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Dietary management of hypercholesterolemia in a bachelor group of zoo-housed slender-tailed meerkats *Suricata suricatta*

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Abstract

Slender-tailed meerkats *Suricata suricatta* are commonly exhibited in zoos across the world. They are primarily insectivores and their wild diet is low in saturated fat and cholesterol. It has been recognised for many years that they are prone to hypercholesterolemia and this can lead to meningeal cholesterol granulomas. Cholesterol blood levels have been established in a free-living meerkat population to allow for comparison to captive populations. This article reports the results of blood cholesterol levels in 11 captive male meerkats fed a whole-prey diet. It was shown that, on this diet, all meerkats had hypercholesterolemia due to the high fat content of their diet. A new diet was introduced; eight months later the same meerkats exhibited a significant reduction in cholesterol levels. This shows the importance of regular health monitoring and diet review based on clinical findings in captive populations.

Background

Meerkats *Suricata suricatta* are small carnivores belonging to the Herpestidae (mongoose) family, and they are native to the Kalahari Desert in southern Africa. They are frequently exhibited across many worldwide zoological collections (Ramsay 2015).

In the wild they are primarily insectivorous; however, they also eat other small animals, plants and fungi (Doolan and Macdonald 1996; AZA Small Carnivore Tag 2011). This wild diet tends to be low in saturated fat and cholesterol compared to a captive diet typically based on mice, chicks or avian eggs (Chaber et al. 2008). A study comparing cholesterol levels in free-living and captive meerkats showed free-living meerkats to have a cholesterol level of 3.55-11.1 mmol/l (Allan et al. 2006a), much lower than captive meerkats in which a mean level of 15.8mmol/l has been found (Chaber et al. 2008). The same study showed higher cholesterol levels in captive meerkats fed a high proportion of vertebrates, and a lower cholesterol level if fed a high proportion of invertebrates. In avian embryos cholesterol ester forms up to 80% of total liver lipid (Speake et al. 2003) which could contribute to the higher cholesterol blood levels seen in captive meerkats fed on day old chicks.

Cholesterol is transported in blood within lipoprotein complexes. The concentration is influenced by increased or decreased production, increased or decreased utilisation and alterations in clearance (Stacy and Hollinger 2018). Cholesterol is present in all animal cells and is an important constituent of

various biological membranes, particularly myelinated structures in the brain and central nervous system (McDonald et al. 2002).

However, hypercholesterolemia is thought to play a significant role in meningeal cholesterol granulomas in meerkats (Sladky et al. 2000; Allan et al. 2006b). Cholesterol granulomas are not commonly reported in animals; however, meerkats seem to be susceptible. A paper published in 2000 described cholesterol granulomas in three meerkats at North Carolina Zoological Park (Sladky et al. 2000). The cause of these granulomas was never fully established but a possible cause was hypercholesterolemia which may predispose individuals to the development of cholesterol granulomas (Sladky et al. 2000). Hypercholesterolemia can be caused by many factors, one of which is diet (Sladky et al. 2000). A further case report published in 2006 described two further cases in UK captive meerkats (Allan et al. 2006b). The conclusion in this report was a recommendation to measure serum cholesterol as part of routine monitoring and to feed diets low in cholesterol (Allan et al. 2006b).

Twycross Zoo has held slender-tailed meerkats since 1983; since 2014 the zoo exhibits a single bachelor group. During the time meerkats have been held at Twycross Zoo, mild hypercholesterolemia has been seen in their routine health checks but no action was taken prior to this study due to lack of keeper buy in with diet changes.

The study group have 24-hour access to an indoor area measuring 7.84 m^2 and an outdoor area measuring 176 m^2. The indoor area has a couple of sleeping areas and a heat lamp. The outdoor area consists of deep sand along with multiple termite mounds and other climbing opportunities to allow for sentry duties. Their diet consisted of day-old chicks or mice, some fruit and vegetables and live insects which was offered in three separate meals throughout the day (detailed information is presented in Table 1).

In 2014-2016, a group of 11 male slender-tailed meerkats were anaesthetised over a 24-month period for routine preventative health checks. Prior to this, they were thought to be healthy, showing no signs of clinical disease. The meerkats were anaesthetised with isoflurane (Isoflo® 100% w/v inhalation vapour liquid, Zoetis, Surrey, UK) in oxygen delivered via a facemask. The animals were maintained on isoflurane. Throughout the anaesthetic heart rate, respiratory rate and body temperature were monitored. Ventro-dorsal and right lateral whole-body radiographs were taken which were unremarkable for all individuals. A blood sample was collected from the cranial vena cava from all individuals and sent to the laboratory for biochemistry and haematology.

Once all the meerkats had been health checked, the results were fully analysed and compared to reference ranges available. All the meerkats were identified to have high blood cholesterol levels (range 11.1-23.5mmol/l) compared to free-living meerkat ranges. Every individual was therefore exhibiting hypercholesterolemia based on the free-living ranges. All other blood parameters were normal for all meerkats and they were all classed as good body condition (range 4-6/9) and weight (adult range 1028-1100 g; subadult range 397-468 g).

Action

Following the results in 2016, the diet was reviewed and found to be high in fat, and especially cholesterol due to the daily access to chicks. A new diet was proposed aiming for lower saturated fat and cholesterol levels.

A significant reduction in serum cholesterol levels has been shown when feeding a diet based on commercial cat food compared to a mouse-based diet (Chaber et al. 2008). Since this study in 2008, pellet diets have been produced specifically for insectivores, which also provide a complete diet; therefore, these were incorporated in the new diet.

A meeting was held between the team leader of carnivores and the veterinary team and the new diet was discussed, to ensure the animal keeping team's support in this change. The details of the new diet can be found in Table 1, but in summary this included the introduction of a specific insectivore pellet, elimination of all fruit and an increase in the amount of vegetables to reduce sugar content, as well as a significant increase in live insects. The amount of animal protein was also drastically reduced from being supplied every day to once a week, primarily to reduce the amount of fat, and specifically cholesterol, due to the decreased feeding of day-old chicks.

A trial of the new diet was started in June 2016 to assess palatability. All of the meerkats ate the new diet with no issues; therefore, a transition diet was put into place. In August 2016, the group of meerkats were completely on the new diet. The group were still fed three times a day: the first and last feed of the day consisted of insectivore pellet and vegetables. The second feed of the day was a scatter feed of vegetables or live insects.

Table 1. Comparison of old and new diet. [1]Dietex International Ltd., Witham, Essex CM8 3TH.

	Old diet (2012-June 2016) per adult per day	New diet (July 2016 onwards) per adult per day
Fruit	45 g (apple, pear, banana, grapes)	0 g
Vegetable	10 g (carrot)	300 g (cucumber, green beans, pepper, mushroom, celery, carrot, aubergine, mange tout, courgette or tomato)
Live insects (locusts, crickets, mealworms)	35 g	200 g
Animal protein	1 mouse or 1 chick (de yolked)	1 mouse or de yolked chick ONCE a week
Pellet	0 g	250 g Mazuri® insectivore (E) FC diet 854201
Supplements	Mazuri ® Carnivore 825186 supplement[1] for whole prey dusted onto chicks	

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Following transition onto the new diet between April 2017 and May 2018, all 11 meerkats were re-anaesthetised using the same protocol described above. Radiographs and blood samples were taken as previously and the samples were sent to the same laboratory for analysis.

Consequences

The repeat biochemistry results showed a marked reduction in the cholesterol levels (Table 2). Cholesterol data were tested for normality using Kolmogorov-Smirnov test and were normally distributed. A paired-samples t-test was conducted, and there was a significant difference between cholesterol levels before (M=15.6, SD=3.94) and after (M=6.77, SD=1.53) diet change; t (9)=7.4485, P=0.001. All individual samples taken post-diet change also showed a cholesterol level well within the recommend cholesterol range of 3.55-11.1mmol/l (Allan et al. 2006a).

Since the blood samples were taken the group have remained on the new diet. One animal was euthanised in August 2017 due to age-related disease and the post mortem showed no evidence of cholesterol granuloma.

Since the meerkats have been on the new diet, no issues with compliance have occurred and they have all remained clinically healthy with a good body condition score and weight. There have also been no incidences of aggression-related trauma.

This study illustrates the importance of constant diet review based on clinical information obtained during health checks. These meerkats were not showing any signs of clinical disease; however, continual elevated serum cholesterol levels could lead to a meningeal cholesterol granuloma along with many other potential disease processes. Cholesterol granulomas tend to mostly be found incidentally at post-mortem examination; however, they are also reported to cause neurological signs, such as hind-limb ataxia when they compress vital areas of brain parenchyma (Chaber et al. 2008).

A species-specific diet, and its regular review, is an important part of captive wild animal care, to ensure the best possible health and welfare is maintained. The ongoing improvement of animal diets based on improved understanding of natural history of the species, animal nutrition, as well as clinical and behavioural information, can prevent previously underdiagnosed health issues. This paper showed that certain conditions can be reversed solely through providing appropriate nutrition, but also emphasises the importance of collaboration between animal keepers, nutritionists and veterinarians.

Table 2. All individual meerkat cholesterol levels pre and post diet change.

Individual animal ID (ARKS ID)	Cholesterol level pre diet change (mmol/l) (2014-2016)	Cholesterol level post diet change (mmol/l) (2017-2018)
4869	11.9	7.1
5599	11.1	6.5
6404	14.7	9.7
6563	17.2	7.7
6568	13.0	6.5
6951	17.4	6.2
6977	18.3	6.6
6978	17.5	6.2
6979	11.3	3.6
7034	Not done	7.5
7041	23.5	7.6
Mean+/-SD	15.6+/-3.94	6.77+/-1.53

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