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Review

Growth promotants in feeding pigs and poultry. I. Growth and feed efficiency responses to antibiotic growth promotants

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Abstract – Since the beginning of the 1950s, growth promoters of antibiotic type have played a major role in the development of intensive and industrialised animal farming systems. The incorporation of such growth promoters into animal feed mixtures has made it possible to improve animal health conditions as well as to increase rearing intensity. Simultaneously, the admixing of these additives has successively lowered food production costs, a development which has been to the benefit of the consumer. The objective of this contribution was to review recent developments in this area and in particular to address growth promoters of antibiotic type authorised in the European Union as additives for pig and poultry. Finally, we also briefly touch upon the potential economic consequences of terminating their use under current European conditions, as well as their potential environmental effects. (© Elsevier / Inra)

growth promoter / antibiotic / pig / poultry

Résumé – Les promoteurs de croissance dans l'alimentation des porcs et des volailles. I. Réponses en terme de croissance et d'indice de consommation à l'addition d'antibiotiques. Les promoteurs de croissance, tels les antibiotiques, ont joué un rôle important durant ces dernières décennies dans le développement des systèmes d'élevage intensif et industriel. Leur incorporation dans l'alimentation animale a permis d'améliorer les conditions sanitaires des animaux et d'accroître la productivité des élevages, tout en diminuant simultanément les coûts de production. L'objectif de cet article est de passer en revue les connaissances nouvellement acquises dans ce domaine, et de s'intéresser plus particulièrement aux antibiotiques autorisés dans l'Union Européenne et utilisés dans l'alimentation des porcs et des volailles. Sont également évoqués les conséquences économiques de leur retrait dans le contexte européen actuel et leurs effets potentiels sur l'environnement. (© Elsevier / Inra)

promoteur de croissance / antibiotique / porc / volaille

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1. INTRODUCTION

The general benefits of using antibiotic growth promotants in livestock production are lower production costs leading to lower market prices and a more plentiful supply of food commodities. For the consumer, the direct benefits are lowered food prices [9]. However, there is growing concern among consumers in many countries about the use of growth promotants [2, 4, 27, 30, 33]. The background for this concern is found in the risks for the occurrence of residues of additives in animal food products, the development of resistance of pathogenic microorganisms in animals against antibiotic preparations, and the transfer of such germ plasma to human pathogenic microorganisms. The more reluctant attitude prevailing in the USA to a withdrawal of antibiotic promotants in livestock feeding is exemplified by the comprehensive review given by DuPont and Steele [11].

2. LIVESTOCK PRODUCTION

Livestock production is the result of an integrated approach of selection, nutrition, housing and health care [16]. Over the centuries there has been a gradual improvement in the efficiency of livestock production. This development has accelerated during recent decades by the introduction of more scientifically approved methods in the different areas of livestock production and by continuously implementing research findings in practice. Scientific contributions in the fields of animal physiology, genetics and nutrition as well as veterinary sciences and housing engineering were of great importance for the development of industrialized livestock production systems. By these means, man's ability to control and manipulate animal production increased tremendously after World War II. For the further development of livestock production systems in the future, one may expect the scientific fields of immunology and ethology to become of increasing importance.

In the development of intensive and industrialized livestock production during recent decades, antibiotic growth promotants, introduced in the early 1950s, have played a decisive role. Responses to growth promotants, and hence return to the farmer, will generally be maximized by keeping target animals healthy and providing them with adequate levels of nutrients and an appropriately balanced diet [30]. There is a variety of feed additives with growth promoting effects under discussion and, according to Laming [26], these can be categorized as follows:

– anabolic agents with the aim to alter nutrient partitioning, i.e., to increase protein deposition and yield of edible cuts;

– antimicrobial agents as to improve growth rate and feed efficiency and/or to prevent decreased growth rate in occurrence of disease; probiotics and acidifiers may be mentioned under this category;

– immunological methods to enhance growth rate or to improve carcass composition;

– β-adrenergic agonists to modify carcass composition by altering nutrient partitioning and lowering fat deposition, simultaneously increasing protein accretion.

Apart from these additives, a more detailed understanding of the mechanisms in the hypothalamic-pituitary endocrinal control of growth and metabolism could in the future lead to other means of improvements in animal production processes.

The term growth promotant is used for feed additives, other than dietary nutrients, which increase growth rate and/or improve feed efficiency in healthy animals, fed a balanced diet (Macgregor (1983) cited in [9]). According to the literature review by De Craene and Viaene [9] and as mentioned in CEAS et al. [7], there is a great variation in responses of animals to antibiotic growth promotants according to different authors (*table I*).

Thus, one of the entries for growing-finishing pigs claims a response in growth rate of up to 20%, whereas for feed efficiency the lowest response was limited to 0.7%. Furthermore, in judging these promoting effects one has to consider age and class of animals and also the duration of feed additive administration as well as the performance level of the control treatment group. In comparing effects of admixing 'antibiotic additives' over time, one has also to consider the change from more potent and medical preparations to other types, approved only as feed additives. The values by CEAS et al. [7] are obviously regarded in the EU as useful for general calculations.

3. ANTIBIOTIC GROWTH PROMOTANTS IN USE IN THE EU

The antimicrobial preparations act either bactericidally (e.g., penicillin) or bacteriostatically (e.g., tetracyclines). There is a third group of antimicrobial

Table I. Percentage of responses in growth performance and feed efficiency as a result of supplementing antibiotic promotants in livestock production compared with unsupplemented control diets as reported by different authors [7, 9].

	Growth, daily weight gain	Feed efficiency
Piglets		
CEAS et al. [7]	16	9
Growing pigs (20–50 kg)		
CEAS et al. [7]	9	5.5
Finishing pigs (50 kg-slaughter)		
CEAS et al. [7]	0	0
Growing-finishing pigs		
Bickel (1983)[a]	5–10	5–7
Hudd [23]	4–5	4–5
Mordenti et al. (1979)[a]	6.5	4.1
Weiss (1989)[a]	1.9–8.6	0.7–5.1
Robinson (1969)[a]	10–20	5–10
CEAS et al. [7]	3.5	3
Broiler chickens		
Birzer and Gropp (1991)[a]	4	4
Hudd [23]	3–4	3–4
Mordenti et al. (1979)[a]	5.0	3.5
Robinson (1969)[a]	5–10	5
CEAS et al. [7]	4	4
CEAS et al. [7] laying hen performance	2	1
Veal calves		
Birzer and Gropp (1991)[a]	10	5
CEAS et al. [7]	7	4

[a] Cited in [9].

additives, ionophores, which also control protozoal growth. These preparations are of particular interest as additives for ruminants and poultry.

The antibiotic growth promotants approved in the EU are listed in *table II*. A brief description of their chemical and microbial properties is given by, e.g., Hudd [23]. The approval of the individual promotants is linked to minimum and maximum levels of inclusion in the target diets. The level of supplementation of a certain promotant may vary between animal species and also between classes. Moreover, the levels of supplementation may be regulated for the different stages of development and to a maximum age of animals. The use of carbadox and olaquindox supplemented diets has to be discontinued not later than 4 weeks prior to slaughter. According to the potential of the additive, the dose of active ingredient may vary between 1 and 100 ppm (mg per kg) in the target diet.

Table II. Antibiotic growth promotants approved in the EU (Council Directive 70/524/EEC, cf. SOU [43]).

Additive	Animal species/ class	Maximum age	Level of inclusion (g/kg[a])		Withdrawal time prior to slaughter
			min.	max.	
Antibiotic growth promotants					
Avilamycin	Pi	4 mo	20	40	
	GFP	4–6 mo	20	20	
	Po		2.5	10	
Flavophospholipol	C	6 mo	6	16	
	GFP	6 mo	1	20	
	Po	16 weeks	1	20	
	BCa		2	10	
Monensin-Na	BCa	4 mo	10	40	
Salinomycin-Na	Pi	4 mo	30	60	
	GFP	6 mo	15	30	
Spiramycin[b]	C	6 mo	5	20	
	GFP	6 mo	5	20	
Tylosinphosphate[b]	Pi	4 mo	10	40	
	GFP	6 mo	5	20	
Virginiamycin	C	16 weeks	5	20	
	GFP	6 mo	5	20	
	Po		5	20	
Zn-bacitracin[b]	C	6 mo	5	20	
	GFP	6 mo	5	20	
	Po	16 weeks	5	20	
For therapeutical use					
Carbadox	Pi	4 mo	20	50	4 weeks
Olaquindox	Pi	4 mo	15	50	4 weeks
	MR	4 mo	50	100	4 weeks

C, calves; GFP, growing-finishing pigs; BCa, beef cattle; Pi, piglets; Po, poultry; MR, in milk replacers; [a]air dry basis; [b]substances which in other galenic preparations are used as medicals.

4. GROWTH AND FEED EFFICIENCY RESPONSES TO PROMOTANTS IN PIGS

The main interest in exploiting antibiotic growth promotants is in the sectors of pig and poultry production [36]. Since the 1950s there has been a strong development in the use of antibiotic promotants. The major part of the research in this area with different animal species has been performed within the manufacturing and feed industries, whereas a relatively limited part has been performed by independent research bodies [5].

Discrepancy exists concerning the effect of antibiotic promotants on sow performance. Speer [44] concluded that the farrowing rate was improved by the use of promotants. However, antibiotic promotants had no effects on oestrus, mating behaviour or breeding efficiency [31]. Litter weights at birth and at weaning were improved [42], which could not be corroborated by Frölich et al. [17] under Swedish conditions.

By testing different antibiotic growth promotants in sows, Frölich et al. [17] found the number of resistant *C. perfringens* strains in faecal samples to increase by supplementation with aureomycin, terramycin, oleandomycin or spiramycin, whereas such an increase was not observed by supplementing Zn-bacitracin or virginiamycin.

The response of younger animals like piglets (as well as broiler chickens and calves) to promotants compared with unsupplemented diets is usually found to be superior compared with adolescent classes of these species. This is demonstrated for piglets, with growth responses to promotants between 9 and 30% and feed efficiency responses between 6 and 12%, whereas for growing-finishing pigs the level of response is inferior (*table III*). The highest value given for piglets was obtained by Nousiainen and Suomi [32] by providing the promotant olaquindox in a water solution. These authors observed a significantly higher colonic digesta dry matter content in connection with promotant supplementation, which indicates better health and also explains the higher feed intake by the supplemented treatment group.

The response to withdrawal of olaquindox from 1986 on piglet health and performance in 220 Swedish piglet producing herds was statistically evaluated by Robertsson and Lundeheim [34] by using the Swedish efficiency monitoring system (RASP). Removal of olaquindox from the piglet diets was followed by a doubling of incidences of diarrhoea and number of medical treatments of diarrhoea post-weaning as well as by an increased mortality by about 1.5 percentage units. On the withdrawal of olaquindox as growth promotant, the age at 25 kg increased by 5–6 days. In recent years the Animal Health Service control programs have further been developed with guidelines for practicing veterinarians and piglet producers, and measures have been taken to improve management, animal environment and feed composition, all of which have led to positive results in lowering the incidence or even preventing the occurrence of diarrhoea [34].

In addition to the information given in *table III*, the report by Tarrago et al. [45] should be quoted as the supplementation of tylosin as well as of virginiamycin resulted in significant improvements in piglet growth performance, but in non-significant improvement of feed efficiency.

This difference in responses between piglets and growing-finishing pigs is further illustrated by a comprehensive Yugoslavian study [48]. These authors investigated responses in piglets (6–20 kg live weight) fed diets supplemented with either of four promotants and which were compared with unsupplemented control

Table III. Growth performance (GP) and feed efficiency ratio (FER) responses of piglets and growing-finishing pigs in relation to unsupplemented control.

	Growth promotant	Weight interval (kg)	Effects on (%) GP	FER	Comment
Piglets					
Gropp and Schultz (1973)[a]	CADX	16–29	24.0	12.0	
Gropp et al. (1991)[a]			16.0	9.0	
Harp (1987)[a]		7–26	16.0	7.0	
Jongbloed (1992)[a]	AVM	8–25	9.2	6.5	
Korniewicz et al. [24]	TYL	5–23	14	12	
Nousiainen and Suomi [32]	OLQ	2–18	30		prov. in water sol.
Zivkovic and Zlatic [48]		6–20	11–15	5–10	3 diff. promotants[b]
Growing-finishing pigs					
Beck and Gropp [3]	PAYZ	12–90	2.7	2.8	SPF animals
	FLM		1.4	2.1	SPF animals
Bruckhard (1984)[a]			4.0	3.0	
Cromwell (1977)[a]	TYL				
	Zn-bac		4.0	2.5	
	VIM				
Cromwell et al. [8]	U-82,127	19–55	3.9	3.2	produced by
		19–89	3.5	2.8	*Str. araginensis*, 5 antimicrobials
Decuypere et al. [10]	VIM		5.0	7.0	
Gropp and Gruber (1988)[a]	diff.	20–50	8.8	6.0	
Gropp et al. (1991)[a]			3.5	3.0	
Gropp and Schulz (1973)[a]		growers	6.0	4.0	
Hellberg [21]	Zn-bac	23–90	0.7	1.3	
Jongbloed (1992)[a]	TYL	25–108	3.3	4.3	
Lindermeyer et al. [29]	TYL	26–100	6.2	4.7	
Schneider [37]	TYL	31–101	3.1	4.2	av. of 35 exp.
Schneider [38] 1974	TYL	31–101	4.0	4.2	
1985	TYL	30–102	3.0	3.9	
Tidén [46]	Zn-bac	22–100	–0.3	–0.3	no diff. in morb.
Weiss (1989)[a]			4.3	2.9	

[a]Cited in Verbeke and Viaene [47]; AVM, avilamycin; CADX, carbadox; FLM, flavomycin; PAYZ, payzon; TYL, tylosin-tylan; VIM, virginiamycin; Zn-bac, Zn-bacitracin; OLQ, olaquindox; [b]one of the four treatments was excluded since it contained Aureo SP-125 (a mixture of chlortetracycline, sulfamethazine and penicillin); the variation given refers to the results for FLM, PAYZ, mecadox and $CuSO_4$.

diets. One of these preparations, Aureo SP–125, was the most potent and was based on therapeutically used antibiotics (see footnote in *table III*). Therefore, the fourth treatment was excluded. For the remaining three promotants the growth responses varied between 10 and 15% and the feed efficiency responses between 5 and 10%. Corresponding values for growing-finishing pigs (20–90 kg) fed diets supplemented with the same promotants varied between 5 and 8% (growth rate) and between 4 and 7% (feed efficiency), respectively.

Similarly, by comparing the promotant effect of tylan on daily weight gains in the growing phase with those in the finishing phase, Schneider [38] arrived at relative responses in growth rate of 4.7 and 2.4%, respectively. For feed efficiency, corresponding improvements were found to be 9.1 and 2.8%, respectively. Lindermeyer et al. [29] also reported higher responses in daily weight gains and feed efficiency in the growing phase (20–50 kg) of 13 and 15%, respectively, versus 6 and 5% for the entire growing-finishing period.

Responses by growing-finishing pigs to the feeding of growth-promoting agents in the period from 1950 to 1984 were studied by Gruber [19]. The most effective group of growth promotants included streptomycin, penicillin and quinoxalines, whereas the least effective group included taomycin, salinomycin, nitrovin and the bacitracins. The results over time within the periods under study suggest a decreasing effect of growth promotants on daily weight gain and feed efficiency. A slight decrease in efficacy over time has also been reported by Rosen [35]. However, one has to consider the use of more potent preparations of therapeutical type in the beginning of this period compared with less potent ones in more recent times, such as the antibiotic promotants approved in the EU and listed in *table II*. When comparing tylan responses on growth rate and feed efficiency in growing-finishing pigs, Schneider [38] was unable to find differences in responses in the period of 1969/79 versus 1980/90 (*table III*). However, the trend of increasing the level of dietary promotants with time has to be considered [27, 35]. Unfortunately, the report by Schneider [38] does not give any information on this issue. Moreover, the change over time in cost of promotants might influence their level of inclusion. Thus in the 25-year period 1967–93 the improvement in feed efficiency for broiler chickens needed to defray cost of, e.g., virginiamycin has decreased from 4.3 to only 0.43% [35]. One would arrive at similar results in calculations on pigs.

In further commenting some entries in *table III*, the extensive body of experimentation by Schneider [37] should be mentioned, in which results from 35 German experiments with tylan performed in the period 1969 to 1990 with a total of 3800 pigs have been compiled. Information on the level of tylan inclusion is, however, not given. This author arrived at relative responses to tylan administration for average daily weight gains and feed efficiency of 3.1 and 4.2%, respectively, compared with unsupplemented control diets.

By comparing some commercial diets without and with supplementation of antibiotics and fed to growing-finishing pigs kept under good environmental conditions, Hellberg [20] observed promoting effects on growth rate and feed efficiency of 3.4 and 1.9%, respectively. In further studies, the promoting effects of Zn-bacitracin were found to be 0.7 and 1.3%, respectively [21]. A general opinion is that growth and feed efficiency responses of pigs and of broiler chickens to antibiotic promotants is lower under improved environmental conditions compared with poorer environments. Rosen [35] estimates the ratio in response between a very good and a poor environment to 1:2.

The main result of the data compiled in *table III* gives an average response by supplementation of piglet diets with antibiotic promotants in comparison with unsupplemented control diets for growth rate and feed efficiency of 17 and 9%, respectively, which is the same value as given by CEAS et al. [7]. In comparison with piglets, corresponding responses for growing-finishing pigs were inferior and averaged 3.6 and 3.1% for growth rate and feed efficiency, respectively. These values are in good agreement with CEAS et al. [7], arriving at average values of 3.5 and 3.0%.

There are difficulties in predicting responses on performance in Swedish pig industry to a re-introduction of antibiotic growth promotants. As a result of changes in the country's animal welfare rules, the current rearing and production models and performance levels differ from those in the international experiments reviewed. Therefore, a lower response level on performance may be expected. In the piglet sector for growth performance and feed efficiency a response to antibiotic promotants of 4–5% may be assumed. For growing-finishing pigs compared with piglets a lower level of responses to promotant additives of 1.5–2% may also be assumed.

5. GROWTH AND FEED EFFICIENCY RESPONSES TO PROMOTANTS IN POULTRY

As earlier outlined for pigs, there has been a strong development in the use of growth promotants in broiler chickens as well as in layers since the 1950s [5]. According to Garland [18], the financial advantage of feed costs by using antibiotic promotants in the UK broiler chicken industry may be calculated to be in the region of 0.035 ECU per bird. On the basis of an annual production of 660 million birds, one arrives at an extra yield of 23100 tons of bird liveweight, and a saving of about 91000 tons feed, which equals a gross financial saving of 25 million ECU in the UK.

The main body of the experimental work on responses of broiler chickens with respect to administration of promotants demonstrates an effect in comparison with the unsupplemented control of between 99 and 106% [5]. In poultry as well as in pig production, the technique of shuttling every 6th month between different growth-promoting preparations was introduced at an early stage in order to avoid adaptation of the microbial flora to a single promotant.

Swedish and Danish experiments, performed during the period of 1967-76 with broiler chickens fed Zn-bacitracin have been reviewed by Elwinger [12]. With the exception of one entry (in which the birds were kept in cages), the broiler chickens were raised in floor pens. The age at termination of the experiments varied between 36 and 56 days. The birds were fed diets supplemented with between 5 and 20 ppm Zn-bacitracin (in 11 entries). This supplement improved growth rate, on an average, by 2.0% and feed efficiency by 1.3% over the unsupplemented control diets. There were no differences in mortality.

In correspondence with the result for pigs, responses in broiler chickens to promotants gave growth rates and feed efficiencies that were superior in the first phase of development compared with the second. This is also in agreement with the situation in turkeys as reported by Küther [25]; *table IV*).

In a comprehensive review, Rosen [36] investigated the nutritional effects of tetracyclines (546 entries) and Zn-bacitracin (483 entries) in broiler chicken diets by using multi-factorial regression analysis. The model included dietary concentration of growth promotant, weight gain, feed efficiency, duration fed, gender, presence of disease and anticoccidial use. The results were also economically evaluated. Minimum levels of growth promotants have been calculated. Heavyweight birds responded better than lightweights. Zn-bacitracin was superior to tetracyclines, mainly as a result of better feed conversion ratios and more limited variation in effects. At the supplementation level of Zn-bacitracin presently recommended, and by using the models worked out by this author [36], one arrives at responses in growth rate and feed efficiency of 2 and 3%, respectively. It was also observed that the promotants were

Table IV. Growth performance (GP) and feed efficiency ratios (FER) of broiler chickens and turkeys in relation to unsupplemented control diets.

	Growth promotant	Age interval, days	Effect on (%) GP	Effect on (%) FER	Comment
Bartov [1]	Zn-bac	7–28	2.3	0	
	VIM		2.2	–3.3	improved AME
2.5%,					decr. N-em. by 5.2%
	AVM		5.8	1.7	
Broz et al. [6]	VIM	1–35	1.8	3.4	
Cabrera et al. (1993)[a]	Zn-bac		5.4	5.5	
Chol and Rya (1993)[a]	Zn-bac		2.6	4.4	
Elwinger et al. [13]	AVM	1–45	4.4	4.5	no diff. in mort., impr. litter qual. and foot health, low. *C.perfring.*
	AVP	1–45	6.4	4.0	as for AVM
Elwinger et al. [14]	AVM	1–43	8.3	2.6	no diff. in mort., impr. foot health,low. *C. perfringens* counts
	AVP	1–43	10.2	3.1	as for AVM
Fonseca and Rostagno (1993)[a]	Zn-bac		6.0	4.7	
Hofshagen and Kaldhusdal [22]	AVP	1–28	4.2		
		1–35		2.5	
Küther [25]	VIM	1–45	2.6	1.0	av. 5 ref., low lev.[b]
		1–45	5.8	4.2	av. 5 ref., high lev.[c]
Laczay et al. (1993)[a]	Zn-bac		5.6	5.2	
Langhout and Schutte [28]	AVM	1–26	2.6	1.8	
	VIM	1–26	–0.2	1.3	
Schutte et al. [40]	VIM	1–38	–0.8	1.5	
Schurz and Jeroch [39]	Zn-bac	1–35	5.0	0.5	
Turkey					
Küther [25]	VIM	1–12	2.7	4.4	
		1–22	1.8	0.4	
	AVP	1–12	1.8	4.5	
		1–22	0.5	0.8	

[a] Cited in Verbeke and Viaene [47]; AVM, avilamycin; AVP, avoparcin; VIM, virginiamycin; Zn-bac, Zn-bacitracin; AME, energy value; [b] low level starter diets containing 2–110 ppm; grower diets 2.5–7.5 ppm; [c] high level starter diets containing 15–20 ppm; grower diets 5–15 ppm.

more effective with respect to live weight gains when used in diseased than in apparently healthy birds. By including anticoccidials the growth-promoting effect of the promotants themselves was clearly limited, depending on the fact that anticoccidials have a growth-promoting effect as well. As a general comment on this investigation, one should recognize that today's recommended dosage for promotants has increased compared with when they were introduced. This increase in recommended dosage over time could be a result of decreasing cost per active unit and/or a way to keep disease level low.

As reported by Bartov [1] (see *table IV*), avilamycin supplementation improved the energy value (AME) over the unsupplemented control diet by 2.5%. Recently, Schutte et al. [40] reported an improvement in the digestibility of gross energy, N, P and amino acids for adult roosters as a result of supplementing a diet with 20 ppm virginiamycin.

As a beneficial effect in addition to growth promotion, the inclusion of promotants has often been reported to improve litter quality, which is a result of decreasing excreta moisture content [13, 14]. This may be regarded as an advantage for bird hygiene and health, but also improves labour and bird environment by decreasing NH_3 formation and environmental air pollution as well [15].

The overall responses of broiler chickens to the promotants listed in *table IV* as regards growth rate and feed efficiency in comparison with unsupplemented control diets may be calculated to be, on average, 3.9 and 2.9%, respectively. These mean values are in fairly good agreement with those given by CEAS et al. [7] of 4% for both traits. However, the value of 2% for growth rate based on Rosen [36] is much lower. This contrast could possibly be explained by zero and negative responses to promotants being noticed in a significant part of the experiments compiled by Rosen [35].

A re-introduction of antibiotic growth promotants into today's Swedish broiler chicken industry would certainly imply responses in performance and feed efficiency at a lower level than mentioned earlier. Explanations of this are that the Swedish broiler industry has introduced production models without the use of antibiotic promotants, with a very high standard of animal hygiene and by the use of feeding programmes including admixture of anticoccidials and enzyme preparations. A tentative response level for performance and feed efficiency of 1–1.5% may be assumed.

6. ENVIRONMENTAL IMPLICATIONS OF FEEDING ANTIBIOTIC PROMOTANTS

As reviewed previously, the feeding of antibiotic promotants improves pig and poultry growth rate and feed efficiency. The response in younger animals is superior to that of more adolescent individuals. The superior growth rate of animals means that the turn-over rate of a certain batch of animals is speeded up, leading to an economic advantage for promotant feeding. From an economic point of view, the improved feed efficiency is, however, of predominant importance.

As a consequence of the improved feed efficiency, the amounts of nutrients excreted by the animals as faeces and urine are lowered in proportion to the decreased amount of feed consumed by the animals, i.e., by approximately 3–4%. For pig and poultry production based on cereal diets, this level corresponds to a relative decrease in nutrient discharge of 15–20%. According to the present literature review on poultry and pigs, dietary administration of antibiotic promotants does not noticeably affect nutrient absorption. However, amino acid balances have been demonstrated to be improved in animals fed antibiotic promotants. On the other hand, any protein-saving effects beyond the lowered amount of feed needed per bird have yet to be proven.

In poultry, antibiotic dietary inclusion has been shown to improve litter quality. Litter quality has also been shown to affect NH_3-formation [15]. As a consequence, housing environment may be expected to be improved by antibiotic promotant feeding, which also leads to an impact for the external environment. With respect to the fact that ionophoric additives have effects similar to those of antibiotic promotants, one could speculate that the environmental effects mentioned are brought about by ionophores as well.

7. ECONOMIC IMPACT OF PROMOTANT WITHDRAWAL IN THE EU

According to De Craene and Viaene [9] studying the economic effects of growth promotants for livestock production within the EU by model calculations at farm level, a withdrawal of antibiotic growth promotants would imply a rise in production costs of up to 8.2% for pig meat. On withdrawal, the pig meat price would rise and intra-Community trade would be affected. For the entire EU, exports would decrease, which would reduce expenditures on export refunds. In the pig meat sector, the annual reduction in economic benefits would amount to $1.21*10^9$ ECU, of which the consumers would have to bear 48% and the producers 52%. The consumers would buy smaller quantities of higher priced meat products and would try to find substitutes. For poultry meat and eggs at farm level, production costs would increase by 3.4 and 1.2%, respectively. The demand for eggs would decrease only slightly, but total loss of benefits in the EU would annually be $29*10^6$ ECU, of which the consumers would bear 70% and the producers 30%. On withdrawal of promotants, broiler meat production is expected to increase by 3.4%. In this sector, the annual economic benefits would decrease by 229 10^6 ECU, of which 57% have to be borne by the producers and 43% by the consumers.

Production costs for beef would increase by 6% and would be followed by a slight decrease in demand. Economic benefits would be lowered by $820*10^6$ ECU. In the dairy cattle sector, withdrawal of promotants is expected to increase production costs by 4.6%. However, this increase would not affect demand. This would result in a forcing out of the less efficient farmers, their milk quotas being bought by more efficient farmers.

It might be stressed that these calculations are based on today's situation in the EU. Future changes in subsidy levels transferred to different sectors of EU agriculture will certainly have an impact on the outcome of this type of calculations.

8. CONCLUSION

Pig and poultry responses to dietary inclusion of antibiotic promotants in terms of growth performance and feed efficiency as compared with unsupplemented control diets are higher in the first phase than in the second phase of the growing period. Thus, piglets respond more clearly than growing pigs (20–50 kg), and these again respond more efficiently than finishing pigs (50 kg to slaughter). In the latter class of animals promotant effects seem to be minute. In poultry, promotant effects decline correspondingly. Responses to promotants of a specific type in recent time seem to be of the same magnitude as compared with 20 years ago, although for some preparations the recommended doses have increased. Obviously, antibiotic promotants decrease animal morbidity. The growth performance response of growing-finishing pigs and broiler chickens to promotant additives presently approved in the EU is 3 to 4% compared with unsupplemented control diets. For feed efficiency in pigs, as well as in poultry meat production, the values are slightly lower. The relative responses to antibiotic promotants are lower under good environmental conditions than under poor. From an economic point of view, responses in feed efficiency are of greater importance than growth performance. Promotant dietary inclusion also leads to improvements (labour and external) through lower excreta nutrient discharges in pigs and poultry, and probably also lower NH_3 formation in poultry litter.

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