Evaluation of veterinary antimicrobial benchmarking systems at farm-level in Europe: Implications for UK ruminant sector

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Introduction

Globally, the use of antibiotics in farm livestock is attracting considerable interest and concern in the wake of growing anti-microbial resistance (AMR) and fears of subsequent repercussions on human health (WHO, 2012; O'Neill Report, 2015). Measurement of antimicrobial usage (AMU) is vital as: 'Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it.' (H. James Harrington). Benchmarking AMU at country-level, prescribing veterinarian-level or farm-level can highlight problem areas such as over-use, aid surveillance for emerging issues such as moves to particular antimicrobial group, aid disease surveillance and form a basis for informed herd health discussions with the veterinarian (Mills et al., 2018). Awareness of AMU and AMR and provides a structure to provide appropriate measures to decrease over-use (Postma et al., 2015a). Benchmarking AMU also enables comparisons between countries, vets, or farms. In 2017, the European Centre for Disease prevention and Control (ECDC), the European Food Safety Authority (EFSA) and the European Medicines Agency (EMA) jointly established a list of indicators to measure progress in reduction of AMU. Sales data, expressed as mg of active substance / population corrected unit (PCU, i.e., an estimated total weight of animal mass), was proposed to measure the overall effect of policy interventions and management measures. Such data are collected by most European countries (EMA, 2018b), but as they are generally based on wholesale data they do not cater for benchmarking at farm level (or even species level). Therefore, numerous other systems have been developed to measure veterinary AMU using different metrics to express use. As there is no overall consensus on the most appropriate metric, this review aims to report the advantages and disadvantages of various systems in use within Europe. However, the list of benchmarking systems described in this report is unlikely to be exhaustive due to the speed of developments around the issue of antimicrobial monitoring as well as difficulties in identifying systems that are described in languages other than English.

Part 1: Types of metrics and implications for the UK ruminant sector

Metrics can generally be divided into count-based, weight (or mass)-based, dose-based and course-base metrics. Count-based metrics are the simplest, only counting the number of animals that were treated, or the number of days that animals were treated in a certain time period. The use of such count-based metrics is rare, usually restricted to providing simplified feedback to farmers (www.aacting.org). Weight-based measures are calculated using the quantity of antimicrobials, while in dose- and course-based the metric is adjusted for the potency of the specific types of antimicrobials used. These three metrics are usually corrected for the estimated weight of the population at risk.

Methods for calculating the ‘total mass at risk’ should be explained as this underpins how the metrics are calculated. Most farms will not have an accurate figure for the total animal mass on the farm throughout the year (or even at one time); therefore, this mass is estimated. Animal numbers are usually multiplied with assumed standard weights for the species category. The European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) has established standard weights which are used for the calculation of European statistics at country level, but several countries diverge from these standard weights to allow a more detailed categorization for farm-level statistics. In addition, the ESVAC methodology is largely based on the number of animals sent for slaughter, which may not accurately reflect the weight of animals treated.

Weight-based metrics

Weight-based metrics are generally easy to calculate and understand. The simplest farm-level weight-based metric is the total quantity of active substance per farm over a specific period, usually a year. However, to allow comparison of different sized farms this quantity must be corrected for the estimated total weight of the population at risk of treatment (on average throughout the monitoring period).

$$\frac{Total\ quantity\ of\ active\ substance\ used\ (mg)}{Estimated\ total\ animal\ mass\ at\ risk\ (kg)}$$

Weight-based metrics could also be expressed per kg or litre of product generated, but this is not a preferred method, as it may suggest to consumers that antibiotics are actually in the product.

Apart from its simplicity, an advantage of weight-based metrics is that they can be calculated for multi-species farms (it is not necessary to know to which of the species a certain drug was given, just how many of each species were present on the farm in total). This could be an advantage in the UK/Ireland context, as many farms stock multiple species. However, although this makes it technically possible to compare between farms that differ in their proportion of those species, in practice the benchmark of these farms depends on the species ratio. Recent studies in the UK suggest a mean AMU on sheep farms was 11 mg/PCU (Davies et al. 2017), compared to 21 mg/PCU on dairy farms (Hyde et al. 2017) and 19 mg/PCU on beef farms (UK-VARSS, 2018). The lower figure for sheep farms suggests that, on farms with multiple species, AMU would likely be higher for farms which stock a smaller proportion of sheep.

The main disadvantage of weight-based metrics is that these ignore variation in dose rate across different types of antimicrobials, which some authors have argued may incentivize use of CIAs due to the lower dosing requirements of CIAs compared to other antibiotics (More, 2017; Mills et al., 2018).

Dose-based metrics

Dose-based metrics are more complicated to calculate and interpret than weight-based metrics. Significantly, these metrics take into account that certain antimicrobials are more potent than others, and thus a smaller quantity will be needed for successful treatment. To calculate dose-based metrics the total weight of active substance used is not just divided by the estimated total mass of animals on the farm (as for the weight-based metrics), but also by the recommended daily dose per kg per day: the Daily Defined Dose for animals (DDDvet). The DDDvet is the arithmetic mean of the daily doses recommended in the Summary of Product Characteristics of nine different EU countries (EMA), per species, substance and route of administration, as specified for the main indication of the product. The resulting metric can be interpreted as the number of days that the average animal is treated with antimicrobials per unit of time it is calculated for (usually a year):

$$\frac{Total\ quantity\ of\ active\ substance\ used\ (mg)\ /\ DDDvet\ (mg/kg)}{Estimated\ total\ animal\ mass\ at\ risk\ (kg)\ *}$$

**Note that some authors (e.g., Mills et al. 2018) use the abbreviation DDDvet to indicate this entire equation (using 'daily dose' where DDDvet is specified here), but this diverges from the original definitions by EMA (2015) which we will use in this report.*

As recommended doses will vary between antimicrobials and routes of administration, this calculation has to be made for each antimicrobial and route separately and then summed. Therefore, this relies on record keeping being detailed and accurate. Critically, dose-based metrics are highly dependent on assumptions about the dosage which may not always reflect drug use in practice. Generally, the European standard for recommended dosages is used (EMA, 2015). This means that within-product variation and national differences in prescription and usage practices will not be accurately reflected. Another issue with dose-based metrics is that for some products no recommended daily dose has been specified. This is usually because these are not easily expressed as daily mg/kg bodyweight, e.g., intramammary dry cow tubes, topical sprays and foot baths (Hyde et al. 2017; Davies et al. 2017). Because of this, these antimicrobials are generally excluded from dose-based benchmarking systems.

Course-based metrics

Course-based metrics are very much like dose-based metrics, except that the Defined Course Dose (DCDvet) is used instead of the DDDvet. The DCDvet is the recommended dose per kg bodyweight throughout the entire antimicrobial course. To calculate a farm's benchmark method based on its total use of antimicrobials the following equation is used:

$$\frac{Total\ quantity\ of\ active\ substance\ used\ (mg) /\ DCDvet\ (mg/kg)}{Estimated\ total\ animal\ mass\ at\ risk\ (kg)}$$

The resulting metric can be interpreted as the number of antimicrobial courses that the average animal receives per unit of time the metric is calculated for (usually a year). Because they are so closely related to the dose-based metrics, the course-based metrics generally have the same advantages (e.g., correction for animal weight and antimicrobial potency) and same disadvantages (limited reflection of actual animal weights and national dosage patterns). However, an advantage of the course based metrics is that for some antimicrobials for which no DDDvet has been specified in the ESVAC standard, there is a specified DCDvet (e.g., intra-mammary tubes for dry cows).

Discussion and recommendations

Weight-, dose-, or course-based metrics are corrected for total animal mass that is at risk of treatment, but exact figures for animal mass are generally lacking, meaning that inaccurate estimates may provide unfair advantages to specific types of farms. For example, European Standard Methodology (EMA, 2018a) has suggested certain standard weights per animal, and the number of animals is estimated using either live animals, slaughtered animals, or a combination of both (depending on the species/production type). Inaccurate estimates of the actual animal mass on farm becomes problematic when comparing farms that diverge from the standardized weights. This could be because of differences in the age (and thus weight) at which animals leave the farm, or because they stock different breeds. For example, native breeds are generally lighter than continental breeds, and it has been suggested that different weights should be used for these when estimating the total mass (Davies et al. 2017). The ESVAC methodology could also unfairly advantage farms selling a greater percentage of their animals for slaughter, rather than selling on to another farm (More, 2017). In practice, farms with heavier animals would require a greater quantity of antimicrobial product for the same level of treatment of an equal number of animals compared with those stocking lighter animals. Regardless of what metric is used, this would affect the mg of active substance (as the other components of the equation are standardized). Therefore, farms with heavier animals would receive a higher benchmark than those with lighter animals despite applying the same level and number of treatments.

It has been suggested that, instead of relying on an estimated weight of live or slaughtered animals, a more accurate way of estimating the total weight would be to integrate animal numbers and ages from national movement databases that record all births, deaths and movements between farms (Hyde et al. 2017). These databases already exist in Great Britain (Cattle Tracing System), Northern Ireland (Animal and Public Health Information System) and

Ireland (Animal Identification and Movement System). Cattle breed information is also available from the databases already established in GB, NI and Ireland; therefore, it would be possible to calculate weight estimates using breed-specific growth curves. This theoretically could lead to a highly accurate estimate of the total weight on farm that can be acquired without the need of any additional data collection from the farmer (as the information is already collected for cattle as a legal requirement). However, breed and age data is currently lacking for sheep; however, ARAMS is a similar, but non-compulsory database for sheep in England.

In weight-, dose- and course-based metrics, the PCU is multiplied by the daily dosage or dosage for an entire treatment. It is important to emphasize that the choice of metric can impact greatly on the figures obtained and the consequent influence on AMR policies (Mills et al., 2018; Hyde et al., 2017; Collineau et al., 2017). For example, a weight-based metric applied to the UK dairy industry was heavily influenced by parenteral therapy, but poorly reflected the use of intra-mammary treatments. Whereas if a dose-based metric was applied to the same data, it was heavily influenced by intra-mammary treatment of lactating cows but did not represent footbath usage (Hyde et al., 2017). While there was a degree of correlation between different metrics, there were several farms that would have gone undetected as high antimicrobial users if only one of the metrics had been used. Such differences could incentivize reductions in specific treatment routes, rather than an actual reduction in antibiotics overall. Therefore, using both weight-based and dose-based metrics could alleviate this problem.

Apart from highlighting different treatment routes, different metrics will also give a different impression of the proportion of the antimicrobials classified as critically important for human health (CIAs). Reduction of these antimicrobials specifically is a main aim of many national reduction programs. If expressed as a weight-based metric, 5% of the antimicrobials used on UK dairy farms were CIAs. However, if expressed as dose-based metrics the figure was 15-18% (Hyde et al., 2017). This difference was largely due to the lower dosing requirements of

CIAs. This lower dosing requirement means that if non-CIAs are replaced by CIAs, antimicrobial use expressed in weight-based metrics would decrease. As such, the use of weight-based metrics could incentivize a shift towards the use of CIAs, whereas the wider goal is to move away from these. This had led some authors to argue for dose-based metrics instead of weight-based metrics (More, 2017). However, other authors have argued that analysis of antimicrobial sales in the UK over the period 2012-2015 shows no evidence that a shift to CIAs is actually happening in practice, indeed there are reductions in HP-CIA usage (Broadfoot, 2017). To mitigate any potential shift towards CIAs, there has been suggestions to set separate calculations and targets for CIAs (Mills et al., 2018) as is already done in the UK VARSS reports.

The main flaw in using dose-based metrics is the level of detail required per antibiotic use (quantity, type and route). However, this may not be an unsurmountable problem in practice, as even when using a weight-based metric, data entry would likely be done as units of product (e.g., four 250 ml bottles of "product X" for injection). The mg of active substance would then be calculated by the benchmarking system, rather than entering the mg of active substance directly by the veterinarian or farmer (which would be complex, time consuming and off-putting). Therefore, if the benchmarking system contains a list of recommended doses for the antimicrobials used, dose-based metrics could be easily calculated from the same data. This approach is simple on single species farms; however, on multi-species farms this is more difficult as recommended daily doses can differ between species (EMA, 2018b). This means that for each quantity of antimicrobial use the receiving species needs to be recorded to calculate a dose-based metric correctly.

Theoretically, dose-based metrics rely on the European Standard for recommended dosage (EMA, 2015). This can be problematic, as Postma et al. (2015b) reported large variations for dosage recommendations between products and countries for the same active substance.

Furthermore, the ESVAC list is based on the mean recommended dose, whereas the maximum dose rate may often be administered on farms. To improve the accuracy of farm-level benchmarking within a country, country-specific recommended doses that reflect the way that antimicrobials are actually used in that country could be developed. If a comparison between countries is desired, recalculation using the ESVAC standard dosages would be possible without a need for additional data collection.

Conclusion

Both the way that the amount of antimicrobials is expressed (count-based, weight-based, dose-based, course-based) and the estimation of the population ‘at risk’ (all animals or kg of animal present on a farm, or those sent for slaughter) will affect the outcome of a benchmarking system. Each metric has its own advantages and disadvantages. For example, weight-based metrics do not take the potency of the product into account which could lead to increased use of more potent antimicrobials. On the other hand, some products cannot be accounted for in a dose- or course-based system as no dosage has been specified and their use may go undetected unless systems are put in place to account for them. As no one metric that will fulfil all requirements when benchmarking AMU on farm level there have been suggestions to use multiple metrics. This has potential to make AMU benchmarking confusing for producers and cumbersome to use; however dealing with multi-metric systems may become the new normal. For mixed species farms common in the UK and Ireland, splitting antimicrobials by receiving species is advisable within any benchmarking system. HP-CIAs should also be benchmarked separately. Daily dose- or course-based metrics can provide an accurate reflection of AMU in cattle by using the cattle movement databases already in place. If the UK wishes to create UK-specific defined doses and courses, a DDD or DCD-based metric could enable a highly-specific benchmarking system. Regardless of what metric is used, it is important that farm-level AMU in Northern Ireland and the wider UK is monitored as accurately and fairly as possible.

Part 2: Overview of benchmarking systems in Europe

Almost all European countries collect AMU data at a national level, allowing assessment of changes in national use over time and comparisons between countries (EMA, 2018b). This is commonly done using sales data derived from wholesale to veterinarians and calculated using national or European databases on animal numbers (using the ESVAC standard weights). Although ESVAC has recently suggested methodology to uniformly collect dose-based and course-based data within Europe (EMA, 2015; 2018a), their most recent reports still use a weight-based metric (mg/PCU, EMA, 2018b) as usage data is obtained from wholesale, which means that the species it will be used for (and thus, the recommended dosage) is unknown.

As several metrics are available for farm-level benchmarking, each of which has its own strengths and weaknesses, it is no surprise that there are different ways in which benchmarking is carried out in practice in different European countries. In some countries (The Netherlands, Belgium, Denmark, Germany, Switzerland) farm-level benchmarking is a legal requirement for certain species. In other countries, providing farm-level data is either voluntary, required (but not used for benchmarking), or systems are currently under development. AACTING (the network on quantification of veterinary Antimicrobial usage at herd level and Analysis, CommunicaTion and benchmarkING to improve responsible usage) has recently proposed guidelines to set up new benchmarking systems (AACTING, 2018).

As of 2019, mandatory benchmarking of farms is performed in five European countries (Belgium, Denmark, Germany, the Netherlands and Switzerland) and often only for certain species. The specific way that benchmarking is carried out within different European countries is discussed below, including descriptions of: the metrics used, what is benchmarked, how data are acquired and processed, and the consequences of having a high level of AMU.

The Netherlands

(In brief: mandatory dose-based benchmarking of farms and vets using country specific bodyweights, drawing data largely from automatically generated databases, with action requirements for high users.)

In the Netherlands, farm-level benchmarking has been mandatory for veal, broiler and pig producers since 2010. In 2012 and 2013 cattle and turkey producers were added, respectively, and mandatory benchmarking of laying hen and rabbit farms started in 2019. Farmers are required to enter all deliveries of antimicrobials to their farm into an online database within 14 days (e.g. www.medirund.nl for cattle). Although data is based on sale rather than use of antimicrobials a large difference between the two is unlikely in The Netherlands, as only veterinarians are allowed to administer veterinary antimicrobials, with an exception of small quantities of first choice antimicrobials which may be kept on site for use by the farmer under specific conditions (Speksnijder et al., 2015). If they purchase antimicrobials from only one veterinarian, as most farms in the Netherlands do, they can authorize this veterinarian to enter data for them. In this case, AMU data is usually derived automatically from practice management software systems, which were already in use for stock-keeping and invoicing purposes. Depending on the type of practice management software used, these either feed in directly to the database, or do so through a specific veterinary database called VetCIS. The online databases are maintained by producer organizations and provide an automatically generated benchmarking report for each farm every 3 months. In addition, the Netherlands Veterinary Medicines Institute (SDa), an independent body reporting to the government, has access to the data to make annual reports. In both cases, the total mass of animals is estimated from animal numbers drawn from existing national (CBS for rabbit, veal and poultry) or European (EUROSTAT for pigs and cattle) databases (SDa, 2013, 2018). Although The Netherlands uses the ESVAC methodology to report county-level back to Europe, it uses country-specific adaptations internally when comparing farm-level data (DDD_{NAT} a variation on DDDvet). DDD_{NAT} uses country-specific recommended dosages and estimated average body weights. Furthermore, total animal mass is estimated based on the average number of live animals throughout the year, in contrast to the ESVAC methodology which mainly relies on numbers of animals slaughtered for most species (EMA, 2018a). In addition, the use of locally administered antimicrobials for mastitis and metritis is included in the $DDDA_{NAT}$, which are absent from the ESVAC metric using the DDDvet. The $DDDA_{NAT}$ values are compared yearly to national veterinary antimicrobial use as indicated by sales data from the federation of the Dutch veterinary pharmaceutical industry. The two datasets do not necessarily give the same impression, as veterinarians may keep antimicrobial in stock for a long time before selling them on to farmers, and because use in some species (e.g., sheep, horses, mink) are not included the $DDDA_{NAT}$. However, significant divergences over a prolonged period of time could be detected in this way (SDa 2013; 2018; MARAN 2018).

To benchmark on farm-level, within production type, the $DDDA_F$ is used. This metric differs from the $DDDA_{NAT}$ in that it uses more detailed subdivision of average bodyweights than the $DDDA_{NAT}$, for example, cattle are split up into 8 different categories (DDDvet and $DDDA_{NAT}$ use only 4). Furthermore, for broilers and turkeys the weight at treatment (rather than a standard weight) is used for calculation of the $DDDA^F$ as this is readily available on these farms. Having a high $DDDA_F$ has direct consequences for the farm. 'Signalling values' and 'Action values' have been established per production type. A farm with a $DDDA^F$ above the Signalling Value receives a warning, but those with a $DDDA^F$ above the Action Value are legally required to 'take action'. Originally the Action Value was the $DDDA_F$ of the 75th percentile (i.e., the 25% of the farms with the highest $DDDA_F$ were required to take action). After several years the Action Value was lowered by 20% to reflect AMU reduction targets set by the Dutch government. Due to the achievement of AMU reduction the Signal Values have continued to develop. For production types where AMU is often 0 and has little variation between farms and over time, definitive Signal Values have been established. For other production types, the Signalling Value is adapted every 2-3 years (SDa, 2018).

The Netherlands not only benchmarks farms, but also veterinarians. Dutch veterinary practices make a direct profit from antimicrobials they prescribe to farmers which became a point of concern as this may increase the amount of antimicrobials prescribed. To counter potential unnecessary prescriptions, the Dutch government introduced the benchmarking of veterinarians (Speksnijder et al. 2015). To this end the $DDDA_{VET}$ is used, which uses calculations identical to the $DDDA_F$ to calculate the antimicrobials one vet has prescribed on each of the farms the vet has a 1-on-1 relationship with compared to the animal mass present on these farms (SDa, 2018). The use of antimicrobials for veterinary purposes has reduced by 63% since benchmarking started. Selective dry cow therapy has led to a considerable drop in antimicrobial use in the dairy sector. However, reduction has been most difficult in the calf sector in which most farms have a $DDDA_F$ above the Signalling Value (SDa, 2018).

Belgium

(In brief: mandatory dose-based benchmarking of farms and vets using some country specific bodyweights, drawing data from multiple sources, with proposed action requirements for high users).

Since 2017 all antimicrobials that are prescribed, delivered or used on veal, pig, broiler and laying hen farms in Belgium have to be entered into a national data base (SANITEL-MED), allowing for farm-level benchmarking. Data collection for cattle other than veal is optional, although certain Belgian farm quality certification bodies require benchmarking for dairy cattle through a separate database. Data entry can be done manually, through an online application, by emailing a predefined standardized excel document, or by integration with certain accounting systems (through an XML protocol). Alternatively, data can be forwarded from other privately owned databases on veterinary antibiotic use. Data are entered by the veterinarian within 15 days after the end of each 3 month period. Farmers are required to check and correct these data (for instance if antimicrobials were prescribed, but not picked up from the pharmacy), after which the correction is reviewed by the veterinarian. Each registration is linked to the farm, species category (production type), and the prescribing veterinarian (FAGG, 2016).

Belgium benchmarks both farms and veterinarians using a country specific metric (BD100) which is dose-based and accounts for long acting antimicrobials. It uses country-specific recommended doses (DDDbel) and although for most species the ESVAC weights are used, country specific weights are used for veal and laying hens. It is calculated for (or standardized to) a period of 100 days. The DDDbel differs from the recommended doses used by ESVAC as it is not based on the main indication of the product, but on an average for all indications and it uses separate values for veal and other cattle. Furthermore, special formulas were created to include products like topical sprays, intra-mammary products for dry and lactating cows and intrauterine products. Apart from using a daily dose that differs from the ESVAC DDDvet, the BD100 also accounts for long acting antimicrobials in a different way to standard ESVAC methodology and is expressed per 100 days rather than per year:

$$BD100 = \frac{mg\ active\ substance/DDDbel}{Total\ animal\ mass\ (kg) * period} * Long\ Acting\ factor * 100$$

The 'long acting factor' reflects that some products are only applied once, but remain active for a long period. It is the number of days after which repetition of the treatment is advised in the standard product documentation. For most products it is 1, and even for some long acting products (e.g., dry cow therapy and intra-uterine products) a value of 1 is used because using a higher value would lead to very high BD100 values and because their exact duration of action is unknown (AMCRA, 2018).

Advice on enforcement and the farms to which it should apply has been formulated by the Belgian 'Centre of expertise on the use of and resistance to veterinary antimicrobials' (AMCRA). The BD100 is compared to two threshold values to determine if the farm is in the Safe Zone, Attention Zone, or Action Zone. These thresholds are currently determined by using the 50th and 90th percentile. In time, the goal is to move to more static thresholds. Farms in the Attention Zone and Action Zone should be stimulated to make changes. Changes are to be quicker and more extensive for those in the Action Zone, and this should be enforced by certification bodies. An example of these changes are as follows: the farm must improve in cooperation with the farm's main veterinarian is a first step. If this does not result in reduced AMU an external expert should contribute to the farm's health plan. If this is also ineffective a 'Strong Signal' (not specified) should be given. In addition to farms with a high use of antimicrobials, veterinarians with a high use should also make corrective changes and these are enforced by the government (AMCRA, 2018).

Denmark

(In brief: mandatory dose-based benchmarking of farms using country-specific bodyweights, drawing data largely from automatically generated databases, with action requirements for high users).

Since 2002 Denmark has collected all information about antimicrobial administrations to farm animals (pigs, poultry, cattle, sheep, goats, fish, and mink) as well as to companion animals on a monthly basis. This information is stored in a government owned central database, VetStat. The data are collected as kg of active substance and then recalculated into the number of Defined Animal Daily Dosages (DADD) that could be acquired from this weight. The methodology for this resembles ESVACs DDDvet methodology, although there are some country specific adaptations (DANMAP, 2017). Antimicrobial usage data originates from pharmacies, veterinarians and feed mills who are obliged to report all sales. The total weight of the population at risk is estimated based on country specific growth estimates, and the animal numbers are acquired from census data. Sometimes medicines are prescribed that are not approved for marketing in Denmark, and these are not in the VetStat system, but this is very rare. Reporting on sales is often linked to the writing of invoices or electronic registration of sales. However, extra data needs to be added for data collection purposes as the database is highly specific. Information on the quantity and type of antimicrobial is linked to the receiving farm, species, age-group, and indication (DANMAP, 2017). This specificity seems to have been problematic at times, as Jensen et al. (2012) states that drugs used by the veterinarian were usually excluded from analyses because precise information on the animal species, age-group, or indication the drugs has been used for was lacking.

Since 2010 the VetStat data has been used for compulsory benchmarking of farms. At that time the Danish Veterinary and Food Administration (DVFA) started the Yellow Card initiative to reverse the trend of the constantly increasing antibiotic consumption in pig production (which is responsible for 80% of the veterinary AMU in Denmark). Only pig and cattle farms are currently covered by this benchmarking initiative. Average AMU over a nine month period is measured as the number of daily doses per 100 animals per day. Separate thresholds have been set for cattle younger than 24 months, cattle older than 24 months, finishing pigs, weaner pigs, and piglets/sows/gilts/boars. In 2017 Denmark started to weight the animal daily dosage in pigs to reflect the critical importance of some antimicrobials in use. Critically important antibiotics (fluoroquinolone, 3rd and 4th generation cephalosporins) are assigned a weight of 10 whilst most other categories have a weight close to 1 (DVFA, 2017; Miljø- og Fødevareministerie, 2018). If a farm's average AMU over a nine month period exceeds the threshold value it gets a Yellow Card, and the DVFA may compel the owner of the holding to reduce AMU. The DVFA may also forbid the owner to use or store any veterinary antimicrobials that have been re-prescribed more than once and that are administered through feed or water. In addition, they may carry out unannounced inspection visits. If this does not reduce AMU to sub-threshold levels within the next 9 month period the farmer has to seek advice from a veterinarian other than the regular veterinarian of the holding to create a plan of action with concrete suggestions for interventions to reduce AMU within the next 5 months. If this fails to reduce AMU to sub-threshold values the DVFA may compel the farmer to implement one or more initiatives from the action plan or – as a last resort – compel the farmer to reduce stocking density with a suitable percentage to ensure that the consumption is reduced to sub-threshold values. In addition to these measures, a farmer has to pay a fee each time the threshold is not met and must pay for all inspection visits and the cost of the expert advice. In the four years after the start of the Yellow Card initiative a 10% decrease in veterinary AMU was achieved. A new reduction target of 15% was then set for the next four years (DVFA, 2017). In Denmark measures to reduce veterinary AMU were mainly established and carried out by the government, whereas the primary responsibility for AMU reduction is with the certification boards in the Netherlands (Speksnijder, 2015). Although the Belgian database on AMU is government owned, enforcement of reduction measures is a task of the certification bodies (AMCRA, 2018).

Germany

(In brief: mandatory count-based benchmarking of farms, usually using data entered manually into an online database).

Since 2014 German pig, veal, beef, broiler and turkey farms are legally required to report their AMU to a central database (HIT). Although this is a national requirement, the HIT database is owned by the Bayern Ministry for the Food Chain, Agriculture and Forestry. Only very small farms are exempt from the mandatory registration. Pigs and cattle are each divided into two age categories, but no further separation is used for either broilers or turkeys. Both veterinarians and farmers can enter data and this is required within 14 days of administration of the antimicrobial product. If the veterinarian reports, the farmer must confirm the data. Farmers provide the information necessary to calculate the number of animal days at risk for treatment. Changes in the number of animals on the farm are reported every 6 months. All data is provided either by using a series of drop-down menus in an online system, supplied in writing, or using an excel document. Automatic export from some types of farm management systems is also an option. The number of treated animals, the number of treatment days and the antimicrobial product used are provided. Germany, therefore, is the only one of the four mandatory benchmarking countries that uses a direct count-based metric rather than relying on a dose-based metrics derived from the total mg of active substance used. Farms are compared to national benchmark values (separately for each animal species and production group). The median value and the upper quartile are calculated and used to categorize farms. Twice a year each farmer receives bi-annual values and is obliged to compare their results with the national values (HI-TIER, 2014)

In addition, the sectorial quality system QS (Qualität und Sicherheit GmbH) which covers about 95% of German broiler, veal, and pork production, and also includes some turkey and duck production collects count-based AMU data from all their producers and provides them with quarterly benchmarking reports. In contrast to the national system that uses 2 categories, pigs are divided into 3 age categories. Veterinarians provide the data on AMU, and farmers provide the number of animals on farm (Q-S.de, online).

Switzerland

(In brief: mandatory dose-based benchmarking of farms, drawing data largely from automatic databases).

A Swiss system for monitoring antimicrobial prescriptions, managed by the Federal Food Safety and Veterinary Office, became mandatory on the 1st of January 2019. It covers AMU in all animal species (including pets). Data collection is the responsibility of veterinarians. Direct export from certain types of practice software is possible, otherwise the data has to be entered manually in an online system or through a dedicated app. The system assumes standard bodyweights for farm animals, but the veterinarian can adapt those if necessary. Dose-based metrics will be used and benchmarking is planned for implementation in 2020 (BLV, online).

Conclusion

Within Europe several farm-level benchmarking systems for anti-microbial usage (AMU) are in place. Of the five mandatory nationwide farm-level benchmarking systems that were identified within Europe, four use a dose-based metric and one uses a count-based metric. The four countries that use dose-based metrics each use a system that is similar to European standard methodology, but each country diverges from it in its own way. Such divergences include the use of national estimates of standard weights per animal (none of the five countries use the European standard weights for all animal categories), the use of national rather than European dosage assumptions and/or differences in the treatment of long-acting antimicrobials. In some countries the benchmarking databases are owned and supported by the government, whereas others are owned by production boards. The accuracy of data collection is the main responsibility of farmers in some countries and veterinarians in others. However, usually both parties are involved to some extent. Most countries allow data entry by multiple methods. In two countries threshold values have been specified and farmers are legally required to take action to reduce their AMU if above such values. Two countries not only benchmark farms, but also veterinarians. In addition, many European countries have voluntary farm-level benchmarking systems, are setting up pilot systems, or are performing research on this topic. No active farm-level benchmarking systems that fully adhere to the European standards proposed by ESVAC (including its metrics, recommended doses, animal categories and estimated bodyweights) have been identified. Indeed, there seems to be a tendency for benchmarking systems to become more specific over time, which leads them further away from the proposed standard methodology, but usually improves their accuracy.

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