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EXPERIENCE OF FEEDING PIGS WITHOUT ANTIBIOTICS: A EUROPEAN PERSPECTIVE

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1 INTRODUCTION

The use of antibiotic growth promoters has been questioned in Europe for several decades. The concern has mainly been related to the risk of creating antibiotic resistant microorganisms that can be transferred to humans. The ethical justification for feeding antibiotics to "healthy animals" has been debated as well and during the last decade, the growing consumer demand for "green" food products has further intensified the discussion and created the current situation. The discussions on the use of feed containing antibiotic growth promoters have mainly taken place in the Northern European countries and in Great Britain while countries in Southern- Central- and Eastern Europe have been less active debating the topic.

2 HISTORICAL PERSPECTIVE

In the 15 European Union countries and in Switzerland, the total consumption of antibiotics in livestock production was approximately 6500 *t* in 1997.[1] Of this amount, approximately 25% was ionophore feed additives primarily used in poultry production. Of the remaining 5000 *t*, approximately 1600 *t* was used as antibiotic growth promoters, while the rest of the usage is estimated to arise from prescriptions issued for therapeutic purposes. The breakdown of the antibiotics used in the European Union and Switzerland is listed in Table 1.

In 1986, a general ban on all antibiotic growth promoters (AGP) in animal feed was introduced in Sweden. The ban was suggested by and followed the recommendations of The Swedish Farmers Organization.[2]

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Table 1. Sales Volumes of Antibiotics in EU and Switzerland in 1997 by Therapeutic Groups (*t* of Active Substances)

Therapeutic Group	Estimated Volume (*t*)
Pennicillins	322
Tetracyclines	2294
Macrolides	424
Aminoglycosides	154
Fluoroquinolones	43
Trimethoprim/sulphonamides	75
Other Therapeutics	182
Subtotal	3494
Growth Promoters	1599
Total	5093

[a]From Boatman, 1998.

In 1995, The Danish Veterinary Laboratory published results indicating that the use of avoparcin as a growth promoter was associated with the occurrence of vancomycin-resistant *Enterococcus faecium* (the so-called "superbugs") in poultry. Because vancomycin was the only effective antibiotic used to treat multiple drug resistant infections in humans, this finding caused some concern. Vancomycin has never been used in animals, but avoparcin that belongs to the same class of drugs as vancomycin, was a popular AGP for pigs and poultry in several European countries. It was, therefore, believed that the usage of avoparcin in pigs and poultry caused the emergence of vancomycin-resistant *Enterococcus faecium* (VRE). These results led to a Danish ban on avoparcin, which was later followed by a ban by the European Union (EU) affecting all countries in the EU. In January 1998, a Danish ban on the use of virginiamycin was introduced and shortly thereafter, the Danish swine producers voluntarily decided to discontinue the use of all AGP in diets for pigs heavier than 35 kg.[3]

Based on the Danish research reports on antibiotic resistance caused by AGP, the Scientific Committee on Animal Nutrition (SCAN) in The European Union decided to evaluate the risk of using AGP in animal feed. This work led to the conclusion that "the use of any antimicrobial agent for growth promotion belonging to the same class of antimicrobials that is also used for therapy in humans is regarded as imprudent".[4] As a consequence, SCAN recommended that the use of tylosin, zinc bacitracin, spiramycin, and virginiamycin be discontinued. The EU-legislators followed the recommendation from the committee, and a ban on these AGP was introduced in all EU countries by mid 1999. A few months later, the use of carbadox and olaquindox was banned as well. Still approved as AGP in the EU are avilamycin, flavomycin, salinomycin, and rumensin.

Due to continued public criticism, the Danish swine producers in late 1998 decided to discontinue the use of all AGP in diets for all groups of pigs. This decision was gradually implemented during 1999, and from the beginning of year 2000, no AGP were used in Denmark.

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3 CONSEQUENCES OF DISCONTINUING THE USE OF ANTIBIOTIC GROWTH PROMOTERS

Because the use of AGP has been completely discontinued in only Sweden and Denmark, the consequences of removing AGP have been experienced in only these two countries.

3.1 Total Use of Antibiotics

The use of antibiotics for growth promotion as well as the therapeutic use of antibiotics for all animal groups in Sweden during the last 20 years is listed in Table 2. The numbers include the total usage for all animal groups and no numbers are available to calculate the usage of antibiotics specifically for swine. Initially, the Swedish ban on AGP led to a twofold increase in the incidence of post-weaning diarrhea. As a consequence, the therapeutic use of antibiotics increased during the following years.[5] In 1988 and 1989, the total use of antibiotics for nursery pigs was 5–6% higher than in 1985.[6] In 1989, 75% of all nursery pigs in Sweden were fed diets containing antibiotics at therapeutic levels. However, changes in management and feeding strategies helped reduce the therapeutic use of antibiotics and by 1995, only 11% of the nursery pigs were fed diets containing antibiotics. This development was partly facilitated by an increase in the number of nursery diets containing zinc oxide at pharmacological levels.[5] It should be noted that in Sweden, pigs are not weaned until they are five weeks old.

The removal of AGP from diets for growing-finishing pigs in Sweden did not have any measurable impact on the disease level or the therapeutic use of antibiotics.[5]

The use of antibiotics for growth promotion as well as the therapeutic use of antibiotics in Denmark is listed in Table 3. As is the case in Sweden, the specific use of antibiotics in swine was not recorded, but it is believed that the majority of the antibiotics listed in Table 2 were used in swine. In 1994, the use of AGP totaled 110 *t* active substance while another 70 *t* of antibiotics was used for the treatment of subclinical and clinical diseases. In 1998, the year when the use of AGP in grow-finishing diets was discontinued, the antibiotic use for growth promotion dropped to 49 *t* active substance, while there was no increase in the therapeutic use of antibiotics although total swine production had increased by approximately 17% compared to 1994. In 1999, the use of antibiotics for growth promotion dropped further due to the gradual removal of AGP from nursery diets, and in year 2000 no antibiotics were used for this purpose. However, the removal of AGP from nursery diets has increased the therapeutic use of antibiotics in 1999, and it is expected that this number will further increase in 2000. In Denmark, as in all other EU countries, early weaning is not permitted and most pigs are weaned between three and four weeks of age.

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Table 2. Total Usage of Antibiotics in Sweden, 1984 to 1998[a]

Year	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998
Usage, *t*[b]	41.3	43.6	50.5	25.8	30.2	30.3	31.0	30.2	20.6	19.3

[a]From Wierup et al., 1999.
[b]Until 1984, the numbers include antibacterial substances used for treatment of animals as well as antibiotic growth promoters included in animal diets. In subsequent years, no antibiotics were used as growth promoters.

In conclusion, the usage of antibiotics in Sweden and Denmark indicate that the removal of AGP from growing-finishing diets causes no increase in the therapeutic use of antibiotics. Omitting AGP from nursery diets, however, results in an increase in subclinical and clinical diseases, which in turn increases the use of antibiotics for disease treatment.

3.2 Pig Performance

In growing-finishing pigs, the improvement in performance resulting from using AGP has been measured in numerous experiments. On average, an improvement in feed efficiency of 2–3% has been reported while average daily gain was improved by 25 g.[7] By omitting AGP from the diets, performance will decrease by these numbers. Other than that, only minor consequences of removing the AGP from growing-finishing pigs have been observed. On a few occasions, diarrhea caused by *Escherichia colibacillosis* (*E. coli*) or other pathogens has surfaced and *Lawsonia intracellularis* has caused outbreaks in some grower units, but in general, only a few clinical or subclinical diseases have been observed in Denmark.[7,8] Similar observations were reported from Sweden.[2,5]

In nursery pigs, the removal of AGP is causing several problems. In Sweden, mortality during the nursery period increased approximately 1.5 percentage units after the ban of AGP,[5] and total feed consumption from weaning to 25 kg increased by 2–3 kg. In addition, daily gain was reduced resulting in animals requiring 5–6 days more to reach the target weight of 25–30 kg. In Denmark, the initial experiences have indicated that on average of all record-keeping farms in Denmark, mortality has increased by some 30% and daily gain is reduced by 19 g per day during the nursery period after the removal of AGP.[9] The majority of the problems that have surfaced after the removal of AGP is diarrhea caused by *E. coli* (Type 138, 139, 149, 157) or by *Clostridium perfringens* (Type A and C). On many farms, medication of the feed or the water is now done routinely, which is the reason for the increase in the therapeutic use of antibiotics already mentioned. While the *E. coli*-diarrheas are mainly surfacing during the immediate post-weaning period, a growing number of farms also have increased morbidity and reduced performance caused by *L. intracellularis* during the later stages of the

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Table 3. Use of Antibiotics for Swine Production in Denmark[a]

Year	Hog Production (Mill Head)	Antibiotics in AGP[b]	Antibiotics for Therapeutic Use[b]	Total Use of Antibiotics[b]	Total Use of Antibiotics[b] (g/Pig)
1994	18	110	70	180	10
1998	21	49	70	119	5.7
1999	23	12	80[c]	92[c]	4[c]
2000	23	0[c]	90[c]	90[c]	3.9[c]

[a]Federation of Danish Pig Producers and Slaughterhouses (2000) and Hedegaard (2000).
[b]*t* active substance, approximate values.
[c]Estimated by the author.

nursery period and sometimes also in the grower period. Like *E. coli* and *C. perfringens*, this disease also has to be treated with an appropriate antibiotic.

In conclusion, omitting the AGP from nursery diets does cause several problems resulting in reduced performance and increased morbidity. At this point, effective strategies to overcome these problems are yet to be identified. It has been estimated that the economic loss to Danish swine producers resulting from omitting AGP in the nursery-feed totals between 0.5 and 1 USD per pig.[9]

4 CHANGES IN MANAGEMENT AND FEEDING STRATEGIES

To ameliorate the consequences of removing AGP from the nursery diets several changes in management- and feeding practices have been reported as having some efficacy in improving pig performance and reducing the economic loss to swine producers.

4.1 Housing and Pig Flow

The importance of appropriate housing and environmental conditions (i.e., pen space, feeder space, room temperature) needs to be highlighted.[10] Off site weaning and all-in all-out pig flow are also measures that will help improve overall herd health status and, thus, reduce the negative consequences of omitting AGP from the feed. No statistics are available to show the benefits of all-in all-out production compared to continued flow production, but in most European countries, this method of production is recommended.

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4.2 Restricted Feeding

Restricted feeding rather than feeding to appetite during the immediate post-weaning period significantly reduces the incidences of scouring.[11] Usually, pigs should be restricted to a feeding level of 2–3% of their body-weight from day 3 to day 8 post-weaning. After this period, feed allowance is gradually increased until the pigs are fed to appetite.[11] Restricting feed intake this much will cause a decrease in average daily gain. To avoid the bigger pigs from overeating, floor feeding or feeding in a trough that allows all pigs to eat at the same time is necessary if feed intake is restricted.

4.3 Liquid Feeding

Feeding a liquid diet where feed is mixed with water in a 1 : 2 ratio prior to feeding is also used to improve pig performance during the immediate post weaning period. In ten experiments, daily gain was improved by 12.3% on average in pigs fed liquid diets compared to pigs fed dry feed.[12] Feeding a liquid diet reduces the atrophy of the intestinal villi that is usually seen 1–2 weeks post-weaning in pigs fed dry feed.[13] With a healthier and more intact villi-structure in the small intestine, it is likely that pigs are less susceptible to *E. coli* infections, which in turn can explain why liquid feeding has a positive influence on overall pig health.

4.4 Fermented Liquid Feed

Feeding fermented liquid diets can also help improve pig performance and reduce the disease level. On average, daily gain was improved by 22.3% in four experiments where fermented liquid feeding was compared to dry feeding.[12] Fermentation of the diet for 8 hours at 20°C and with 50% residual feed in the fermenter is an efficient way of decreasing pH in the feed. This decrease in pH may be due to a proliferation of lactic acid producing bacteria naturally occurring in the feed.[14] Also yeast species present in the feed will proliferate during fermentation; therefore, yeast present in the GI-tract of pigs fed fermented liquid feed is higher than in pigs fed non-fermented liquid feed.[12,15] Yeasts are believed to be able to bind certain enterobacteria such as *E. coli* and *Salmonella* and thereby blocking these pathogens from binding to the intestinal wall. Therefore, higher concentrations of yeast in the GI-tract may be beneficial.[15] This hypothesis is supported by the fact that the concentration of *E. coli* in the stomach, small intestine, and the hindgut of pigs fed fermented liquid feed is significantly reduced compared to pigs fed non-fermented feed.[12,16]

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5 DIET MODIFICATIONS

5.1 Protein Concentration and Protein Sources

It has been demonstrated that scouring in nursery pigs increases with increased levels of dietary crude protein.[11] Therefore, the most efficient way of reducing the incidence of diarrhea in newly weaned pigs fed diets containing no AGP is by feeding low protein starter diets. Often, it is necessary to formulate diets containing only 17–18% CP to avoid scouring. While the dietary needs for lysine, methionine, threonine, and tryptophan can be met by adding these amino acids to the diet in a synthetic form, it may be necessary to add one or two alternative protein sources to meet the requirements for the other indispensable amino acids. Therefore, low-glycoalkaloid potato protein concentrate and egg protein concentrate are often added to low protein barley-based starter diets because of the favorable profile of indispensable amino acids in these ingredients. Other protein sources in low-protein starter diets include skim milk powder, whey protein concentrate, and fishmeal dried at low temperatures (fishmeal LT), while soy proteins are usually excluded from these diets.

5.2 Cereal Grains

Results of several experiments showed that pig performance is improved and scouring is reduced if barley or oats is used as the major cereal grain in starter diets rather than wheat or corn (Stein, 1999, unpublished results). The reason for this finding remains to be elucidated, but it may be due to the higher fiber content in barley and oats compared to wheat and corn as will be discussed later. A mixture of barley, oats, wheat and corn is often recommended in starter diets containing no AGP with barley being the dominant cereal grain.

To further improve performance, the cereal grains in starter diets containing no AGP are usually cooked, popped, or otherwise heat-processed. Heat processed barley improved average daily gain by 13% compared to non heat-processed barley.[17] Also, in other cereal grains, heat processing was shown to improve performance.[18,19] The reason why heat processing improves growth rates in newly weaned pigs may be that nutrient digestibility is improved.[19,20] To avoid pigs getting diarrhea, diets containing no AGP need to have high nutrient digestibility, which is one of the reasons for the usage of heat-processed cereal grains in such diets.

The use of cooked or broken rice as a major ingredient in starter diets is not common in Europe at this point. Recent results indicate, however, that pigs consuming diets with a high content of cooked rice are less susceptible to infections caused by *Serpulina Hyodysenteria* compared to pigs fed diets with no inclusion of rice.[21] It was speculated that this might be due to the low content of resistant starch and non-starch polysaccharides in rice as compared to other cereal grains resulting in fewer fermentable carbohydrates entering the large intestine in

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pigs fed rice-based diets.[21] If cooked rice also can prevent other pathogenic bacteria from colonizing in the hind gut of newly-weaned pigs, rice might become an important ingredient in starter diets in the future.

5.3 Minerals

Because of the high buffering capacity of limestone and inorganic phosphate sources, decreasing or omitting the dietary inclusion of these ingredients can reduce scouring. Exogenous phytase is added to improve the digestibility of phytate-bound phosphorus and the requirement for calcium can be met by using calcium salts rather than limestone.

Copper sulfate is added to all nursery diets at levels between 150 and 175 ppm. Zinc oxide is often added to starter diets at levels of 2000–4000 ppm. However, this routine cannot be legally practiced in Denmark, while it is a common routine in Sweden and several other European countries.[2] High concentrations of zinc oxide in starter diets for pigs have been shown to control post-weaning diarrhea with the same efficiency as do AGP without causing any toxicity symptoms.[2] In addition, in several experiments, zinc oxide fed at pharmacological levels (i.e., 2000–4000 ppm) was shown to have a growth promoting effect of the same magnitude as what is usually expected from AGP.[22,23,24]

5.4 Dietary Fiber

Certain dietary fibers have been shown to improve intestinal secretions and growth of the digestive mucosa,[10] and a number of different fiber fractions have been tested for their ability to enhance pig growth and suppress pathogenic bacteria colonization. The mode of action of the dietary fibers is believed to depend on the specific fraction in question. Readily fermentable non-digestible oligosaccharides (i.e., fructo-oligosaccharides and trans-galactooligosaccharides) are believed to improve pig performance by stimulating the proliferation of Bifidobacteria in the large intestine. Bifidobacteria suppress the growth of pathogenic bacteria (i.e., *E. coli*) by stimulating the production of acetate, which decreases the pH and may reduce the incidence of diarrhea.[25] Other fiber fractions (i.e., mannan-oligosaccharides) are believed to improve pig health and performance by binding to specific lectin ligands on the surface of epithelial cells, thus preventing pathogenic bacteria from binding to these ligands resulting in a “flushing” effect on pathogenic bacteria. At this point, results with these products obtained in practical diets for pigs are inconclusive, and in general, specific fractions of dietary fibers are not included in diets for neither nursery pigs nor growing finishing pigs. However, as already pointed out, the inclusion of barley and oats in diets for nursery pigs has been shown to improve pig performance and

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decrease scouring indicating that these cereal grains may contain certain fibers that are beneficial to the animals. Also other intact fiber sources (i.e., soy hulls, alfalfa meal, sugar beet pulp) are sometimes included in nursery diets, although the experimental evidence of a possible positive influence of these products does not exist.

6 ALTERNATIVE FEED ADDITIVES

A number of novel feed additives have been introduced to the European swine industry as alternatives to AGP. Many of these alternatives are now included routinely in nursery diets for pigs, while they are usually not included in diets for growing-finishing pigs. Dietary acidifiers (e.g., organic acids, inorganic acids, and acid salts) are the most popular of these additives and there is some experimental evidence for the ability of acidifiers to improve pig performance and pig health.[26,27] Certain probiotics, enzymes, or enzyme combinations, and oligosaccharides are also used to some extend, while the use of essential oils, herbs, and plant extracts at this point is limited.

7 CONCLUSIONS

Skepticism towards the use of AGP in animal feed in Western Europe is widespread. For that reason, only a few AGP are still in use in the European Union, and in Denmark and Sweden, no AGP are used in livestock production. So far, the experience has shown that AGP can be omitted from diets for growing and finishing swine without any measurable impact on pig health and only minor effects on performance. However, in both countries, the incidence of post-weaning diarrhea has increased after the removal of AGP from diets for weanling pigs, and on many occasions, antibiotics are now included in feed or water for nursery pigs at therapeutic levels. Therefore, the therapeutic use of antibiotic has increased after the removal of AGP, but the total usage of antibiotics has decreased in both countries. The economic loss to swine producers due to the removal of AGP from animal feed is significant.

The most efficient way to ameliorate the negative impact of removing AGP from nursery diets has been to reduce the crude protein content of the diets, to included low-glycoalcaloid potatoprotein concentrate in nursery diets, and to change the use of ingredients towards more barley and oats and less wheat and corn. The usage of pharmacological levels of zinc oxide in nursery diets is widespread in many countries – but it is not always in accordance with national law. Although many alternative feed additives are on the market, none of them have been able to completely replace AGP in diets for nursery pigs.

More research is warranted to better understand the digestive processes of the pig and, thus, overcome the problems associated with omitting AGP from swine

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diets. Future research will likely focus on measures that can improve the immune status of weaned pigs and at the same time enhance performance.

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