FEED SUPPLEMENTS

Antibiotics in the Nutrition of Ruminants

J. THOMAS REID, RICHARD G. WARNER, and JOHN K. LOOSLI
Cornell University, Ithaca, N. Y.

A review and analysis of the effects of antibiotics upon the nutrition of ruminants are presented. It is well established that certain antibiotics repress various infectious diseases in young ruminants, stimulate appetite, and result in rapid growth rates. The influence of various factors upon the response to antibiotic supplementation and the significance of these responses to applied feeding and husbandry are examined.

INCREASED GROWTH RATE OF CHICKS due to streptomycin, as observed by Moore *et al.* (*42*), was followed by the findings that crude Aureomycin fermentation products containing vitamin B_{12} yielded a growth response in chicks greater than the maximum growth secured with pure vitamin B_{12} (*59*) and that a residual product from the manufacture of Aureomycin produced a growth response in pigs (*19*). Later Stokstad and Jukes (*58*) found that pure Aureomycin produced a response in chicks similar to that yielded by crude antibiotic-containing products. The early observations leading to the supplementation of animal diets with antibiotics were reviewed recently by Stokstad (*57*).

Studies (*1*, *34*, *50*) of the effects of feeding antibiotics to ruminants were first reported in 1950 when it was found that an increased growth rate in calves was attributable to Aureomycin-containing products. Since that time many aspects of the effects of antibiotics upon the nutrition of ruminants have been investigated.

Although Aureomycin has been studied more extensively than other antibiotics, the following antibiotics have been fed to various kinds of ruminants: Terramycin, calves (*11*, *29*, *40*, *60*, *61*) and suckling lambs (*30*); penicillin, calves (*31*, *33*, *61*, *63*) and lambs (*18*, *30*); streptomycin, calves (*63*, *65*) and lambs (*18*); tyrothricin, lactating cows (*23*); and Bacitracin, calves (*62*, *63*).

Antibiotic Supplementation of Diet of Young Ruminants

Growth of Calves

Increase in Body Size. The results of most experiments (*1–5*, *8*, *20*, *25*, *26*, *34*, *36*, *39*, *44*, *50*, *52*, *53*, *61*) demonstrate that the addition of small quantities (10 to 100 mg. daily) of Aureomycin to the ration of young calves (3 to 116 days of age) results in body weight gains ranging generally from 10 to 40% greater than those of calves consuming unsupplemented diets. Similar increases were effected by the feeding of 10 to 100 mg. of Terramycin daily (*29*, *40*, *60*, *61*), though in one experiment (*29*) in which Terramycin supplemented both whole-milk and milk-replacement diets, calves receiving whole milk gained as much weight as those receiving the whole-milk diet supplemented with Terramycin. This was in marked contrast to the results obtained with a milk-replacement diet (*29*).

Both potassium and procaine penicillin were found to depress growth rate (*31*, *33*, *61*) but, in one experiment (*62*), growth was not affected by procaine penicillin. Williams and Knodt (*65*) reported that the addition of a streptomycin-containing animal protein factor (APF) supplement to a milk-replacement diet for calves did not increase the rate of gain in body weight or in height at withers. Warner (*62*) found that bacitracin fed at a level of approximately 100 mg. per day resulted in an increase in body weight gains of 7%. Bacitracin fed at levels of 10 to 40 mg. per 100 pounds of body weight daily appears to be inferior to Aureomycin (*63*).

Although most workers have employed weight gains as the criterion of growth, other body measurements have been used (*8*, *25*, *48*, *55*, *60*, *61*, *65*). In general, the feeding of those antibiotics which produce weight increases appears to effect some increase in skeletal size also.

Rusoff *et al.* (*55*) secured a larger yield of meat and larger skeletons in Aureomycin-supplemented calves than in control animals. Analysis made of rib sections would suggest that the empty bodies of the supplemented calves contained about 9% more fat than those of control calves. Jacobson *et al.* (*25*) reported that the increase in height at withers and depth of chest was statistically insignificant at 200 days of age, whereas a highly significant increase in body weight existed. These observations suggest that the increase in muscle and fat may be more pronounced than that of the skeleton and may represent most of the increase in body weight resulting from the feeding of antibiotics.

Some of the increases in weight gains of calves attributable to the feeding of several antibiotics under a variety of conditions and during various periods of life are summarized in Table I.

Effect of Dietary Factors. Although the kinds of rations used, the degree of exposure to infectious diseases, levels of antibiotic fed, and other factors may have affected the responses to antibiotic supplementation, it is difficult to assess these influences. It would appear, that antibiotics stimulate growth to about the same extent regardless of whether the diet fed during early calfhood is composed of whole milk and skim milk (fluid or reconstituted) or limited whole milk and a milk-replacement diet. Appreciable gains in body weight were obtained when milk was fed during only the first 30 days of life and hay and concentrates were fed thereafter (*53–55*). When calves were restricted to a diet of reconstituted skim milk, no response to Aureomycin was found during the first 8 weeks of life (*44*).

The addition of hay and concentrates to the Aureomycin-supplemented diet resulted in a 17% increase in body weight gains during the next 8-week

period. Other calves fed concentrates and hay in addition to skim milk during the first 8 weeks showed an increase in rate of gain attributable to the feeding of aureomycin (*44*). Rusoff (*51*) and Jacobson (*25*) obtained different responses to Aureomycin supplementation of the diets of calves approximately 16 to 34 weeks of age. A major difference between the two experiments was that pasture was available to the calves which did not respond to Aureomycin (*51*).

Aureomycin was found to stimulate growth in calves receiving rations consisting of low levels of concentrates, high levels of roughages, and cud inoculations during the first 6 weeks of life (*24*). Aureomycin supplementation of a dry starter containing soybean meal as the main source of nitrogen effected a greater gain in weight of calves fed from birth to 16 weeks of age than the Aureomycin supplementation of starters containing cottonseed meals (*52*).

Effect of Age. The results of several experiments suggest that the age of animals or dietary qualities associated with age are related to the amount of response obtained. In general, the growth-promoting value of antibiotics appears to be greater during very early life than during late calfhood (*3, 4, 8, 21, 26, 40, 43, 44, 50*). Bloom and Knodt (*8*) observed that Aureomycin stimulated a greater gain in weight during the first 4 weeks of life than during later periods. Others (*3, 21, 29, 43*) have drawn attention to a smaller increase in the rate of gain of calves older than 6 to 16 weeks of age.

An examination was made of the data reported by several groups of workers to determine the increase in the amount of weight gained as a result of feeding antibiotics to calves during various age periods (in some cases the data employed here were interpolated from growth curves). In one experiment (*4*) the increased gains in weight through 32, 60, and 100 days were 71, 49, and 40%, respectively, greater than those of calves fed the unsupplemented diet.

In experiments in which whole milk was fed for 116 days with concentrates and hay, the increases in gain during periods of various duration and as a result of feeding Aureomycin were: first 32 days, 44% (*26*) and 37% (*44*); first 60 days, 29% (*26*) and 29% (*44*); first 88 days, 30% (*26*) and 26% (*44*); first 116 days, 33% (*26*) and 23% (*44*); and first 200 days, 24% (*25*). These values suggest that the greatest stimulation of growth by antibiotics is exerted during the first 4 weeks of life.

Since a high incidence of scours is most commonly observed during this period of life, it is not known to what extent the growth response is indebted to the control of microorganisms causing digestive and other disturbances. Although Bartley *et al.* (*1*) suggested that the increased growth of calves during the first 7 weeks is stimulated as a result of antibiotics preventing scours and others (*4, 36, 50, 53, 54*) have observed an increased rate of gain accompanied by a reduction in scours, antibiotic supplementation has effected an increased rate of gain in calves whose controls were not disturbed by diarrhea (*7–9, 32, 38–40, 44, 48*).

The age of calves at the time of introduction or withdrawal of the antibiotic supplement appears to affect the rate of body weight gain. In an experiment (*4*) in which Aureomycin supplementation during the first 7 weeks of life was compared to that during the first 12 weeks, the increase in body weight gains over the controls at various ages were, respectively: 32 days, 71 and 71%; 60 days, 27 and 49%; and 84 days, 9 and 40%. The average weight gains (pounds per day) during the period of 8 to 12 weeks of age were: control group, 1.02; group fed Aureomycin for 7 weeks, 0.87; and group fed Aureomycin for 12 weeks, 1.35. The withdrawal of Aureomycin at 7 weeks of age effected a marked reduction in the rate of weight gain, whereas the continued feeding of the antibiotic maintained weight gains at approximately the same rate as those found at 60 days of age.

Although the calves fed Aureomycin during the first 7 weeks of life grew more slowly during the period of 8 to 12 weeks than previously, they were somewhat heavier at 12 weeks of age than the control calves. Bloom and Knodt (*7, 8*) found that a rapid rate of gain was maintained through the twelfth week of age, even though Aureomycin supplementation was discontinued at eight weeks of age.

Although Kesler and Knodt (*29*) found a 23% increase in weight gain as a result of Terramycin supplementation of a milk-replacement diet fed during the first 8 weeks of life, the withdrawal or initial introduction of Terramycin after 8 weeks had no effect upon the rate of growth. Only a small increase (7%) in weight gains was obtained by MacKay *et al.* (*40*) during an 8-week period of Terramycin supplementation begun when calves were approximately 2 months of age. During a subsequent 8-week period, at the beginning of which the calves were 14 to 17 weeks old, Terramycin was fed to the calves previously used as controls and the calves, previously fed Terramycin, became the controls. An insignificant increase (3%) in the body weight gains of Terramycin-fed calves resulted.

In another experiment, Rusoff (*50, 51*) found that Aureomycin-fed calves (14 weeks of age at the beginning) gained 31% more weight than their controls during a 6-week period, but this advantage decreased to only 8% through the eighth week, and by the end of a 20-week feeding period (when the calves were 34 weeks of age), the gains of the control calves were the same as those of calves fed the Aureomycin. These results are contrary to those obtained by Jacobson *et al.* (*25*), though the animals used by Rusoff (*51*) had access to pasture in addition to hay and concentrates.

Calves fed Aureomycin during the first 28 weeks of life gained 21% more weight during the period of 16 to 28 weeks of age than control calves (*25*). Furthermore, the introduction of Aureomycin into the ration of calves (16 weeks of age but not having received Aureomycin previously) resulted in a 29% increase in weight gain during the period of 16 to 28 weeks. Calves which received Aureomycin during only the period of 16 to 28 weeks of age were heavier at 28 weeks of age than those fed Aureomycin during only the first 16 weeks of life. In another experiment (*3*), in which calves having an advantage of about 26% in weight at 7 months of age (as a result of previous supplementation with Aureomycin) maintained only an 11% advantage at 13 months of age even though supplementation was continued throughout. During the last 6-month period the amount of weight gained by the control animals was the same as that by the group receiving Aureomycin.

Fincham and Voelker (*21*) found a 9 and a 3% increase in weight gained to 12 and approximately 18 months of age, respectively, by heifers receiving an Aureomycin-supplemented ration since birth. Yearling heifers not having received antibiotics previously did not show an increased rate of gain when fed a fattening ration supplemented with Aureomycin during a 150-day period (*45*).

These data suggest that Aureomycin stimulates growth in calves up to 6 months of age but that it has little or no effect thereafter. Although it has been studied in only a limited number of experiments, Terramycin appears to influence the rate of gain only slightly in calves older than 2 to 3 months of age.

Effect of Antibiotic Level. Very few studies have been designed to determine the minimum level of antibiotic in the ration which will result in maximum increases in gains in weight. The data summarized in Table I show that daily levels of 1 to 240 mg. of Aureomycin have yielded weight responses of varying magnitude. Bloom and Knodt (*9*) found no appreciable difference in the amount of weight gained by calves receiving daily 20 to 154 mg. of Aureomycin from birth to 8, 12, or 16 weeks of age. Also, the various levels of the antibiotic did not influence the amount of feed

consumed or the efficiency of feed utilization. A very low incidence of scours was encountered in this experiment (*9*).

In an earlier study, Bloom and Knodt (*8*) found similar rates of weight gains in calves fed daily 7 to 34 mg. of Aureomycin. Others (*41*) observed no differences in the effects of levels of Aureomycin ranging from 9 to 64 mg. per pound of concentrates. Similar results were obtained when 6 and 18 mg. of Aureomycin were fed daily (*5*). Very little difference in the effects of daily levels of 10 to 40 mg. of Aureomycin per 100 pounds of body weight was found by Warner *et al.* (*63*).

Warner (*62*) concluded from a review of the literature available at the time that 30 mg. per calf per day should be as effective as higher levels and that even lower levels stimulate weight gains if scours are repressed. Rusoff (*54*) has suggested that higher levels (above 45 mg. per day) of antibiotic should be fed during the first few weeks of life than later in order that the incidence of scours may be reduced.

No deleterious effects were observed in calves 12 to 16 weeks of age fed daily 200 to 800 mg. of Aureomycin (*5*). Also, no effect on feed consumption, rumination, or growth by a calf 16 weeks of age resulted from the feeding of 2.5 grams of Aureomycin daily during a 4-week period. This calf had not received antibiotics previously.

The possible detrimental effects (*6*) of feeding high levels of antibiotics to cattle older than 6 months of age would seem to be more important than the resulting insignificant increase in size of animal (*21*). Severe diarrhea and anorexia were reported to have occurred within 2 to 3 days as a result of feeding 0.6 gram of Aureomycin per day to 620-pound steers (*6*). When 0.2 gram of Aureomycin was fed, the digestive upsets were milder but the digestibility of the ration was depressed.

Fincham and Voelker (*21*) did not observe any ill effects in heifers fed as much as 240 mg. of Aureomycin up to 30 months of age. Two-year-old steers fed as much as 1.0 gram of Aureomycin per day had good appetites and showed no signs of distress (*12–14*). These conflicting results indicate that factors in addition to age and the amount of antibiotic fed influences the kind and degree of response.

Mode of Administering Antibiotic. The effects of different methods of administering Aureomycin to calves have been examined. Rusoff *et al.* (*55*) compared the response to injecting intramuscularly 400 mg. of Aureomycin once weekly with that to feeding Aureomycin daily at approximately the same total level. The average weight gains (pounds per day) for calves during the first 16 weeks of life were: controls 0.79; intramuscularly injected, 1.07; and orally administered, 0.94. The fat content of the rib sections would indicate that the bodies of calves receiving Aureomycin orally had gained about 9% and those of calves administered the antibiotic by intramuscular injection had gained about 50%.

These findings indicate that the bodies of the injected calves contained approximately 38% more fat than those of calves fed Aureomycin. In addition the gains in height at the withers and body length were considerably greater for the intramuscularly injected calves than for either the orally administered or control calves. Less feed per unit of gain appeared to be needed by the injected calves than by the calves receiving other treatments (*55*).

In another experiment (*48*), five treatments were employed to study the effects of different methods of aureomycin administration: control; 250 mg. per week, orally; 60 mg. per week, subcutaneous implantation; 70 mg. per day, orally; and 60 mg. per week, intramuscular injection. Although no growth response to Aureomycin implanted or injected at these levels resulted during a 4-week period, the oral administration of 250 mg. per week was equally as effective in promoting growth as 70 mg. of Aureomycin fed daily.

The results of another test indicated that body weight gains are increased by the intramuscular injection of 250 mg. once weekly (28%), or by the oral administration weekly of 500 mg. (28%) or 125 mg. (30%) of Aureomycin, but that the increase in weight gains was considerably less than that (87%) effected by the feeding of 70 mg. per day during a 4-week period (*48*).

The existing information on the relative efficacy of the various means of administering antibiotics to ruminants is based upon studies conducted with small numbers of animals. Although growth responses to intramuscular injection have been observed, insufficient data are available to ascertain whether this route of administration is as effective as oral administration or whether there are conditions under which it may be more feasible than oral administration.

Table I. Increases in Weight Gains of Calves Affected by Antibiotics

Reference	Period of Supplementation, Weeks	Diet Fed During Early Life[a]	Level of Antibiotic Fed, Mg. Daily[b]	Increase in Weight Gain, %[c]
		Aureomycin		
(*48*)	0–4	Whole milk	70	32
(*38*)	0–5		70	19
(*1*)	0–6	Whole milk and skim milk	15/100 lb. body wt.	71
(*34*)	0–8	Milk replacement	1–5	12
(*35, 36*)	0–8	Whole milk or replacement	8–40	22
(*36*)	9–16		8–40	0
(*8*)	0–8	Milk replacement	7–34	6–29
(*4*)	0–8	Whole milk and skim milk	15/100 lb. body wt.	49
	9–12			40
(*61*)	0–12	Milk replacement (whey)	40 until 60 days and 80 until 88 days	20
(*55*)	0–12	Whole milk for 30 days	50>	15
(*39*)	0–12	Whole milk and skim milk	35/100 lb. body wt.	16
(*53, 54*)	0–16	Whole milk for 30 days	75 until 70 days and 150 until 112 days	21
(*43*)	0–6	...	25 mg./kg. dry feed	17
	7–12	...		0
(*44*)	0–8	Whole milk	80	29
	0–8	Skim milk (reconstituted)	80	19
	9–16	Whole milk	80	23
	9–16	Skim milk (reconstituted)	80	35
	0–8	Reconstituted skim milk (no concentrates or hay)	80	0
	9–16	Reconstituted skim milk + concentrates + hay	80	17
(*5*)	0–8	Whole milk and skim milk	6/100 lb. body wt.	20
	0–8		18/100 lb. body wt.	35
	0–22		6/100 lb. body wt.	21
	0–22		18/100 lb. body wt.	17
(*26*)	0–8	Whole milk	80	33
	0–28		80–240	30
(*25*)	16–28	Reconstituted skim milk or whole milk	80 (none previously)	21
	1–28		80	24
(*60*)	ca. 19–27	Conc. + pasture for 19–27 wks.	4.5 gm./100 lb. concd. mix. (none previously)	17
(*50*)	14–20	Conc. + pasture + hay for 14–20 wks.	3.6 g./100 lb. concd. mix. (none previously)	31
(*3*)	0–28	Whole milk and skim milk	45 to 90/100 lb. body wt.	12

Table I (Continued)

Reference	Period of Supplementation, Weeks	Diet Fed During Early Life[a]	Level of Antibiotic Fed, Mg. Daily[b]	Increase in Weight Gain, %[c]
		Aureomycin		
(*3*)	ca. 29–55	Conc. + hay during period 29 to 55 weeks	3.6 g./lb. concd. feed (Aureomycin fed since birth)	1.7
(*62*)	0–16	Whole milk	ca. 35	3
(*45*)	ca. 52–73	Fattening ration	2 mg./lb. dry feed (none previously)	−5
(*21*)	0–52	...	up to 240	9
	0–ca. 78	...	up to 240	3
		Terramycin		
(*11*)	0–6	Whole milk	15 and 30/100 lb. body wt.	16
(*29*)	0–8	Milk replacement	20/100 lb. body wt.	23
	8–16		20/100 lb. body wt.	0
	0–8	Whole milk	20/100 lb. body wt.	0
(*60*)	(young calves)	Not given	30/100 lb. body wt.	21
			100/100 lb. body wt.	28
(*61*)	0–12	Milk replacement (whey)	40 until 60 days and 80 until 88 days	22
(*40*)	0–12	Whole milk and skim milk	30/100 lb. body wt.	5
	ca. 8–16		ca. 25/100 lb. body wt.	7
		Penicillin		
(*62*)	0–16	Whole milk	ca. 35	−1.5
(*7*)	0–8	Milk replacement	6	−57
(*61*)	0–8		86 until 60 days and 80 until 88 days	−14
		Bacitracin		
(*62*)	0–16	Whole milk	ca. 100	7

[a] Main ingredient of diet fed generally during first 8 to 16 weeks of life unless otherwise indicated. Unless otherwise indicated, concentrates and hay fed beginning with the first or second week and continued throughout feeding period. When milk-replacement diets were fed, some whole milk was fed generally for a few weeks. When whole milk and skim milk were fed, the former was gradually replaced by the latter.

[b] When level is not qualified in terms of body weight or unit of feed, value listed represents total amount of antibiotic fed daily. In several instances these were computed from the data presented by the various authors.

[c] Increase in weight gained by antibiotic-fed calves expressed as a percentage increase over that gained by control animals. Values were computed from the data recorded by the various authors.

Effect of Breed. Several workers (*40, 44, 52–54*) reported that the response to antibiotic supplementation may vary with breeds; however, there is contradiction among these reports.

Growth of Lambs Although several antibiotics have been fed to sheep, the published data indicate that no consistent advantage in weight gains has been obtained. In studies with young lambs (4 to 12 weeks of age at the beginning), Colby (*16*) fed an animal protein factor supplement providing a level of Aureomycin of about 9 mg. per pound of concentrates. About 18 mg. per pound of concentrates were fed during the first 2 weeks of the experiment, but since this level appeared to depress appetite, it was reduced by 50%. The average daily gains in weight to the time of weaning and during the period following weaning, respectively, were: control group, 0.46 and 0.38 pound and Aureomycin-fed group, 0.45 and 0.22 pound. Feed intake after weaning was depressed by Aureomycin.

In other experiments, Colby *et al.* (*17, 18*) found that control lambs gained 0.52 pound per day, whereas Aureomycin supplementation (100 mg. per day) of the same fattening ration resulted in body weight losses of 0.1 to 0.2 pound daily. Jordan and Bell (*28*) reported several experiments in which an increase in the rate of gain was obtained as a result of Aureomycin supplementation of the rations of suckling and fattening lambs. The addition of 5 and 15 mg. of Aureomycin to the ration of suckling lambs during a 42-day period resulted in gains of 0.64 and 0.59 pound daily, respectively, as compared to 0.54 pound for the controls.

In another trial, fattening lambs receiving Aureomycin (6 mg. per day) gained 0.49 pound and their controls gained 0.39 pound. The feeding of 10.9 mg. of Aureomycin daily resulted in gains of 0.40 pound as compared to 0.36 pound per day gained by control lambs (*28*). In four subsequent experiments conducted by Jordan (*27*), the feeding of Aureomycin at levels of 7.2 to 10.8 mg. per day resulted a range of responses from 0.01 pound less to 0.09 pound more of gain in Aureomycin-fed lambs than in control animals. When 14.4 mg. of aureomycin was fed daily the body weight gains were somewhat lower than those of the controls. Although the significance of the differences obtained in these experiments (*27, 28*) was not indicated, it would appear that levels of Aureomycin greater than approximately 14 mg. per day depress the growth rate of suckling or growing-fattening lambs.

Kinsman and Riddell (*30*) did not influence the rate of gain in suckling lambs by supplementing a creep ration (concentrates) with Aureomycin, Terramycin, or penicillin. The antibiotics (15 mg. per pound of concentrates) were fed during an 8-week period. The efficacy of antibiotics as a growth stimulant for lambs must await further work. It would appear that the composition of rations and the level of antibiotics fed may influence the response of lambs.

Effects on Health **Calves.** The occurrence of scours and other calfhood diseases poses a major economic problem in the raising of young calves. A number of workers (*4, 8, 11, 32, 36, 40, 44, 53, 54, 60*) have drawn attention to the reduced incidence and/or severity of diarrhea or the greater firmness of feces of antibiotic-fed calves as compared to that of controls. A striking example of the effectiveness of Aureomycin (15 mg. per 100 pounds of body weight daily) in the control of common calfhood digestive and respiratory ailments is illustrated by the work of Bartley *et al.* (*4*).

The quarters used to house the calves employed in their experiment (*4*) were not considered to be satisfactory because scours and colds were prevalent and death rates were high in calves previously housed there. Despite this history and the fact that the control calves used in their experiment (*4*) were affected by colds and scours, Aureomycin supplementation largely prevented these disturbances. The existing evidence indicates that the feeding of Terramycin or Aureomycin tends to help control infectious calfhood diseases, but they do not afford complete protection from slovenly husbandry practices.

The results of several experiments indicate that antibiotics are relatively ineffective in the control of certain kinds of scours. In these cases (*6, 8, 30*), the diets fed generally contained large amounts of nonfat dry milk solids and aureomycin, Terramycin, or penicillin. Since lactose is known to cause laxation in calves (*49*) and other animals, it may have contributed to the occurrence of diarrhea in some of these instances. On the other hand, Flipse *et al.* (*22*) reported that other carbohydrates may be as offensive as lactose in producing diarrhea in calves.

A sleeker hair coat, a more pleasing

physical appearance, and greater thriftiness have been observed in antibiotic-fed calves than in controls (*40, 44, 50, 54, 55*). Several studies dealing with other criteria which reflect general health suggest that the feeding of antibiotics at levels which promote weight increases does not have detrimental effects. The pulse rate (*2*), body temperature (*2*), number and strength of rumen movements (*2, 4, 5*), pH of feces (*61*), blood levels of fat (*61*), hemoglobin (*61*), certain B-complex vitamins (*56*), and the numbers of erythrocytes and leucocytes (*61*), were not affected by the feeding of antibiotics.

Although Hibbs and Conrad (*24*) did not indicate the significance of the difference, they found the blood sugar level of Aureomycin-fed calves to be approximately 9 mg.% higher than that of unsupplemented calves. This observation is of interest since a reduction in the blood sugar of young ruminants is believed to accompany the development of the rumen flora (*37*), though the kind of diet and other factors may modify the rate of reduction (*47*).

The lack of effect upon appetite, rumination, or growth of feeding 200 to 2500 mg. of Aureomycin per day to 16-week calves not having received the antibiotic previously, indicates that young calves have a high level of tolerance for Aureomycin (*5*).

Lambs. Very limited observations have been made of the effects of antibiotics upon the general health of lambs. Colby *et al.* (*17*) reported that lambs having received Aureomycin (100 mg. per day) had smaller rumens and ruminal contents of a much drier nature than those of lambs previously fed the unsupplemented diet. Although the ruminal ingesta of lambs fed the Aureomycin-containing diet had a larger number of bacteria than that of lambs fed the control diet, this would appear to be the result of a concentration of the ruminal contents.

Aureomycin fed at levels of 7.2 to 14.4 mg. per day did not afford complete protection for lambs against enterotoxemia (*27*). Colby *et al.* (*18*) found that the feeding of 100 mg. of penicillin per day caused lambs to "go off feed" and to have diarrhea for about one week. Aureomycin supplementation had no effect upon wool-fiber length or diameter (*16*).

Effects upon Feed Consumption And Nutrient Utilization

Feed Consumption Aureomycin or Terramycin supplementation of the ration of calves has been found to stimulate the appetite (*4, 5, 8, 24, 29, 36, 44, 54, 60, 61, 65*), whereas penicillin depressed the consumption of feed (*31, 33, 61*). Since, in the experiments reviewed, the amounts of milk fed were generally restricted so that the intakes of control and supplemented calves were the same, appetite was expressed in the consumption of hay and concentrates. Varying increases in feed consumption have been reported.

When the level of both milk and concentrates was restricted, hay consumption in one experiment (*44*) was increased by 21% as a result of Aureomycin supplementation. In other experiments in which the intake of only milk was restricted, increases in concentrate consumption attributable to Aureomycin supplementation were: 22% during the first 12 weeks of life (*5*); 67% during the first 7 weeks and 22% from the seventh through the twelfth week (*4*); 40% during the first 8 weeks (*36*) and 30% during the first 8 weeks of life (*35*). In most of these experiments the consumption of hay by supplemented calves was about the same as that by the controls.

No definite conclusion can be drawn at this time on the effects of antibiotics upon the feed intake by lambs. A marked depression of appetite as a result of feeding Aureomycin has been reported (*16–18, 28*), though in two experiments the rate of gain was increased above that of the controls even though less feed was consumed (*28*). In other tests (*27*) the feed intake of Aureomycin-fed lambs was the same or slightly greater than that of control animals. The level of Aureomycin fed in these experiments ranged from 5 to 100 mg. per day. Appetite appeared to be depressed when more than 14 mg. was fed daily. Penicillin (100 mg. per day) effected marked reductions in feed intakes.

Nutrient Utilization Although several reports indicate that antibiotics effect an improvement in the efficiency of feed utilization (*6, 24, 44, 55*) the differences do not appear to be significant in all instances. Others have recorded no difference in the amount of feed required to produce a unit of gain in body weight (*4, 5, 8, 9, 15, 21, 32, 39, 40, 45, 48, 54, 60*). Consequently, it appears that the increased rate of body weight gains in young calves is due largely to the consumption of greater amounts of feed rather than to a more efficient utilization.

Murley *et al.* (*44*) examined the utilization of nutrients by calves fed a diet consisting of reconstituted nonfat dry milk solids during the initial 60 days of life. The influence of Aureomycin supplementation (80 mg. per day) upon nutrient utilization was determined when the calves were 16 to 19, 36 to 38, and 58 to 60 days of age. There was no difference in the utilization of the dry matter, carbohydrates, nitrogen, or ash by the control and Aureomycin-supplemented calves. Aureomycin added to this restricted diet did not effect an increase in the rate of gain.

The effects of Aureomycin on digestion found by Bell *et al.* (*6*) are in marked contrast to those reported by Murley *et al.* (*44*). The digestibility of the nutrients of a basal ration when fed alone and when supplemented with Aureomycin alone and in combination with urea was studied during five consecutive 3-day periods subsequent to the addition of the supplements. Although the digestibility of all nutrients in the basal ration increased progressively from the first to the fifth period, that of the nutrients of the Aureomycin-containing diets decreased markedly (*6*). The most pronounced effects of feeding 200 mg. of Aureomycin daily in this experiment were the depressions in the digestibility of crude fiber and in the retention of nitrogen.

Since the animals used by Bell *et al.* (*6*) were much older than those employed by Murley *et al.* (*44*) and probably had a "mature" rumen flora, it would appear that the age of ruminants to which antibiotics are fed determines to a large extent the degree to which nutrients are utilized. Although the age at which ruminant animals have an active flora has not been definitely determined and may be modified by the nature of the diet, it is generally believed to be approximately 6 to 10 weeks. The animals used by Bell *et al.* (*6*) had not received antibiotics previously.

In experiments in which antibiotics were fed to calves during the first 6 to 16 weeks of life and at levels promoting an increased rate of body weight gain, no effect has been found upon the total number or kinds of bacteria in rumen ingesta (*36, 54*), feces (*52*) or ingesta from the colon (*60*). With calves fed aureomycin from birth through 22 weeks of age, Bartley *et al.* (*5*) reported that direct microscopic observation disclosed no differences in the rumen microflora attributable to the antibiotic, but that the use of cultural methods indicated some differences between the flora of supplemented and control animals.

Supplementation of the rations of yearling cattle with Aureomycin resulted in no change in total numbers of bacteria in rumen ingesta; however, the bacteria observed were of "less diverse" types than those from the ingesta of cattle fed the unsupplemented ration (*45*). The level of Aureomycin (2 mg. per pound of air-dry feed) fed to these animals (*45*) would appear to be somewhat lower than that fed to young calves used in the experiments (*36, 52, 60*) discussed previously.

Recently Chance *et al.* (*14*) studied the effects upon rumen bacteria of feeding 0.5 and 1.0 gram of Aureomycin daily to 2-year-old steers. Aureomycin fed at these levels effected an increase in the total number of bacteria in the rumen ingesta and feces. The increase was greater when 1.0 gram of Aureomycin was fed daily than when 0.5 gram was fed.

The number of streptococci decreased, whereas the number of coliform organisms in the ingesta of one animal remained the same while that of the ingesta of the other animal increased. Although these findings are difficult to interpret, they do suggest that antibiotics effect both quantitative and qualitative changes in the flora of older ruminants. With the 0.5 gram level of Aureomycin, the increase in coliform population was correlated with the increased rate of removal of nutrients from the rumen reported by Chance *et al.* (*13*) earlier.

The in vitro digestion of cellulose by the ingesta from calves receiving Terramycin was 24% as compared to 67% for that from control calves at 12 and 16 weeks of age (*29*). Wasserman *et al.* (*64*) reported on a detailed study of the effects of penicillin, streptomycin, neomycin, and Chloromycetin upon the digestion of cellulose in vitro. Low concentrations of penicillin stimulated the cellulytic activity of ruminal microorganisms, neomycin was stimulatory at all concentrations studied, and streptomycin caused a slight stimulation at a low concentration, whereas Chloromycetin had an adverse effect.

No differences in the levels of total fatty acids and acetic acid were found in the rumen ingesta of control and Aureomycin-supplemented calves 12 weeks of age (*24*). Aureomycin had been fed and cud inoculations were administered during the first 6 weeks. The ingesta of Aureomycin-fed calves had smaller amounts of propionic and butyric acids than that of the controls. The thiamine and riboflavin content in rumen ingesta of control calves was not different from those of calves fed Terramycin (*29*). Smith and Allen (*56*) reported no effect of Aureomycin as a supplement to a milk-replacement, hay, and grain diet fed during a 12-week period upon the blood levels of niacin, vitamin B_{12}, pantothenic acid, riboflavin, or thiamine.

Recently a study (*13*) was made of the effects upon digestion within the rumen of feeding 0.5 and 1.0 gram of Aureomycin daily to steers 2 years of age and receiving a ration of 4 pounds of corn and 15 pounds of hay. Although, in general, Chance *et al.* (*13*) found more dry matter and various nutrients in the rumen immediately before feeding and at 6- and 12-hour intervals after feeding during periods when Aureomycin was fed than when it was not, data of this kind are difficult to interpret.

The rumen is a dynamic system in which materials are entering either directly as a result of ingestion or as a result of passage into the rumen following absorption, and in which absorption from the rumen, utilization of nutrients by microorganisms, synthesis of certain materials, and the passage of materials from the rumen to the lower digestive tract are in progress apparently concurrently. Despite the complexity of these events, it appeared that the feeding of Aureomycin, particularly at the 0.5-gram-per-day level, effected an increased rate of removal of dry matter and all nutrients, with the exception of ether extract, from the rumen (*13*). To what extent these findings are related to the utilization of nutrients was not determined.

In a corollary experiment, Chance *et al.* (*12*) found that the amounts of the 10 essential amino acids in the rumen ingesta were decreased as a result of Aureomycin supplementation. The data are not adequate to determine whether this means that protein synthesis is impaired, the rate of removal of amino acids by absorption or passage to other parts of the gut is increased, or that the utilization of amino acids by the microorganisms is increased when Aureomycin is fed. These workers (*12*) concluded that the amount of riboflavin in the rumen was less when 0.5 gram of Aureomycin was fed than when the Aureomycin-free diet was fed; Aureomycin tended to reduce the synthesis of nicotinic acid during the first 12 hours after feeding the Aureomycin-free ration.

The limited studies made of the use of antibiotics in lamb rations make it impossible to determine the effects of these substances upon feed utilization. Although in some instances the feeding of low levels (5 to 10.8 mg. per day) of Aureomycin resulted in slightly larger average gains per unit of feed consumed (*27*, *28*, *30*), in other tests the same or greater amounts of feed per unit of gain were required by supplemented lambs than by the controls (*27*). The significance of these results was not established mathematically.

Effects of Antibiotic Supplementation Upon Lactating Cows

In recognition of the possible hazards to the health of cows and human beings, as antibiotics may be fed to cows either accidentally or intentionally, the effects of feeding antibiotics to cows has been examined in a few experiments (*2*, *23*, *35*, *62*). Haq *et al.* (*23*) found that the feeding of 130 mg. daily of either Aureomycin or tyrothricin had no detrimental effects upon lactating cows during a 60-day period. Appetite remained normal and no diarrhea was observed. The feeding of the antibiotics did not affect the bacterial flora of milk, the development of lactic acid in incubated milk, or the production of a normal acid curd.

The feeding of 100 mg. daily of aureomycin to cows in other experiments (*35*, *62*) also did not cause either beneficial or harmful effects. Appetite, milk yield, and body-weight changes were not influenced by the antibiotic. In additional tests (*35*, *62*) in which 700 mg. of Aureomycin was fed daily during a 10-day period, no appreciable change in the intake of feed occurred. However, the feeding of 1.0 gram of Aureomycin (as Aurofac) per day resulted in the refusal of concentrates, while the amount of hay and silage consumed remained unchanged.

No Aureomycin was found in the milk of cows fed 700 mg. of the antibiotic daily and the activity of cheese starters was not depressed in the milk of cows fed 500 mg. per day for 6 weeks. If appreciable quantities of Aureomycin are present in milk, the activity of cheese starter is inhibited (*10*). Bartley *et al.* (*2*) also found no effect upon milk yield, feed intake, weight gains, number or strength of rumen movements, pulse rate, and body temperature of cows fed 32 mg. of Aureomycin per 100 pounds of body weight per day (total of 300 to 500 mg. daily).

In a study of the effects of feeding aureomycin from birth to maturity, Fincham and Voelker (*21*) reported control heifers and Aureomycin-fed heifers were of similar size at time of first conception, produced similar amounts of milk, and utilized feed to about the same degree of efficiency. The Aureomycin-fed heifers required more services (1.64) per conception than the control heifers (1.21), but both values are within the usually accepted normal range. Antibiotics would seem to have no significance in nutrition of mature cattle.

Significance of Antibiotics To Nutrition of Ruminants

The feeding of antibiotics to mature ruminants has not been beneficial. Antibiotic supplementation of the diet of ruminants during their preruminant phase of life has demonstrated a species difference in response. Although the appetite and rate of weight gains are stimulated and the incidence of diarrhea is reduced in calves, the effects upon lambs have been inconsistent. In a few experiments in which the rate of gain by lambs appeared to be increased, the significance of the increase was not established. In some instances the loss of weight may have been the result of the high level of antibiotics fed.

The existing data suggest that the feeding of antibiotics to lambs has not been beneficial, although insufficient study has been made to determine possible effective levels and the influence of composition of diet upon response. Since a large proportion of the gain in weight of calves is as muscle and fat rather than as skeleton (though skeletal size has been increased to varying extents) and the size of the growth response appears to be largely the result of increased feed intakes rather than an improved efficiency of feed use, the importance of antibiotics to calf nutrition would seem to depend upon the ultimate disposition of the calf.

Of the physical traits of normal, mature cows, size is the only one apparently related to productive capacity. It has been demonstrated that the early advantage in size gained by feeding antibiotics becomes insignificant, if not nonexistent, by the time of first calving. In an experiment now in progress, heifers which have been badly stunted even as late as the time of first calving (32 months of age) as a result of a restricted nutrient intake attain "normal" size by the time of second calving (44 months of age) despite the burden of lactation, provided that sufficient feed is furnished (*46*). Surprisingly, this delayed attainment of normal size appears to be as efficient in terms of feed consumed per unit of size gained as uniform, uninterrupted growth during the same period.

Consequently, from the standpoint of raising herd replacements, the only advantage gained from the feeding of antibiotics is that resulting from the control of certain infectious calfhood diseases, notably scours. The importance of supplementation for this purpose would seem to depend upon the quality of husbandry practiced, particularly regarding sanitation.

If the calf is to be disposed for meat purposes at an age of 2 to 6 months, antibiotic supplementation would seem to be advantageous. Whether this is advantageous under all conditions must be determined by balancing the value of the increased rate of weight gain against the cost of the additional feed required and the cost of the antibiotic. The limited data available at this time indicate that the supplementation of fattening rations for beef cattle is without effect upon the rate of gain.

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