

## STUDIES ON THE HOST RANGE OF *EIMERIA CHINCHILLAE* DE VOS & VAN DER WESTHUIZEN, 1968

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### ABSTRACT

A. J. DE VOS. Studies on the host range of *Eimeria chinchillae* De Vos & Van der Westhuizen, 1968. *Onderstepoort J. vet. Res.* 37 (1), 29-36 (1970).

A case of an *Eimeria* sp. with a lack of host specificity is reported. *Eimeria chinchillae* De Vos & Van der Westhuizen, 1968, originally described from the chinchilla, was successfully transmitted to seven other rodents, viz. *Praomys (Mastomys) natalensis* (Smith, 1847), *Rhabdomys pumilio* (Sparrman, 1784), white mice, *Otomys irroratus* (Brants, 1827), white rats, *Mystromys albicaudatus* (Smith, 1834) and *Arvicantbis niloticus* (Desmarest, 1822). Of these, the first four species were more susceptible to infection than the last three and showed symptoms of coccidiosis and even mortality after administration of 400,000 sporulated oocysts. Susceptible chinchillas were infected with oocysts obtained from *P. (M.) natalensis*, *R. pumilio*, white mice and white rats.

In the chinchilla the endogenous stages were found only in the caecum but in *P. (M.) natalensis*, *R. pumilio* and white mice small numbers were also found in the small intestine. The prepatent period of the infection in chinchillas was 8 or 9 days as compared to 7 or 8 days in the new hosts. The oocysts discharged by these animals were indistinguishable from those passed by chinchillas.

### INTRODUCTION

Clinical coccidiosis of chinchillas has been encountered in three widely separated localities in Southern Africa in recent years. Stampa & Hobson (1966) found the infection on several farms in the Grahamstown district of the Cape Province but did not describe or identify the organism involved. In 1967 serious losses occurred on two farms in the Pretoria district of the Transvaal. Oocysts obtained from affected animals on both farms were later described as a new species, *Eimeria chinchillae* De Vos & Van der Westhuizen, 1968. In the same year, workers in Matabeland, Rhodesia, encountered an outbreak of coccidiosis in chinchillas (Lawrence, Veterinary Research Laboratory, Salisbury, personal communication, 1968). Several farms were involved. The species responsible was thought to be identical to *E. chinchillae*. The burrow system was the principle method used for the housing of chinchillas on these farms.

No survey has yet been made of the incidence of coccidiosis on chinchilla farms in other parts of Southern Africa but it is likely that the infection is more widespread than is known at present. In other parts of the world coccidiosis of chinchillas is apparently unknown, even though they are bred extensively in some countries.

An attempt was therefore made to find a reason for the high incidence of the infection in Southern Africa. In the experiments recorded below the susceptibility of various potential hosts, including eight rodent species commonly found in or near farm buildings in South Africa, was investigated.

### MATERIALS AND METHODS

#### 1. Experimental animals

The animals used represented seven genera of wild rodents, five genera of domestic rodents, one lagomorph and an insectivore.

*Praomys (Mastomys) natalensis* (Smith, 1847). One group of ten and a second group of five.

*Rhabdomys pumilio* (Sparrman, 1784). Two groups of five each.

White mice. One group of ten and a second group of five.

White rats. One group of ten and a second group of five.

*Otomys irroratus* (Brants, 1827). One group of three.  
*Mystromys albicaudatus* (Smith, 1834). One group of five.  
*Arvicantbis niloticus* (Desmarest, 1822). One group of five.

*Saccostomus campestris* (Peters, 1846). One individual.

*Tatera leucogaster* (Peters, 1852). Three animals; one received oocysts from the first batch (see below) and the other two oocysts from the second batch.

Golden hamsters. Two groups of five individuals each.

Guinea pigs. Two groups of five each.

Rabbits. Two groups of five each.

*Crocidura* sp. One unidentified shrew.

Chinchillas. A total of six individuals was used for passaging *E. chinchillae* and for reinfection experiments (see below).

The *O. irroratus*, *S. campestris* and *Crocidura* sp. were trapped in various regions of the Transvaal two to three months prior to the start of this experiment. The chinchillas were obtained from a local chinchilla farm where all the animals were kept in cages with wire mesh floors from birth and where regular examination of faeces specimens over a 12 months period failed to reveal any evidence of coccidia. The other animals were all bred at this Institute. Of these only *P. (M.) natalensis*, *R. pumilio* and *T. leucogaster* were born and reared apparently free from coccidia.

With the exception of the rabbits, all the groups of animals were housed in cages with wire mesh floors for the duration of the experiment. Faeces samples were collected from every group and examined for oocysts after flotation with a saturated salt solution. These examinations were done on alternate days for 21 days prior to inoculation of the animals. After inoculation (see below) examinations were carried out daily for 16 days and thereafter on alternate days until the 30th day.

#### 2. Production of oocysts of *E. chinchillae*

One batch of fresh *E. chinchillae* oocysts was obtained by infecting a susceptible chinchilla with approximately 20,000 sporulated oocysts of a strain which had been serially propagated in chinchillas since its isolation from a naturally infected case. The animal died on the ninth day after infection. Oocysts were collected by rinsing the intestines in tap water, cleaned by repeated sedimentation and thereafter concentrated by flotation as mentioned above. These were then sporulated at 28°C in a 2 per cent potassium dichromate solution. After

72 hours the dichromate was removed by repeated sedimentation of the oocysts in tap water. The percentage sporulation was determined and the oocysts counted with the aid of a Fuchs Rosenthal haemocytometer.

The second batch of oocysts was obtained by initially passing *E. chinchillae* in chinchillas, thereafter twice in *P. (M.) natalensis* and finally once again in a chinchilla. The oocysts were collected from the latter and sporulated as described above. Fifty oocysts and 25 sporocysts were measured with the aid of an ocular micrometer for comparison with the original description of *E. chinchillae*.

### 3. Method of infection

The animals were infected with either 100,000 or 400,000 sporulated oocysts each as outlined in Table 1. The oocysts were deposited in the pharynx or initial portion of the oesophagus by means of a slightly curved 101.6 mm 18 gauge needle with a blunt end. The only exception was the shrew which was given an undetermined number of oocysts inoculated into a small piece of meat.

Animals that died during the 30 days of observation after inoculation were autopsied as soon as possible after death. The contents of the large and small intestines were examined for the presence of oocysts by using the flotation method. Smears were made of intestinal scrapings from different parts of the gut, stained with Giemsa and examined microscopically for developmental stages of coccidia. Tissues of the small and large intestines were collected from one *P. (M.) natalensis* and one *R. pumilio* and preserved in 10 per cent formalin. Sections approximately 4 microns thick were then prepared for histological examination in the routine manner using paraffin embedding, a sliding microtome and the haematoxylin and eosin staining technique.

Oocysts recovered from the faeces of 11 groups, representing seven rodent genera, were concentrated and allowed to sporulate. Fifty sporulated oocysts and 25 sporocysts were measured from each sample (Table 2).

### 4. Reinfection of chinchillas

To provide further proof that oocysts, recovered from some of the above-mentioned rodents, were those of *E. chinchillae*, they were given to four susceptible chinchillas. Two received 10,000 sporulated oocysts each from *P. (M.) natalensis* and *R. pumilio* respectively. The other two each received 5,000 sporulated oocysts from white mice and white rats respectively. Faeces collected daily from each chinchilla was examined for the presence of oocysts. One of the chinchillas died and was autopsied as above.

## RESULTS

Most of the experimental animals passed unsporulated *E. chinchillae* oocysts as well as empty oocysts during the first 24 to 48 hours after inoculation (Table 1). These oocysts obviously originated from the inoculum and positive results on these two days were therefore ignored in the results given below.

### *P. (M.) natalensis*

All faeces samples collected from the two groups of *P. (M.) natalensis* were negative for oocysts prior to infection. The animals in the first group, however, passed oocysts indistinguishable from those of *E. chinchillae* in their faeces from the 7th to the 26th day after infection (Table 1). They were particularly numerous from the 9th to the 12th day. Identical oocysts were also present in the faeces of the second group from the 8th

to the 22nd day, being plentiful from the 9th to the 13th day.

Clinical signs of disease such as diarrhoea, anorexia and inappetence were first noticed in the animals of the first group on the 5th day and persisted until the 10th day. One animal died on the 6th day. At autopsy the wall of the large intestine was hyperaemic and oedematous but the small intestine appeared to be unaffected. The large intestine contained a small amount of semi-fluid faeces. No oocysts could be found in the contents of the entire intestinal tract, but in stained preparations made from scrapings of the walls of the caecum and colon large numbers of merozoites, developing macrogametes and immature oocysts were seen. In similar preparations made from scrapings of different parts of the wall of the small intestine a small number of macrogametes and merozoites was observed.

Another animal died on the 8th day after infection. The same lesions were seen macroscopically as in the previous animal. Microscopically, however, large numbers of unsporulated oocysts were observed in the caecal contents and a smaller number in the small intestine. In stained smears made from scrapings of the walls of the caecum and colon a large number of oocysts, macrogametes, biflagellar microgametes and a small number of merozoites were identified. Only a small number of macrogametes was present in similar scrapings made from the wall of the small intestine. The eight remaining animals recovered rapidly and appeared clinically healthy from the 14th day.

The animals in the second group showed clinical signs of coccidiosis resembling those seen in the first group from the 5th to the 13th day after infection. One animal died six days after receiving the oocysts. The macroscopical and microscopical lesions observed at autopsy resembled those found in the animal of the first group that died on the same day (see above).

A second animal died 24 hours later while the remainder showed signs of severe depression, diarrhoea and dehydration. An autopsy performed immediately after death revealed that the wall of the large intestine was hyperaemic and somewhat oedematous while the contents were reduced in volume and semifluid in consistency. The small intestine appeared to be normal. Small numbers of unsporulated oocysts were present in the contents of both the large and small intestines. Large numbers of developing macrogametes, immature oocysts, biflagellar microgametes and merozoites were, however, seen in stained smears made from scrapings of the walls of the caecum and colon. A small number of macrogametes was also found in a similar preparation made from the jejunal wall. Histological sections revealed that in the walls of the caecum and colon the glandular epithelium harboured large numbers of macrogametes in different stages of development as well as oocysts. A smaller number of microgametocytes and schizonts was also present. The infection was almost entirely limited to the glandular epithelium with very few parasites present in the epithelial cells lining the lumen of the caecum and colon. In a similar section of the jejunum a small number of crypts was found to be heavily infected while others were completely free from parasites. The stages present were macrogametes and a few microgametocytes. No parasites were observed in the epithelial lining of the villi.

The remaining animals recovered and appeared healthy from the 15th day onwards.

*Oocyst morphology:* Morphologically the oocysts obtained from the two groups of *P. (M.) natalensis* were indis-



TABLE 2 *Measurements of oocysts and sporocysts of E. chinchillae*

Name of host	Group	Oocysts				Sporocysts				
		Length ( $\mu$ )	Width ( $\mu$ )	Average ( $\mu$ )	Length-Width Ratio	Average	Length Width ( $\mu$ )	Average ( $\mu$ )	Length-Width Ratio	Average
<i>P. (M.) natalensis</i>	1	15-23	13-20	18.6	1.0-1.3	1.13	9-13	11.1	1.5-2.2	1.72
	2	14-23	13-20	19.3	1.0-1.3	1.12	9-13	11.3	1.5-2.0	1.76
<i>R. pumilio</i>	1	13-23	13-19	18.8	1.0-1.3	1.13	8-13	10.6	1.6-2.0	1.75
	2	15-22	13-19	18.7	1.0-1.4	1.14	9-12	10.6	1.6-2.0	1.82
White mice	1	15-23	14-20	18.9	1.0-1.3	1.11	10-13	11.5	1.4-2.0	1.74
	2	15-21	13-19	18.2	1.0-1.3	1.12	10-12	10.8	1.6-2.2	1.79
White rats	1	16-22	13-19	19.4	1.0-1.3	1.13	9-13	10.6	1.5-2.0	1.72
	2	14-23	13-21	18.8	1.0-1.3	1.11	8-12	10.4	1.5-2.0	1.73
<i>O. irroratus</i>	1	15-22	13-19	18.0	1.0-1.3	1.12	9-12	10.8	1.5-2.3	1.79
<i>M. albicaudatus</i>	1	15-21	13-19	18.4	1.0-1.2	1.11	9-12	10.8	1.5-2.2	1.80
<i>A. niloticus</i>	1	16-22	14-19	19.6	1.0-1.4	1.14	9-13	10.9	1.6-2.3	1.77
<i>C. laniger</i> *	1	15-23	13-19	18.4	1.0-1.2	1.10	9-13	10.6	1.6-2.0	1.78
<i>C. laniger</i> **	—	13-22	11-18	17.5	1.0-1.3	1.13	8-12	10.0	1.4-1.9	1.60

\*Chinchilla used for obtaining the second batch of oocysts

\*\*Naturally infected chinchillas discharged oocysts described as *Eimeria chinchillae* by De Vos & Van der Westhuizen (1968)

tinguishable from each other. They were ovoidal, subspherical or spherical in shape, the ovoidal forms frequently being slightly asymmetrical and somewhat flattened at one or both poles. The wall was smooth, light brown in colour and apparently consisted of a single layer only. It was approximately 1 micron thick and sometimes slightly thinner at one or both poles in nonspherical oocysts. No definite micropyle was visible. There was no oocystic residual body but a single polar granule, usually situated between the sporocysts, was observed in some of the oocysts.

The sporocysts were ellipsoidal or ovoidal with a small spherical or slightly flattened Stieda body. A compact sporocystic residual body, consisting of fine granules and frequently spherical or somewhat rectangular in shape, was present, usually near the centre of the sporocyst. The sporozoites were elongated and contained one or two small indistinct refractile globules.

The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts from each group are given in Table 2.

*Sporulation time:* The oocysts obtained from both groups of *P. (M.) natalensis* were fully sporulated after 72 hours at 28°C.

*Reinfection of chinchilla:* The chinchilla given 10,000 oocysts from the first group of *P. (M.) natalensis* remained healthy until the 6th day when signs of listlessness and anorexia were first noticed. There was a concurrent reduction in the faecal output with the faeces pellets becoming smaller and more irregular in shape. Typical *E. chinchillae* oocysts were noticed for the first time on the 8th day when the faeces were blood-tinged and of a tarry consistency. The animal died 24 hours later. Macroscopically the walls of the caecum and colon as well as the mesentery were congested and somewhat oedematous. The contents of the caecum and initial portion of the colon were blood-tinged and had an increased consistency while the rest of the large intestine was relatively empty. Oocysts were extremely plentiful in the contents of the large intestine. In stained smears made from scrapings of the wall of the caecum large numbers of oocysts and macrogametes as well as a smaller number of merozoites were observed. No developmental stages or oocysts were found in the wall and contents of the small intestine.

#### *R. pumilio*

No oocysts were found in the faeces samples obtained from the two groups of *R. pumilio* prior to infection. However, the animals in the first group passed oocysts indistinguishable from those of *E. chinchillae* from the 7th to the 26th day after infection. They were particularly plentiful from the 10th to the 12th day. Identical oocysts were also discharged by the second group from the 8th to the 10th day after infection when the last surviving animal died (Table 1).

Symptoms such as diarrhoea, anorexia, and severe listlessness were shown by the animals in the first group from the 6th to the 13th day. All the animals recovered, however, and appeared healthy again from the 15th day onwards. The animals in the second group showed practically the same symptoms as those mentioned above but were more severely affected. One animal died on the 8th day and a post mortem examination was performed immediately. The wall of the large intestine was hyperaemic and oedematous while the contents of the entire tract were reduced in volume and very fluid in consistency. The small intestine appeared to be normal. Large numbers of merozoites and developing macrogametes

could be identified in stained smears made from scrapings of the walls of the caecum and colon but only a few macrogametes were found in a smear of the wall of the jejunum. Oocysts were scarce in the intestinal contents. Large numbers of the endogenous stages were observed in the glandular epithelium in a histological section of the wall of the caecum. The stages consisted mainly of developing macrogametes and immature oocysts as well as a smaller number of developing microgametocytes and schizonts. In a section of the jejunal wall only one infected crypt was found which contained developing macrogametes and microgametocytes.

Three of the remaining four animals were found dead the following (9th) day. Autopsies revealed the same macroscopic lesions as in the above-mentioned animal. The endogenous stages seen in scrapings of the caecum and jejunum were also very similar but a large number of oocysts was found in the contents of the large intestines.

The remaining animal died 24 hours later after showing symptoms of muscular weakness, dehydration and a severe diarrhoea. The mesenteric blood vessels were congested and the entire length of the intestinal tract was hyperaemic, with petechial haemorrhages visible in the caecal mucosa. Except for a small amount of semi-fluid ingesta in the caecum which contained large numbers of oocysts, the intestinal tract was virtually empty. Only a small number of oocysts was present in the small intestine. A stained smear of the caecal mucosa revealed large numbers of oocysts whereas only a few were found in a similar preparation from the jejunum.

Oocysts obtained from the two groups of *R. pumilio* were structurally indistinguishable from those passed by *P. (M.) natalensis* and will therefore not be described. The sporulation time was also the same. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts from each group are given in Table 2.

*Reinfection of a chinchilla:* Faeces examinations of the chinchilla infected with 10,000 oocysts from the first group of *R. pumilio* remained negative for oocysts until the 8th day after infection. From the 9th day to the 16th day typical *E. chinchillae* oocysts were passed. They were particularly numerous on the 10th and 11th day. The only indications of disease were present from the 7th to the 10th day when the animal was listless and slightly constipated.

#### *White mice*

Faeces examinations of both groups were negative for oocysts prior to infection. Oocysts virtually indistinguishable from those of *E. chinchillae* were, however, present in the faeces of the first group from the 7th to the 15th day after infection. They were abundant only on the 10th day. Identical oocysts were passed by the second group from the 8th to the 14th day. They were particularly plentiful on the 9th and 10th day.

None of the animals in the first group showed any signs of ill health but those in the second group were listless, had a decreased appetite and passed semifluid faeces from the 6th to the 10th day when one of them died. At autopsy the wall of the large intestine, and, to a lesser extent, that of the small intestine, was found to be hyperaemic. The contents of the large intestine were semifluid, reduced in volume and contained a moderate number of unsporulated oocysts. Very few oocysts were present in the contents of the small intestine. In a stained smear made from a scraping of the caecal wall a large number of macrogametes and developing oocysts as well as a few merozoites were observed.

A small number of macrogametes was seen in a similar smear from the wall of the jejunum.

Morphologically the oocysts resembled those obtained from *P. (M.) natalensis* in all respects except for the sporocystic residuum which, instead of being a compact body in all the oocysts, consisted of granules dispersed throughout the sporocyst in a small number of them. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts from each group are given in Table 2. The sporulation time of these oocysts was the same as for oocysts from *P. (M.) natalensis*.

*Reinfection of a chinchilla:* The faeces of the chinchilla infected with 5,000 sporulated oocysts from the first group of white mice remained negative for oocysts for 7 days. From the 8th to the 15th day typical *E. chinchillae* oocysts were present in the faeces. The animal appeared to be slightly listless on the 9th day but soon recovered.

#### White rats

Unsporulated oocysts indistinguishable from those of *E. chinchillae* were discharged in small numbers from the 8th to the 13th day after inoculation by the first group and from the 8th to the 12th day by the second group. At no other time before or after inoculation were oocysts of any species found in the faeces. No signs of disease were noticed in any of the animals.

The oocysts obtained from the two groups of white rats were morphologically indistinguishable from those passed by *P. (M.) natalensis* and are therefore not described. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts from each group are given in Table 2. The sporulation time of oocysts from both groups was the same as for oocysts from *P. (M.) natalensis*.

*Reinfection of a chinchilla:* The chinchilla received approximately 5,000 sporulated oocysts obtained from the first group of white rats. Faeces samples remained negative for oocysts until the 8th day but typical *E. chinchillae* oocysts were present from the 9th to the 16th day although no clinical signs of coccidiosis were noticed.

#### *O. irroratus*

No oocysts were found in faeces samples from this group prior to infection. However, oocysts virtually indistinguishable from those of *E. chinchillae* were present in the faeces from the 8th to the 23rd day after inoculation. They were particularly plentiful from the 9th to the 14th day. No clinical signs of disease were seen in any of the animals except for a softening of the faeces from the 6th to the 12th day.

Morphologically the oocysts recovered from *O. irroratus* were indistinguishable from those discharged by the white mice and therefore again differed slightly from those from *P. (M.) natalensis*. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts are given in Table 2. The sporulation time of the oocysts was the same as for oocysts from *P. (M.) natalensis*.

#### *M. albicaudatus*

Faeces examinations conducted prior to inoculation were all negative for oocysts. Oocysts indistinguishable from those of *E. chinchillae* were, however, recovered from the faeces of this group from the 8th to the 14th day after infection, being abundant on the 9th day only. The animals failed to show any signs of ill health.

The oocysts obtained from *M. albicaudatus* were morphologically indistinguishable from those recovered

from *P. (M.) natalensis*. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts are given in Table 2. The sporulation time of the oocysts was the same as for those from *P. (M.) natalensis*.

#### *A. niloticus*

Oocysts very similar to those of *E. chinchillae* were discharged from the 8th to the 14th day after infection but were numerous on the 9th day only. No oocysts were seen before or after this period.

Although no clinical signs of disease were observed, one animal died on the 8th and another on the 14th day. They were severely mutilated by the other animals in the cage and in both the rectum was the only remaining part of the gut. A small number of oocysts was present in the faeces of the first animal while a few developing macrogametes, young oocysts and merozoites were seen in a stained smear made from a scraping of the wall of the rectum. No developmental stages or oocysts could be found in the second animal. The cause of their deaths could not be determined but the absence of symptoms of enteritis in any of the animals in this group makes it unlikely that coccidiosis was responsible.

The oocysts obtained from *A. niloticus* were structurally identical to those obtained from white mice and *O. irroratus*, hence also differing only slightly from those from *P. (M.) natalensis*. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts are given in Table 2. The sporulation time of oocysts obtained from *A. niloticus* was the same as for all the others.

#### *S. campestris*

Oocysts were present in the faeces of this animal in very small numbers from the 8th to the 13th day after inoculation. At no other time were oocysts found and no signs of ill health were noticed. The unsporulated oocysts were ovoidal or subspherical in shape with a smooth light brown wall but due to the small number no attempt was made either to sporulate or measure them. Therefore, even though these unsporulated oocysts resembled those of *E. chinchillae* very closely they could not be identified with absolute certainty.

#### *T. leucogaster*

Faeces examinations of the animal that received 100,000 oocysts were negative throughout. The same applied to the two animals inoculated with 400,000 oocysts, except for the 8th and 10th day after inoculation when objects resembling damaged oocysts were found. These objects could, however, not definitely be identified as oocysts.

#### Golden hamsters

All faeces examinations conducted on the two groups were negative for coccidial oocysts.

#### Guinea pigs

The animals in the first group passed oocysts which were later identified as *Eimeria caviae* Sheather, 1924 during the first 16 days of observation prior to inoculation. No oocysts were, however, observed in the faeces after inoculation. The faeces of the second group remained negative throughout.

#### Rabbits

*Eimeria perforans* (Leuckart, 1879) and some of the larger *Eimeria* spp. of rabbits were passed by both groups for the duration of the experiment. Oocysts of *E. chinchillae*, amongst others distinguishable from *E. perforans* by the persistent absence of an oocystic residual body, were, however, never observed.

*Crocidura* sp.

All faeces examinations were negative for oocysts.

*Chinchillas*

The chinchilla used for the production of the first batch of oocysts died on the 9th day after infection after showing signs of depression, anorexia and constipation from the 6th day. An autopsy showed that the caecum was severely impacted. The walls of the caecum and initial part of the colon were markedly congested and oedematous while the small intestine appeared to be unaffected. A very large number of oocysts was present in the contents of the large intestine as well as in scrapings of the wall together with developing macrogametes. No oocysts or developmental stages were, however, found in the lumen or wall of the small intestine. The chinchilla used for the production of the second batch of oocysts also died on the 9th day and an autopsy revealed essentially the same lesions as in the first animal.

The oocysts from the second batch were morphologically indistinguishable from those passed by *P. (M.) natalensis*. The ranges, averages and length-width ratios of 50 oocysts and 25 sporocysts from this batch are given in Table 2. The oocysts were fully sporulated after 72 hours.

The measurements of the oocysts described originally are also given in Table 2 for comparative purposes.

## DISCUSSION

The morphological features of the oocysts obtained from the various rodents that were susceptible tally well with the original description of *E. chinchillae*. A few minor differences were, however, observed. As can be seen in Table 2 there are small variations between the measurements of the oocysts and sporocysts from the different groups of animals. These differences are, however, no greater than those between the oocysts described originally and the second batch of *E. chinchillae* oocysts. Although not observed in the oocysts described originally, a polar granule was seen in some of the oocysts from all the groups of animals, including the oocysts of the second batch. Pellerdy (1965), however, does not consider the presence or absence of a polar granule a significant feature in the identification of *Eimeria* spp. The sporocystic residual body, which is a compact body near the centre of the sporocysts in oocysts from chinchillas, consisted of granules scattered between the sporozoites in some of the oocysts from white mice, *O. irroratus* and *A. niloticus*. The reason for this is unknown.

Because these differences are so slight no significance was attached to them. On the basis of the morphology of the oocysts they passed, it can therefore be concluded that *P. (M.) natalensis*, *R. pumilio*, white mice, white rats, *O. irroratus*, *M. albicaudatus*, *A. niloticus* and probably *S. campestris* were susceptible to infection with *E. chinchillae*. This was substantiated by the successful infection of chinchillas with oocysts obtained from *P. (M.) natalensis*, *R. pumilio*, white mice and white rats and the recovery of typical *E. chinchillae* oocysts from them.

The endogenous development in *P. (M.) natalensis*, *R. pumilio* and white mice showed two notable differences when compared with that in the chinchilla. Firstly, limited development occurred in the small intestine whereas no endogenous stages or oocysts were observed in the small intestine of the chinchillas that were autopsied. Secondly, the prepatent period of the infection in these rodents was 7 to 8 days compared with 8 or 9 days in the chinchillas. Clinically the chinchillas were constipated whereas the *P. (M.) natalensis*, *R. pumilio* and

white mice that showed noticeable signs of disease had a diarrhoea.

This euryxenous behaviour of *E. chinchillae* is unusual since *Eimeria* spp. are generally considered to be strictly host specific (Andrews, 1927; Yakimoff & Iwanoff-Gobzem, 1931; Pellérdy, 1956, 1965 and others). Levine & Ivens (1965) refer to 47 attempts to transmit *Eimeria* spp. from one rodent genus to another, none of which were successful. More recently, however, Todd & Hammond (1968a, b) reported that *Eimeria callospermophili* Henry, 1932 and *Eimeria larimerensis* Vetterling, 1964 were transmissible between species of two related rodent genera *viz.* *Spermophilus* Cuvier, 1825 and *Cynomys* Rafinesque, 1817.

In animals other than rodents exceptions to the rule also occur but usually only where the animals involved are closely related. Hanson, Levine & Ivens (1957) found several *Eimeria* spp. occurring in different species of the genera *Branta* Scopoli, 1769 and *Anser*, Brisson, 1760. Farr (1953, according to Hanson *et al.*, 1957) also succeeded in transmitting some of these coccidia from the one host genus to the other. Tyzzer (1929) transmitted *Eimeria dispersa* Tyzzer, 1929, originally described from quail, from this host to turkeys while Hawkins (1950) found it to be a common parasite of turkeys and Moore & Brown (1952) succeeded in transmitting it from turkeys to quail. Norton (1967) found *Eimeria colchici* Norton, 1967 of the English covert pheasant to be transmissible to turkeys and was also successful in maintaining the parasite in them, albeit with some difficulty. A number of *Eimeria* spp. have also been transmitted between species of *Oryctolagus* Lilljeborg, 1874 and *Sylvilagus* Gray, 1867 (Jankiewicz, 1941; Pellérdy, 1954; Carvalho, 1943, according to Pellérdy, 1956). Other reports exist describing the successful transmission of *Eimeria* spp. from one host genus to another but most of these have been disproved by other workers.

The presence of mainly unsporulated and empty oocysts during the first 24 to 48 hours after inoculation in the faeces of some of the groups in which no sign of infection was detectable, indicates that excystation took place. This corresponds with the work done by Lotze & Leek (1963) who found that sheep coccidia excysted when given to hamsters and rats. Marquard (1966) reported that oocysts of *Eimeria nieschulzi* Dieben, 1924, when administered to laboratory mice, excysted and infection resulted which, however, did not progress beyond the level of the first generation schizont. It is therefore possible that animals such as the hamsters and guinea pigs, which did not discharge any oocysts of *E. chinchillae*, may have become infected but that the infection did not progress very far. It is also theoretically possible that the developmental cycle may proceed even further, to early gametogony for instance, if the host is slightly more suitable for the parasite. This may have happened in the case of the two *T. leucogaster* which passed objects resembling damaged oocysts in small numbers on 2 days.

The *S. campestris* passed a very small number of apparently live oocysts resembling those of *E. chinchillae*. This seems to indicate that infection took place but that the greater majority of the organisms failed to complete their life cycle. Slightly larger numbers of *E. chinchillae* oocysts were recovered from the faeces of the white rats, *M. albicaudatus* and *A. niloticus*, but even these were so few that it seems doubtful if the parasite could be maintained in them. None of these animals showed any signs of disease.

The four remaining hosts, viz. *P. (M.) natalensis*, *R. pumilio*, *O. irroratus* and white mice, were noticeably more susceptible. They passed larger numbers of oocysts over longer periods and, when given 400,000 oocysts each, showed symptoms of coccidiosis and even mortality.

A number of *Eimeria* spp. has already been described from the above-mentioned rodents now shown to be susceptible to *E. chinchillae*. Data on the morphology, prepatent period and endogenous development of *E. chinchillae* were compared with the information available on these *Eimeria* spp. to ascertain whether *E. chinchillae* had not been described previously. The information on some of them is, however, very scanty, making it difficult to exclude them with certainty.

At least eight *Eimeria* spp. are known to occur in the house mouse. Of these, *Eimeria falciformis* (Eimer, 1870) is the commonest. There are no striking morphological differences between the oocysts of this species and those of *E. chinchillae* but the prepatent period of the former is 4 to 5 days, which is at least 48 hours shorter than that of *E. chinchillae*. Nöller (1920) was unable to infect rats with *E. falciformis* whereas they are susceptible to *E. chinchillae*. *Eimeria ferrisi* Levine & Ivens, 1965 and *Eimeria hansonorum* Levine & Ivens, 1965 can both be eliminated on the morphology of their oocysts. The former has no sporocystic residual body and oocysts of the latter are subspherical in shape and the Stieda body broad and thick. Five *Eimeria* spp. described from the house mouse in Russia can also be eliminated on the morphology of their oocysts. *Eimeria keilini* Yakimoff & Gousseff, 1938 and *Eimeria bindlei* Yakimoff & Gousseff, 1938 are both larger than *E. chinchillae*; *Eimeria musculi* Yakimoff & Gousseff, 1938 are spherical and *Eimeria schueffneri* Yakimoff & Gousseff, 1938 cylindrical in shape; *Eimeria krijgsmanni* Yakimoff & Gousseff, 1938 is more elongated, having an oocystic length-width ratio average of 1.37 compared with the 1.12 of *E. chinchillae* in white mice. In the latter five species the presence of a sporocystic residual body is uncertain.

At least six *Eimeria* spp. are known to occur in the rat (Levine & Ivens, 1965). Because of the low degree of susceptibility of rats to infection by *E. chinchillae* none of these species were, however, considered even though the oocysts of some of them resemble those of *E. chinchillae* to some extent.

An unnamed *Eimeria* sp. was described by Fantham (1926) from *P. (M.) natalensis* (syn. *Mus coucha*). The oocysts were oval in shape and measured 16 to 21 by 15 to 16 microns as compared to the 14 to 23 by 13 to 20 microns of *E. chinchillae* in *P. (M.) natalensis*. In the absence of further information this species cannot be readily distinguished from *E. chinchillae* on oocyst morphology alone. However, it was found mainly in the ileum and jejunum, thereby differing from *E. chinchillae* which occurs mainly in the caecum and colon of *P. (M.) natalensis* and to a much lesser extent in the small intestine.

As far as is known no *Eimeria* spp. have been described from *R. pumilio* and *O. irroratus*, the other rodents which are very susceptible to *E. chinchillae* infection.

If one considers the apparent confinement of *E. chinchillae* to Southern Africa as well as its lack of host specificity, it seems quite possible that it was present before the introduction of chinchillas. Lawrence (Veterinary Research Laboratory, Salisbury, personal communication, 1968) believes that the coccidium involved in the outbreak in Matabeleland is probably a species

with a wide host range occurring naturally in wild rodents. He bases his theory on the following: The outbreak coincided with an explosive increase in the numbers of wild rodents in the area, and a *P. (M.) natalensis* trapped in a chinchilla house was found to harbour oocysts identical to those passed by the affected chinchillas. One way to prove this theory would be to find the parasite in the above-mentioned or other hosts in natural surroundings unassociated with chinchillas. Investigations are being carried out along these lines.

#### SUMMARY

A case of an *Eimeria* sp. with a lack of host specificity is reported. *E. chinchillae*, originally described from the chinchilla, was successfully transmitted to seven other rodents, viz. *P. (M.) natalensis*, *R. pumilio*, white mice, *O. irroratus*, white rats, *M. albicaudatus* and *A. niloticus*. *S. campestris* is probably slightly susceptible while hamsters, guinea pigs, rabbits, *T. leucogaster* and a shrew were refractory to infection. Susceptible chinchillas were infected with oocysts obtained from *P. (M.) natalensis*, *R. pumilio*, white mice and white rats.

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#### REFERENCES

- ANDREWS, J. M., 1927. Host-parasite specificity in the coccidia of mammals. *J. Parasit.*, 13, 183-194.
- DE VOS, A. J. & VAN DER WESTHUIZEN, I. B., 1968. The occurrence of *Eimeria chinchillae* n. sp. (Eimeriidae) in *Chinchilla laniger* (Molina, 1782) in South Africa. *Jl S. Afr. vet. med. Ass.*, 39, 81-82.
- FANTHAM, H. B., 1926. Some parasitic protozoa found in South Africa. IX. *S. Afr. J. Sci.*, 23, 560-570.
- HANSON, H. C., LEVINE, N. D. & IVENS, V., 1957. Coccidia (Protozoa: Eimeriidae) of North American wild geese and swans. *Can. J. Zool.*, 35, 715-733.
- HAWKINS, P. A., 1950. Coccidiosis of the turkey. *J. Parasit.*, 36, Suppl. Dec. 1950, 42.
- JANKIEWICZ, H. A., 1941. Transmission of the liver coccidium, *Eimeria stiedae*, from the domestic to the cottontail rabbit. *J. Parasit.*, 27, Suppl. Dec. 1941, 28.
- LEVINE, N. D. & IVENS, V., 1965. The coccidian parasites (Protozoa, Sporozoa) of rodents. Urbana: University of Illinois Press.
- LOTZE, J. C. & LEEK, R. G., 1963. Excystation of coccidian parasites in various animals. *J. Parasit.*, 49, Suppl. Oct. 1963, 32.
- MARQUARDT, W. C., 1966. Attempted transmission of the rat coccidium *Eimeria nieschulzi* to mice. *J. Parasit.*, 52, 691-694.
- MOORE, E. N. & BROWN, J. A., 1952. A new coccidium of turkeys, *Eimeria innocua* n. sp. (Protozoa: Eimeriidae). *Cornell Vet.*, 42, 395-402.
- NÖLLER, W., 1920. Kleine Beobachtungen an parasitischen Protozoen. *Arch. Protistenk.*, 41, 169-189.
- NORTON, C. C., 1967. *Eimeria colchici* sp. nov. (Protozoa: Eimeriidae), the cause of cecal coccidiosis in English covert pheasants. *J. Protozool.*, 14, 772-781.
- PELLERDY, L. P., 1954. Beiträge zur Spezifität der Coccidien des Hasen und Kaninchens. *Acta Vet. hung.*, 4, 481-487.
- PELLERDY, L. P., 1956. On the status of the *Eimeria* species of *Lepus europaeus* and related species. *Acta Vet. hung.*, 6, 451-467.
- PELLERDY, L. P., 1965. Coccidia and coccidiosis. Budapest: Akadémiai Kiadó.
- STAMPA, S. & HOBSON, N. K., 1966. Control of some internal parasites of chinchillas. *J. Am. vet. med. Ass.*, 149, 929-932.
- TODD, K. S. & HAMMOND, D. M., 1968a. Life cycle and host specificity of *Eimeria callospermophilus* Henry, 1932 from the Uinta ground squirrel *Spermophilus armatus*. *J. Protozool.*, 15, 1-8.
- TODD, K. S. & HAMMOND, D. M., 1968b. Life cycle and host specificity of *Eimeria larimerensis* Vetterling, 1964, from the Uinta ground squirrel *Spermophilus armatus*. *J. Protozool.*, 15, 268-275.
- TYZZER, E. E., 1929. Coccidiosis in gallinaceous birds. *Am. J. Hyg.*, 10, 269-383.
- YAKIMOFF, W. L. & IWANOFF-GOBZEN, P. S., 1931. Zur Frage der Infektion der Tiere mit heterogenen Kokzidien. *Zentbl. Bakt. ParasitKde. Abt. I. Orig.*, 122, 319-328.