The Nutritive Value of Colostrum for the Calf*

11. The Effect of Aureomycin on the Performance of Colostrum-deprived Calves

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Many workers in the United States have demonstrated the beneficial effect of certain antibiotics, particularly aureomycin (chlortetracycline) and (oxytetracycline terramycin), on the growth and well-being of the young calf. One of the first reports was from Loosli & Wallace (1950) at Cornell, who studied the performance of calves given crystalline aureomycin or Aurofac (Lederle Laboratories Inc.) as a supplement to a diet of whole milk or to a milk-substitute diet that replaced the whole milk at 10–14 days of age. The calves, irrespective of the basal diet, grew significantly better than unsupplemented control animals, and the incidence of scouring was reduced. At Kansas, Bartley, Fountaine & Atkeson (1950) gave (as Aurofac) 15 mg aureomycin/100 lb. live weight to calves reared on whole milk until the 21st day and on skim milk thereafter. In 42 days the treated calves gained an average of 30·8 lb., whereas the control calves gained 18·0 lb. only, the incidence of scouring being much lower in the treated animals. The growth rate of the controls was, however, subnormal, being well below the Ragsdale (1934) standard weight gain attained by the calves given aureomycin.

In the following year, many United States research stations reported on the value of aureomycin for the calf. Jacobson, Kaffetzakis & Murley (1951) gave 80 mg crystalline aureomycin/day to calves reared on whole milk. By the end of the 1st month, the supplemented calves weighed 9 lb. more than the controls. Bartley, Wheatcroft, Claydon, Fountaine & Parrish (1951), using Aurofac at two levels, 3 and 9 g/100 lb. live weight, found that, even when the growth rate of control animals was above the Ragsdale (1934) standard, supplemented calves grew significantly better in a 22-week period. The calves given Aurofac consumed 22% more concentrates than the controls, but there was no difference in the consumption of hay or in the efficiency of food utilization. Rusoff & Davis (1951) and Rusoff, Davis & Alford (1951) gave the first indication that calves of various breeds might respond differently to aureomycin. These workers supplemented an all-vegetable protein calf starter with 75–150 mg aureomycin/day either in crystalline form or as Aurofac, and found that, in 16 weeks, Jersey calves gained 25% more weight, whereas Holsteins

* For earlier publications in this series see Roy, Palmer, Shillam, Ingram & Wood (1955).

gained 18% more, than untreated controls. Although the calf starter was offered at the 8th day of life, the increase in growth rate occurred mainly after the calves were weaned from milk at 30 days of age.

A greater efficiency of food utilization, as well as an increased appetite for concentrates, in calves given Aurofac during the first 8 weeks of life was found by Loosli, Wasserman & Gall (1951). However, as in the previous report from Cornell (Loosli & Wallace, 1950), the growth of the control animals was subnormal, the Holstein calves used gaining only 0·95 lb./day during the experimental period. Morrison & Deal (1951) restricted the feeding of Aurofac to the first 2 weeks after the calves had been removed from their dams at 3 days of age, and found no effect on scouring, weight gains, or on consumption of milk, hay and grain. Reports from Iowa (Murley, Jacobson, Wing & Stoddard, 1951; Murley, Allen & Jacobson, 1951; Murley, Jacobson & Allen, 1952) confirmed the effect of crystalline aureomycin in stimulating appetite for concentrates and increasing efficiency of food utilization. When 80 mg crystalline aureomycin/day was given to calves reared on whole milk or on dried skim milk reconstituted at the rate of one part to four parts of water, live-weight gain of the supplemented calves was significantly higher irrespective of the basal diet, but aureomycin did not reduce the high incidence of scouring that resulted from the use of the concentrated skim-milk diet. When calves that received the skim-milk diet were muzzled to prevent consumption of other foods, growth rate and efficiency of food utilization were not increased by aureomycin. In these experiments, Ayrshire, Guernsey and Jersey calves showed a greater response to aureomycin supplementation than Holsteins. Bloom & Knodt (1951, 1952) and Knodt & Ross (1952) found that up to 200 mg aureomycin/day either in crystalline form or as Aurofac caused no harmful effects. In a further experiment, under conditions of a low incidence of scouring, and using sulphathalidine as a therapeutic treatment when scouring occurred, Bloom & Knodt (1953) were unable to find any difference in the performance of calves given aureomycin in either form over a range of 20–154 mg daily. The same workers (Bloom & Knodt, 1951; Knodt & Bloom, 1952) also used potassium penicillin as a supplement to their milk-replacement diets but found that it decreased significantly the growth rate of the calves. Gardner, Nevens, Folkerts & Johnson (1952) compared procaine penicillin with crystalline aureomycin (15 mg/lb. milk) and found improved weight gains with aureomycin, whereas pencillin had no effect. Voelker & Jacobson (1953) compared aureomycin, oxytetracycline and procaine penicillin given during the first 88 days of life; 40–80 mg daily of aureomycin or oxytetracycline caused a 20–22% increase in weight, whereas the same quantity of penicillin caused a 14% decrease in weight over controls. A further experiment by Rusoff and his colleagues (Rusoff, Alford & Hyde, 1952, 1953) in which 50 mg crystalline aureomycin/day were added to the milk and Aurofac to the vegetable-protein starter at the rate of 1·8 g/100 lb. still showed that such supplementation had very little effect before the calves were weaned off milk at 30 days of age, probably owing to the low incidence of scouring during the experiment. That aureomycin affects growth in other ways than by reducing scouring was indicated by the earlier work of Jacobson *et al.* (1951), and also by MacKay, Riddell & Fitzsimmons

(1952) whose control calves did not scour and gained 21 lb. more than the Ragsdale (1934) standard in 12 weeks, whereas calves given 36 mg aureomycin/100 lb. live weight as Aurofac gained 38 lb. more than the standard.

The first indication that the response to aureomycin might vary according to the environmental conditions under which calves were kept, came from Bartley and his collaborators. Bartley, Fountaine, Atkeson & Fryer (1953), in an experiment conducted in a calfhouse that had previously proved unfavourable for calf rearing, obtained at 12 weeks an increase in weight of 228% over the initial weight for calves receiving 15 mg aureomycin/100 lb. live weight as Aurofac, whereas the controls showed only 190% increase at this time. When aureomycin feeding to one group of calves was stopped at 7 weeks of age, the gain in weight decreased. In the following year, they (Bartley, Atkeson, Fryer & Fountaine, 1954) repeated the experiment in a building not previously used by calves giving aureomycin as Aurofac at levels of 15 and 45 mg/100 lb. live weight. The controls in this experiment grew at the same rate as the treated calves in the earlier experiment and reached 228% of their initial weight whereas those receiving 15 mg aureomycin weighed 246% of their initial weight and those receiving 45 mg weighed 255%. Like Rusoff & Davis (1951) and Murley *et al.* (1952), Bartley *et al.* (1954) found a breed difference in response: Holsteins did not benefit from the high level of aureomycin, whereas Jerseys grew better on the high than on the low level. Unlike most other workers, they found that Aurofac stimulated the appetite for hay more than for concentrates.

Comparisons of the effect of injections of aureomycin with administration by mouth have been made by several groups of workers. Rusoff, Fussell, Hyde & Crown (1953) and Rusoff, Fussell, Hyde, Crown & Gall (1954), found slightly, but not significantly, greater weight gains (30% over controls) with weekly injections of 400 mg aureomycin than with 50 mg/day given by mouth together with 1% of Aurofac given in a calf starter (20% over controls). Richardson, Ronning, Berousek & Norton (1953) gave 70 and 250 mg aureomycin weekly by mouth to two groups of calves, and 60 mg weekly either as a subcutaneous implantation or by intramuscular injection to two further groups, all for a period of 4 weeks. Administration by mouth was effective, whereas subcutaneous implantation and intramuscular injection had no effect.

The only trial reported from this country is by Kon, Oliver, Porter & Ridler (1953) in which calves were given either 50 mg aureomycin/calf/day as Aurofac or 80 mg procaine penicillin/calf/day. The effects of aureomycin were similar to those found in the United States, whereas penicillin appeared to have a slight but not significant beneficial effect.

The use of oxytetracycline has been studied in fewer experiments; in general the results are similar to those from experiments in which aureomycin was used (Cason & Voelker, 1951; Voelker & Cason, 1951; Voelker & Jacobson, 1953; MacKay *et al.* 1953). Murdock, Hodgson & Blosser (1951), who compared aureomycin and oxytetracycline, with calves kept in a calfhouse of the open-shed type, found that aureomycin had a slight effect during the first 6 weeks of life, whereas oxytetracycline had no effect. With milk-replacement diets, Kesler & Knodt (1952) and Kesler (1954) found that supplementation with oxytetracycline resulted in weights equal to those of calves reared on whole milk. Pritchard, Riddell & Durrell (1954), who gave oxytetracycline at two levels, 15 and 60 mg/100 lb. live weight for 12 weeks, found no improvement in growth rate, all calves gaining 37–43 lb. more than the Ragsdale standard. This was in contrast to an earlier trial in which control calves gained only 25 lb. above the Ragsdale standard, whereas those supplemented with 30 mg oxytetracycline/100 lb. live weight gained 40 lb. above the standard. Lassiter, Denton & Rust (1954) gave calves a mixture of aureomycin and oxytetracycline, and compared their growth rate with that of calves given aureomycin or oxytetracycline singly. There was no difference in weight gain or efficiency of food utilization between the three groups of calves, and none were significantly better than the controls.

From this brief review, it is clear that under most environmental conditions, the routine feeding of aureomycin and oxytetracycline is of benefit to the young calf, whereas the value of penicillin is uncertain. Since at least part of the beneficial action of aureomycin and oxytetracycline is their ability to control scours, probably to a large extent associated with *Bacterium coli*, it is not surprising that penicillin is not as effective as the other two antibiotics. Smith (1954) studied in vitro the sensitivity of fifty-eight strains of *Bact. coli* mostly isolated from calves in our experimental calfhouse, and found that these strains were very resistant to penicillin, whereas all were completely inhibited by 1–8 μg/ml. oxytetracycline, and fifty of them were completely inhibited by 1–8 μg/ml. aureomycin. Nevertheless, a number of other bacteria pathogenic to the young calf are inhibited by penicillin, and it may well be that penicillin will enhance the growth rate of calves exposed to such infections.

Even under conditions where the incidence of scouring is low, there is strong evidence to suggest that aureomycin and oxytetracycline stimulate growth rate, especially during the period after weaning from milk. This increased growth rate may result from the control of a subclinical infection or may be more strictly nutritional in origin; even so the dividing line between these two effects is hard to distinguish.

All the experiments so far reported have been done with calves that had received liberal quantities of colostrum, usually remaining with their dams for 3–4 days. In continuation of our studies of the protective action of colostrum, an experiment was planned to find whether aureomycin either in crystalline form or as Aurofac could control scouring and prevent mortality in colostrum-deprived calves.

METHODS

Plan of experiment

The experiment was done in the early spring months of 1954 after the calfhouse had remained filled with successive calves since the previous autumn. A randomized block design was used with four treatments in each of ten blocks as follows:

Treatment no.	Initial diet	Aureomycin given
27	No colostrum	None
28	No colostrum	Aurofac (for quantity see p. 98)
29	No colostrum	Crystalline aureomycin (for quantity see p. 98)
30	6 pt. colostrum	None

Six blocks consisted of Shorthorn bull calves and four of Ayrshire.

Diets

Basic diet

The calves were reared on bulked whole milk from the Institute herd for 3 weeks; the daily allowance was 1 lb./10 lb. live weight, except when scouring occurred (see below).

Colostrum

Six batches of colostrum, obtained within 24 h of calving from Shorthorn cows were used; 1 pt. samples were stored separately at -25°. Each calf on treatment 30 was given 6 pt. colostrum consisting of 1 pt. from each batch of colostrum.

Aureomycin

Aureomycin was given to the calves on treatments 28 and 29 for the first 10 days of life, since from previous experience it was known that this period was the most critical for the survival of the colostrum-deprived calf.

Aurofac. Calves on treatment 28 were given 30 g Aurofac 2A (Lederle Laboratories Inc.) containing 3·6 g aureomycin/lb. for the first 5 days of life followed by 15 g for the subsequent 5 days, one-third of the daily allowance being added to the milk at each of the three daily feeds. Thus, calves on this treatment received 238 mg aureomycin daily for the first 5 days and 119 mg for the subsequent 5 days.

Crystalline aureomycin. Calves on treatment 29 were given one capsule daily containing 250 mg crystalline aureomycin hydrochloride (Lederle Laboratories Inc.) for the first 5 days of life followed by half a capsule daily containing 125 mg for the next 5 days. The capsules were added to the milk of the calves at the first feed of life, and thereafter daily at the 2.30 p.m. feed.

Calves

Collection and management of the calves were as in earlier experiments (Aschaffenburg, Bartlett, Kon, Terry, Thompson, Walker, Briggs, Cotchin & Lovell, 1949). If a calf scoured, one feed was omitted and at the next two feeds the quantity of milk was reduced; the amount of milk was gradually increased at subsequent meals until the full allowance was again given. This practice was repeated when scouring recurred. As in an earlier experiment (Aschaffenburg, Bartlett, Kon, Roy, Sears, Thompson, Ingram, Lovell & Wood, 1953) a record was also kept of the time by which each of the calves had passed its meconium. From unpublished data, there is a strong indication that variations in this time are related to the degree of intestinal disturbance that occurs before clinical symptoms of scouring are apparent. The statistical treatment was as for the experiments reported by Aschaffenburg *et al.* (1953).

RESULTS

General

The results are given in Table 1. All calves given colostrum survived, whereas four untreated colostrum-deprived calves died. One colostrum-deprived calf died on each of the two treatments in which aureomycin was given.

The untreated colostrum-deprived calves gained less weight, scoured more severely and had a greater incidence of a high rectal temperature (> 102·8° F) than colostrum-fed calves or colostrum-deprived calves given aureomycin as a supplement. There

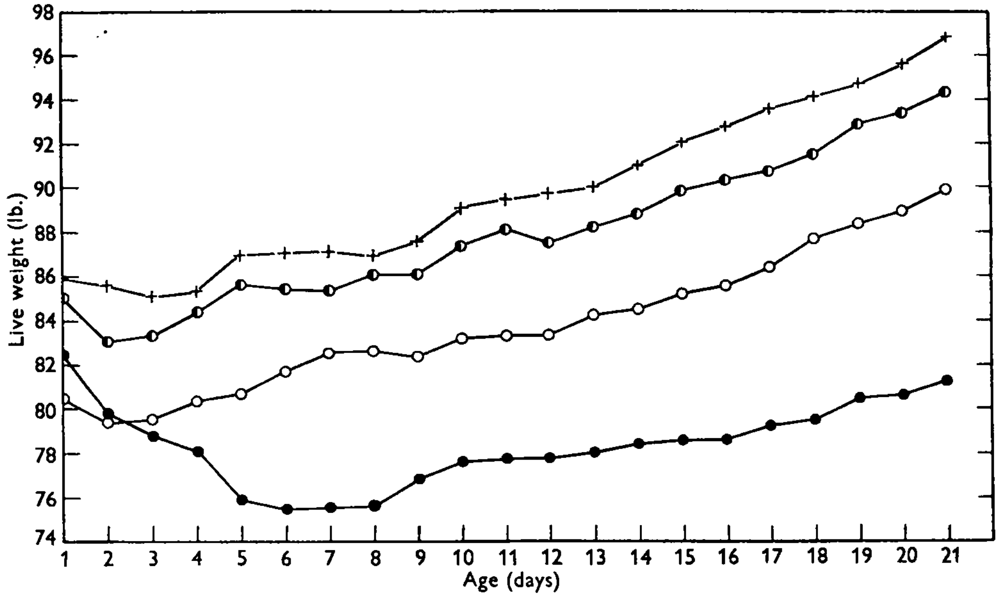

Fig. 1. The growth rate of colostrum-deprived calves, calves given colostrum, and colostrum-deprived calves given supplements of Aurofac 2A or crystalline aureomycin for the first 10 days. +, colostrum; ●, unsupplemented; ◐, Aurofac 2A; ○, crystalline aureomycin.

was, however, no difference in performance between calves given colostrum and the aureomycin-treated calves that had been deprived of colostrum, or between the performance of colostrum-deprived calves given Aurofac and crystalline aureomycin. From Fig. 1, it can be seen that the growth rate of the colostrum-deprived calves, after the first 10 days when aureomycin was discontinued, did not differ from that of calves given colostrum. On all treatments, the performance of Ayrshire calves did not differ from that of Shorthorns.

The mean time between birth and complete passage of the meconium of the colostrum-fed calves was greater than that of calves on the other three treatments. The effect of feeding colostrum and different basal diets on the time of complete passage of the meconium will be the subject of a further communication.

When the mean daily live-weight gains were analysed by multiple covariance and adjusted for the affecting variables, birth weight and total milk consumption, there was no difference between the live-weight gain of calves on the four treatments. The

Table 1. *Comparison of the performance of colostrum-deprived calves given Aurofac or crystalline aureomycin with that of calves given colostrum or deprived of it*

	Treatment no. 27 (No colostrum)	Treatment no. 28 (No colostrum)	Treatment no. 29 (No colostrum)	Treatment no. 30 (Colostrum)	Significance of difference between treatments
	No aureomycin	Aurofac	Crystalline aureomycin	No aureomycin	nos. 27, 28, 29 and 30
Calves					
No. used	10	10	10	10	—
No. died	4	1	1	0	—
Mean age at death (days)†	11 ± 2	7‡	3‡	—	—
Mean live-weight gain/day of surviving calves (lb.)†	+0·10 ± 0·09	+0·52 ± 0·07	+0·49 ± 0·07	+0·57 ± 0·07	28 > 27***, 29 > 27**, 30 > 27***
Mean no. of days on which surviving calves scoured†	9 ± 1·4	2 ± 0·7	1 ± 0·3	3 ± 0·5	28 + 29 + 30 < 27***
Mean no. of days on which surviving calves had a high rectal temperature (> 102·8° F)†	3 ± 1·2	1 ± 0·3	1 ± 0·3	1 ± 0·3	28 + 29 + 30 < 27*
Mean time between birth and complete passage of meconium (h)†	28·9 ± 2·1	34·5 ± 2·5	30·2 ± 2·5	47·9 ± 3·2	30 > 27***, 30 > 28**, 30 > 29***
Adjusted mean live-weight gain/day of surviving calves (lb.)†§	+0·43 ± 0·06	+0·48 ± 0·04	+0·42 ± 0·04	+0·47 ± 0·04	—

* Significant at $P < 0{\cdot}05$. ** Significant at $P < 0{\cdot}01$. *** Significant at $P < 0{\cdot}001$.
† In calculating the standard errors the arrangement in blocks has been ignored.
‡ One calf only. § See p. 99.

Table 2. *Post-mortem findings in the colostrum-deprived calves*

Post-mortem findings		No. of calves that died on treatment no. 27 (No aureomycin)	28 (Aurofac)	29 (Crystalline aureomycin)
Bact. coli, *Bact. aerogenes* or intermediates	Septicaemia	1*	—	1
Bact. coli, *Bact. aerogenes* or intermediates	Localized brain infection	1†	—	—
Bact. coli and *Proteus* sp.	Mixed infection	1‡	—	—
Bact. coli and *Pasteurella septica*	Mixed infection	1§	—	—
Proteus sp.	Septicaemia	—	1	—

* Associated with *Bact. coli* polyarthritis, and *Bact. coli*, *Corynebacterium pyogenes* and streptococcal omphalophlebitis.
† Localized encephalitis involving parts of the thalamus and cerebral cortex.
‡ *Proteus* sp. in heart blood. *Bact. coli* and *Proteus* sp. in mesenteric lymph nodes.
§ *Pasteurella septica* septicaemia and serofibrinous pleurisy, pericarditis and peritonitis. *Bact. coli* from mesenteric lymph nodes.

relevant partial regression coefficients with their standard errors are given below; the adjusted mean values are given in Table 1.

	General mean	Partial regression coefficient with its standard error
Live-weight gain/day (lb.)	0·451	—
Birth weight (lb.)	83·69	−0·0137 ± 0·0039**
Total milk consumption (pt.)	131·68	+0·0149 ± 0·0022***

** Significant at $P<0·01$. *** Significant at $P<0·001$.

Post-mortem findings

Table 2 shows the post-mortem findings of calves that died. Unlike in the earlier experiments in which the basic diet was 'synthetic milk' (Aschaffenburg *et al.* 1949), the post-mortem findings showed a wide variation in the cause of death. In addition to the calves that died, one calf on treatment 28 that appeared to be unhealthy but nevertheless survived the 3-week period was examined *post mortem*. The findings for this calf indicated a localized intestinal infection with *Bact. coli*.

DISCUSSION

The results of this experiment show clearly that aureomycin in either form will reduce the incidence of scouring and improve the growth rate of colostrum-deprived calves to that attained by calves given colostrum. If the effect of aureomycin is due to its antibacterial activity alone, then these results underline further the importance of the antibacterial (immunological) rather than of the nutritional value of colostrum. There is some evidence also that aureomycin given by mouth to calves deprived of colostrum will reduce mortality.

Further, it is clear that the performance of calves deprived of colostrum and reared on whole milk is very different from that of similarly treated calves reared on the 'synthetic milk' fed in earlier experiments, for in these previous experiments nearly all colostrum-deprived calves given the 'synthetic milk' died (Aschaffenburg *et al.* 1953), whereas in this experiment the majority lived. This finding may be compared with the higher rate of build-up of 'infection' for calves reared on 'synthetic milk' than for calves given whole milk (Roy, Palmer, Shillam, Ingram & Wood, 1955).

From the differences in the rate of complete passage of the meconium, and from the deaths that occurred in the treated calves, it is apparent that aureomycin given by mouth cannot eliminate completely the intestinal disturbance that occurs in the first 24 h of life. This fact is depicted in Fig. 1, which shows that colostrum-deprived calves on all three treatments lost more weight during the first 24 h of life than colostrum-fed calves.

In spite of the conditions of moderately high infection under which the experiment was conducted, there was no evidence that growth rate was impaired after aureomycin was discontinued at 10 days of age.

From a study of the mean daily live-weight gains adjusted for the affecting variables, there is no indication that aureomycin had any effect other than that of reducing scouring. As scouring did not affect significantly the live-weight gain, the treatment means were adjusted only for differences in birth weight and milk consumption. However, as the milk intake of the calves was considerably reduced when scouring occurred, this adjustment is in fact largely one for scouring.

SUMMARY

1. Forty newborn bull calves, twenty-four Shorthorns and sixteen Ayrshires, were used in an experiment to find the effect of feeding Aurofac and crystalline aureomycin to colostrum-deprived calves.

2. Of thirty calves that were deprived of colostrum, ten were given Aurofac for the first 10 days of life and ten were given crystalline aureomycin for the same period, the allowance for the first 5 days containing about 250 and for the remaining 5 days about 125 mg aureomycin/calf/day. The ten remaining calves received colostrum, and all were reared on whole milk for 3 weeks.

3. The feeding of crystalline aureomycin or Aurofac to colostrum-deprived calves increased significantly live-weight gain and reduced the incidence of scouring and of an abnormally high rectal temperature. There was no difference in performance between supplemented colostrum-deprived calves and colostrum-fed calves.

4. There was some indication that the antibiotic reduced the mortality of colostrum-deprived calves.

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Choice of Diet by Rats

4. The Choice of Purified Food Constituents during Growth, Pregnancy and Lactation

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Whether or not animals have the ability to select for themselves a diet capable of satisfying all their nutritional requirements is debatable. In many recorded experiments animals have been offered a variety of foodstuffs from which they could select their own diets, but the results have often been contradictory. For example, Evvard (1929) found that the food preferences of a pig varied with its degree of development and reflected in general terms the animal's physiological needs, but Braude (1948) concluded that it is essentially a matter of individual taste as to what ingredient of the diet is preferred by a pig. Pearl & Fairchild (1921) compared the egg production and body-weight gains of sixty chickens allowed free access to twelve common food materials with those of sixty birds fed on a standard poultry mixture. They concluded that chickens given freedom to choose the quantity and quality of their ration make a better physiological utilization of their ration than when kept under a system of controlled mass feeding, however excellent that system may theoretically be. Trials have been conducted to determine whether calves can be raised satisfactorily by allowing them choice of concentrates besides supplying milk and roughage (McCandlish, 1923*a*,*b*, 1924). These showed that calves and heifers, allowed free access to maize, oats, wheat bran, linseed meal and other protein supplements, will usually eat much more of the protein supplements than is required to balance their ration. Also, even if the animals choose freely from a mixture containing the correct proportion of protein supplements, after 2–4 months they will often eat an excess quantity