. For example, a single injection of long acting oxytetracycline (Ilium Oxytet-200 LA) will result in 5 ADDs (as it has a therapeutic effect over 5 days). If this single injection is given to an animal in a small herd of only 25 animals (average population of 25 head per year), then the AMU result for the herd is equal to 20 ADD/100 hd/yr. So the standardised metric will need to be explained carefully to avoid perceptions that the App 'does the maths all wrong' (actual quotation).
- Several usability improvements were suggested:
    - The App should accommodate producers with zero AMU during the time frame.
    - The approach to handling livestock numbers and weights is imperfect (as we knew). For example, it does not accommodate traded mobs that spend a short period of time on the farm. This is the challenge of balancing simplicity and accuracy.
    - There is probably too much content in the report. It seems that the few users who have trialled the App so far have not read the report thoroughly, despite being likely to be more progressive producers.

- Whilst the report explains what ASTAG is, the explanation is quite hidden and comes well after the term is first used in the upfront summary report. It may be better to avoid mentioning 'ASTAG' and simply refer to 'medically-important antimicrobials' until ASTAG can be explained in the more detailed content.
- The App could be set to provide reminders to fill it in.
- A reporting bug was identified (and fixed) that resulted in 'NA' values being returned in the standard metric calculations for certain ASTAG groupings in some cases.

4.3 Capturing data for industry-level analysis and comparison

Producers contacted during the pilot seem to acknowledge that antimicrobial resistance is an important issue that the red meat industry needs to address, but most consider that the risks posed by their use (and the industry's use more widely) are low.

The pilot also provided some interesting insights into how producers feel about completing the App (and so contributing their data for industry level AMU reporting). The major constraints to using the App seemed to be as follows:

- *Time constraints.* This was the main challenge. Producers are very busy, and the same ones (often the members of research councils and producer innovation groups) are continually being asked to participate in projects. Anecdotally, and in the experience of the project team, it is becoming increasingly difficult to convince producers to contribute time to projects.
- *Lack of a driver or value to the individual producer.* The 'what's in it for me?' proposition was not overly compelling for producers using the App – the only appeal was to assist the industry to address what many perceive to be a problem for others / long term issue.
- *A perception that producers are 'being checked up on' in regard to their use of antimicrobials.* The team progressively modified its approach to emphasise the confidentiality of data, and even to suggest that people could use dummy rather than real data – and also to highlight the message that developing this App goes some small way towards defending the industry's access to antimicrobials.
- *A perception that 'my input is of no value because I use so little antibiotic anyway'*. When contacted by phone, several producers indicated that they had decided not to participate as they had no data to contribute. There are likely to have been a number of producers who decided not to express interest in the pilot for this reason. Messaging was progressively modified as the project rolled out to encourage people to participate even if they did not have real data to submit.

These issues will need to be addressed if MLA wish to recruit producers to collect AMU data using this or any similar tool. As it stands, the App offers only a summary report on the producer's AMU (using a metric that is difficult to understand), highlighting the use of 'High' (ASTAG) importance antimicrobials. A fundamental issue in promoting the AMU metric is that there are currently no available benchmarks for the metric, and in fact benchmark figures may be quite meaningless because of the lumpy distribution of AMU on farms. A sheep producer might, for example, institute a regime of long-acting oxytetracycline on their flock as part of a footrot eradication program. This regime might follow best practice AMS, and oxytetracycline is a low-importance medical antibiotic, yet the producer may return a high ADD/100 hd/yr figure relative to other flocks. This would not indicate poor management on the part of the producer.

The App does not assist producers to record AMU in real time, nor to track withholding periods, export slaughter intervals or to record batch numbers and expiry dates to meet LPA requirements. The report generated by the App does not benchmark the producer's AMU results or provide concrete recommendations for improving AMS.

Insufficient quantitative enterprise level data was received during the pilot to derive any industry level statistics. A separate MLA project seeking data sourced from drug manufacturers was abandoned, so no comparisons of enterprise level 'use' and industry level 'supply' data was possible.

5. Conclusion

5.1 Key findings

- Capturing enterprise level data is a key challenge facing the red meat sector in measuring enterprise level AMU, with enterprise level AMU records kept in a large variety of paper-based and electronic formats.
- Producers only want to make a record once, so re-entering data from one source into the App is a significant barrier to its adoption. An App to handle all treatments, not just antimicrobials, is strongly preferred.
- Although dose-based metrics seem most relevant to producers to drive AMS, producers are unfamiliar with key terms and found the calculations and reports difficult to understand.
- The data contained in PubCRIS is not suitable to calculate enterprise level AMU. Significant resources were required to create a suitable data resource (AVAP data resource), including adding in additional data fields for dose rate and therapeutic days.
- An on-line application (App) is well suited to capturing AMU data and offers significant advantages compared to other tools, such as paper-based sheets and downloadable programs.
- Currently, producers have no clear drivers to motivate them to collate their AMU data or use a tool to generate enterprise level or industry level AMU statistics. Assisting them to more easily meet compliance obligations (such as those of LPA) would provide one such driver.
- A significant program of producer engagement (communications and education) would be required to support an industry-wide release of the *MyFarmAMU* App if it is being considered as a tool to generate industry-wide AMU statistics.

5.2 Benefits to industry

This project delivers some practical tools that can be applied for measuring enterprise level AMU, as well as some valuable insights on how they might be received by red meat producers. The following project outputs are of benefit to the red meat industry:

- The number of Animal Daily Doses per 100 head per year (nADD/100 hd/yr) is the metric recommended to measure AMU at the enterprise level for red meat producers.
- Weight-based metrics (mg of antimicrobial / kg liveweight) aligned to international protocols (OIE & EU/ESVAC) are recommended to be used for industry level reporting.
- A simple and robust online App (*MyFarmAMU* App) has been developed as a tool which red meat producers can use to enter their data and receive a report on their AMU.

- A new data resource, the Australian Veterinary Antimicrobial Products data resource (AVAP data resource), has been constructed, housing the data about registered products that is required to calculate AMU metrics. Semi-automated systems and protocols to keep this data current have been established, although this resource will require regular maintenance.
- A range of strategies to improve the uptake and use of the App have been suggested, largely to improve the 'value proposition' for using the App and to increase awareness of the need for AMU data and reporting.
- An alternative method to derive industry level AMU statistics using data captured by the App and from veterinary practices have also been presented.

6. Future research and recommendations

6.1 Options for generating AMU statistics

Key recommendation #1	In consultation with industry stakeholders, develop an agreed industry plan for monitoring and reporting AMU in the red meat industry. Key issues to address in the plan include: • the current and future need for red meat industry AMU data; • the most appropriate metrics to use at both the enterprise and industry level; • the source/s of data and the methods used to collect it; • the method/s used to collect and analyse the data; and • the governance of the plan, data and reporting.

6.1.1 Using the *MyFarmAMU* App

Additional considerations

- The App could be used on a representative sample of producers to generate industry-wide statistics. Recruiting producers to participate in a survey would require active targeting and incentives. An alternative would be to pay LPA auditors to complete the App during enterprise audits. The producer sample size has already been validated and the LPA auditors could be trained in the use of the App, which should reduce the impost on individual producers.
- Using the App to model 'typical' enterprise AMU is possible, with simulations based on disease prevalence or veterinary 'supply' data used to estimate industry AMU. Whilst an interesting exercise, it is likely that these estimations of AMU would need additional verification to be acceptable to international customers.
- An active, incentivised program of data collection from sentinel producers, veterinary practitioners and stock feed suppliers could be established to verify enterprise AMU data collected from a small sample of producers using the *MyFarmAMU* App.

6.1.2 Using data sources from veterinary practitioners

Additional considerations

- Prescribing vets should be able to provide data on the quantity of antibiotics dispensed but may not have corresponding data on the species, age, liveweight and number of livestock in the herds where the antimicrobial products have been used.
- A system to harvest data from leading small animal and equine veterinarians has already been established by Vet Compass Australia (VCA). Prescribing and patient data is automatically uploaded from practice software via an application programming interface (API) to a centralised research database, allowing researchers access to investigate a range of issues, including antimicrobial supply and use. This system is currently based on individual patient records, rather than 'herd' treatments, but provides a useful model to manage data sourced from veterinarians, stock feed suppliers and potentially drug registrants.
- VCA itself could be used for the collection of antimicrobial prescription and supply data but would require some investment to make necessary upgrades. The system is owned by the Australian and New Zealand universities that have veterinary schools. Upgrades to VCA to accommodate herd data would also offer the industry disease surveillance benefits. Such an initiative might be progressed in conjunction with the Australian Cattle Veterinarians (ACV).

6.1.3 Using industry population data

Additional considerations

- Accurate estimates of the total number and liveweight of the Australian cattle, sheep and goat populations are required in the denominator to generate industry-wide AMU metrics. Small differences in these estimates can have a large impact on the AMU results being calculated and reported.

6.2 Systems to capture enterprise data

Key recommendation #2	Clear market signals, industry messaging and an improved 'value proposition' are needed to get the *MyFarmAMU* App used more widely by producers.

Additional considerations

- Producers need to be educated on the importance of AMR and why contributing their de-identified AMU data for centralised analysis and reporting is necessary. It is anticipated that resources, time and a range of drivers (incentives and/or penalties) will be required for these concepts to be accepted by producers and industry stakeholders.
- Enterprise AMU data entry/recording systems should be electronic and animal-side.
- Enterprise AMU recording systems should be integrated into systems that capture all chemical treatments (drenches, vaccines) for LPA/regulatory purposes, preferably as a part of a complete herd management system.
- An industry supplied, mandatory online electronic record keeping system, based on LPA record keeping requirements, including antimicrobial treatments or purchases and a stock

register, would standardise data collection across the industry and solve the issue of entering data twice to generate AMU statistics.

- A centralised system to capture data on antimicrobial products supplied in stock feed needs to be implemented, which includes data on the antimicrobial type and quantities supplied, and the population of animals that the treatments are given to.
- Existing commercial herd data record keeping systems (herd management systems) should be able to export data in a format suitable to calculate AMU statistics, or be capable of calculating and reporting AMU according to standard industry requirements.

6.3 Systems to calculate and analyse enterprise AMU

Key recommendation #3	The data resource created to house information about registered antimicrobial products (the AVAP data resource) should be maintained and made available to facilitate the calculation of AMU by interested parties.

Additional considerations

- The recommended enterprise level AMU metric for red meat producers is the dose-based metric: the number of animal daily doses (ADD) per 100 head per year (nADD/100 head/yr).
- The recommended industry level AMU metrics for the red meat industries should be weight-based metrics, as per OIE & ESVAC requirements and include reporting on volumes of specific classes of antimicrobials (i.e. critically important antimicrobials in human medicine as per WHO AMR ratings) as required by customers/trading partners.
- The Australian industry may wish to consider establishing their own industry level AMU metrics to suit Australian conditions and needs. Other countries have modified the EU's mg/PCU, DDDvet and DCDvet metrics to accommodate differences in their production systems and registered medicines.
- APVMA's PubCRIS database needs to be upgraded to list dose rates (and therapeutic days) for each product, and remove inconsistencies, text and records that cannot be analysed.
- The code written to collate PubCRIS and other data into a single data source (i.e. the AVAP data resource) worked well.
- The AVAP data resource constructed by the project team for use by the App requires regular updating and maintenance. Initially some technical review would be beneficial to ensure the assumptions made and figures used in the tables (e.g. for the dose rate and number of therapeutic days) are reasonable. Longer term, the tables must be updated and checked as new data from PubCRIS is added to the archive data source (data.gov.au site).

6.4 Systems to report enterprise AMU

Key recommendation #4	Education and veterinary advice should be provided to producers (and their advisors) to properly interpret enterprise AMU results and use them to drive improvements in antimicrobial stewardship in herds and flocks.

6.4.1 For producers

Additional considerations

- Producers showed a preference for a short report (1 page), providing their AMU result and what to do about it. A different, more detailed report could be created for more technically-minded producers, vets and advisors.
- The producer report should use common language (no jargon, acronyms etc). Terms like 'antimicrobial' (rather than antibiotic) were seen to be off-putting to some producers.
- Vets and other advisors could play a role in supporting producers to interpret their AMU report. Some initial training would be required to familiarise advisors with the key AMU terms and concepts.

6.4.2 For industry

Additional considerations

- It would be preferable to have de-identified enterprise level AMU data available to industry for aggregation and analysis in real-time (via database backend).
- Industry agreement is required on the preferred industry-level AMU metrics for use in the Australian red meat industry, noting that the EU requirements for suppliers have yet to be published.
- A wide range of AMU calculations can be made from the data collected by App, although creating an industry reporting function in the App was beyond the scope of this project and has not been attempted.

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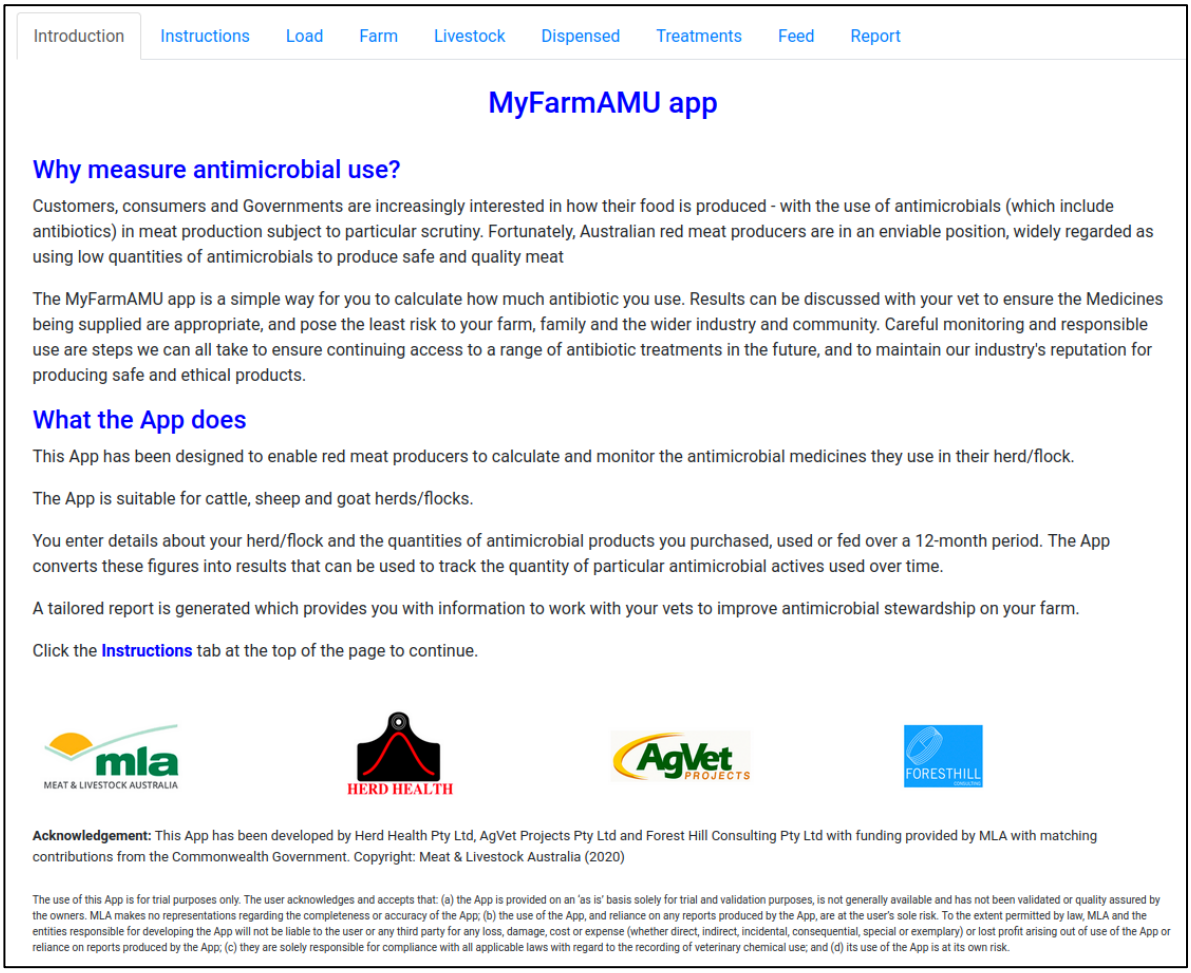
8. Appendices

8.1 Software developed in the project

The following software developed in the project has been forwarded to MLA separately:

- MVP Tool – MS Excel spreadsheet version used in beta-testing.
- Australian Veterinary Antimicrobial Products (AVAP) data resource – a data resource housing the information about every antimicrobial product registered for use in cattle, sheep and/or goats, that is required to calculate AMU.
- Code required to update the AVAP data resource from PubCRIS data
- *MyFarmAMU* App – Shiny App used for the pilot.

8.2 Appearance of the *MyFarmAMU* App (screenshots)



Introduction | Instructions | Load | Farm | Livestock | Dispensed | Treatments | Feed | Report

Data requirements

IMPORTANT! Only proceed if you used antibiotic in the last financial year. A report can only be generated if antibiotic use is entered.

How to enter the data

There are two ways to input data: by loading a data file generated by this App from a previous session (*.RData* - note this file can only be read using the R program); OR enter details on the herd/flock and all antimicrobial products purchased, used for treatments or fed over a 12 month period individually.

Loading data

Load: This page allows you to upload a data file generated from a previous session. Once loaded, you can add or edit entries as below

Entering data

First, enter details on your livestock and all antimicrobials you used during the last financial year.

Farm: Enter details on your farm.
Livestock: Enter numbers of all cattle, sheep and goats carried

Then, EITHER

Medicines Dispensed Records - of all veterinary antimicrobials that were prescribed and supplied to you by your vet. These will be listed on your vet. invoices.

OR

Individual Treatment Records - of all antimicrobial treatments given from your herd management records.

AND, (if used)

Feed Treatment Records - of any medicated feed fed during the year to groups of animals, such as records of medicated feed purchased from your stock feed supplier, or on the labels of any bagged product. Note that you will need to know the antimicrobial active ingredient added to the feed, and the number of animals and days it was fed.

Generating a report

The **Report** page includes two options - one to see the report on line and another to email the (final) report and data file to the email address you entered in the Farm tab. You may also choose to withhold your (de-identified) farm summary data from contributing to industry statistics button.

Introduction | Instructions | Load | Farm | Livestock | Dispensed | Treatments | Feed | Report

Loading Existing Data Guide

This is an option to upload an existing data file (generated from a previous session). Use the **Upload** button to navigate to and upload the *.RData* file stored on your computer to the App (note, this file can only be read using the R program). Only data files generated using this App can be uploaded.

First time users must enter all data manually to start.

Upload data file

Upload | ShinySessionListV2.RData

Upload complete

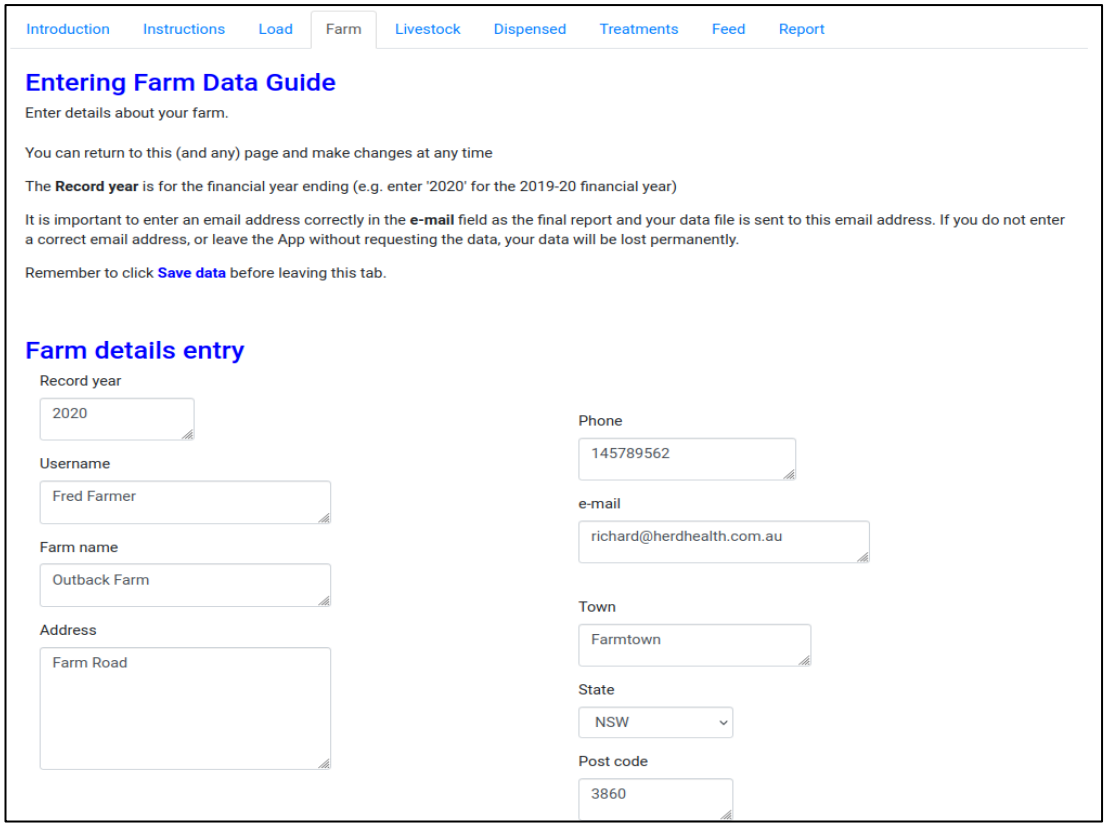
The data from your file is imported!
If you are unable to complete all data entry in a single session, save your work, go to the **Report** tab and click the **Mail Report** button to receive an email with an attached *.RData* file containing your completed entries to date. You can upload the saved file at a later date to complete your work.

Saved sessions

The data file generated from this App includes all entered data (farm, livestock, dispensed, treatments and feed) and derived summary calculations on antimicrobial rating and use rates.

The calculations begin by linking the products you have used to the antimicrobial actives that they contain, the concentration of actives within each product and the antimicrobial active rating (ASTAG) of each active. The data is combined and summarised to give a standardised estimate of the number of animal doses of each antimicrobial active group for your livestock. These tables of results are stored with the data file (in *.RData* format) generated by this application. This data file is an important record for your farm and you are encouraged to save the file alongside the report that is generated from the data.

The *.RData* data file can be uploaded in the future for editing. The report and data file have unique names allowing you to store multiple versions from across multiple years.


Introduction
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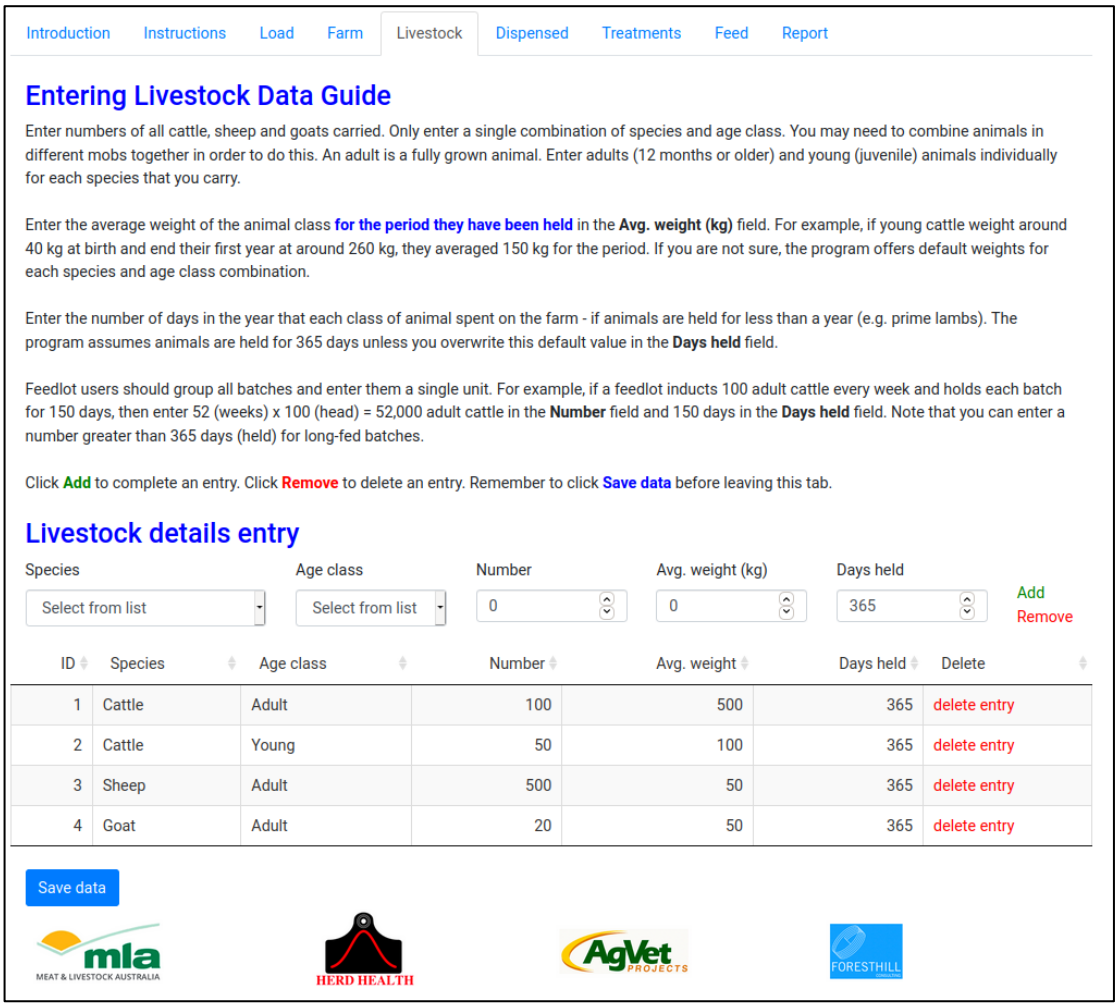
Entering Farm Data Guide
Enter details about your farm.
You can return to this (and any) page and make changes at any time
The Record year is for the financial year ending (e.g. enter '2020' for the 2019-20 financial year)
It is important to enter an email address correctly in the e-mail field as the final report and your data file is sent to this email address. If you do not enter a correct email address, or leave the App without requesting the data, your data will be lost permanently.
Remember to click Save data before leaving this tab.
Farm details entry
Record year
2020
Username
Fred Farmer
Farm name
Outback Farm
Address
Farm Road
Phone
145789562
e-mail
richard@herdhealth.com.au
Town
Farmtown
State
NSW
Post code
3860


Introduction
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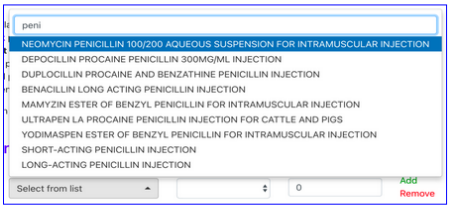
Report
Entering Livestock Data Guide
Enter numbers of all cattle, sheep and goats carried. Only enter a single combination of species and age class. You may need to combine animals in different mobs together in order to do this. An adult is a fully grown animal. Enter adults (12 months or older) and young (juvenile) animals individually for each species that you carry.
Enter the average weight of the animal class for the period they have been held in the Avg. weight (kg) field. For example, if young cattle weight around 40 kg at birth and end their first year at around 260 kg, they averaged 150 kg for the period. If you are not sure, the program offers default weights for each species and age class combination.
Enter the number of days in the year that each class of animal spent on the farm - if animals are held for less than a year (e.g. prime lambs). The program assumes animals are held for 365 days unless you overwrite this default value in the Days held field.
Feedlot users should group all batches and enter them a single unit. For example, if a feedlot inducts 100 adult cattle every week and holds each batch for 150 days, then enter 52 (weeks) x 100 (head) = 52,000 adult cattle in the Number field and 150 days in the Days held field. Note that you can enter a number greater than 365 days (held) for long-fed batches.
Click Add to complete an entry. Click Remove to delete an entry. Remember to click Save data before leaving this tab.
Livestock details entry
Species
Select from list
Age class
Select from list
Number
0
Avg. weight (kg)
0
Days held
365
Add
Remove
ID
Species
Age class
Number
Avg. weight
Days held
Delete
1 Cattle Adult 100 500 365 delete entry
2 Cattle Young 50 100 365 delete entry
3 Sheep Adult 500 50 365 delete entry
4 Goat Adult 20 50 365 delete entry
Save data
mla
MEAT & LIVESTOCK AUSTRALIA
HERD HEALTH
AgVet PROJECTS
FORESTHILL

Introduction | Instructions | Load | Farm | Livestock | Dispensed | Treatments | Feed | Report

Entering Dispensed Medicines Guide



Use this tab if you are using a tally of the medicines dispensed to you over the financial year as your source data for individual animal treatments. This is an efficient way to enter data for those enterprises that use significant quantities of antimicrobial products and the best way for large enterprises to enter individual animal treatments. The alternative is to enter each treatment individually using the **Treatments** tab.

Select the species/age class of animal that were treated (choice is restricted to livestock that you entered in the **Livestock** page), select the product by typing a few letters from the name of the product into the **Product** drop-down list (as shown on the right). This will help limit selection options. Then select the pack size and enter the number of packs bought. You can enter fractions of a pack to cover partial pack use. For example, if you bought two packs of a Medicine but have half a pack left unused at the end of the financial year, simply enter 1.5 in the **Number packs** field.

Click **Add** to complete an entry. Click **Remove** to delete an entry. Remember to click **Save data** before leaving this tab

Dispensed Medicines entry

Species/Age class | Product | Pack size | Number packs | Add / Remove

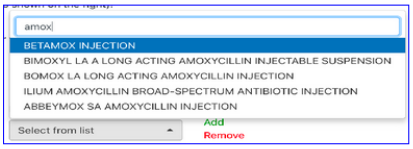
Select from list | 0

Species	Age class	Product	Pack size	No. packs	Delete
Cattle	Adult	BENACILLIN LONG ACTING PENICILLIN INJECTION	250 mL	3	delete entry
Cattle	Young	NEOMYCIN PENICILLIN 100/200 AQUEOUS SUSPENSION FOR INTRAMUSCULAR INJECTION	100 mL	2	delete entry
Sheep	Adult	COOPERS ENGEMYCIN 100 OXYTETRACYCLINE HYDROCHLORIDE 100MG/ML INJECTION	250 mL	5	delete entry

Save data

Introduction | Instructions | Load | Farm | Livestock | Dispensed | Treatments | Feed | Report

Entering Treatments Guide



Use this tab if you are using herd treatment records as your source data for individual animal treatments. This option will suit those enterprises that use only a few treatments over the financial year. The alternative is to enter (grouped) animal treatments using the **Dispensed** tab.

Select the species/age class of animal that were treated (choice is restricted to livestock that you entered in the **Livestock** page), enter the number of animals treated and the number of doses administered to each animal (in the course). To select the antimicrobial product you used, type a few letters from the name of the product into the **Product** drop-down list (as shown on the right). This will help limit selection options.

Click **Add** to complete an entry. Click **Remove** to delete an entry. Remember to click **Save data** before leaving this tab

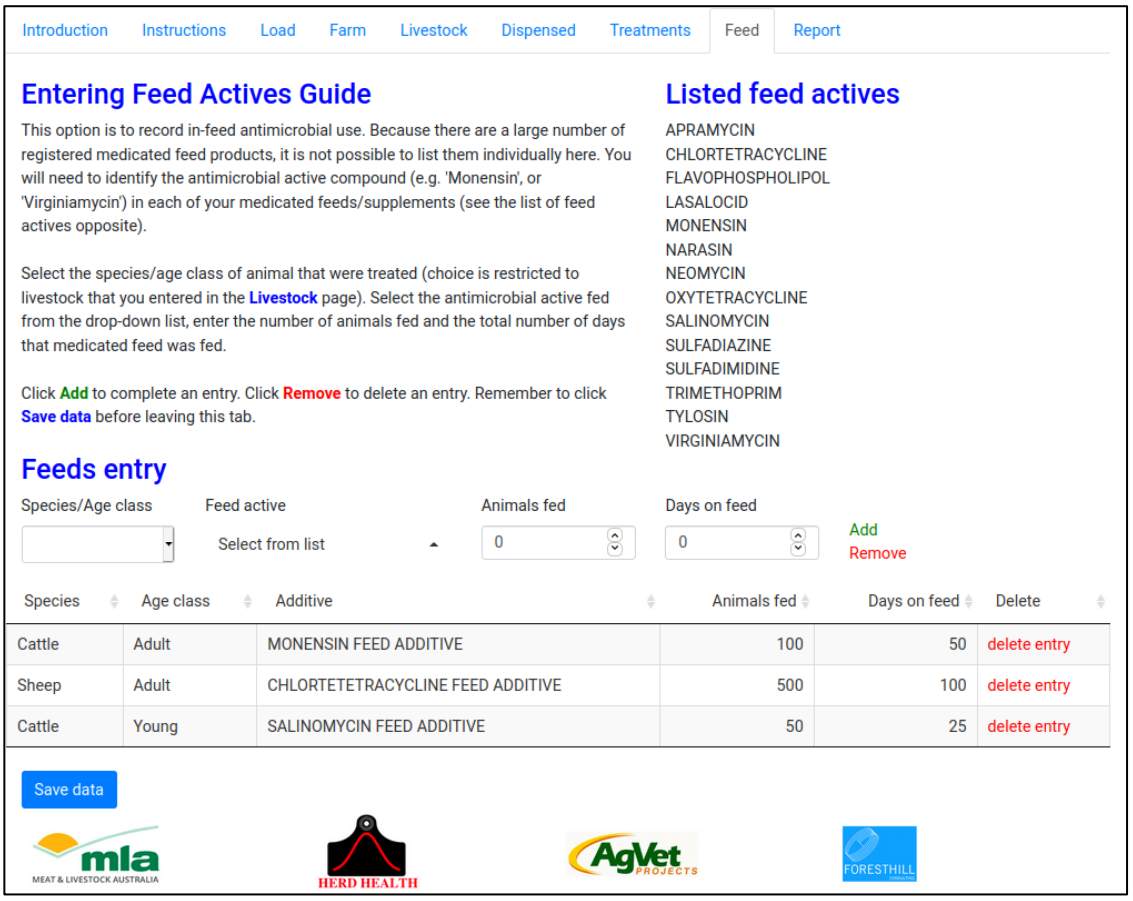
Treatments entry

Species/Age class | Animals treated | Treatment per animal | Product | Add / Remove

0 | 0 | Select from list

Species	Age class	Animals treated	Treatment per animal	Product	Delete
Goat	Adult	5	5	TRISOPRIM-480 ANTI-BACTERIAL INJECTION	delete entry
Cattle	Young	20	4	BETAMOX INJECTION	delete entry
Cattle	Adult	2	5	TRIBRISSEN INJECTION-480	delete entry

Save data



Introduction | Instructions | Load | Farm | Livestock | Dispensed | Treatments | Feed | Report

Entering Feed Actives Guide

This option is to record in-feed antimicrobial use. Because there are a large number of registered medicated feed products, it is not possible to list them individually here. You will need to identify the antimicrobial active compound (e.g. 'Monensin', or 'Virginiamycin') in each of your medicated feeds/supplements (see the list of feed actives opposite).

Select the species/age class of animal that were treated (choice is restricted to livestock that you entered in the **Livestock** page). Select the antimicrobial active fed from the drop-down list, enter the number of animals fed and the total number of days that medicated feed was fed.

Click **Add** to complete an entry. Click **Remove** to delete an entry. Remember to click **Save data** before leaving this tab.

Listed feed actives

APRAMYCIN
CHLORTETRACYCLINE
FLAVOPHOSPHOLIPOL
LASALOCID
MONENSIN
NARASIN
NEOMYCIN
OXYTETRACYCLINE
SALINOMYCIN
SULFADIAZINE
SULFADIMIDINE
TRIMETHOPRIM
TYLOSIN
VIRGINIAMYCIN

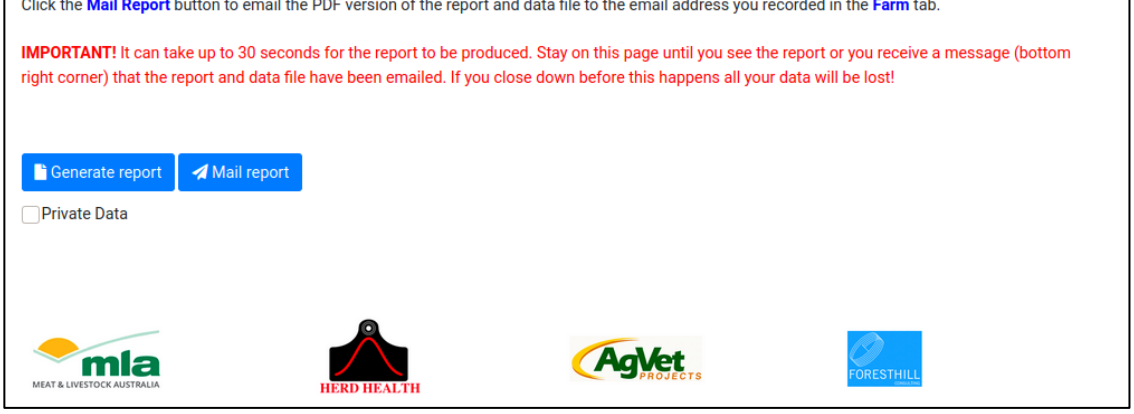
Feeds entry

Species/Age class | Feed active | Animals fed | Days on feed | Add | Remove

Select from list | 0 | 0

Species	Age class	Additive	Animals fed	Days on feed	Delete
Cattle	Adult	MONENSIN FEED ADDITIVE	100	50	delete entry
Sheep	Adult	CHLORTETETRACYCLINE FEED ADDITIVE	500	100	delete entry
Cattle	Young	SALINOMYCIN FEED ADDITIVE	50	25	delete entry

Save data



Introduction | Instructions | Load | Farm | Livestock | Dispensed | Treatments | Feed | Report

Generating & Emailing Report Guide

This report page includes two options - one to see the report on line and another to email the (final) report and data file to the email address you entered in the **Farm** tab. Use the **Generate Report** button to view the report in your browser to allow to you check your data entries. If you see a mistake, or require an addition or change, simply return to the appropriate tab to make changes or additions.

Once you confirm you have entered all antimicrobial use data for the year of analysis, click the **Mail Report** button to receive a copy of your report and your data file into your inbox. Save the data file when you receive it. This file can be uploaded again should you need to add entries or make changes.

Check the **Private** button to withhold your (de-identified) summary data from contributing to industry statistics.

Report generation

Click the **Generate Report** button to view the HTML version of the report at the bottom of this webpage.

Click the **Mail Report** button to email the PDF version of the report and data file to the email address you recorded in the **Farm** tab.

IMPORTANT! It can take up to 30 seconds for the report to be produced. Stay on this page until you see the report or you receive a message (bottom right corner) that the report and data file have been emailed. If you close down before this happens all your data will be lost!

Generate report | Mail report

Private Data

8.3 Report example

Antimicrobial Use Report

MyFarmAMU App

Report date: 27 April, 2021

This is a report of antimicrobial usage for your farm. Refer to the 'Notes' section for further guidance.

Summary report

Enterprise

Farm: **Nerk Farm** User: **Fred Nerk** Ref.: **1G8CN7G**

Location: **Farm Road**, **Farmtown**, **NSW** Year: **2020**

Medically-important antimicrobial use for year

A total of **105** Animal Daily Doses (ADD) of medically-important antimicrobials were used per 100 head per year in 2020.

Medically-important antimicrobial use by ASTAG rating for year

Low importance ASTAG: **101** ADD per 100 head per year
Medium importance ASTAG: **0** ADD per 100 head per year
High importance ASTAG: **3** ADD per 100 head per year

Detailed report

Farm details

Table 1: Farm details

User	Farm	Address	Town	State	FY (ending)
Fred Nerk	Nerk Farm	Farm Road	Farmtown	NSW	2020

Species	Adult	Young	Total
Cattle	100	50	150
Goat	20	0	20
Sheep	500	0	500
Total	620	50	670

1

Antimicrobial active	No. doses	No. days	Total mg	ADD/100 Hd/Yr
CEFTIOFUR	20	20	2 000	3
CLOXACILLIN	2	4	1 000	0
OXYTETRACYCLINE	179	179	3 500	26
PENICILLIN	100	500	13 500	74
TOTAL	301	703	20 000	105

Your antimicrobial (AMU) use

You used **105** Animal Daily Doses (ADD)/100 head/year of medically-important antimicrobials in 2020.

IMPORTANT! You have recorded using antimicrobial products containing medically-important actives with a **High ASTAG rating**. Consider asking your veterinarian if lower ASTAG-rated alternatives can be used.

The barchart of your medically-important antimicrobial use rate by ASTAG rating — animal daily doses per 100 animals per year (ADD/100 hd/yr) — by species is presented in Figure 1.

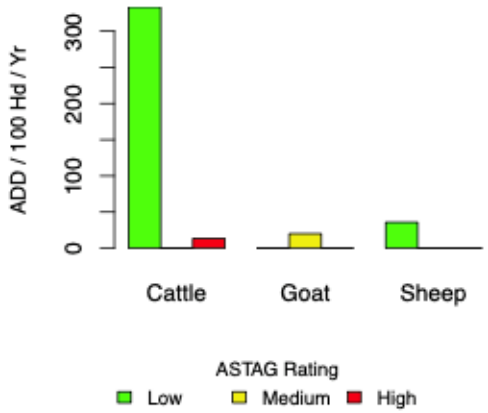


Figure 1: Antimicrobial use by species

Your data

The antibiotic administrations that contributed to your rate of antibiotic use are presented below.

Livestock details

Table 2: Livestock details

Species	Adult	Young	Total
Cattle	100	50	150
Goat	20	0	20
Sheep	500	0	500
Total	620	50	670

2

Antimicrobial products used

You recorded using antimicrobials in the year of analysis. The sections that follow provides a more detail analysis on antimicrobial use on your farm based on your reported usage. The antimicrobial products that you used are presented below (Table 3).

Table 3: Antimicrobial products used by species, age class and number of doses

Product name (truncated)	Species	Age Class	No. doses
BENACILLIN LONG ACTING PENICILLIN INJECT	Cattle	Adult	100
COOPERS ENGEMYCIN 100 OXYTETRACYCLINE HY	Sheep	Adult	179
EXCENEL RTU ANTIBIOTIC SUSPENSION FOR IN	Cattle	Young	20
MONENSIN (FEED)	Cattle	Adult	5 000
ORBENIN EYE OINTMENT	Goat	Adult	2

The individual actives, the active medical importance classification and active ASTAG rating, contained within each of the antimicrobial products that you used are presented below (Table 4).

Table 4: Antimicrobial products used with the medical importance (MI) and ASTAG ratings of the antimicrobial actives

Product name (truncated)	Active name (truncated)	MI	ASTAG
BENACILLIN LONG ACTING PENICIL	BENZATHINE PENICILLI	Yes	LOW
	PROCAINE PENICILLIN	Yes	LOW
COOPERS ENGEMYCIN 100 OXYTETRA	OXYTETRACYCLINE HYDR	Yes	LOW
EXCENEL RTU ANTIBIOTIC SUSPENS	CEFTIOFUR AS CEFTIOF	Yes	HIGH
MONENSIN (FEED)	MONENSIN	No	LOW
ORBENIN EYE OINTMENT	CLOXACILLIN AS THE B	Yes	MEDIUM

Rate of use analysis

The following section examines your rate of use of medically-important antimicrobial actives in more detail. You can compare the estimated rates to those from previous years and to those from other farms.

The antimicrobials used with medically-important actives is presented below by number of doses and rate of use by species and age class (Table 5).

Table 5: Medically-important antimicrobial active use by species and age class summary

Species	Age class	Antimicrobial active	No. doses	No. days	Row ADD/100 Hd/Yr
Cattle	Adult	PENICILLIN	100	500	500
Cattle	Young	CEFTIOFUR	20	20	40
Goat	Adult	CLOXACILLIN	2	4	20
Sheep	Adult	OXYTETRACYCLINE	179	179	36
		TOTAL	301	703	105

The number of doses, therapeutic days, milligrams and number of animal daily doses per 100 animals per year (ADD/100 hd/yr) of medically-important antimicrobial actives that were used is presented below (Table 6).

Table 6: Medically-important antimicrobial active used by number of doses, therapeutic days, milligrams and animal daily doses per 100 animals per year (ADD/100 hd/yr)

Antimicrobial active	No. doses	No. days	Total mg	ADD/100 Hd/Yr
CEFTIOFUR	20	20	2 000	3
CLOXACILLIN	2	4	1 000	0
OXYTETRACYCLINE	179	179	3 500	26
PENICILLIN	100	500	13 500	74
TOTAL	301	703	20 000	105

Actives used in individual animal treatments (excluding feed) You recorded using antimicrobial-containing products to treat individual animals. The summary of medically-important antimicrobial actives used for individual animal treatments (i.e. excluding feed administration) is summarised below (Table 7).

Table 7: Medically-important antimicrobial actives used to treat individual animals summary

Antimicrobial active	No. doses	No. days	Total mg	ADD/100 Hd/Yr
CEFTIOFUR	20	20	2 000	3
CLOXACILLIN	2	4	1 000	0
OXYTETRACYCLINE	179	179	3 500	26
PENICILLIN	100	500	13 500	74
TOTAL	301	703	20 000	105

Medically-important antimicrobials used ASTAG summary

The summary of medically-important antimicrobial actives that you used by the active ASTAG rating, dose, therapeutic days, milligrams and the number of animal daily doses per 100 animals per year (ADD/100 hd/yr) is presented below (Table 8).

Table 8: Medically-important actives used by ASTAG rating, number of doses, therapeutic days, miligrams and animal daily doses per 100 animals per year (ADD/100 hd/yr)

ASTAG rating	No. doses	No. days	Total mg	ADD/100 Hd/Yr
LOW	279	679	17 000	101
MEDIUM	2	4	1 000	0
HIGH	20	20	2 000	3
TOTAL	301	703	20 000	105

Notes

How to use this report

This report has been designed to assist you to monitor usage of antimicrobials (including antibiotics) on your livestock. You may choose to share this confidential report with your veterinarian or just keep it to monitor trends in your antimicrobial use over time. Either way it's a valuable tool to explore ways to monitor antimicrobial use and so improve antimicrobial stewardship on your farm.

Your role in combating antimicrobial resistance

Antimicrobial resistance (AMR) is an emerging threat to human and animal health. AMR occurs when infective micro-organisms, such as bacteria, become resistant to the drugs used to treat the infection. The main cause of AMR is antimicrobial use — inappropriate use of antimicrobials in both humans and animals accelerates the development of AMR.

AMR makes antibiotics less effective in the treatment of infections which can be life-threatening. It is important that all antimicrobials are used carefully and appropriately to limit the risk of developing AMR.

The report provides you with your calculated animal daily doses (ADD) per 100 head per year, a measure that can be compared between years — even if your livestock numbers vary. See below for an explanation of how ADD/100 head/year is calculated.

The report also describes the ASTAG[1] rating of the antimicrobial medicines used on your livestock. This is the national system used to rate the importance of each antimicrobial chemical with the aim of reducing antimicrobial resistance. There are three ASTAG rating levels: Low, Medium and High. Antimicrobials rated as 'High' by ASTAG are essential for the treatment or prevention of infections in humans where there are few or no treatment alternatives available.

Clearly, it is in everyone's interests to limit the use of 'High' importance antimicrobial medicines as far as possible. By doing so, these medicines will remain effective well into the future.

See https://www.amr.gov.au for more information.

Metrics and definitions

The following terms are used in this report:

- **Medically-important antibiotic/active**: These antibiotic actives are used in human medicine.
- **No. doses**: A dose is a single administration of an antimicrobial — for example, an injection of penicillin. The number of doses is the total count of treatments delivered.
- **No. days**: Because some antimicrobials are long-acting, the number of days that animals have therapeutic levels of antibiotic within their system may differ from the number of doses applied. This metric calculates the total number of days that animals have therapeutic levels of antibiotics in their system following a single administration (dose) of the product. Note that this is not the same as the withholding period (WHP), which relates to the period over which unacceptable drug residues are detectable in the animal.
- **Animal Daily Dose (ADD)**: A single ADD is equivalent to having a therapeutic level of a single antimicrobial active constituent in a single animal for one day.
- **No. head**: This is the average number of livestock on the farm across the year. The number of young stock and adults are counted separately, although both are considered equally in the head count.
- **No. Animal Daily Doses per 100 head per year (ADD/100 head/yr)**: This is the primary metric used to monitor antimicrobial use in livestock at the farm enterprise level. Being a 'dose rate-based' metric, it allows comparisons to be made between herds of different sizes and between years. It also accommodates antimicrobial medicines with differing durations of action (e.g. short-acting vs long-acting medicines).

[1] ASTAG is the *Australian Strategic and Technical Advisory Group* on Antimicrobial Resistance. This expert group has developed a national rating system for antimicrobials to indicate their importance to human health.

Contacts

If you have any questions regarding the use of this App, please contact the app development team on **amudevteam@gmail.com**

Confidentiality

This report is created and sent to the email recipient entered in the App. Your data is not stored on-line and so cannot be retrieved from our website or via the App. Unless you have elected to keep your data private, the administrator and MLA may use de-identified summary extracts of the data you have entered, together with data entered from other producers, to monitor antimicrobial use trends in the red meat industry.

Privacy

The App conforms with MLA's privacy policy at **www.mla.com.au/general/privacy/**

Acknowledgements

This App has been developed with funding from MLA with matching contribution from the Commonwealth Government. This report is derived using the following software: PubCris: 11.09.2020, Server: 0.1, GUI: 0.1, and with Settings: P = 0

Disclaimer

This report has been compiled based on information provided by the user and other sources believed to be reliable. The *MyFarmAMU* App uses this data to estimate antimicrobial use. Whilst every care has been taken in the preparation of the report, the developers and MLA gives no warranty that the said sources are correct and accepts no liability for any resultant errors contained herein, any damages or loss, whatsoever caused or suffered by any individual or corporation.

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