Antimicrobial drug use in Austrian pig farms: plausibility check of electronic on-farm records and estimation of consumption

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Electronic drug application records from farmers from 75 conventional pig farms were revised and checked for their plausibility. The registered drug amounts were verified by comparing the farmers’ records with veterinarians’ dispensary records. The antimicrobial consumption was evaluated from 2008 to 2011 and expressed in weight of active substance(s), number of used daily doses (nUDD), number of animal daily doses (nADD) and number of product-related daily doses (nPnDD). All results were referred to one year and animal bodyweight (kg biomass). The data plausibility proof revealed about 14 per cent of unrealistic drug amount entries in the farmers’ records. The annual antimicrobial consumption was 33.9 mg/kg/year, 4.9 UDDkg/kg/year, 1.9 ADDkg/kg/year and 2.5 PrDDkg/kg/year (average). Most of the antimicrobials were applied orally (86 per cent) and at group-level. Main therapy indications were metaphylactic/prophylactic measures (farrow-to-finish and fattening farms) or digestive tract diseases (breeding farms). The proportion of the ‘highest priority critically important antimicrobials’ was low (12 per cent). After determination of a threshold value, farms with a high antimicrobial use could be detected. Statistical tests showed that the veterinarian had an influence on the dosage, the therapy indication and the active substance. Orally administered antimicrobials were mostly underdosed, parenterally administered antimicrobials rather correctly or overdosed.

Introduction

The occurrence of antimicrobial resistance is an increasing phenomenon and represents a global problem both for human and animal health. One main risk factor for the development and the spread of resistant bacteria is an increased antimicrobial use (van den Bogaard and Stobberingh 2000). Evidence for an association between antimicrobial consumption in veterinary medicine and the occurrence of resistant bacteria in human beings is not fully investigated but exists (Tollefsen and Miller 2000, Angulo and others 2004). As a consequence, the application of antibiotics in animal husbandry is strongly criticised. International organisations recommend monitoring programmes for the measurement of antimicrobial use in veterinary medicine in order to contribute to the containment strategies for antimicrobial resistance (WHO 1997, EMEA 1999, Nicholls and others 2001).

However, the collection of reliable drug application data in veterinary medicine is challenging. At that time, the only internationally standardised monitoring system consists of the collection of overall sales data in the context of the ‘European Surveillance of Veterinary Antimicrobial Consumption’ project (ESVAC) (EMA 2013). It enables the representation of antimicrobial use per country using the unit ‘weight of active substance(s)’ related to the animal bodyweight.

Unfortunately, sales data analyses are not helpful for their relation to resistance data for several reasons. First, the unit ‘weight of active substance(s)’ may lead to false interpretation when comparing results, as therapeutic potency differs from one antimicrobial substance to another one (Chauvin and others 2001, Nicholls and others 2001, Jensen and others 2004). Studies measuring the use of antibiotics can therefore be compared only when the units take into account differences in potency of antimicrobial substances (Chauvin and others 2001). Furthermore, sales data do not allow the quantification of antimicrobial consumption per animal species, as several drugs are accredited for more than one species. Yet, this is a prerequisite for the fixation of daily doses, which allow the expression of antimicrobial use as treatment frequency, taking into account differences in potency. In addition, sales data do not provide any information about the indications for antibacterial prescription.

For the development of antimicrobial reduction strategies, knowledge about what animal species and for which diagnosis antimicrobial substances are prescribed is of particular importance. Data including this information could be provided by the end-users, such as the farmer. Unfortunately, sources of information from farmers are rarely officially accredited and are reputed to be inefficient or expensive unless well managed and thoroughly designed (Grave and others 2006). However, there are only few studies testing the feasibility and describing the quality of such application data (Menéndez González and others 2010, Merle and others 2012).

In Austria there are about 27,000 pig farms holding 2,900,000 pigs and producing around 530,000 tons of meat per year (Statistics
Austria 2014). Till now, little knowledge about how many antimicrobials are used in the Austrian pig sector exists.

In this study, drug application data, which were recorded directly by the farmer, were evaluated. The aims of the project were to (1) determine the plausibility of such application data and to (2) estimate the total amount of antimicrobial consumption in the study swine population using four different units of measurement.

**Material and methods**

**Data collection**

In Austria, when disease treatment requires a repeated or long-term medication, the dispensary of drugs from the veterinarian to the farmer is allowed and statutorily subject to the official documentation rules of the Animal Health Service Regulation 2009 (Anonymous 2009). Additional to this compulsory documentation, some meat production companies have implemented private quality-assurance systems, with extended supervision from the animal up to the food product. For the study at hand, data were collected in cooperation with a meat production company using such a private system for more than 10 years. The company in question contracts 76 pig farms and produces 10,750 tons of meat per year.

In the context of their system, farmers as well as veterinarians are obligated to record each drug application (farmers) or dispensary (veterinarians) via online platforms. As main source of data served the drug application records from farmers, who are required to enter the following information: (i) farm registration number, (ii) treatment date, (iii) drug name, (iv) drug authorisation number, (v) drug serial number, (vi) treatment duration (days), (vii) number of applications per day, (viii) therapy indication, (ix) swine age class (piglets (1.5–10 kg), weaner pigs (10–30 kg), fattened pigs <60 kg biomass, fattened pigs >60 kg biomass, sows, boars), (x) number of animals treated, (xi) type of treatment (group-level or individual), (xii) drug quantity per animal with unit and (xiii) total drug quantity with unit.

Drug dispensary records from veterinarians were additionally evaluated and served as a plausibility control for the farmers’ records. They included the following information: (i) veterinarian’s identity, (ii) farm’s registration number, (iii) date of dispensary, (iv) drug name, (v) drug authorisation number, (vi) drug serial number, (vii) number of packs/pack art (package or flagon) and (viii) amount (pack size) with unit.

The platform of the farmers is equipped with drop-down lists for the information ‘drug name’ and ‘unit of the drug quantity’ in order to facilitate data entry. In addition, automatic plausibility checks are programmed into the software in order to reduce the occurrence of mistakes. For each drug application entry, it is verified whether the corresponding dispensary record of the veterinarian has been registered. In the case of non-accordance, farmers as well as veterinarians are automatically advertised by the system.

For this study, application and dispensary records from 75 conventional pig farms and their supervising veterinarians (19 in total) were analysed in the time period from January 2008 to December 2011. In that time period, 85,299 drug application records were registered. 49 of the farms were farrow-to-finish (FF), 21 were fattening and five were breeding farms (farms only holding sows and selling piglets at an average weight of 50 kg biomass). In total, they kept around 77,300 pigs, representing about 3 per cent of the Austrian swine population. In FtF farms, the biomass of the sows was added to the production output. In breeding farms, the total biomass was calculated as the sum of the sows’ biomass (number of sows ×200 kg) and the piglets’ biomass (number of sows ×22 piglets per sow per year ×30 kg).

**Antimicrobial consumption**

**Units of measurement**

The easiest way to represent antimicrobial consumption is its expression in weight of active substance. Information about the composition of each preparation was obtained from the SPCs. The weight of active substance(s) used in each record was calculated: weight of active substance (mg) = drug amount (ml or g) × weight of active substance per unit (mg/ml or mg/g). For benzylpenicillin and colistin, which were given in international units (IU), the conversion factors were assigned based on the standards for the ESVAC project (benzylpenicillin: 1 IU = 0.0006 mg; colistin: 1 IU = 0.000049 mg) (EMA 2013).

In addition, three different daily doses were defined:

- The used daily dose per kg biomass (UDD$_{kg}$) was introduced by Timmerman and others (2006) and is defined as the administered dose per day per kg biomass of a drug. As it is based on real consumption data, it can differ between and within herds. In contrast to the definition of Timmerman and others (2006), where median values are calculated when different dosages for a drug are applied, the UDD$_{kg}$ in this study was calculated separately for each data entry, according to the formula:

  \[
  \text{UDD}_{kg}(mg/kg/day) = \frac{\text{weight of active substance (mg)}}{\text{number of treated animals \times average weight (kg) \times treatment duration (days)}}
  \]

- The animal daily dose per kg biomass (ADD$_{kg}$) is internationally defined as the maintenance dosage per day and per kg biomass of a drug for its main indication in one species (Jensen and others 2004). In this study, the average dosage per day and per kg biomass for the active substance(s) of each antibiotic product was defined according to the SPC. Subsequently, the median of all average dosages was calculated for each substance or substance combination and fixed as the ADD$_{kg}$ (Fuchs and Obritzhauser 2010).

- The product-related daily dose for 1 kg biomass (PrD$_{kg}$) was defined as 80 per cent of the maximal dosage per day and per kg biomass for the active substance(s) according to the SPC. This daily dose respects different dosage recommendations for each single product, even if the active substance is the same.

The treatment frequency was assessed by dividing the weight of active substance(s) by the UDD, the ADD or the PrD, representing the number of UDDs (nUDD), the number of ADDs (nADD) or the number of PrDDs (nPDD), respectively.

The antimicrobial consumption was evaluated per year and the results were referred to the animal bodyweight (kg biomass produced). For this purpose, farmers were required to provide information about their annual production output. In FtF farms, the biomass of the sows (number of sows ×200 kg) was added to the production output. In breeding farms, the total biomass was calculated as the sum of the sows’ biomass (number of sows ×200 kg) and the piglets’ biomass (number of sows ×22 piglets per sow per year ×30 kg).

**Plausibility check of data**

For further evaluations, only antimicrobial treatments for oral and parental application (counting 36,757 antimicrobial records) were considered and other medications (e.g. analgesics, vaccinations) were eliminated. Farmers’ entries were completely reviewed and tested for implausibility or incorrect data. In the case of missing or questionable data, consultations were held with the quality-assurance representative of the given company. Drug-related entries (drug name, drug authorisation number, treatment duration) were verified for their accordance with the summary of the product characteristics (SPC, Austria Codex, www.pharmazie.com). The indicated number of animals treated was compared with the farm’s production parameters.
Quantification of antimicrobial consumption

The antimicrobial consumption was evaluated at three levels: in total, per farm-type and per farm. Means were calculated by dividing the total quantity of the yearly-consumed antimicrobials (in total, per farm-type or per farm) by the sum of the kg biomass produced (in total, per farm-type or per farm, respectively). As 14 per cent of antimicrobial records were eliminated in the course of the plausibility proof, the results were extrapolated to 100 per cent, because eliminating antimicrobial records that have taken place would have resulted in an underestimation. The first two levels were broken down to some variables such as the application form (oral or parenteral), the type of treatment (group-level or individual), the therapy indication and the active substance(s) according to the ATCvet classification system (The Anatomical Therapeutic Chemical classification system for veterinary medicinal products, www.whocc.no/atcvet). At farm-level, the between-farm variability was evaluated by calculating minimum, q_{25}, median, q_{75} and maximum values (descriptive statistics). In order to identify farms with a high antimicrobial use compared with the other farms within the same farm-type, a threshold value was fixed for the nADD_{kg/ADD_{kg/year}} according to the definition for outliers: Threshold value=\overline{x}\pm 1.5*IQR (Tukey 1977). Farms exceeding the threshold value were designated as ‘outlier farms’. For graphic visualisation, a ratio was calculated by dividing the antimicrobial consumption per farm by the threshold value.

The correlation between the antimicrobial consumption and the farm size was evaluated with a bivariate Pearson correlation analysis. Furthermore, \chi^2 tests for independence were performed in order to verify to what extent the veterinarian had an impact on the therapy indication and on the chosen active substance (ATCvet Code), and to verify if there were differences between the veterinarians concerning the frequency of supervising ‘outlier farms’ (Software: IBM SPSS Statistics V.20, 2011). For this purpose, metric UDD_{kg}/ADD_{kg} ratios were encoded into ordinal data: underdosage, correct and overdosage. Again, only the six most relevant veterinarians were selected for the test. Contingence coefficients (C) as well as P values (P) were calculated.

**Results**

**Plausibility check of data**

Inaccurate information, usually due to simple typing errors or confusions in choosing preformulated answers, could be observed. In some entries, unrealistic treatment durations were seen (101 antimicrobial records; 0.3 per cent). Because of their small number, the adjustment of these durations to the maximal treatment duration according to the SPF seemed to be justified. Furthermore, the given age class was not always plausible, for example, mastitis in piglets (162 records; 0.5 per cent). In such cases, the indications were considered to be plausible and the age class was adjusted. Sometimes, the number of treated animals exceeded the farm’s production parameters (59 records; 0.1 per cent). As the farmers could enter the therapy indication freely, this information was very heterogeneous and colloquially described. For this reason, therapy indications were categorised according to the categories described above. In general, the plausibility check of data revealed inconsistencies, causing a time-consuming data processing.

Verifying the drug serial numbers of each drug package or flagon for accordance between the dispensed and applied drug amounts showed accordance for 57 per cent of the records. In 22 per cent of the records, the farmers applied less and in 10 per cent the farmers applied more than the veterinarian did dispense to them; 11 per cent of data were not evaluable because of missing serial numbers. For antimicrobial consumption analyses, data with more applications than dispensaries were eliminated together with some other implausible entries. Finally, for the quantification of the antimicrobial use, 86 per cent of the data (51,664 antimicrobial records) were evaluated.

**Accuracy of drug dosage**

UDD_{kg}/ADD_{kg} ratios were calculated (Timmerman and others 2006) and a ratio between 0.75 and 1.25 was defined as the correct dosage. A lower ratio (<0.75) was considered as an underdosage, and a higher ratio (>1.25) as an overdosage. \chi^2 Tests for independence were performed in order to verify the relation between the dosage accurateness and the active substance (ATCvet Code) (separately per application form) and between the dosage accurateness and the veterinarian (Software: IBM SPSS Statistics V.20, 2011). For this purpose, metric UDD_{kg}/ADD_{kg} ratios were encoded into ordinal data: underdosage, correct and overdosage. Again, only the six most relevant veterinarians were selected for the test. Contingence coefficients (C) as well as P values (P) were calculated.

**Antimicrobial consumption**

**Quantification of antimicrobial consumption**

Table 1 visualises the weight of active substance(s) annually consumed, the kg biomass annually produced, as well as the antimicrobial consumption (units of measurement: mg/kg/year, nUDD_{kg}/ADD_{kg/year}, nADD_{kg}/ADD_{kg/year} and nPrDD_{kg}/ADD_{kg/year}) in 75 conventional pig farms from 2008 to 2011.

|                          | Σ Weight of active substance (kg) | Σ Biomass produced (kg) | mg/kg/year | nUDD_{kg}/ADD_{kg/year} | nADD_{kg}/ADD_{kg/year} | nPrDD_{kg}/ADD_{kg/year} |
|--------------------------|----------------------------------|------------------------|------------|-------------------------|-------------------------|--------------------------|
| In total (n=75)          |                                  |                        |            |                         |                         |                          |
| 2008                     | 414                              | 11,072,000             | 37.4       | 4.8                     | 2.3                     | 2.9                      |
| 2009                     | 419                              | 11,011,000             | 36.1       | 5.3                     | 2.0                     | 2.7                      |
| 2010                     | 310                              | 11,872,500             | 26.1       | 4.6                     | 1.8                     | 2.2                      |
| 2011                     | 484                              | 13,465,000             | 35.9       | 4.8                     | 1.8                     | 2.3                      |
| Average                  | 407                              | 12,005,125             | 33.9       | 4.9                     | 1.9                     | 2.5                      |
| Farrow-to-finish farms (n=49) |                                  |                        |            |                         |                         |                          |
| 2008                     | 198                              | 7,358,000              | 27.0       | 2.6                     | 1.5                     | 1.8                      |
| 2009                     | 237                              | 7,732,000              | 30.6       | 2.3                     | 1.5                     | 2.0                      |
| 2010                     | 173                              | 7,919,000              | 21.9       | 2.2                     | 1.3                     | 1.6                      |
| 2011                     | 230                              | 9,078,000              | 25.4       | 1.9                     | 1.2                     | 1.5                      |
| Average                  | 210                              | 8,021,000              | 26.2       | 2.2                     | 1.4                     | 1.7                      |
| Fattening farms (n=21)   |                                  |                        |            |                         |                         |                          |
| 2008                     | 158                              | 2,670,000              | 59.3       | 9.3                     | 3.7                     | 4.5                      |
| 2009                     | 97                               | 2,779,500              | 35.0       | 8.3                     | 2.0                     | 2.9                      |
| 2010                     | 64                               | 2,791,500              | 22.8       | 5.3                     | 1.5                     | 2.1                      |
| 2011                     | 60                               | 3,328,500              | 19.1       | 4.9                     | 1.4                     | 1.9                      |
| Average                  | 97                               | 2,842,500              | 34.1       | 6.9                     | 2.2                     | 2.8                      |
| Breeding farms (n=5)     |                                  |                        |            |                         |                         |                          |
| 2008                     | 57                               | 1,044,000              | 54.5       | 9.3                     | 3.9                     | 5.9                      |
| 2009                     | 83                               | 1,099,500              | 77.6       | 19.0                    | 5.3                     | 7.1                      |
| 2010                     | 73                               | 1,162,500              | 63.0       | 19.7                    | 5.4                     | 6.3                      |
| 2011                     | 192                              | 1,262,500              | 153.5      | 25.0                    | 6.8                     | 9.1                      |
| Average                  | 102                              | 1,142,125              | 87.2       | 18.2                    | 5.4                     | 7.1                      |

*Treatment frequency: nUDD, number of used daily doses; nADD, number of animal daily doses; nPrDD, number of product-related daily doses
4.9 UDD/kg/year, 1.9 ADD/kg/year and 2.5 PtDD/kg/year were consumed (average). Overall, 86 per cent of the total use (nADD/kg/year) were administered via oral, and 14 per cent via parenteral application form. The antimicrobial use per farm-type is also illustrated in Table 1. FtF farms showed a stable and fattening farms a decreasing antimicrobial consumption from 2008 to 2011. In general, breeding farms consumed the most antibiotics. In FtF farms, 61 per cent of the total use were group-treatments, which is a low percentage compared to the fattening and the breeding pigs farms (both 92 per cent).

Differences were found concerning the distribution of the antimicrobial use to the therapy indication (Table 3). Metaphylactic/prophylactic measures constituted the major indication in FtF and fattening farms (29 and 46 per cent, respectively), followed by respiratory tract diseases (22 and 23 per cent, respectively) and digestive tract diseases (14 and 15 per cent, respectively). In breeding farms, digestive tract diseases played a dominant role (36 per cent), followed by infections with involvement of several organ systems (25 per cent). The active substances that were used for the treatment of metaphylactic/prophylactic measures and for respiratory tract diseases in FtF and fattening pig farms are illustrated in Table 4.

Median values of the antimicrobial use at farm-level ranged between 0.3 ADD/kg/year (fattening farms, 2010) and 2.3 ADD/kg/year (fattening farms, 2008) (Table 5). Fig 1 visually brings out the FtF farms with a higher antimicrobial consumption than the threshold value. Particularly in 2011, several FtF farms used higher amounts of antimicrobials.

The farm size had no significant impact on the antimicrobial consumption. χ² Tests for independence revealed that the veterinarian had a significant impact on the therapy indication (C = 0.5; P < 0.001) in FtF farms (in fattening farms the conditions for statistical tests were not fulfilled) and on the chosen active substance (ATCvet Code) (C = 0.7; P < 0.001). In addition, differences between the veterinarians concerning the frequency in supervising ‘outlier farms’ were exploratory detected but could not be verified by a statistical test because the prerequisites for the χ² test were not fulfilled.

**Accuracy of drug dosage**

Table 6 illustrates the dosage accurateness for oral and parenteral anti-biotic treatments. The UDD/ADD₁ ratio revealed that oral applications were correctly dosed in 8 per cent and parenteral applications in 42 per cent of the entries. The oral application form was generally underdosed (73 per cent), whereas the parenteral application form was rather overdosed (41 per cent). χ² Tests revealed a relation between the dosage and the active substance in parenteral applications (C = 0.5; P < 0.001). In oral treatments, colistin, amoxicillin, tylosin, enrofloxacin and lincomycinides in combination with other antibacterials were often underdosed (out of the most used antimicrobials). In parenteral treatments, primarily tylosin, danofloxacin and penicillins in combination with other antibacterials were generally overdosed (out of the most used antimicrobials) (Table 1). It was also noted that the veterinarian had a significant impact on the dosage accurateness (C = 0.3; P < 0.001). Overall, a wide distribution concerning the veterinarians’ dosage choice was seen. Whereas some veterinarians mostly applied a correct dosage, some few veterinarians showed a high number of under- or overdosages.

**Discussion**

Collecting reliable data for the measurement of antimicrobial consumption in animal husbandry is a great challenge. Whereas overall sales data are relatively easy to gather, the collection of on-farm data is difficult and rarely standardised. In 2010, Fuchs and Obritzhauser successfully estimated antimicrobial use in Austrian cattle, pig and poultry production by evaluating veterinarians’ dispensary records. Yet, the evaluation of dispensary records is subject to limitations, because

### Table 2: Active substances used for antimicrobial treatment in 75 conventional pig farms

| ATCvet Code | Active substance | 2008 | 2009 | 2010 | 2011 | Average | Per cent |
|-------------|------------------|------|------|------|------|---------|----------|
| QA07AA01    | Neomycin         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QA07AA10    | Trolein          | 0.3  | 0.3  | 0.4  | 0.3  | 0.3     | 16.2     |
| QA07AA91    | Gentamicin       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01AA02    | Doxycycline      | 0.2  | 0.1  | 0.0  | 0.1  | 0.1     | 5.6      |
| QJ01AA03    | Chlorotetracycline| 0.0 | 0.0  | 0.0  | 0.0  | 0.0     | 0.8      |
| QJ01AA06    | Oxytetracycline  | 0.3  | 0.3  | 0.3  | 0.4  | 0.3     | 16.5     |
| QJ01AA56    | Oxytetracycline, combinations | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 4.1 |
| QJ01BA90    | Florfenicol      | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.4      |
| QJ01CA01    | Ampicillin       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.1      |
| QJ01CA04    | Amoxicillin      | 0.3  | 0.5  | 0.3  | 0.4  | 0.4     | 19.1     |
| QJ01DE99    | Procaine benzylpenicillin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 |
| QJ01DD90    | Cefotiofur       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.1      |
| QJ01DE90    | Cefquinome       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.1      |
| QJ01E003    | Sulfadimidine and trimethoprim | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| QJ01E010    | Sulfadiazine and trimethoprim | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 |
| QJ01E011    | Sulfamethoxazole and trimethoprim | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| QJ01E013    | Sulfadoxine and trimethoprim | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| QJ01F090    | Tylosin          | 0.2  | 0.1  | 0.1  | 0.1  | 0.1     | 6.4      |
| QJ01F091    | Tilmicosin       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01F094    | Tulathromycin    | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01G090    | Dihydrostreptomycin | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| QJ01G030    | Gentamicin       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01G050    | Neomycin         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01M090    | Enrofloxacin     | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01M092    | Danofloxacin     | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01M093    | Marbofloxacin    | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01R001    | Penicillin, combinations with other antibacterials | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| QJ01R094    | Lincosamides, combinations with other antibacterials | 0.6 | 0.3 | 0.5 | 0.2 | 0.4 | 20.4 |
| QJ01X001    | Tiamulin         | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| QJ01X002    | Valnemulin       | 0.0  | 0.0  | 0.0  | 0.0  | 0.0     | 0.0      |
| Total       |                  | 2.2  | 2.0  | 1.8  | 1.8  | 1.9     | 100.0    |

Represented as a percentage of total antimicrobial consumption (expressed in nADD/kg/year) *Treatment frequency. nADD, number of animal daily doses
dispensed antibiotics are not always applied, as demonstrated in this study. The next step to head for antimicrobial consumption analyses is the involvement of the end-user in data collection form, which was previously described in several studies (Chauvin and others 2002, Timmerman and others 2006, Stevens and others 2007, Jordan and others 2009, Menéndez González and others 2010, Moreno 2012). The plausibility control of the data showed that the collection of drug application data by the farmer is feasible, but associated with some limitations. Inaccurate information in farmers’ records was frequently observed, but attention must be drawn to the fact that veterinarians’ records were not completely plausible either. Analogous findings have also been described in another study (Menéndez González and others 2010). One can conclude from this that training courses and educational advertising both for farmers and veterinarians would be beneficial for the implementation of such a system.

The comparison between dispensed and applied drug amounts for the drug serial numbers revealed accordance in only 57 per cent of records. This might be due to the fact that the farmers could choose the following units from a drop-down list: ml, mg, g, kg, pieces or injectors. As a consequence, confusions in quantity units were foreseen. In response to the results of this study, the software of the given company will be extended with advanced automatic plausibility checks in the future. This upgrade includes:

### TABLE 3: Therapy indications for antimicrobial treatments in farrow-to-finish (FtF), fattening and breeding pig farms (expressed in nADD$_{kg/kg/year}$)

| Therapy indication                                      | FtF farms (n=49) | Per cent | Fattening farms (n=21) | Per cent | Breeding farms (n=5) | Per cent |
|--------------------------------------------------------|------------------|----------|------------------------|----------|----------------------|----------|
| Cannibalism                                            | 0.0              | 0.0      | 0.0                    | 1.4      | 0.1                  | 1.1      |
| Chirurgical interventions                              | 0.0              | 0.0      | 0.0                    | 0.0      | 0.0                  | 0.0      |
| Digestive tract diseases                               | 0.2              | 13.6     | 0.4                    | 18.2     | 1.9                  | 35.9     |
| General infections                                     | 0.1              | 6.8      | 0.0                    | 0.1      | 0.1                  | 1.9      |
| Gynaecological diseases                                | 0.0              | 1.7      | 0.0                    | 0.0      | 0.4                  | 7.9      |
| Infections/Inflammations                               | 0.1              | 4.6      | 0.0                    | 0.0      | 0.0                  | 0.5      |
| Infections with involvement of several organ systems   | 0.2              | 11.7     | 0.1                    | 7.2      | 1.3                  | 25.2     |
| Injuries                                               | 0.0              | 0.3      | 0.0                    | 0.2      | 0.1                  | 1.1      |
| ‘Implausible indications’                              | 0.1              | 4.0      | 0.0                    | 0.0      | 0.2                  | 3.4      |
| Mastitis mitritis agalactia                            | 0.0              | 3.0      | 0.0                    | 1.3      | 0.1                  | 1.5      |
| Metaphylactic/prophylactic measures                    | 0.4              | 29.1     | 1.0                    | 46.1     | 0.1                  | 1.5      |
| Orthopaedic diseases                                   | 0.0              | 2.1      | 0.0                    | 1.8      | 0.2                  | 3.0      |
| Other diseases                                         | 0.0              | 0.8      | 0.0                    | 0.6      | 0.0                  | 0.8      |
| Respiratory tract diseases                             | 0.3              | 21.9     | 0.6                    | 23.2     | 0.9                  | 16.1     |
| Total                                                  | 1.4              | 100.0    | 2.2                    | 100.0    | 5.4                  | 100.0    |

*Treatment frequency: nADD, number of animal daily doses

### TABLE 4: Active substances used for metaphylactic/prophylactic measures and respiratory tract diseases in farrow-to-finish (FtF) and fattening pig farms

| ATCvet | Metaphylactic/prophylactic measures | Respiratory tract diseases |
|--------|-------------------------------------|---------------------------|
|        | FtF farms (n=49)                    | Fattening farms (n=21)    | FtF farms (n=49) | Fattening farms (n=21) |
|        | Percentage of total antimicrobial consumption in nADD$_{kg/kg/year}$ | Percentage of total antimicrobial consumption in nADD$_{kg/kg/year}$ |
|        |                                    |                          |                |                          |
| QA07AA10 | Colistin                          | 34.4                     | 0.0             | 0.0                    | 0.0             |
| QA07AA91 | Gentamicin                        | 0.1                      | 0.0             | 0.0                    | 0.0             |
| QJ01AA02 | Doxycycline                       | 2.0                      | 11.5            | 18.2                   | 4.3             |
| QJ01AA03 | Chlorotetracycline                | 0.0                      | 0.0             | 0.3                    | 0.0             |
| QJ01AA06 | Oxytetracycline                   | 23.9                     | 3.5             | 47.3                   | 21.6            |
| QJ01AA56 | Oxytetracycline, combinations     | 0.0                      | 0.7             | 0.0                    | 0.9             |
| QJ01AA90 | Flornitrofen                       | 0.0                      | 0.0             | 2.7                    | 2.2             |
| QJ01CA01 | Ampicillin                        | 0.0                      | 0.0             | 3.0                    | 0.0             |
| QJ01CA04 | Amoxicillin                       | 7.2                      | 0.4             | 4.9                    | 47.6            |
| QJ01CE09 | Procaine benzylpenicillin         | 0.0                      | 0.0             | 0.2                    | 0.0             |
| QJ01DD09 | Cefotaxim                         | 1.3                      | 1.7             | 0.2                    | 0.0             |
| QJ01E90  | Cefquinomine                      | 0.0                      | 0.0             | 1.2                    | 1.8             |
| QJ01EW10 | Sulfadiazine and trimethoprim     | 0.0                      | 0.0             | 1.1                    | 8.1             |
| QJ01EW11 | Sulfamethoxazole and trimethoprim | 3.3                      | 0.0             | 0.0                    | 0.2             |
| QJ01FA90 | Tylosin                           | 1.3                      | 3.1             | 2.0                    | 2.4             |
| QJ01FA91 | Tilmicosin                        | 0.0                      | 0.0             | 0.9                    | 0.0             |
| QJ01FA94 | Tualathromycin                    | 1.2                      | 0.0             | 4.3                    | 0.0             |
| QJ01GB05 | Neomycin                          | 3.2                      | 0.0             | 0.0                    | 0.0             |
| QJ01MA90 | Enrofloxacin                      | 0.0                      | 0.0             | 0.3                    | 0.0             |
| QJ01MA92 | Danofloxacin                      | 0.9                      | 0.0             | 0.9                    | 1.0             |
| QJ01MA93 | Marbofloxacin                     | 0.1                      | 0.0             | 0.8                    | 0.4             |
| QJ01RA01 | Penicillins, combinations with other antibacterials | 0.6 | 0.0 | 0.2 | 0.0 |
| QJ01RA94 | Lincomoxides, combinations with other antibacterials | 18.8 | 79.1 | 13.6 | 8.7 |
| QJ01XQ01 | Tiamulin                          | 1.5                      | 0.0             | 0.0                    | 0.8             |
| Total    | 100.0                            | 100.0                    | 100.0           | 100.0                  | 100.0           |

Represented as a percentage of total antimicrobial consumption (expressed in nADD$_{kg/kg/year}$)

*Treatment frequency: nADD, number of animal daily doses
automatic comparison between the entered drug amount and the recommended dosage according to the SPC; automatic comparison between the entered therapy indication and the indications given in the SPC; as well as a restriction of the available drug amount units (ml or g).

Expressing antimicrobial consumption in number of daily doses takes into account differences in potency of antimicrobial substances (Chauvin and others 2001). Whereas the defined daily dose in human medicine has been developed, an analogous daily dose for veterinary medicine has not been defined yet. The ADDkg has been introduced by Jensen and others (2004) as the maintenance dose per day per kg biomass for a drug for its main indication in one species. The results of this study can be converted into the Belgian ‘T reatment Incidence’, which indicates how many animals per 1000 receive a daily dose of an antibiotic, by multiplying the daily doses per year with the factor 2.74 (Ghent University 2014). Thus, one can conclude that 1.9 ADDkg/kg/year (average, 75 farms) is coequal to the treatment of 0.5 per cent of the study swine population per day. This is a relatively low consumption compared with other Austrian studies (Obritzhauser and others 2011). However, the treatment frequency expressed in nUDD showed an antimicrobial consumption of 4.9 UDD kg/kg/year, which means that 1.3 per cent of the study swine population has been under antimicrobial treatment on a certain day. The UDD has been defined by Timmerman and others (2006) as the administered dose per day per kg biomass of a drug. It is based on real consumption and is independent of farmer’s non-compliance; it may therefore describe the actual consumption more accurately than daily doses based on theoretical dosage recommendations.

One reason for the discrepancy between nADD and nUDD is underdosage. Other possible reasons could be an overestimation of the fixed ADDs, the application of different dosage regimen or the use for other therapy indications (Chauvin and others 2001). In Austria, dosage recommendations according to the SPC are widely divergent for one active substance, essentially complicating the fixation of ADDs. For this reason, the PrDD, which takes into account these differences in dosage recommendations, has been defined as a potential alternative to the ADD. Between the nPrDD and the nUDD, minor discrepancy was detected, which approves these considerations. Finally, it is important to state that the daily doses described in this and in other studies (Timmerman and others 2006, Menéndez González and others 2010, Obritzhauser and others 2011, Callens and others 2012) are developed at national level. As a consequence, a comparison of antimicrobial consumption between countries is not possible with these indicators.

The evaluation of the dosage accuracy revealed a high number of inappropriate dosages with an underdosage for orally and a correct/overdosage for parenterally applied antimicrobials. Similar results have been illustrated in other studies (Timmerman and others 2006, Regula and others 2009, Callens and others 2012). Misuse of antimicrobial substances in animal husbandry is assumed to be one main risk factor for the development and spread of resistant bacteria (Wise and others 1998, Aarestrup 2005). Catry and others (2003) pointed out:

**Table 5: Descriptive statistics for the antimicrobial consumption at farm-level (expressed in nADDkg/kg/year*)**

|             | Valid | Missing | Average | Min | q25 | Median | q75 | Max |
|-------------|-------|---------|---------|-----|-----|--------|-----|-----|
| **Farrow-to-finish farms (n=49)** |       |         |         |-----|-----|--------|-----|-----|
| 2008        | 48    | 1       | 1.5     | 0.0 | 0.3 | 1.0    | 2.7 | 4.7 |
| 2009        | 48    | 1       | 1.5     | 0.0 | 0.3 | 0.9    | 2.3 | 5.8 |
| 2010        | 48    | 1       | 1.4     | 0.0 | 0.3 | 0.7    | 2.4 | 5.8 |
| 2011        | 49    | 0       | 1.2     | 0.0 | 0.3 | 0.6    | 1.7 | 4.7 |
| **Fattening farms (n=21)**    |       |         |         |-----|-----|--------|-----|-----|
| 2008        | 19    | 2       | 3.5     | 0.0 | 0.8 | 2.3    | 6.5 | 12.8|
| 2009        | 19    | 2       | 2.0     | 0.0 | 0.1 | 1.2    | 3.8 | 5.8 |
| 2010        | 19    | 2       | 1.6     | 0.0 | 0.0 | 0.3    | 2.4 | 9.3 |
| 2011        | 21    | 0       | 1.3     | 0.0 | 0.2 | 0.7    | 1.6 | 5.8 |
| **Breeding farms (n=5)**       |       |         |         |-----|-----|--------|-----|-----|
| 2008        | 5     | 0       | 3.6     | 0.0 | 0.5 | 0.7    | 8.3 | 9.3 |
| 2009        | 5     | 0       | 3.5     | 0.0 | 0.6 | 0.9    | 7.7 | 14.0|
| 2010        | 5     | 0       | 3.5     | 0.0 | 0.4 | 0.6    | 8.1 | 14.0|
| 2011        | 5     | 0       | 5.0     | 0.0 | 0.8 | 2.2    | 10.5| 15.1|

*Treatment frequency: nADD, number of animal daily doses

**Figure 1:** Exceeding of the threshold value (threshold value = q75 + (1.5 × IQR) (Tukey 1977)) for the antimicrobial consumption (in number of animal daily doses per kg biomass per year - nADDkg/kg/year) in 49 farrow-to-finish farms from 2008 until 2011. Ratios were calculated by dividing the antimicrobial consumption per farm by the threshold value. Consequently, a ratio of 1 represents an antimicrobial consumption equal to the threshold value. In the figure, farms with a higher consumption than the threshold value (‘outlier farms’) are coloured. Farms are sorted by their total consumption in four years.
out that the underdosage of antimicrobials might positively influence the occurrence of antimicrobial resistance. As approximately 86 per cent of antimicrobials were applied orally in this study, one can conclude that the main part of the therapies was given in an underdosed quantity. Reasons for under- or overdosages in prescribing antimicrobials are thought to be a misestimating of dosed quantity. Reasons for under- or overdosages in prescribing antimicrobials are thought to be a misestimating of dosed quantity.

In this study, the definition for outliers was fixed as threshold value, which is an arbitrary determination. In other countries, different thresholds are described (Alban and others 2013, Anonymous 2014). A significant correlation between the antimicrobial consumption and the farm size could not be detected. However, it is conspicuous that the usage of antimicrobials varied considerably between the average weight of the animals and the real bodyweight, might distort the results.

The mean over the study population per farm-type showed a high productivity pressure still leads the farmers to consult prophylactic antimicrobial treatment in order to reduce animal mortality.

The definition of a threshold value brought out the farms with a higher consumption than other farms within the same farm-type. In this study, the definition for outliers was fixed as threshold value, which is an arbitrary determination. In other countries, different thresholds are described (Alban and others 2013, Anonymous 2014).

A significant correlation between the antimicrobial consumption and the farm size could not be detected. However, it is conspicuous that the breeding farm mentioned above not only showed the highest consumption but also kept the most animals. In contrast to this outcome, other researchers reported a higher antimicrobial consumption in association with smaller pig herds (Hybschmann and others 2011, Vieira and others 2011). This proportion might even be higher, because an overlap of other therapy indications cannot be completely excluded. In Austria, the preventive treatment with antimicrobial substances is only allowed for metaphylactic reasons. Nevertheless, in the study at hand, metaphylactic measures only played a minor role, whereas prophylactic measures were much more often indicated. Apparently, high productivity pressure still leads the farmers to consult prophylactic antimicrobial treatment in order to reduce animal mortality.

The discrepancy between the mean and the evaluation at farm-level strongly influence the results. Therefore, metaphylactic and prophylactic measures were consolidated in one category. They represented the main indication for antimicrobial therapy in FTf and fattening pig farms (29 and 46 per cent, respectively), which is an outcome also found in another study (Callens and others 2012). This proportion might even be higher, because an overlap of other therapy indications cannot be completely excluded.

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consumption were administered at group-level, which is a low proportion compared to the other two farm-types. This is in line with their low share of orally applied antibiotics (80 vs 93 per cent in fattening and 95 per cent in breeding farms) and their minor discrepancy between nUDD and nADD. One can conclude from this outcome that less treatment at group-level may result in a higher amount of parenterally applied antibiotics and consequently lead to a higher level of correct dosages.

The results of this study clearly underline the need for on-farm data for the measurement of antimicrobial use in veterinary medicine. However, further measures are necessary in order to improve data quality. It is important to note that the results of this study are not representative for the whole country because a sampling frame of 75 pig farms (representing about 3 per cent of the Austrian swine population) is too small. The non-finite evaluation possibilities that can be performed by means of those informative data must be emphasised. Well established and technically mature quality-assurance systems should be officially accredited in future. In particular, the labelling of each single drug package or flagon with a serial number/systems should be officially accredited in future. In particular, the labelling of each single drug package or flagon with a serial number should be officially accredited in future.

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