15

Mineralisation during Antler Growth in Red Deer

P. D. Muir, A. R. Sykes, and G. K. Barrell

Animal Sciences Group, Lincoln College, Canterbury, New Zealand

Abstract

Antler growth, mineralisation patterns, and calcium deposition rates were investigated. One antler was harvested from each of 3 red deer (*Cervus elaphus*) stags at 4, 6, 8, 10, 13, and 16 weeks after casting. The remaining antler was allowed to harden and was removed after commencement of velvet stripping. Antlers were sequentially sectioned from tip to base and analysed for ash and calcium contents.

Ash concentration was lowest in the growing antler tip with a band of rapid mineralisation occurring 5.0 – 7.5 cm below the tip. Ash deposition in the antler shaft accelerated 7 weeks prior to stripping, particularly in tip sections.

Mineralisation of the whole antler progressed relatively slowly from week 4 (ash:organic matter (A:R) 0.47) to week 13 (A:R, 0.83); thereafter bone mineralisation was rapid until hard antler removal at 23 ± 0.5 weeks (A:R, 1.73). Approximately 65% of total bone ash was laid down in the latter period, and an average rate of antler calcium deposition of 5.0 g/day was demonstrated during this time for growth of hard antlers weighing 3 kg.

Keywords: Cervus elaphus, *antlers, growth, mineralisation, ash, calcium*

Introduction

Antler growth has been described in detail by a number of workers (e.g. Wislocki 1942; Chapman 1975). Differentiating cartilaginous tissue in the antler tip is mineralised to form primary bone spongiosa (Banks 1974), and this in turn is replaced by compact and cancellous secondary spongiosa towards the antler base. Kay *et al* (1982) described a zone of mineralisation 2 – 4 cm below the tip of growing antlers in young red deer (*Cervus elaphus*). Brown *et al* (1978) demonstrated with radiography that antler development is associated with an increase in relative bone mass. Ash composition of hard antler appears to vary with nutritional status and possibly with the age of the animal (Hyvarinen *et al* 1977), but ash concentrations of calcium and phosphorus remain remarkably constant (Bernard 1963).

Antlers are formed rapidly over several weeks, so a marked increase in requirements for bone materials could be expected during the period of antler growth. However, rates of antler development and mineral requirements for antler growth have not been quantified.

This study was conducted to determine the pattern of antler growth and mineralisation and the rate of calcium decomposition. The initial trial design included an investigation of the role of nutrition on antler growth.

Materials and Methods

Eighteen red deer stags were individually penned and offered pelleted rations at the rate of 0.95 megajoules of metabolisable energy (MJME) per kilogram of metabolic bodyweight (i.e. body weight$^{0.75}$). This permitted an average liveweight gain of 327 ± 16.0 g/day over the period of antler growth. Diets were isocaloric (12.5 MJME/kg dry matter, DM) and based on wheat, peas, and linseed meal. A control diet (A) contained 130 and 7.6 g/kg DM of crude protein and calcium respectively. Two further diets (B and C) had either a high protein (formaldehyde-protected linseed meal) or a low calcium content with crude protein and calcium contents of 199 and 6.7, and 132 and 3.0 g/kg DM, respectively.

Animals were allocated hierarchically at random on records of past velvet antler weight and current liveweight to 3 nutritional groups. Within each group the 6 stags were allocated at random to 6 dates for removal of antler tissue. One antler was removed from 1 stag in each treatment group at 4, 6, 8, 10, 13, and 16 weeks after casting. Mean casting date was 13 September. The remaining antler was allowed to harden and was removed at commencement of stripping of velvet (mean: 24 February). Stags were lightly anaesthetised and antlers sawn above the antler/pedicle junction. Cut antlers were inverted immediately to prevent blood loss and frozen in polythene bags to prevent weight loss. Frozen antlers were later weighed and length measurements recorded around the external curvature from tip (distal) to base (proximal). Portions of antler below the abscission line but above the pedicle were accounted for in determining rates of antler elongation.

Each antler was sequentially sectioned from tip to base at 2.5 cm intervals over the first 10 cm and at 5 cm intervals thereafter. After measurement of volume by water displacement, antler sections including epidermal tissue or "velvet" were cut longitudinally into 2 – 3 cm sections and oven dried at 100°C for 48 hours for dry matter determination. Fat was extracted by twice boiling for 6 hours in petroleum ether and fat-free dry weight determined by re-drying. Samples were then dry-ashed at 550°C for 16 hours in a muffle furnace. Ground antler ash was extracted for 15 min into 2 N HCl at 60°C and calcium was determined by atomic absorption spectrophotometry.

The ratio of ash to organic matter (A:R ratio) provided an index of the degree of bone mineralisation in the antler. To provide estimates of growth and calcium deposition, antler length and ash present at the various stages of growth have been expressed in relation to the values obtained from the contralateral antler at commencement of stripping.

Results

Since no differences in hard antler weight or composition could be attributed to dietary treatment, results for the 3 nutritional groups were combined.

Growth of the antler

Antler growth, from casting to velvet stripping, occurred during a period of 23 ± 0.5 weeks. Growth, expressed as a percentage of final stripped antler length, was slow during the first 4 weeks after casting (Fig. 1). By this time the antler had attained 21% of its final length. After 4 weeks, growth accelerated so that by 16 weeks 95% of growth in length had been completed.

Mineralisation in the antler shaft

A gradient of ash deposition occurred down the shaft of the developing antler (Fig. 2 – for clarity antlers harvested at 6 and 10 weeks after casting have been omitted). Mean ash concentrations (± s.e.m.) were lowest in tip sections with little change between 4 weeks (1.2 ± 0.09 g ash/100 g dry weight) and 13 weeks (0.7 ± 0.35%). After 16 weeks of growth, ash content in the tip section had risen to 9.1 ± 3.17%. Within an antler, mineral deposition occurred most rapidly in the section 5.0 – 7.5 cm below the antler tip. Ash concentrations in this section remained constant from 4 weeks (37.7 ± 1.41%) to 16 weeks (36.6 ± 5.05%). Although mineralisation down the antler shaft was gradual, the process had accelerated by week 16. At this stage the base sections contained 61.4% ash which was 97% of the hard antler ash on a dry weight basis. In the period from 16 weeks of growth to stripping of velvet at 23 weeks, mineralisation occurred rapidly, particularly in the distal 20 cm of the antler.

Whole-antler mineralisation

Mineralisation of the whole antler progressed slowly from the time of first harvest at 4 weeks (A:R, 0.47 ± 0.013) until 13 weeks after casting (A:R, 0.83 ± 0.023). Rapid bone mineralisation then occurred from week 13 until the time of hard antler removal (week 23), when the A:R ratio was 1.73 ± 0.027.

Rates of antler ash deposition were determined by expressing the ash content of each harvested antler as a proportion of that in its paired antler which had been allowed to grow to completion. During the final 10 weeks of growth 65% of total antler ash was deposited.

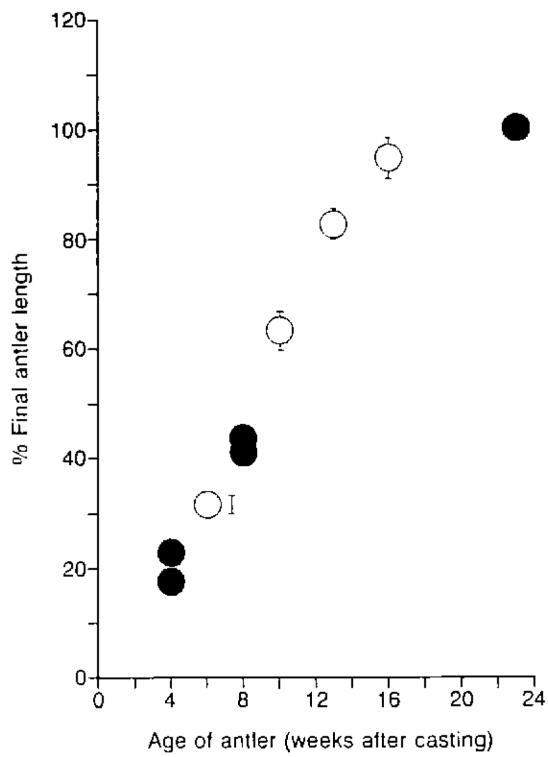

Fig. 1: Antler elongation in red deer stags. Antler length has been expressed as a percentage of the contralateral antler length at velvet stripping at 23 weeks, ●. ○ represents the mean of 3 animals; vertical bars indicate standard error of the mean. ● at 4 and 8 weeks represents individual points.

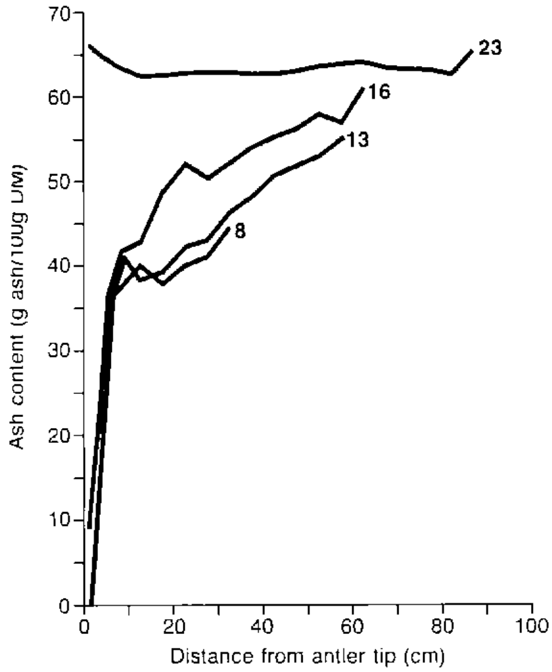

Fig. 2: Distribution of ash content within the shafts of antlers removed from red deer stags at 4 different stages of growth. Each line represents the mean of 3 stags, except that for hard antler (23 weeks) which incorporates data from 16 stags. Numbers refer to weeks after casting. The lines for 4 and 8 weeks were virtually coincident, so only week 8 data are shown.

Discussion

The findings of low ash concentrations in the antler tip and a zone of rapidly increasing ash content 5.0 – 7.5 cm below the tip confirm the observation of Kay *et al* (1982) that a discrete band of rapid mineralisation occurs behind the growing point of the antler. Tip sections were poorly mineralised while antlers were still undergoing rapid growth. An increase in ash concentration in tip sections and an acceleration in ash deposition in the antler shaft coincided with the slowing of growth in length at 16 weeks. Ash concentration in the zone of mineralisation appeared to remain constant over the antler growth period sampled. This band of mineralisation was less well defined in antlers harvested at 16 weeks. During the final few weeks of antler development the pattern of mineralisation changed with a rapid increase in ash deposition especially in the distal sections.

The tendency towards high ash concentrations in the tip of the hard antler may be due to a high ratio of compact to cancellous bone in this region. Ash contents of hard antlers in the present study (63.0%) were higher than others reported in the literature (51.7%, Kay *et al* 1982; and 55.3 – 59.0%, Hyvarinen *et al* 1977). This could be attributed to the fact that the stags used in this trial were mature and pen-fed and may support the hypothesis of Hyvarinen *et al* (1977) that hard antler composition is influenced by age and nutrition.

Mineralisation (A:R ratio) of the whole antler appeared to follow an inverse pattern to that of growth in antler length. Mineral deposition in organic matrix was slow during the phase of rapid growth; possibly slow mineralisation is necessary over this period to permit rapid growth. The subsequent spurt in mineralisation from 16 weeks coincided with the reduced rate of increase in antler length.

The daily requirement for antler calcium can be predicted from the rate of ash deposition, since calcium concentration in ash was constant (at $35.0 \pm 0.64\%$) throughout the antler growth period. Thus, a stag producing 3 kg of hard antler (DM 81%; ash 63% of DM) would deposit 1533 g ash containing 536 g calcium in approximately 23 weeks. During the latter 10 weeks 65% of antler ash (996 g) and calcium (348 g) would be deposited and antler calcium deposition would average 5.0 g/day over this period.

Acknowledgements

We are grateful to the Game Industry Association (N.Z.) for providing stags used in these studies. Pelleted rations were prepared and kindly donated by NRM Feeds Ltd, Hornby, Christchurch. Mr M. Keeley provided valuable assistance with animal feeding and handling and with laboratory analyses.

References

Banks W J 1974 The ossification process of the developing antler in the white-tailed deer *(Odocoileus virginianus)*. *Calcif. Tissue Res. 14:* 257 – 274.

Bernard R 1963 Specific gravity, ash, calcium and phosphorus content of antlers of Cervidae. *Le Naturaliste Canadien 90:* 310 – 322.

Brown R D, R L Cowan and L C Griel 1978 Correlation between antler and long bone relative bone mass and circulating androgens in white-tailed deer *(Odocoileus virginianus)*. *Amer. J. Vet. Res. 39:* 1053 – 1056.

Chapman D I 1975 Antlers — bones of contention. *Mamm. Rev. 5:* 121 – 172.

Hyvarinen H, R N B Kay and W J Hamilton 1977 Variation in the weight, specific gravity and composition of the antlers in red deer *(Cervus elaphus* L). *Brit. J. Nutr. 38:* 301 – 311.

Kay R N B, M Phillippo, J M Suttie and G Wenham 1982 The growth and mineralisation of antlers. *J. Physiol. 322:* 4P, abstract.

Wislocki G B 1942 Studies on the growth of deer antlers. *Amer. J. Anat. 71:* 371 – 415.