”The Swedish experience”

– a summary on the Swedish efforts towards a low and prudent use of antibiotics in animal production

Johanna Grundin, Isabel Blanco-Penedo,
Nils Fall, Susanna Sternberg Lewerin

SLU Framtidens djur, natur och hälsa
Rapportnummer 5 | 2020

Förord

Denna text skrevs ursprungligen för att tillhandahålla data inom ett större internationellt forskningsprojekt (ROADMAP, EU Horizon2020, grant agreement 817626). Då det blev uppenbart att det fanns en stor okunskap bland forskarkollegorna inom antibiotikaresistensområdet om vad som gjorts i Sverige och hur framgångsrikt detta arbete varit, kom texten att innehålla mer än bara de data som behövdes i projektet. Trots att Sverige och svensk veterinärmedicin ofta ses som föregångare när det gäller ansvarsfull antibiotikaanvändning och god djurhälsa råder samtidigt stor okunskap om hur detta utvecklats och vilket arbete som ligger bakom. Det förekommer missuppfattningar som att vi har så få djur, så gles djurpopulation och så kallt klimat att inga sjukdomar sprids, eller att vi inte behandlar våra sjuka djur. För att svenska forskare som medverkar i internationella projekt ska komma in med rätt förutsättningar och på bästa sätt dra nytta av de erfarenheter, goda såväl som dåliga, som rönts under alla de år vi arbetat för en ansvarsfull antibiotikaanvändning behöver vi kunna förklara hur det ligger till. Denna text kan fungera som stöd när svenska forskare går in i internationella projekt om antibiotikaanvändning och förebyggande djurhälsoarbete.

“The Swedish experience” – a summary on the Swedish efforts towards a low and prudent use of antibiotics in animal production

Utgivningsår: 2020, Uppsala
Utgivare: SLU Framtidens djur, natur och hälsa
Layout: Cajsa Lithell
Omslagsfoto: Jenny Svennås-Gillner, SLU
Tryck: SLU Repro
ISBN nummer: 978-91-576-9745-5 (elektronisk), 978-91-576-9746-2 (tryckt)

Contents

Sammanfattning

Redan 1986 förbjöd Sverige, som första land i världen, användandet av antibiotika i djurfoder i tillväxtbefrämjande syfte. Idag är antibiotikabehandlingen av djur i Sverige den tredje lägsta i Europa. Den totala mängden till djur 2018 var, baserat på försäljningsdata, 10 042 kg aktiv substans. Detta kan jämföras med 1984, innan förbudet mot tillväxtbefrämjande antibiotika, då siffran låg på 53,4 ton. Den låga antibiotikaanvändningen och det jämförelsevis fördelaktiga antibiotikaresistensläget i Sverige är resultatet av åratals samarbete mellan olika sektorer och ett hårt arbete med att förebygga sjukdomar och förbättra djurhälsan. Denna översikt beskriver kortfattat delar av det svenska arbetet för att uppnå ansvarsfull användning av antibiotika till djur liksom viktiga framgångsfaktorer och erhållna lärdomar.

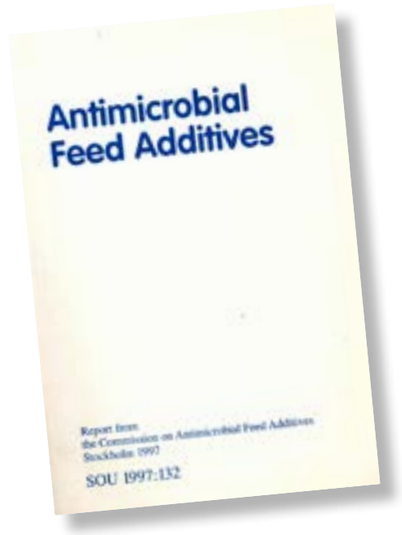
Abstract

In 1986, Sweden, as the first country in the world banned all use of antibiotics as growth promoters in food animal production. Today Sweden has the third lowest sales of veterinary antimicrobial agents for food producing animals in Europe. In 2018, total sales of antibiotics for animal use in Sweden were 10 042 kg active substance as compared to 53.4 tonnes in 1984 (before the ban). The low use of antibiotics in animals and the comparatively favorable situation in Sweden with regards to antibiotic resistance are the results of decades of inter-sectorial collaboration and work on disease prevention and animal health. This review is a quick summary of the Swedish work towards a low and prudent use of antibiotics, including figures on antibiotic use in Swedish production animals and a discussion about important success factors as well as lessons learned.

Introduction

Concerns about a continuous low-dose use of antibiotics in animal feed without any veterinary prescription for the purpose of improving growth and feed conversion in production animals (antibiotic growth promoters, AGP) were raised in several European countries soon after the approval of such use back in the early 1950s[1]. These concerns led to a report issued by the Swann Committee[2] (established by the British government) in 1969 calling for restricted use of AGP due to the risk of resistance development. The Swann report argues that antibiotics in livestock, particularly in subtherapeutic doses, poses certain hazards to human and animal health and that only antibiotics which have little or no application as therapeutic agents should be used as AGP. This report led to the subsequent withdrawal of antibiotics important for therapeutic use in humans and animals such as penicillin, streptomycin and tetracyclines as AGP in many European countries with the implementation of Council Directive 70/524/EEC[3]. This was the first harmonization of the legislation regarding the use of antibiotics in animal feed as, in the 1950s and 60s, national regulations of each member state differed with regards to their basic principles. Important to note is that this regulation did not include the provision to withdraw approvals of AGP should members of the same class of antimicrobials come into use for humans at a later time[4]. Sweden was a global forerunner in the fight against antibiotic resistance. As early as 1986, nine years before entry into the EU, Sweden, as the first country in the world, banned all use of AGP in food animal production. It wasn't until twenty years later and after intensive Swedish lobbying, in 2006, that this ban was introduced in the rest of the EU with the implementation of EC regulation 1831/2003[5] stating that after 21st December 2005 medicinal substances in animal feeds will be limited to therapeutic use by veterinary prescription. Today there is plenty of evidence that AGPs select for antibiotic resistance in bacteria. This association between AGP use and resistance is most thoroughly studied for avoparcin and the occurrence of Glycopeptide-Resistant Enterococci (GRE) in feces and meat products of animal origin[6–14], but also for other AGPs such as

Today there is plenty of evidence that antibiotic growth promoters select for antibiotic resistance in bacteria. PHOTO: PATRIK SÖDERMAN

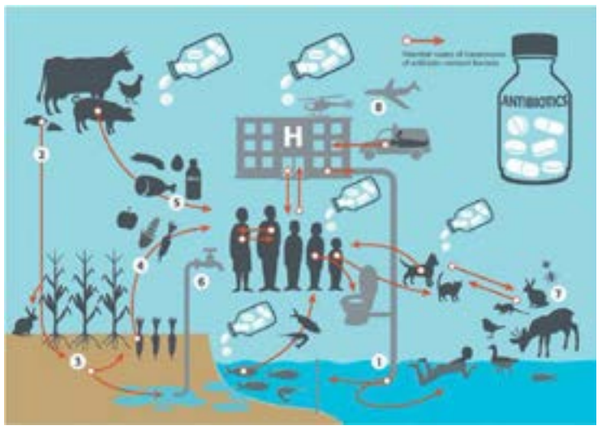


The Swedish lobbying for an EU-wide ban on AGP included a scientific report presented to the EU Commission. READ THE REPORT: HTTPS://WWW.GOVERNMENT.SE/LEGAL-DOCUMENTS/1997/01/SOU-1997132/

Macrolides (tylosin and spiramycin), Evernimicins (avilamycin) and bacitracin[10] and for Streptogramins (virginiamycin)[10,15]. However, the scientific position on the consequences for human and animal health is ambiguous. The decision to ban AGP in Sweden and later in the EU was therefore made with the support of "the precautionary principle"[16]. The precautionary principle encourages policies protecting public- and environmental health in the face of uncertain risks[17]. It emphasizes that precautionary measures should be taken if an activity poses significant harm to public health or to the environment even if the harm is not yet fully proven or understood. The use of antibiotics in Sweden is low compared to international statistics and the situation is favorable with regards to antibiotic resistance[18]. Sweden's long history of working towards a prudent use of antibiotics has provided experience regarding alternatives for the prevention of disease, and publication of treatment guidelines for several species[39-41]. This has also led to Sweden having one of the strictest animal welfare legislations in the world.

The beginning

The process towards a more restrictive use of antibiotics in Sweden was actually initiated by the media[19]. During this time Sweden had seen a hard rationalization and industrialization of farming practices and agriculture. This started growing discussions on animal welfare and an awakening environmental movement. A debate among politicians and the public was started by the media when they revealed how each year thirty tonnes of antibiotics were given to healthy animals. Swedish farmers, through the Federation of Swedish Farmers (LRF), reacted proactively and tried to improve *their* image by petitioning for a total ban on AGP. The Swedish parliament reacted by banning all AGP from 1986 and all antimicrobials where classed as veterinary medicines, available on veterinary prescription only[19]. Limited access to antibiotics puts a high demand on an optimal environment and optimal management routines to reach high productivity, hence this restrictiveness has an important animal-welfare aspect. With the ban on AGP, Sweden began a reform change towards a more sustainable animal production. These early actions taken by professional, official and industry bodies marked the beginning of the development of the so-called "Swedish Model" of consensus thinking and a cooperative, supportive approach. The Swedish Model is characterized by a close collaboration between stakeholders such as farmers, veterinarians, authorities, advisors and academy and a holistic view on the connection between preventive work, healthy animal environments and a low use of antibiotics[53]. No negative clinical effects of the ban on AGP were described in the production of slaughter pigs, cattle (milk and meat production) and turkeys. It was in piglet production and in broiler chicken production the consequences of the ban were most significant[19-21]. For piglet production there was an increase in post-weaning mortality and a decreased growth connected to an increase in post-weaning diarrhea[22]. During the years following the ban, huge efforts were put into field studies and research projects leading to improved management routines, housing systems and changes in feed. As a result, health problems arising as a consequence of the ban could be managed and the initial increase in the prescription of antibiotics for therapeutic use could be reduced, and in the case of broiler production completely discontinued[20, 21]. In 1986 total sales of antibiotics for animal use decreased to about 29.5 tonnes of active substance as compared to 53.4 tonnes in 1984 (36 % of sales 1984 were AGP)[23]. The following years (1987-1988) sales increased slightly to stabilize at about 35 tonnes of active substance per year during 1988-1993. During 1994 and 1995 sales decreased to 31.9 and 25.4 tonnes respectively. After a transitional period, the products used as AGP disappeared from the market or where registered for therapeutic use.



Links between different sources of antibiotic resistance. SOURCE: BIOMÉRIEUX

Sweden has shown that it is possible to reduce the use of antibiotics in animal husbandry radically while maintaining production. PHOTO: MÅRTEN GRANERT

Past and present work in Sweden

There is a strong agreement today among veterinary personnel, animal keepers and animal health organizations in Sweden on a restrictive and responsible use of antibiotics. This is the result of a long tradition of preventive measures to keep animals healthy.

National strategies influencing the use of antimicrobials

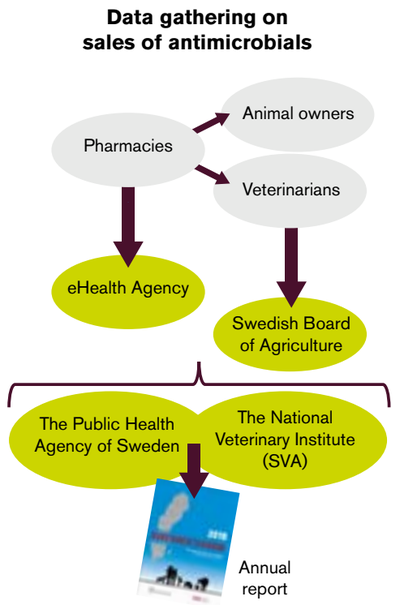
The first One Health national strategy against antimicrobial resistance (AMR) was presented in 2005. This strategy has since been updated and the latest version was published in 2020 and is based on current AMR work, the Global Action Plan on AMR (WHO)[24] and other relevant documentation (evaluations, action plans and other strategies)[25]. In this strategy seven objectives are presented; (1) increased knowledge through enhanced surveillance, (2) continuous strong preventive measures, (3) responsible use of antibiotics, (4) increased knowledge for preventing and managing bacterial infections and antibiotic resistance with new methods, (5) improved awareness and understanding in society about antibiotic resistance and countermeasures, (6) supporting structures and systems and (7) leadership within the EU and international cooperation. This strategy points out the direction and priorities of Swedish efforts to tackle AMR and is also intended for international actors wishing to benefit from Swedish experience. An action plan for these seven objectives has been established[26]. The Swedish Board of Agriculture and the Public Health Agency put together an inter-sectional coordination mechanism, involving 23 agencies, to bring together the expertise from appropriate sectors to work against AMR.

Monitoring of sales and AMR

Monitoring systems and surveillance are fundamental parts of any recommendations to combat AMR and work towards a more prudent use of antibiotics[27]. The prevalence of some resistant bacteria, for example ESBL-forming *E-coli* in poultry, has decreased substantially in Sweden as a result of surveillance but also as a result of the close collaboration between authorities, farmers, trade organizations and individual food companies. To

continuously gather data on the use of antibiotics and the occurrence of resistant bacteria makes it possible to analyze trends over time and notice changes that could indicate a spread of resistant bacteria, but also to communicate findings and take measures at an early stage[23]. It also creates a possibility to monitor the effects of measures taken and to evaluate them.

Sweden has been gathering data on sales of antimicrobials for the use in animals since 1980. The data gathered includes sales from pharmacies to animal owners (prescription dispensed) and to veterinarians (requisition based). Pharmacies are obliged to report their sales to the eHealth Agency who keeps a database and veterinarians are required to report their use of medicinal products (including antimicrobials) to the Swedish Board of Agriculture with regards to production animals and horses (antimicrobials for systemic use). The Public Health Agency of Sweden and the National Veterinary Institute (SVA) have a collaboration where analysis of data with regards to sales of antibiotics as well as AMR in animals, humans and food is gathered and presented in an annual report called the Swedres-Svarm report[27].



When antimicrobials are sold from pharmacies to animal owners via prescription the species of animal for which the product is intended is recorded. This enables the extraction of information regarding the sales of antimicrobials for use in major species of animals. Antimicrobials sold via requisition to veterinarians or veterinary clinics are recorded under a broad classification, limiting the ability of the data system to identify the species for which they are used. Species specific information on the use of antimicrobials can however be obtained from a number of other sources such as Växa Sverige (the biggest advisory organization in the dairy sector) and Svensk Fågel (Swedish Poultry Meat Association) that gather information on animal disease and flock/heard health. This makes it possible to follow the antibiotic use in their respective sector.

SVA[28] has responsibilities with regards to supporting the prudent use of antimicrobials, follow and analyze AMR in bacteria from animals and act as a national reference laboratory for AMR by performing routine susceptibility tests. They also conduct research relating to AMR. The result of this work is published in the annual Swedres-Svarm reports. In 2005 increased surveillance of AMR in pathogenic bacteria causing disease in farm animals was initiated through the Svarm-PAT program[29]. This program is a collaboration between SVA and Farm and Animal Health (Gård och Djurhälsan, an advisory organization for preventive animal health in beef cattle, sheep and pigs) and financed by the Swedish Board of Agriculture. Farm and Animal Health collect samples in herds and provide expertise on husbandry and clinical disease. The samples are analyzed, data assembled and results analyzed by SVA.

"The objective of Svarm-Pat is to improve the monitoring of pathogens in farm animals by collecting high-quality unbiased data on antimicrobial resistance for an appropriate number of isolates. Results are reported yearly in the Svarm report and are communicated in other ways as well. Updated knowledge on susceptibility of animal pathogens is thereby available for practitioners, facilitating the therapeutic choice in the clinical setting. Moreover, high-quality data allows appropriate analysis of trends in resistance and of underlying causes for such trends"[29]. Included in the program are pathogens like *E-coli* in cattle and pigs, *Pasteurella spp.* and *Mannheimia spp.* from cattle, pigs and sheep, *Brachyspira spp.* from pigs and udder pathogens. *"By long term monitoring, Svarm-Pat will lead to increased and in-depth knowledge of antimicrobial resistance in pathogens from Swedish farm animals. This will be a keystone for prudent use of antimicrobials, which, in a wider perspective, curbs the emergence and spread of antimicrobial resistance. Thereby, effective antimicrobial therapy of farm animals, imperative for a good animal health status, is ensured in the future"*[29].

The analysis of data collected under the AMR monitoring programs enables developing risks to be identified. In case of any increased level of resistance SVA initiates investigations to identify the causes. The knowledge within the Svarm and Svarm-PAT programs has been applied in the development of guidelines for use of antibiotics, published by the Swedish Veterinary Association and the Medical Products Agency[39-41].

In 2016, the Swedish Civil Contingencies Agency funded a three-year project conducted by SVA aiming to improve the quality of AMR diagnostics, and capacity building. The aim is to promote a high standard of performance for susceptibility testing in Swedish laboratories. Worth mentioning in this context is also the obligation to report findings of certain infectious agents. MRSA/MRSP, other methicillin resistant *Staphylococcus* spp. and carbapenemase-producing *Enterobacteriaceae* are notifiable, meaning that laboratories have to notify the veterinarian who sent the sample, the County Administrative Boards and the Swedish Board of Agriculture, on suspicion of any of these agents.

SVA, the Swedish national reference laboratory for AMR, performs routine susceptibility tests to follow and analyze AMR in bacteria from animals.
PHOTO: JULIO GONZALES

Distribution

In Sweden, as in other Nordic countries, there are rules that limit financial interests that may incentivize veterinarians to prescribe antibiotics[30]. These rules prevent veterinarians from offering medicinal products for retail sale as they can only be handed out by pharmacies on veterinary prescription. One exception is the supply (without profit) of sufficient doses of antimicrobials for immediate treatment until the product can be acquired from a pharmacy. This limits veterinarians' interest in prescribing antimicrobials unless really needed.

Farmers in Sweden have access to a substantial range of support and advisory services such as Farm and Animal Health, Växa Sverige, the Swedish Poultry Meat Association and the District veterinarians. The District veterinarians are on call 24 hours/day for all animals and work both with acute cases and disease control. They also perform planned visits with regards to preventive animal health. This substantial support for Swedish farmers encourages practices to avoid the use of antibiotics and helps to ensure good health management practices are followed.

Farmers working with certain species of animals (i.e. dairy or beef cattle, pigs, sheep, goats, poultry or fur animals that are kept for the production of meat, eggs, wool, fur or skin, and farmed fish) can choose to sign a contract with a veterinarian for "conditional use of veterinary medicinal products"[42]. This contract enables them to identify and treat specified clinical conditions with a limited range of veterinary medicinal products. Farmers wishing to enter such a contract need to take an educational course approved by the Swedish Board of Agriculture and the veterinarian must perform regular control visits on the farm (about every 5 weeks). Certain criteria must be met at farm level with regards to animal health and welfare and the use of medicinal products if the contract is to remain valid. These criteria and regular on-farm visits from the veterinarian motivate a focus on preventive work. There are

currently no specific legal requirements for authorization and distribution of veterinary medicinal products containing critically important antimicrobials, legislation restricting the use of such substances has however been in place since 2013[42].

National practices

Thanks to national control programs, organized health surveillance and comprehensive import control, Sweden has managed to eradicate or prevent the introduction of several serious diseases causing animal suffering, economic losses or that poses a potential risk for human health.

Health controls of imported animals are longstanding. When Sweden joined the EU in 1995, the Swedish Farmer´s Disease Control Program (Svenska Djurbönders Smittskyddskotnroll, SDS) was formed[31]. SDS is owned by the producers and run by the Swedish company Farm & Animal Health in cooperation with LRF Dairy Sweden (LRF Mjölk). They have established additional voluntary import requirements, consequently demanded by the importing farmer or company,

Bovine viral diarrhea is one of the diseases that affect herd health. PHOTO: ERIK CRONWALL

in addition to the official requirements set by the Swedish Board of Agriculture. These import requirements must be followed in order to be allowed to send animals to the slaughterhouses and to deliver milk to the dairy plant. Strict conditions for import help to prevent introduction of diseases and aid in eradication programs. In addition to strict health controls during import Sweden also has national control programs for *Salmonella* and *Campylobacter* as well as for other diseases/infectious agents such as Maedi Visna (MV) in sheep and Caprine Arthritis Encephalitis Virus (CAE) in goats. There are also well-established surveillance programs for devastating diseases such as Porcine Reproductive and Respiratory Syndrome (PRRS) in pigs. Strict import conditions together with control and surveillance programs have contributed to the fact that Sweden today is free of many devastating conditions in farm animals such as Aujeszky's disease (AD), transmissible gastroenteritis (TGE), bovine viral diarrhea (BVDV) and PRRS. These diseases affect herd health in general and lead to an increased use of antibiotics in infected herds. BVDV is a common disease in cattle in many other countries. The virus impairs the immune system making the cow susceptible to many other diseases which often leads to treatment with antibiotics.

The comprehensive Swedish *Salmonella* control program was initiated back in 1953 when more than 9000 people fell ill in salmonellosis caused by *Salmonella* contaminated meat from a single slaughterhouse[32]. The program constitutes three separate, but linked parts; prevention, control and sampling, and eradication. Authorities and the industry work in close collaboration to prevent and eradicate *Salmonella* on farms through legislated and voluntary control programs with the goal to keep domestic foodstuffs of animal origin free from *Salmonella*. Only a very small part of the 2000-2500 human cases of salmonellosis in Sweden each year can be attributed to Swedish production animals (most are infected abroad or by imported feedstuffs)[33]. *Salmonella* is being combatted in all parts of the food chain; from animal feed (heat treatment and HACCP-based testing during manufacture) to the finished food product. Surveillance is mandatory on all poultry farms where regular sampling for *Salmonella* is performed at farm level. For pigs and cattle random spot checks are being performed at slaughter and sampling of young animals is being done at necropsy. This has led to a very low prevalence of *Salmonella* infection in Swedish production animals. According to the Swedish Board of Agriculture[33], since 2013, the prevalence of newly infected cattle herds has been below five per year, with an exception for 2013 when infected feed led to an outbreak in ten herds. Since the end of the 1970s the number of infected pig herds has been about four to five per year but in later years this number has decreased further and now the number of newly infected herds is less than one per year. During the last few years up to five poultry farms each year are infected, with the exception of occasional outbreaks. If salmonella is detected in a farm, restrictions are put on the facility, blocking all movements of animals and animal products, and an eradication plan is initiated[33]. The eradication strategy depends on animal species, type of production, salmonella type etc. Hygiene- and management routines are enforced, the facility is cleaned and disinfected and manure and other potentially contaminated products are destroyed or disposed of. Sometimes it can be necessary to cull animals on the farm for welfare reasons instead of waiting for natural healing of the infection, or in order to be able to empty and clean infected areas. In the case of salmonella outbreaks in poultry farms all animals are euthanized instantly because any other way to stop the infection is not practically feasible. Based on research and field trials Sweden is probably one of the world's leading countries in minimizing the occurrence of *Campylobacter* in poultry[34]. In 1988, the Swedish Poultry Meat Association, together with the authorities, launched a control program with the purpose of reducing *Campylobacter* in Swedish poultry. The ambition of the industry was to reach the same low prevalence as for *Salmonella*. In 2001, this control program was upgraded to a four-year EU-financed project together with the Swedish Board of Agriculture, Swedish Food Agency, SVA and the Public Health Agency to perform targeted studies on individual farms with the purpose to further reduce the number of positive flocks. Today the program is managed by the Swedish Poultry Meat Association and besides testing for *Campylobacter* in every flock at slaughter, targeted studies are conducted. According to the Swedish Poultry Meat Association[34] this work has reduced the number of positive flocks from 60 % in 1989 to 8.7 % in 2018.

MV/CAE are chronic, deadly diseases of sheep and goats and subject to Swedish eradication programs. PHOTO: PXHERE

PRRS and AD in pigs are eradicated in Sweden and are now part of surveillance programs. PHOTO: PIXABAY

The control program for MV/CAE started back in 1993 and its primary goal is to prevent the spread of these diseases in the sheep and goat population and ultimately to eradicate these diseases in Sweden[35]. An important milestone has been to create an MV- and CAE free live animal trade.

A surveillance program differs from a control program[35]. In a control program the primary purpose is to prevent and combat or eradicate a

disease or an infectious agent. In a surveillance program the purpose is to monitor the occurrence of a disease or an infectious agent and to quickly be able to act in case of positive samples. In Sweden we have surveillance for diseases that have been eradicated, such as PRRS and AD in pigs and paratuberculosis in cattle. These diseases are all notifiable under the Swedish Epizootic Act. Sweden was declared free from AD in 1996 after an eradication program. Now, as part of the surveillance, samples are taken at slaughter and investigation is initiated in all cases of clinical signs of AD. AD has not been detected in Sweden since 1996. PRRS was first detected in Sweden in 2007 in a sample taken within the surveillance program. The outbreak was controlled thanks to a resolute intervention from the industry and the government and PRRS was eradicated the same year. Since 2008 the program constitutes both sampling of pigs at slaughter and in herds. Sweden is also free from Paratuberculosis. In 1991 a voluntary control program was set up by Farm and Animal Health that constitutes three yearly fecal samples on animals above two years of age. After reaching the highest status in the program surveillance is done by necropsy of animals that have been culled or died of natural causes.

Housing, management and animal welfare

Sweden has shown that it is possible to keep a high productivity in animal production with a very restricted use of antibiotics. However, this puts a high demand on a clean environment and optimal management routines.

A reform change towards a more sustainable animal production started after the ban of AGP in 1986 when huge efforts were put into research and field studies on how to prevent disease without the continuous use of antibiotics. An example of one of these studies in the pig sector was in 1994 when Holmgren and Lundeheim[36] performed a study in 55 piglet producing herds in Sweden. They concluded that the need for medication in feed differed with regards to housing and management systems and that production results were highly related to the degree of segregation and the level of hygiene. With the rearing of post-weaning pigs on deep litter beds both the segregation and hygiene were better and the use of antibiotics much lower as compared to rearing pigs in traditional post-weaning pens. After the ban a lot of work has been undertaken and is still being carried out to improve rearing systems and management methods and to employ available techniques regarding age-grouping, sectioning and planned production[21]. This has led the development of the currently used rearing systems with sectioning of stables, age segregation and all-in-all-out systems followed by cleaning and disinfection. Sweden also has a high level of on-farm biosecurity with quarantine for breeding animals and animals that are being bought into the herd, strict hygiene requirements for visitors and deliveries as well as for feed/water and good routines for managing pests and dead animals leading to a better hygiene and healthier animals. A lot of focus is also put on housing design, stocking density and the quality of the feed.

For the broiler industry, the ban of AGP led to a big concern on how to prevent Necrotizing Enteritis (NE) [20]. The necessary knowledge to be able to handle the ban had to be developed in Sweden. The industry, together with academy and authorities, initiated research studies and field studies to find ways to control NE, to help with the transition. The conclusion of these studies was that NE, as well as many other health problems, is multifactorial and that factors such as the construction and climatic conditions of the stables, management, hygiene and feed could be contributing to outbreaks. The most essential changes with regards to the feed was the reduction of protein content, adding of more fiber and supplementing the feed with enzymes. Work was also put into improving the environment, first and foremost the ventilation, as inadequate airflow was affecting animal health negatively. The industry and authorities jointly decided to temporarily continue to use antibiotics to prevent NE and it was recommended that veterinarians, for a period of two years, prescribed the same antibiotics, but in a higher dose, to all flocks at risk of developing NE[53]. During this time the results from the studies were put into practice so that the routine treatment could cease. An important contributor to the good health status in Swedish broiler production and to the successful adaptation of the broiler production to the new situation is that a majority of producers are members of the industry body the Swedish Poultry Meat Association (Svensk Fågel). The mission of this organization is to make sure that members follow the Swedish animal health- and welfare legislation and the even stricter quality- and control programs for animal welfare set up by the organization[37]. To motivate farmers to continue working for good animal management and care, a classification system was introduced by the organization for breeding and production farms, giving a special bonus for producers following the animal welfare program improving the total level of quality for the production[21]. Producers who fulfil certain requirements are permitted higher maximum population density with up to 36 kg per square meter (basic population density is 20 kg per square meter). If providing good care, producers are rewarded with higher allowed population densities, without risking animal welfare, reaching an economically competitive production level while at the same time retaining the best animal welfare. Producers with low standards are forced out of business. The organization's welfare program is even stricter than the Swedish animal welfare legislation and is approved by the Swedish Board of Agriculture[37].

The long-standing Swedish control programs for Salmonella and Campylobacter in broiler production keep these infections from the food chain. PHOTO: USDA, CC2.0

The long-standing control programs for *Salmonella* and *Campylobacter* in Swedish broiler production certainly also contributed to the successful adaptation after the ban in 1986, by improving the general health situation and facilitating further organized actions[21]. However, the use of ionophore coccidiostats cannot be ignored as part in the adaptation process because it has some preventive effects on NE.

Sweden's long history of collaborative work by professional, official and industry bodies towards optimal environment and management routines to be able to reach a high productivity with limited use of antibiotics has had important animal welfare aspects. Sweden has stricter animal health and welfare regulations than the rest of the EU.

Collaboration is key. The Swedish Model is characterized by close collaboration between stakeholders such as farmers, veterinarians, authorities, advisors and academy. PHOTO: JENNY SVENNÅS-GILLNER

Swedish policies, guidelines and legislation regarding antibiotic use

The use of antibiotics in Swedish animals is based on legislation but stems from a long-standing voluntary policy work and a common aim to preserve the usefulness of antibiotics for veterinary treatments and the so far comparatively low prevalence of resistance among animal pathogens. As in other Nordic countries, Swedish veterinarians are not allowed to sell pharmaceuticals that they

prescribe, this "decoupling" of prescription and economic return is regarded as one of the pillars of the low use of antibiotics.

Policies and guidelines

In 1998 the Swedish Veterinary Association (Sveriges Veterinärförbund, SVF) adopted a general policy document[38] for the use of antibiotics in animals. Since then specific policies/guidelines for antibiotic use in dogs and cats[39], horses[40] and production animals (i.e. cattle, pigs, sheep and goats)[41] have been accepted. The overall goal of the guidelines is to preserve and if possible to improve the comparatively favorable situation in Sweden with regard to antibiotic resistance, to limit environmental consequences and to provide consumers with safe foods[38]. For production animals this implies achieving a low and controlled use of antibiotics so that the first-hand choices of treatment remain efficient and that the spread of antibiotic resistance, among animals and herds as well as in the food chain, is kept at a minimum[41].

The Swedish general policy document emphasizes the crucial importance of preventive measures to ensure that infectious disease does not occur and conveys the following message: It is essential that antibiotics only be used when absolutely necessary and that occurrence of infection should be counteracted, when possible, by preventive measures. Use of antibiotics for treatment of infectious disease should only be initiated after careful consideration and if the treatment is likely to be successful. If there are equivalent treatment methods without the use of antibiotics, these should be the chosen course of therapy. Antibiotic treatment for general prevention ("just in case") in the absence of a confirmed diagnosis is not acceptable and prophylactic use of antibiotics should never compensate for poor hygiene. Also, lifelong treatment of chronic or recurring conditions is not compatible with good veterinary practice. The same goes for prolonged treatments with a low dose of antibiotics such as the use of antibiotics as growth promoters. Antibiotic treatment of an individual animal is motivated if the animal suffers from a bacterial infection that is not likely to heal without the use of antibiotics and animal welfare and/or production would thereby be compromised. Treatment of groups or flocks of animals can be motivated if there are signs of a bacterial infection in the group/flock and the risk for continuing spread of disease is apparent. Also, in a few specific situations, prophylactic antibiotic treatment can be motivated in connection with specific surgical procedures, where the risk of a bacterial infection is high or where an infection can severely worsen the prognosis. The policy also puts emphasis on important factors for veterinarians to consider when choosing type of antibiotic and treatment regime. The individual properties of the animal/group of animals to be treated are important factors (i.e. species, gender, age, clinical status and potential other medications). Also, important to consider is the diagnosis and the susceptibility of the causative agent. When possible, the actual infectious agent should be demonstrated by means of laboratory examination, especially in cases of therapy failure, relapse and on other occasions when antibiotic resistance can be suspected. The choice of antibiotic should consider the specific agent's natural susceptibility. Pharmacokinetics and site of infection are also important factors, as well as known side-effects. Current resistance patterns and the risk of development of antibiotic resistance should always be taken into consideration. This means that the antibiotic and treatment regime should be chosen so that the animal's normal flora is affected as little as possible (narrow-spectrum antibiotics and a course of treatment as short as possible which is discontinued if the treatment indication is no longer applicable). Eco-toxicological effects, animal welfare and food hygiene aspects are also important in this context. In the interest of public health, the choice of an antibiotic agent normally used for treatment of animals or humans in situations where few or no other treatments are proven to be effective should be done with restraint and only for very good reasons. Swedish legislation contains restrictions on the use of quinolones and 3rd and 4th generation cephalosporins to exceptional cases where susceptibility testing demonstrates an absolute need, and a ban on veterinary use of certain antimicrobial substances (SJVFS 2019:32, D9)[42]. "Off-label" use of antibiotics should only be considered if there are good reasons for this use and only if no equivalent product is approved for veterinary use. For food-producing animals a legally valid withdrawal period must be available.

To summarize the Swedish Veterinary Association's general antibiotic policy, antibiotic treatment is normally only motivated if both criteria described below are fulfilled:

- There is a bacterial infection (or if there is sufficient cause to suspect that an actual bacterial infection is present)
- If this infection most likely will not resolve without the support of antibiotic treatment

There are some underlying principles for the use of antimicrobials[41]:

- Antibiotics should only be used to treat diseases with bacterial etiology or when a bacterial etiology is strongly suspected
- Diagnosis of bacterial infection accompanied by sensitivity testing should precede treatment whenever possible
- When treating bacterial infections in production animals the ambition should always be to use products with a narrow antibiotic spectrum
- When treating groups of animals an etiological diagnosis should be obtained and a treatment plan established
- When high treatment rates are discovered, the underlying reasons/predisposing factors should be investigated and corrected by means of preventive measures whenever possible

Swedish legislation

Veterinary medical products, including antimicrobials, can only be provided by pharmacies on veterinary prescription (HSLF-FS 2016:34)[43]. The use of veterinary medical products is regulated by the Swedish Board of Agriculture.

Veterinary rights to prescribe certain antibiotics was limited in 2013 with the introduction of SJVFS 2013:42, after a few amendments now SJVFS 2019:32[42]. This legislation regulates the use of antimicrobials as well as the use of other veterinary pharmaceuticals and limits the rights of veterinary professionals to prescribe two of the three classes of antibiotics classified by the WHO as "highly prioritized and critically important" (i.e. 3rd generation cephalosporins, fluoroquinolones and polymyxins).

According to SJVFS 2019:32 all drugs must be used with restraint and only when there is an absolute need. The risk of resistance development towards antibiotics and antiparasitic drugs must be considered. A veterinarian can only prescribe treatment with pharmaceuticals containing quinolones or 3rd or 4th generation cephalosporins in situations where their use is considered of the utmost importance to the animal's welfare, when microbiological examination and resistance testing shows that no other antibiotic is effective for treatment of the existing infection or when there is a valid basis to suspect that alternative treatments will not have the desired effect. There are some exceptions from the demand for microbiological examination and resistance testing preceding treatment for quinolones and 3rd generation cephalosporins, for example if the localization of the infection or type of disease makes sampling impossible or in acute life-threatening conditions. However, emphasis is put on always considering science and well-proven experience (should prove that treatment with any other drug is ineffective) and that microbiological examination and resistance testing should be done even if treatment is commenced before results are available. The reasoning behind the choice of therapy should then be recorded.

In the interest of public health SJVFS 2019:32 also forbids antibiotics such as mupirocin and substances from classes such as the carbapenems, oxazolidines and glycopeptides for the treatment of animals. These are antibiotics critically important in human medicine and must therefore be restricted for human use only. The full list of antibiotics not allowed for animal use are: Aztreonam, ceftarolin, daptomycin, doripenem, ertapenem, ethambutol, imipenem, isoniazid, linezolid, meropenem, mupirocin, rifabutin, rifampicin (except for the treatment of horses with infection caused by *Rhodococcus equi*), teicoplanin, tigecycline and vancomycin.

Antibiotic use in Sweden

In Sweden, statistics on total sales of antibiotics for animal use are available since 1980. All antimicrobials are only available on veterinary prescription and may only be sold by pharmacies that are obliged to report all sales to the Swedish eHealth Agency that maintains a database. All statistics in this section are obtained from the Swedres-Svarm report for 2018[27] unless stated otherwise. Swedres-Svarm is an integrated report from the Public Health Agency of Sweden and SVA including data from humans, animals and food, a collaboration which started in 2002. Data presented include sales of veterinary medicinal products with antibiotics indicated for terrestrial animals (except topical products) i.e. aquaculture not included. The data source is the information in the database of the eHealth Agency on sales from pharmacies to animal owners (prescription dispensed) or to veterinarians (requisition). During the last decades the use of antibiotics in Sweden has decreased both in human and veterinary medicine. Apart from seeing a decrease in the total use of antibiotics there is also a decrease in the use of broad-spectrum antibiotics in favor of products with a narrow antibacterial spectrum[27,44].

Total sales

The reported total sales of antibiotics for animal use in 2018 were 10 042 kg active substance, of which 58 % (5 848 kg) was benzylpenicillin (table 1). In 2009 the corresponding figures were 15 368 kg active substance and 50 % (7 721 kg) benzylpenicillin. More than 90 % are products for treatment of individual animals (tablets, injectables, and intramammaries) and less than 10 % for treatment of groups or flocks (premixes, oral powders and solutions for medication in water). Sales of all classes of antimicrobials have decreased notably since 2009. During the last five years (since 2014) sales of narrow spectrum penicillins (mainly benzylpenicillin), aminopenicillins, aminoglycosides and polymyxins, macrolides and lincosamides and amphenicols and pleuromutilins have been relatively unchanged. Other classes have decreased more than 10 %.

There has been an overall decrease in the total number of livestock in Sweden (mainly cattle, sheep and pigs) between 1980 and 2016 (table 2), but the numbers increased again between 2016 and 2018. The amounts of veterinary antimicrobial agents sold are linked to the animal demographics, which vary over time. To correct for changes in animal populations the total sales of antibiotics for animals can be presented as mg active substance per PCU (population correction unit)[45] where 1 PCU = 1 kg of the different categories of livestock and slaughtered animals. Overall sales have decreased by around two thirds compared to 1980-1984 (before the Swedish ban on growth promoters in 1986) (figure 1). According to the Public Health Agency and SVA, this is explained by the ban of growth promoting antimicrobials followed by a major gradual decrease from the mid-90s of the sales of products for medication via feed or water[27]. In the past decade, a decrease in sales of products for individual medication is also noted. In 2018, sales of the three classes of antibiotics classified by the WHO as "highly prioritized and critically important" (i.e. 3rd generation ceph-

TABLE 1 *Yearly sales of antibiotics for animal use expressed as kg active substance*[a].

ATCvet code	**Antimicrobial class**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
QJ01AA, QG01A	Tetracyclines	1 174	1 115	1 073	881	935	787	685	515	521	515
QJ01CE, -R, QJ51	Benzylpenicillin[b]	7 721	7 546	6 696	6 362	5 954	5 509	5 861	5 997	5 940	5 848
QJ01CA, QJ01CR	Aminopenicillins	1 068	907	723	649	645	635	642	677	640	678
QJ01D	Cephalosporins	738	575	498	410	330	299	267	242	210	187
QA07AA, QJ01G, -R, QJ51R	Aminoglycosides and polymyxins	609	557	503	483	341	378	414	385	357	351
QA07AB, QJ01E	Sulphonamides	2 128	1 998	1 867	1 813	1707	1 699	1 634	1 643	1 678	1 448
QJ01E	Trimethoprim & derivatives	379	357	338	329	320	314	313	318	326	279
QJ01F	Macrolides & lincosamides	988	739	648	632	564	484	485	472	514	578
QJ01MA	Fluoroquinolones	164	148	120	106	52	45	34	30	26	29
QJ01BA, QJ01XX92, - 94	Amphenicols and pleuromutilins	398	174	140	100	129	121	133	264	99	129
	Total sales	**15 368**	**14 117**	**12 606**	**11 763**	**10 975**	**10 270**	**10 468**	**10 543**	**10 310**	**10 042**

[a]Data from 2010-2015 are uncertain because of a lack of completeness mainly affecting injectable products.

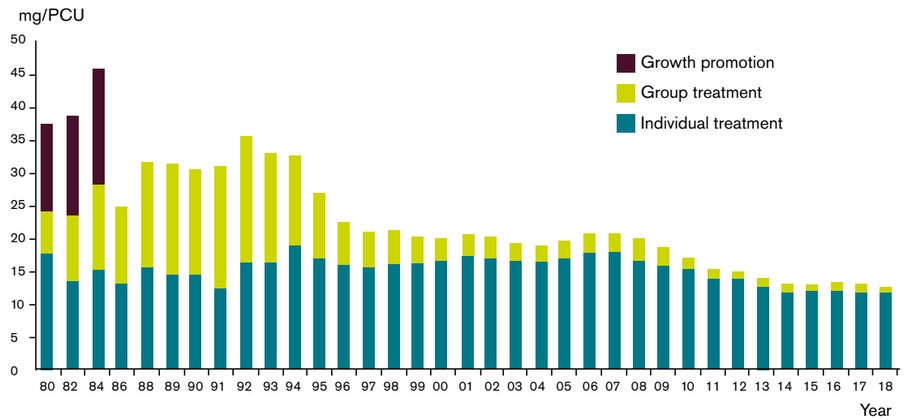
[b]Also includes small amounts of phenoxymethylpenicillin and penicillinase stable penicillins. Source: Swedres-Svarm 2018. Consumption of antibiotics and occurrence of resistance in Sweden. Solna/Uppsala ISSN1650-6332.

TABLE 2 *Number of livestock and horses (in thousands) 1980-2018. From the statistical database of the Board of Agriculture.*

Animal Species	**1980[a]**	**1985[a]**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2016**	**2017**	**2018**
Cattle											
Dairy cows	656	646	576	482	428	393	348	338	331	322	319
Beef cows	71	59	75	157	167	177	197	184	194	208	214
Other cattle >1 year	614	570	544	596	589	527	513	487	489	500	498
Calves <1 year	595	563	524	542	500	509	479	466	476	472	475
Total, cattle	1 935	1 837	1 718	1 777	1 684	1 605	1 537	1 475	1 490	1 502	1 507
Sheep											
Ewes and rams	161	173	162	195	198	222	273	289	281	301	296
Lambs	231	252	244	266	234	249	292	306	297	304	291
Total, sheep	392	425	406	462	432	471	565	595	578	605	587
Pigs											
Boars & sows	290	260	230	245	206	188	156	142	140	141	132
Fattening pigs >20 kg [a]	1 254	1 127	1 025	1 300	1 146	1 085	937	830	835	836	901
Piglets <20kg [b]	1 170	1 113	1 009	769	566	539	427	384	378	385	361
Total, pigs	2 714	2 500	2 264	2 313	1 918	1 811	1 520	1 356	1 354	1 362	1 393
Laying hens											
Hens	5 937	6 548	6 392	6 100	5 670	5 065	6 061	7 571	8 174	7 294	7 699
Chickens reared for laying	2 636	2 159	2 176	1 812	1 654	1 697	1 647	1 842	1 575	1 994	1 927
Total, hens	8 573	8 708	8 568	7 912	7 324	6 762	7 707	9 413	9 750	9 288	9 626
Horses											
Total, horses						283[c]	363		356		

[a]Before 1995, the figure denotes pigs above 3 months of age; [b]Before 1995, the figure denotes pigs below 3 months of age; cData from 2004. Source: Swedres-Svarm 2018. Consumption of antibiotics and occurrence of resistance in Sweden. Solna/Uppsala ISSN1650-6332.

FIGURE 1 *Sales of antibiotics for animals expressed as mg per population correction unit (PCU)[a].*



[a]Data from 2010–2015 are uncertain because of a lack of completeness mainly affecting injectable products. This is indicated by a paler color for antibiotics for individual treatment. In the present figure, all products (including tablets) are included while in data presented in the European surveillance of veterinary antimicrobial consumption tablets are excluded when calculating mg/PCU.

Source: Swedres-Svarm 2018. Consumption of antibiotics and occurrence of resistance in Sweden. Solna/Uppsala ISSN1650-6332.

alosporins, fluoroquinolones and polymyxins) were 0,002, 0,037 and 0,044 mg/PCU respectively (decrease by 92 %, 82 % and 66 % since 2009). For the 3rd generation cephalosporins and fluoroquinolones, the decrease is partly explained by the regulation SJV FS 2019:32 limiting veterinarian's rights to prescribe these types of antimicrobials.

The total numbers of pigs and dairy cows have decreased over time while heard sizes have increased. During the same period, an increase in the number of sheep and beef cows and in the number of chickens slaughtered has been reported (table 3, 4 and 5). Changes in the number of animals may affect trends in statistics on the total sales of antibiotics (presented as total weight or volume). According to the Swedish Board of Agriculture[44], sales of antibiotics has continued to decrease even though we have seen an increase in livestock numbers 2016-2018 which is reflected in figure 1 using PCU. This can be partly explained by the fact that available statistics from the pharmacies do not give a complete distribution per species as a big part of requisition sales may have been used for both livestock or companion animals as the product can be approved for several species and there is no way of knowing which species the product was intended for.

TABLE 3 *Number of animals slaughtered (in thousands) at slaughterhouses, 1980-2018. From the statistical database of the Board of Agriculture.*

Animal species	1980	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Cattle											
Cattle >1 year	574	584	523	502	490	433	425	406	395	392	410
Calves < 1 year	130	152	70	30	39	33	27	22	16	14	15
Total, cattle	704	736	593	532	529	466	453	428	411	406	426
Sheep	302	328	280	189	202	206	255	256	251	261	280
Pigs	4 153	4 283	3 653	3 743	3 251	3 160	2 936	2 560	2 526	2 576	2 646
Broilers	40 466[a]	36 410[a]	38 577[a]	61 313	68 617	73 458	78 507	95 974	101 322	101 876	100 535
Turkeys							495	475	527	526	526

Source: Swedres-Svarm 2018. Consumption of antibiotics and occurrence of resistance in Sweden. Solna/Uppsala ISSN1650-6332.

TABLE 4 *Number of holdings with animals of different types, 1980-2018. From the statistical database of the Board of Agriculture.*

Animal Species	1980	1985	1990	1995	2000	2005	2010	2015	2016	2017	2018
Cattle											
Dairy cows	44 143	35 063	25 921	17 743	12 676	8 548	5 619	4 161	3 872	3 614	3 477
Beef cows	12 436	10 310	10 883	17 069	13 861	12 821	12 190	10 405	10 349	10 471	10 418
Other cattle >1 year	63 179	52 652	42 696	39 160	30 457	24 808	20 295	16 432	16 060	15 722	15 343
Calves <1 year	62 314	52 001	41 986	36 542	27 733	22 888	18 494	15 186	14 839	14 517	14 139
Total holdings with cattle	70 503	58 872	47 292	41 990	32 063	26 179	21 586	17 466	17 046	16 674	16 317
Sheep	10 238	10 595	9 749	10 037	8 089	7 653	8 657	9 110	8 699	9 219	9 120
Pigs	26 122	19 937	14 301	10 753	4 809	2 794	1 695	1 228	1 252	1 272	1 346
Laying hens	23 603	17 531	12 900	9 593	5 678	4 916	3 703	2 927	2 897	2 911	3 197
Chickens reared for laying	5 093	2 714	1 875	1 405	715	634	487	730	389	825	852

Source: Swedres-Svarm 2018. Consumption of antibiotics and occurrence of resistance in Sweden. Solna/Uppsala ISSN1650-6332.

TABLE 5 *Average number of animals per holding 1995-2018. From the statistical database of the Board of Agriculture.*

Animal Species	1995	2000	2005	2010[a]	2015[a, b]	2016[a]	2017[a, b]	2018[a,b]
Cattle								
Dairy cows	27.2	33.7	46	61.9	81.5	85.4	89.1	91.8
Beef cows	9.2	12.0	13.8	16.2	17.7	18.7	19.8	20.6
Sheep	19.5	24.8	29.2	31.7	31.8	32.5	32.7	32.4
Boars and sows	31	63	156	156	186	182	165	158
Fattening pigs	157	294	471	664	845	820	825	852
Laying hens	640	995	471	1 638	2 587	2 822	2 506	2 413

[a]The definition of holdings included changed from 2010; [b]For sheep, pigs and poultry data for 2015, 2017 and 2018 are estimated from a sample and therefore have a larger uncertainty. Source: Swedres-Svarm 2018. Consumption of antibiotics and occurrence of resistance in Sweden. Solna/Uppsala ISSN1650-6332.

Use of antibiotics in production animals

As stated earlier, there are limitations in the data system used by the eHealth agency with regards to registering species specific information on antibiotic use via requisition sales. However, there are a number of other sources where it is possible to obtain some broad information with regards to species specific use, such as Växa Sverige (dairy cattle), the Swedish Poultry Meat Association (poultry) and the guidelines for antibiotic use (mentioned in the policies and guidelines section). The guidelines, besides emphasizing the overall principles for the use of antibiotics and considerations prior to treatment, also give an overview of the most common conditions, their diagnosis and preferred treatment (including the most appropriate choice of antibiotics).

Cattle and sheep

Växa Sverige (the biggest advisory organization in the dairy and beef sector) have a service for dairy producers called *Kokontrollen* ("*Cow control*") in which about 70 % of Swedish dairy producers are active members. This service program focuses on gathering, storing, processing, quality assurance and compiling of data from affiliated farms. These data are analyzed and used to advice farmers with regards to animal health, to be able to optimize their production[46]. In August 2019, Växa presented a report concerning the treatment incidence with antibiotics for systemic use for dairy cattle between the years 2001-2018[47]. The data in this report was collected from the Swedish Board of Agriculture. The Swedish Board of Agriculture has a database for disease registration where veterinarians are obliged to report information on diagnoses and prescription sales for cattle. Only antibiotics for systemic use intended for an individual animal have been used in the calculations. This report shows that the treatment incidence with antibiotics for systemic use in dairy cattle is low with only 7.48 treatments per 100 cow-years for milking cows and heifers, in 2018, and 12.92 prescriptions per 100 cow-years for milking cows, heifers excluded. The majority of diseases are treated with Benzylpenicillin (table 6 and 7).

TABLE 6 *Treatment incidence (number of prescriptions per 100 cow-years) with antibiotics for systemic use for milking cows and heifers in Cow control affiliated herds, 2001-2018.* SOURCE: VÄXA SVERIGE

Year	Total	Tetracyclines	Beta-lactam antibiotics (penicillins)	Other Beta-lactam antibiotics	Sulphonamides and trimethoprim	Macrolides, lincosamides and streptogramins	Quinolone derivatives	Other antibiotics
2001	10.61	0.75	7.84	0.16	0.54	0.31	0.94	0.07
2003	10.72	0.74	7.80	0.30	0.51	0.22	1.11	0.06
2005	9.63	0.79	6.89	0.36	0.40	0.14	0.99	0.06
2007	9.62	0.81	6.96	0.34	0.20	0.11	1.13	0.06
2009	9.97	0.74	7.67	0.25	0.18	0.01	1.06	0.06
2011	9.09	0.70	7.19	0.10	0.20	0.00	0.84	0.06
2013	9.59	0.76	7.94	0.02	0.50	0.00	0.30	0.06
2014	9.14	0.69	7.56	0.01	0.63	0.00	0.22	0.00
2015	7.58	0.53	6.36	0.01	0.52	0.00	0.14	0.00
2016	6.25	0.29	5.45	0.00	0.40	0.00	0.09	0.01
2017	7.05	0.51	5.99	0.00	0.46	0.01	0.07	0.02
2018	7.48	0.56	6.40	0.00	0.43	0.01	0.07	0.01

TABLE 7 *Treatment incidence (number of prescriptions per 100 cow-years) with antibiotics for systemic use for milking cows (heifers excluded) in Cow control affiliated herds, 2001-2018.* SOURCE: VÄXA SVERIGE

Year	Total	Tetracyclines	Beta-lactam antibiotics (penicillins)	Other beta-lactam antibiotics	Sulphonamides and trimethoprim	Macrolides, lincosamides and streptogramins	Quinolone derivatives	Other antibiotics
2001	24.22	1.57	18.05	0.38	1.22	0.72	2.17	0.11
2003	23.86	1.46	17.53	0.68	1.11	0.49	2.50	0.08
2005	21.46	1.61	15.50	0.82	0.88	0.32	2.24	0.09
2007	21.18	1.62	15.48	0.77	0.42	0.26	2.54	0.10
2009	22.55	1.54	17.45	0.58	0.40	0.01	2.47	0.10
2011	20.40	1.44	16.31	0.23	0.39	0.01	1.94	0.09
2013	17.93	1.24	15.09	0.04	0.90	0.00	0.60	0.06
2014	16.80	1.11	14.15	0.02	1.09	0.00	0.42	0.02
2015	13.80	0.84	11.78	0.01	0.88	0.00	0.27	0.01
2016	11.07	0.47	9.76	0.00	0.66	0.01	0.17	0.01
2017	12.35	0.77	10.64	0.00	0.78	0.01	0.13	0.01
2018	12.92	0.80	11.24	0.00	0.72	0.00	0.14	0.01

Looking at the proportions of the different antibiotics for systemic use, out of the total number of prescriptions, the proportion of Penicillin G (benzylpenicillin) is high with 85.5 % of the total number of prescriptions for cows and heifers (table 6) and 87 % for cows, heifers excluded (table 7). Tetracyclines, sulphonamides and trimethoprim have the second highest proportions after penicillin G. As much as 60 % of the total number of prescriptions of systemic antibiotics for cows and heifers are for mastitis, 13 % are for other infections and 12 % for infections of the locomotor system (figure 2). The choice of antibiotics differs depending on disease complex. For mastitis specifically, in 2018, penicillin G represented about 90.9 % of the total number of ordinations for cows (figure 3). Ordinations with quinolones for mastitis treatment in cows are very few (1.5 % in

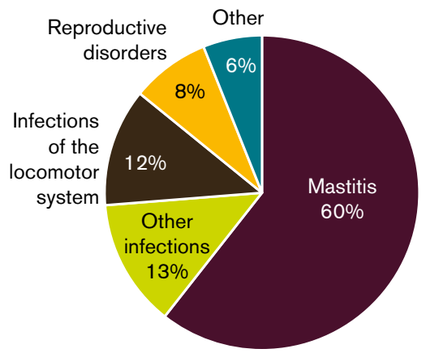


FIGURE 2 *Proportions of prescribed antibiotics for systemic use, divided into disease complex, for cows and heifers in cow control affiliated herds, 2018.* SOURCE: VÄXA SVERIGE

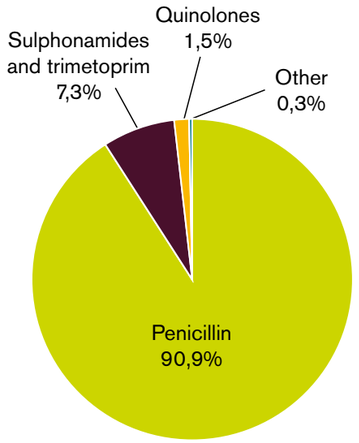


FIGURE 3 *The proportion of prescribed antibiotics for systemic use for mastitis treatment in cows (heifers excluded) in cow control affiliated herds, 2018.* SOURCE: VÄXA SVERIGE.

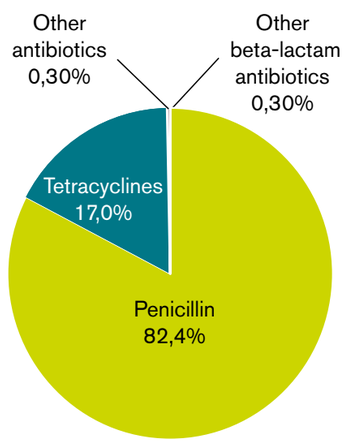


FIGURE 4 *The proportion of prescribed antibiotics for systemic use for treatment of infections in the locomotor system in cows (heifers excluded) in cow control affiliated herds, 2018.* SOURCE: VÄXA SVERIGE.

2018). For treatment of infections in the locomotor system penicillin G is also the number one choice with 82.4 % of ordinations in 2018 (figure 4), but there is also some use of tetracyclines (17 %).

The data in this report demonstrate a good compliance in the dairy sector to national policies and guidelines. In the guidelines for the use of antibiotics in production animals[41] four major disease complexes are mentioned for cattle (udder infections and teat injuries, infections of the reproductive organs, infections of the locomotor systems and calves and recruitment animals) and for almost all conditions benzylpenicillin is recommended as the most appropriate choice of antibiotics, the exceptions being sepsis in newborn calves and enteritis in calves where trimethoprim/sulphonamides are the recommended first choice for treatment.

No specific information on the sales of antibiotics for sheep were available at the time of writing this report.

Domestic fowl

The domestic fowl production in Sweden consists mainly of laying hens and broilers. The Swedish Poultry Meat Association actively and successfully work towards minimizing the usage of antibiotics in poultry production. The health in commercial herds is better in Sweden than in many other countries[48]. Through good hygiene and biosecurity measures infection of many disease-causing pathogens can be avoided. Antibiotic treatment of laying hens or broilers in Swedish commercial production is very rarely needed. According to SVA, during 2018, only four out of 3 223 (0.12 %) broiler flocks were treated with antibiotics. When antibiotics are needed the whole flock is treated via the water or the feed[48]. Diseases where antibiotics could be required are, for example, botulism

Antibiotic treatment is very rarely needed in Swedish layer and broiler production. PHOTO: PIXABAY

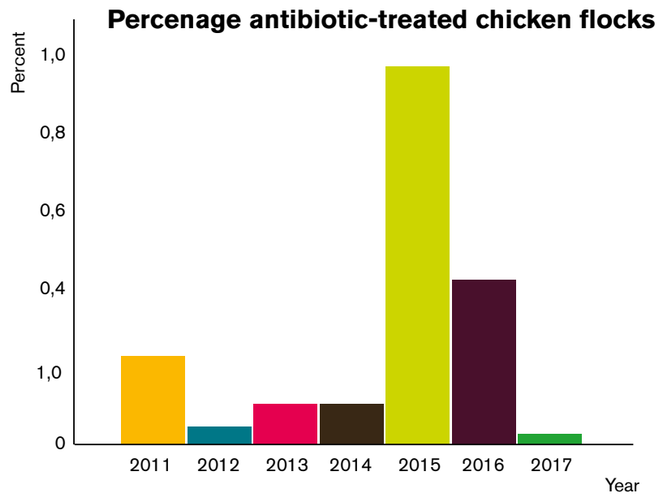


FIGURE 5 *Proportion of broiler flocks treated with antibiotics 2011-2017.* SOURCE: HTTPS://SVENSKFAGEL.SE/NYHETER/FRAGOR-OCH-SVAR-OM-ANTIBIOTIKA-I-KYCKLING/

and pericarditis. In Sweden coccidiostats are given to broilers to prevent coccidiosis. The substances used also have some preventive effect on NE.

The Swedish treatment levels were below 1% during the last six years[49]. International levels are significantly higher, 20-80 %. The comparatively higher level of treatments in 2015 was due to an *E-coli* outbreak among parent animals, but it was still below 1 %.

Pigs

The health status for Swedish pigs is better than in many other countries[50]. Many infections have been limited with the use of control programs and biosecurity measures to prevent the spread of disease. Statistics regarding sales of antibiotics for pigs have not been possible to obtain for 2018. According to SVA, in 2016, 2967 kg of active substance was sold corresponding to 12.7 mg/kg slaughtered pig. These numbers are low in international comparison. Most, 77 %, of sales are preparations for injection, of which 64 % consists of penicillin. The sales of antibiotics for group treatment have halved since 2007. Tetracycline, tiamulin and tylosin are the antibiotics mostly used in group treatment. Sales of colistin (used for treatment of post-weaning diarrhea) was 0.3 mg/kg in 2016.

Sales of antibiotics for pigs in Sweden is low in international comparison. PHOTO: JENNY SVENNÅS-GILLNER

General discussion

The favorable situation in Sweden with regards to the use of antibiotics and levels of AMR is a result of several important contributing factors. One of the most essential keys to success has been the long tradition of evidence-based guidelines and strong local commitment, but also strategic work on both regional and national level. Since the ban on AGP in 1986 a lot of work has been put into lowering the need for antibiotics without this having a negative impact on animal health and welfare. This has been done with the use of preventive routines for infectious disease control and extensive improvement of animal husbandry. Control- and eradication programs are being applied for some diseases that can drive antibiotic use such as MV in sheep and BVDV in cattle.

As a result of being two decades ahead of the rest of the EU, Sweden has a long-standing consciousness of AMR and actions to avoid resistance development and also long-standing efforts to eradicate and prevent introduction of infectious diseases. In other European countries, and other countries around the globe, there are a number of infectious diseases in livestock driving up the use of antibiotics, diseases which do not occur in Sweden. Reduced spread of infection and a higher resilience among Swedish production animals is also a direct consequence of the fact that Sweden has EU: s most far-reaching animal protection legislation. Sweden has a long-standing strategy of consensus thinking and collaboration between veterinarians, stakeholders, the industry and the government on how diseases should be controlled and combatted. This collaboration leads to known knowledge being used in practice. It is important to note, however, that the path has not been strewn with roses. Swedish farmers have suffered consequences along the way, most notable within the piglet production. The ban in 1986 and the new animal protection legislation in 1988 forced farmers to make big changes and the industry has paid a high price. Sometimes, however, it can be required to go against economic interests and make the hard, but necessary system changes.

One important change in the industry's attitude towards a restrictive use of antibiotics came with the transition from a closed agricultural market to a free one with the entry into the EU in 1995. To specialize in providing the country's own citizens with safe and healthy foods was seen as a way for the industry to assert itself on this new competitive market. Since then Sweden has demonstrated that it is possible to combine a low use of antibiotics with good production results, even if this can present economic challenges. Unfortunately, however, there is surprisingly little documentation regarding the overall methods used. The seventh objective in Sweden's national strategy on AMR is to take leadership within the EU and in the international cooperation. To find an interested audience it is important to have documentation of facts; are the animals kept healthy? How is the productivity? Is it profitable? It is important to be able to motivate others with health and productivity measures on how much there is to gain in production with good animal husbandry instead of a high use of antibiotics. The progress made can be matched with large-scale animal production. The Swedish situation can also be attributed to the long-standing monitoring and evaluation of the development of AMR and acting before a negative trend becomes problematic. In collaboration with the industry and other authorities, SVA provides a science-based incentive for the restrictive use of antibiotics. In addition, in the absence of data on antibiotic use, it is not possible to control their usage. In Sweden, there is a long tradition and a high level of expertise in surveillance, but the systems used need to be improved, as the data collected today cannot be attributed to animal species and production type, neither per region or establishment. Veterinarians also need to be able to access their own prescription data and compare them to national figures. In the future, this type of information is needed for monitoring and quality work. To be able to identify production systems with a high use and high risk of resistance, species-level data are necessary. This makes it possible to identify focus areas for promoting prudent use. An important part in lowering the unnecessary use of antibiotics is taking steps to limit financial conflicts of interest that may incentivize veterinarians to prescribe antibiotics excessively. A prerequisite for this is that ways exists for veterinarians to earn a living without the selling of pharmaceuticals. In Europe many veterinarians have this as a main source of income. It is important that veterinarians can charge for their knowledge and their advisory services, not just for medicines and other products.

The example of Sweden illustrates the importance of structural and cultural change in the behavior of both veterinarians and farmers. In a qualitative study performed by Fischer et al. (2019)[51] dairy farmers in Sweden were interviewed on their perspectives on antibiotic use. Farmers in the study expressed that, despite strict antibiotic use regulations in Sweden, they do not feel a lack of access to antibiotics when needed. However, they do feel disadvantaged in international trade and that they are poorly treated by the government when imports of cheaper meat and dairy products produced under less strict conditions are allowed. Farmers also expressed that they feel knowledgeable regarding disease and how to prevent it, but that they greatly value the advice of their local veterinarian. The farmers interviewed did not justify antibiotic use by its importance from an animal health and welfare perspective but rather expressed that antibiotics were used when there was no other alternative or sometimes as a result of lack of time spent on preventive or curative measures. They seemed to agree with the stricter animal health and welfare regulations and the restrictions on antibiotic use and did not express a need for more antibiotics than they had access to. The authors draw the conclusion that, in Sweden, veterinary advice largely determines antibiotic use and that Swedish farmers' attitudes and behavior on antibiotic use has over time been shaped by the stricter regulations in Sweden. Overall stricter and more uniform global regulations on antibiotic use could be an effective measure for reducing antibiotic use. This study also proposes that the fact that Swedish farmers, in contrast to farmers in other studies, do not feel limited in their antibiotic use can be, at least partly, a result of them following the comparatively high Swedish animal health and welfare regulations. This fact suggests that the

To be able to identify production systems with a high use and high risk of resistance, species-level data are necessary.
PHOTO: JULIO GONZALES

Field veterinarians and producers are being educated on preventive work and the correct use of antibiotics. Here, students from the Veterinary programme at SLU are examing a cow. PHOTO: SLU

amount of antibiotics farmers and veterinarians in other studies perceive as needed is in part connected with a culture of using more antibiotics, rather than working on animal health and welfare in other ways[51]. This shows that it could be useful to put the focus on preventive health work and optimal environments rather than on the lowering of antibiotic use. With intersectional, collaborative work towards optimizing environments and prevent diseases, lower antibiotic use should come as a secondary effect. Motivation is an important success factor in the work towards prudent use of antibiotics. Many times, motivation is connected to knowledge and education. In Sweden, through the program for AMR surveillance, Svarm-PAT, there is an ongoing work to connect science and expertise with veterinary field work. Knowledge is gathered by monitoring the disease situation and the susceptibility against antibiotics in the disease-causing pathogens. Field veterinarians and producers are being educated on preventive work and the correct use of antibiotics. Preventive measures to avoid the need for antibiotics are backed up by comprehensive guidelines and restrictions and a broad support for farmers and veterinarians to encourage the prudent use of antibiotics, when needed. The long-standing knowledge and evidence-based work in Sweden to motivate farmers and veterinarians towards prudent antibiotic use have led to a change in the attitude of farmers, but also of veterinarians.

An interesting example of how far Sweden has come in the attitude towards antibiotic use is from a study by De Briyne et al. (2013)[52] trying to identify which sources of information and factors that influence veterinarians in choosing which antibiotic to prescribe. The authors found that the main sources of information were literature and own experience. They postulate how this can create a problem as literature is mostly international while resistance patterns for pathogens may vary between countries. Also, personal experience may lead to choosing a drug that will definitely cure the disease, this is likely to involve a broader spectrum antibiotic. In contrast, Swedish veterinarians gave the highest importance to sensitivity testing compared to other countries in the study and listed prescribing policies and guidelines as the most important source of knowledge. This, according to the authors, is probably a result of decades of veterinary cultural change.

Besides motivating producers and veterinarians through knowledge, education, policies and guidelines it seems advisable to build up a system with an economic incentive for the producer to undertake action as in the case of the Swedish broiler production.

The interest in combatting AMR is big in the EU[53], despite this there are large differences in prescribing patterns between member states[18]. Legal restrictions can have an impact; for example, limiting the use in veterinary medicine of critically important antimicrobials in human medicine. Sweden is one of the European countries with the lowest use of these important antibiotic classes (i.e. mainly 3rd and 4th generation cephalosporins and fluoroquinolones)[18]. As mentioned before, Sweden has legal restrictions limiting the use of these antibiotics. Regulation of the overall use is more complex. Strategies to reduce use must be targeted toward both disease prevention and non-responsible use[54].

Another big difference between Sweden and the rest of the EU is that, in Sweden, a large proportion (90 %) of all antibiotics prescribed are used for individual treatment. Only the animal that is sick is given antibiotics. Only 10 % are used to treat groups/flocks. In some EU member states up to 90 % of antibiotics are given as group/flock treatment via feed or drinking water. Once again, this shows the importance of national policies and guidelines on antibiotic use. We have already established that the sales of antibiotics to animals in Sweden show a good compliance with national guidelines as narrow spectrum antibiotics are being used instead of the critically important ones. The Swedish policy also states that "antibiotic treatment for general prevention ("just in case") in the absence of a confirmed diagnosis is not acceptable and prophylactic use of antibiotics should never compensate for poor hygiene". These Swedish policies and guidelines are based on science, and the fact that Swedish veterinarians see these guidelines as an important source of information in the choice of antibiotic treatment most likely plays a big part in the usage of antibiotics in Swedish production animals.

In December 2018 a new EU regulation ((EU) 2019/6) on veterinary medicinal products was adopted. An important addition to this new regulation is that it includes provisions on the responsible use of antibiotics more similar to the already existing policies and practices in Sweden. For example, it states that; "*Antimicrobial medicinal products shall not be applied routinely nor to compensate for poor hygiene, inadequate husbandry or lack of care or to compensate for poor farm management…Antibiotic medicinal products shall not be used for prophylaxis other than in exceptional cases, to an individual animal*". The Swedish model is finding its way into European legislation. It is important however that producers have the tools for change before implementing a new law/regulation. Strategies must be followed by resources. With todays' knowledge one can say that Sweden could have made the transition easier for both animals and producers with a clear strategy to counteract expected problems. But maybe it is first when faced with reality that the real motivation for change is seen.

References

[1] Cogliani, C., Goossens, H. & Greko, C. (2011). Restricting Antimicrobial Use in Food Animals: Lessons from Europe. *Microbe*, 6 (6): 274-279.

[2] *Report of Joint Committee on the Use of Antibiotics in Animal Husbandry and Veterinary Medicine* (Swann Committee, Her Majesty's Stationery Office, London, September 1969).

[3] Council Directive of 23 November 1970 (70/524/EEC). Concerning additives in feeding-stuffs.

[4] Wegener, H.C. (2003). Antibiotics in animal feed and their role in resistance development. *Current Opinion in Microbiology,* 6:439-445.

[5] Regulation (EC) No. 1831/2003 on additives for use in animal nutrition (22 September 2003).

[6] Aarestrup, F. M. (1995). Occurrence of Glycopeptide Resistance among *Enterococcus faecium* Isolates from Conventional and Ecological Poultry Farms. *Microbial Drug Resistance,* 1(3): 255-257.

[7] Bager, F., Madsen, M., Christensen, J. & Aarestrup, F.M. (1997). Avoparcin used as a growth promoter is associated with the occurrence of vancomycin-resistant *Enterococcus faecium* on Danish poultry and pig Farms. *Preventive Veterinary Medicine,* 31: 95-112.

[8] Klare, I., Heier, H., Claus, H., Böhme, G., Marin, S., Seltmann, G., Hakenbeck, R., Antanassova, V. & Witte, W. (1995). Enterococcus faecium Strains with vanA-Mediated High-Level Glycopeptide Resistance Isolated from Animal Foodstuffs and Fecal Samples of Humans in the Community. *Microbial Drug Resistance,* 1(3): 265-272.

[9] Wegner, H.C., Madsen, M., Nielsen, N. & Aarestrup, F.M. (1997). Isolation of vancomycin resistant *Enterococcus faecium* from food. *International Journal of Food Microbiology,* 35:57-66.

[10] Aarestrup, F.M., Kruse, H., Tast, E., Hammerum, A.M. & Jensen, L.B. (2000). Associations Between the Use of Antimicrobial Agents for Growth Promotion and the Occurrence of Resistance among *Enterococcus faecium* from Broilers and Pigs in Denmark, Finland, and Norway. *Microbial Drug Resistance,* 6(1): 63-70.

[11] Del Grosso, M., Caprioli, A., Chinzari, P., Fontana, M.C., Pezzotti, G., Manfrin, A., Di Giannatale, E., Goffredo, E. & Pantosti, A. (2000). Detection and Characterization of Vancomycin-Resistant Enterococci in Farm Animals and Raw Meat Products in Italy. *Microbial Drug Resistance,* 6(4): 313-318.

[12] Robredo, B., Singh, K.V., Baquero, F., Murray, B.E. & Torres, C. (2000). Vancomycin-resistant enterococci isolated from animals and food. *International Journal of Food Microbiology,* 54:197-204.

[13] Gambarotto, K., Ploy, M.C., Dupron, F., Giangiobbe, M. & Denis, F. (2001). Occurrence of Vancomycin-Resistant Enterococci in Pork and Poultry Products from a Cattle-Rearing Area of France. *Journal of Clinical Microbiology,* 39(6): 2354-2355.

[14] Manson, J.M., Keis, S., Smith, J.M.B. & Cook, G.M. (2003). A Clonal Lineage of VanA-Type *Enterococcus faecalis* Predominates in Vancomycin-Resistant Enterococci Isolated in New Zealand. *Antimicrobial agents and Chemotherapy,* 47(1): 204-210.

[15] McDonald, L.C., Rossitier, S., Mackinson, C., Yong Yu Wang., Johnson, S., Sullivan, M., Sokolov, R., DeBess, E., Gilbert, L., Benson, J.A., Hill, B. & Angulo, F.J. (2001). Quinupristin-Dalfopristin–Resistant Enterococcus faecium on Chicken and in Human Stool Specimens. *N Engl J Med*, 345 (16): 1155-1160.

[16] Greko, Christina. 2014. Antibiotika användning – djur i Sverige och EU. I Karin Brantestrom, Bengt Kopp, Lotta Fredholm and Gunilla Eldh (red.). *Antibiotika boten och hoten*. Stockholm: Formas, 101-110.

[17] Kriebel, D., Tickner, J., Epstein, P., Lemons, J., Levins R., Loechler, E.L., Quinn, M., Rudel, R., Schettler T. & Stoto, M. (2001). The Precautionary Principle in Environmental Science. *Environmental Health Perspectives,* 109: 871-876.

[18] European Medicines Agency. Sales of veterinary antimicrobial agents in 31 European countries in 2017 – Trends from 2010 to 2017, Ninth ESVAC report. Retrieved 2020 March 13 from https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-31-european-countries-2017_en.pdf

[19] Ståhle, G. (1996). Sweden banned antimicrobial growth promoters 1986 – the reasons (in Swedish). *K Skogs- och Lantbr Akad Tidskr,* 135(15): 53-56.

[20] Weirup, M. (1996). Sweden banned antimicrobial growth promoters 1986 – what happened to animal health (in Swedish). *K Skogs- och Lantbr Akad Tidskr,* 135(15): 69-78.

[21] Weirup, M. (2001). The Swedish experience of the 1986 year ban of antimicrobial growth promoters, with special reference to animal health, disease prevention, productivity, and usage of antimicrobials. *Microbial Drug Resistance,* 7(2): 183-190.

[22] Robertsson, J.A. & Lundeheim, N. (1994). Prohibited use in antibiotics as a feed additive for growth promotion – effects on piglet health and production parameters. Proc 13th Intern PigVet Soc Congr, 282, Bangkok, Thailand.

[23] Björnerot, L. (1996). Sweden banned antimicrobial growth promoters 1986 – what happened with the use? (In Swedish). *K Skogs- och Lantbr Akad Tidskr,* 135(15): 57-68.

[24] World Health Organization (WHO). Global Action Plan on Antimicrobial Resistance. Retrieved 2020 March 13 from https://www.who.int/antimicrobial-resistance/publications/global-action-plan/en/

[25] Swedish strategy to combat antibiotic resistance 2020-2023. Adopted on 13 of February 2020. Retrieved 2020 March 13 from https://www.regeringen.se/491cdd/globalassets/regeringen/dokument/socialdepartementet/fokhalsa-och-sjukvard/svensk-strategi-for-arbetet-mot-antibiotikaresistens-2020-2023.pdf

[26] Reviderad tvärsektoriell handlingsplan mot antibiotikaresistens 2018-2020 (in Swedish). Retrieved 2020 March 13 from https://www2.jordbruksverket.se/download/18.48293d89160e4e709217084/1515674773003/ovr432.pdf

[27] Swedres-Svarm 2018. Consumption of antibiotics and occurrence of antibiotic resistance in Sweden. Folkhälsomyndigheten och SVA. Retrieved 2020 March 13 from https://old.sva.se/globalassets/redesign2011/pdf/om_sva/publikationer/swedres_svarm2018.pdf

[28] https://www.sva.se/en

[29] https://www.sva.se/en/antibiotics/antibiotics/svarm-resistance-monitoring/svarmpat-focus-on-antimicrobial-resistance-in-animal-pathogens/ (Retrieved 2020 March 13)

[30] Maron, D.F., Smith, T.J.S. & Nachman, K. E. (2013). Restrictions on antimicrobial use in food animal

Production: an international regulatory and economic survey. *Globalization and Health,* 9 (48)

[31] http://www.sds-web.se/en/ (2020 March 13)

[32] The history of the Swedish animal infectious disease control – up until 2000 (in Swedish). Retrieved 2020 March 13 from http://cerenius.se/onewebmedia/Folke/Veterin%C3%A4r%20smittskyddshistoria/Smittskyddets%20historia%20Rapport.pdf

[33] http://www.jordbruksverket.se/amnesomraden/djur/sjukdomarochsmittskydd/smittsammadjursjukdomar/salmonella/sabekampassalmonellaisverige.4.5fe620a913671cf1a6b80002330.html (2020 March 13)

[34] https://svenskfagel.se/program/campylobacter/ (2020 March 13)

[35] https://www.gardochdjurhalsan.se/nationellt-ansvar/kontroll-overvakningsprogram/ (2020 March 13)

[36] Holmgren, N. & Lundeheim, N. (1994). The clinical need of antimicrobial feed additive in piglet producing herds (in Swedish). *Svensk Veterinärtidning,* 46: 217-222.

[37] https://svenskfagel.se/nyheter/en-kycklings-liv-sa-har-kycklingen-det-i-bondens-stall/ (2020 March 13)

[38] The Swedish Veterinary Association (Sveriges Veterinärförbund, SVF). (1998). Antibiotic Policy (in Swedish). Retrieved 2020 March 13 from https://svf.se/forbundsfragor/policydokument/antibiotika-policy/

[39] The Swedish Veterinary Association (Sveriges Veterinärförbund, SVF). (2002). Guidelines for the clinical use of antibiotics in the treatment of dogs and cats (English version). Retrieved 2020 March 13 from https://www.svf.se/media/jzqbjer5/policy-ab-english-dogs-and-cats.pdf

[40] The Swedish Veterinary Association (Sveriges Veterinärförbund, SVF). (2013). The Swedish Veterinary Association's Guidelines for the clinical use of antibiotics in the treatment of horses (English version). Retrieved 2020 March 13 from https://www.svf.se/media/tztkij4b/guidelines-antibiotics-in-horses.pdf

[41] The Swedish Veterinary Association (Sveriges Veterinärförbund, SVF). (2017). Guidelines for the use of antibiotics in production animals – Cattle, pigs, sheep and goats (English version). Retrieved 2020 March 13 from https://www.svf.se/media/vd5ney4l/svfs-riktlinje-antibiotika-till-produktionsdjur-eng-2017.pdf

[42] Statens jordbruksverks föreskrifter om läkemedel och läkemedelsanvändning (SJVFS 2019:32, D9). Statens jordbruksverks författningssamling. Retrieved 2020 March 13 http://www.jordbruksverket.se/download/18.7c1e1fce169bee5214fb24f1/1553856326087/2019-032.pdf

[43] Gemensamma författningssamlingen avseende hälso- och sjukvård, socialtjänst, läkemedel, folkhälsa m.m. (HSLF-FS 2016:34) Retrieved 2020 March 13 https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/foreskrifter-och-allmanna-rad/2019-1-10.pdf

[44] Jordbruksverket. Försäljning av djurläkemedel 2018. Retrieved 2020 March 13 http://www.jordbruksverket.se/download/18.1241d16d16a504ebd3f833fc/1556263815980/F%C3%B6rs%C3%A4ljning%20av%20djurl%C3%A4kemedel%202018.pdf

[45] EMA. 2011, 'Trends in the sales of veterinary antimicrobial agents in nine European countries (2005-2009)' (EMA/238630/2011). https://www.ema.europa.eu/en/documents/report/trends-sales-veterinary-antimicrobial-agents-nine-european-countries_en.pdf (2020 March 13).

[46] https://www.vxa.se/radgivning-och-kurser/analysera-nulaget/kokontrollens-nyckeltal/kokontroll/ (2020 March 13)

[47] Nyman, A. Treatment incidence with antibiotics for systemic use between 2001 and 2018 (in Swedish). Växa Sverige. Retrieved 2020 March 13 https://www.vxa.se/globalassets/dokument/statistik/antibiotikaforbrukning-2001-2018.pdf

[48] Swedish Veterinary Institute (SVA, Sveriges Veterinärmedicinska Anstalt). (11 of June 2019). Antibiotic resistance in bacteria from Swedish domestic fowl (in Swedish). Retrieved 2020 March 13 from https://old.sva.se/globalassets/redesign2011/pdf/om_sva/publikationer/antibiotikaresistens-fjaderfa-2018.pdf

[49] https://svenskfagel.se/nyheter/fragor-och-svar-om-antibiotika-i-kyckling/ (2020 March 13)

[50] Swedish Veterinary Institute (SVA, Sveriges Veterinärmedicinska Anstalt).). (11 of June 2019). Antibiotic resistance in bacteria from Swedish pigs (in Swedish). Retrieved 2020 March 13 from https://old.sva.se/globalassets/redesign2011/pdf/om_sva/publikationer/antibiotikaresistens-gris-2018.pdf

[51] Fischer, K., Sjöström, K., Stiernström, A. & Emanuelson, U. (2019). Dairy farmers' perspectives on antibiotic use: A qualitative study. *J. Dairy Sci.* 102: 2724-2737.

[52] De Briyne, N., Atkinson, J., Pokludova, L., Borriello, S.P. & Price, S. (2013). Factors influencing antibiotic prescribing habits and use of sensitivity testing among veterinarians in Europé. *Veterinary Record* doi:10.1136/vr.101454.

[53] Nordéus, K. (2019). Sweden and the growth promoting antibiotics (in Swedish). *Svensk Veterinär Tidning.* 71(9):33-37.

[54] Jensen, V.F. (2013). Promoting prudent antimicrobial use in the veterinary field. *Veterinary Record* doi: 10.1136/vr.f6801.

SCIENCE AND EDUCATION **FOR SUSTAINABLE LIFE**

SLU, Sveriges lantbruksuniversitet, har verksamhet över hela Sverige. Huvudorter är Alnarp, Uppsala och Umeå.
SLU är miljöcertifierat enligt ISO 14001 • Telefon: 018-67 10 00 • Org nr: 202100-2817