Gastro-Intestinal Parasite Control in Small Ruminants in Fiji – A Review of the Literature

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1.0 Introduction.

This review is prepared to provide information on completed research in Fiji.

This review attempts to bring together the results of research into the area of Gastro-Intestinal Parasite (GIP) control in Fiji. Where the results of the research have not been published in the scientific literature, an attempt has been made to provide as much information as possible on the research trials. If the research has been previously published in the scientific literature only a brief description has been provided.

It is hoped that the information provided will be useful in the design of best bet parasite control options, and that through the sharing of the results of the research that costly duplication of research activities can be avoided.

2.0 Gastro-Intestinal Parasites and the Small Ruminant Industries of the Fiji

Gastro-intestinal parasites (GIPS) have been a constraint to small ruminant production in Fiji ever since small ruminants were introduced into the country in the 1850's. It is of interest that much of the early literature on livestock production in Fiji does not mention GIPs as a constraint to goat production. This is thought to be due to the fact that goats tended to be reared in small herds under close supervision. However, early attempts at sheep farming carried out in Fiji were modeled on the extensive systems of Australia and New Zealand with the aim of producing wool for export and mutton for local consumption. Under this management system GIPs were found to be a major constraint to the establishment of a local sheep industry.

3.0 Importance of Gastro-Intestinal Parasites

Despeissis (1922) in a paper in the Agricultural Circular entitled "Sheep in Fiji" stated that:

> "Of all pests worms are probably the most serious".

This view is supported by Turbett (1929) who states that:

> "Worm infestation probably causes a greater loss than is recognised as, where the inspection of flocks and pastures is not carried out regularly sheep which die are not missed until the counting of the flock at the general muster……"

By 1940 (Turbett, 1940) it was apparent that of all reasons given for the failure of the sheep industry in Fiji to prosper:

> "…. infestation with worm parasites was the most important."

This view is still current today and it is generally acknowledged that GIPs are the major animal health problem limiting small ruminant production in Fiji (Walkden-Brown and Banks, 1986; Manueli, 1996) with *Haemonchus contortus* and *Trichostrongylus colubriformis* being the most common. Effects of GIPs on small ruminant production include stock mortalities, reduced animal productivity and increased production costs due to the need to carry out preventative treatments. The parasites of small ruminants in Fiji are presented in the table below

Species	Site	Frequency of Observation[A]
Haemonchus contortus	Abomasum	+++
Trichostrongylus axei	Abomasum	+++
Trichostrongylus colubriformis	Small Intestine	+++
Strongyloides papillosus	Small Intestine	+++
Moniezia expansa	Small Intestine	+++
Oesophagostomum columbianum	Large Intestine	++
Trichuris spp.	Large Intestine	+
H. similis	Abomasum	*
H placei	Abomasum	*
Mecistocirrus digitatus	Abomasum	*

[A] +, Occasional; ++, Common; +++, Very Common; * Present in cattle and potentially infectious to goats and sheep but not yet identified in these species. Source: Walkden-Brown and Banks (1986).

The development of anthelmintic resistance in a number of small ruminant herds and flocks in Fiji (Banks, Singh and Pratap, 1987), has made the importance of the development of sustainable parasite control methods imperative for the survival of small ruminant industries in Fiji.

A recent participatory survey of 34 progressive small ruminant farmers carried out in Fiji (Manueli unpublished data) indicated that GIPS remain a major constraint to the expansion of the small ruminant industries in Fiji. During the survey the farmers identified 3 dimensions of the GIP problem that needed to be addressed. These were

- The availability of anthelmintics.
- The cost of anthelmintics.
- The effect of the worms on production.

These areas will now form the basis for GIP research and extension initiatives by the Division of Animal Health and Production Division.

4.0 Early Research into GIP Epidemiology and Control

The first documented report of research into GIP control in Fiji is that of Baker (1970). This report documents five years of research work carried out from 1965-1969 on the newly established Government Sheep Farm at Nawaicoba. Trials into gastro-intestinal parasitism carried out during this period include a comparison of locally available anthelmintics and the use of a rotational grazing system.

The comparison of anthelmitics Phenothiazine, Thiobendazole and Minitic was carried out by comparing the effects of dosing on the subsequent growth rates of yearling sheep transferred to the Animal Quarantine Station on the wet side of the island. The results did not show any great increase in lamb liveweight gains following treatment with any specified drug. Neither was there any retardation in weight gain in animals in the period before the next anthelmintic treatment. However, no information is available on the total worm burdens or faecal egg counts (FECs) of animals in the trial though it is reported that larvae of all of the normal species of bowel worms were cultured and that eggs of *Dicrocoelium dendriticum* were seen in one faeces sample. The results of the trial indicated that GIPS were not a major problem with yearling stock in the wet zone.

Research into the development of a rotational grazing system was also carried out during this period. Unfortunately there is little available information on the design of the trials and no parasitologcal data is presented in the report.

The results of the research indicated that the adoption of a system of grazing paddocks for 4 days followed by a 28 day spell was effective for the control of parasites in adult stock, and that only 2 – 3 drenches a year are necessary to maintain health.

At the conclusion of the research programme the following recommendations on parasite control were made for farmers:

- Rotationally graze all stock as far as it is economically possible to build the fences
- Drench adult stock as necessary and definitely once before the start of the wet season, once during the wet season and once again after the wet season
- Drench growing stock fortnightly during the wet season and monthly during the dry season
- Alternate anthelmintics used for successive drenches

Singh, MacIntyre and Mua (1972) compared the use of suppressive fortnightly anthelmintic treatment as recommended by Baker (1970) for growing stock with a 30 day rotational grazing system using 5 paddocks. The trial used four groups of animals set stocked undrenched (SU) set stock drenched (SD), rotationally grazed undrenched (RU) and rotationally grazed drenched (RD) and was carried out over a period of 9 months. The mean liveweights if the RD and SD groups were found to be higher at the completion of the trial than those of the SU and RU groups. Faecal Egg Counts (FECs) of all groups were carried out at 4 weekly intervals. FECs of the SU and RU groups were higher than those of the RD and SD groups at all stages of the trial, and eggs were recovered from the faeces of animals in SU and RU groups more frequently than in the SD and RD groups. It was necessary to drench a number of the sheep in the undrenched groups three or four times over the period of the trial to prevent deaths. On the basis of these results Singh et. al. (1972) concluded that helminth control was absolutely necessary for sheep rearing in Fiji, that it would be feasible to drench animals less frequently than fortnightly and that rotation with a 4 weekly resting period was useless.

With the initiation of a series of ACIAR funded collaborative research programmes between the Ministry of Agriculture (Fiji) and the CSIRO of Australia in 1984 there was an increase in the amount of parasitology research carried out in Fiji. The series of 4 projects carried out from 1984 covered a wide range of topics from parasite epidemiology, genetic resistance to parasites, and the use of medicated feed blocks and the effects of improved nutrition on the ability to resist parasitic infestation.

ACIAR PN8418: The Epidemiology and Control of Gastrointestinal Nematodes of Small Ruminants in the Pacific Islands.

ACIAR PN8913: Ecological and Host-Genetic Control of Internal Parasites of Small Ruminants in the Pacific Islands.

ACIAR PN8523: Self Medication of Ruminants in Tethered Husbandry Systems.

ACIAR PN9132: Nutritional and Chemotherapeutic Strategies for Sustainable Control of Gastrointestinal Parasites of Ruminants.

5.0 ACIAR PN8418: The Epidemiology and Control of Gastrointestinal Nematodes of Small Ruminants in the Pacific Islands.

5.1 Survey for Anthelmintic Resistance.

A total of 24 herds/flocks were surveyed for anthelmintic resistance. Management practices varied from tethering (4 farms), uncontrolled grazing (4) and fenced commercial farms. A random selection of 40 goats or sheep on each farm were used to evaluate the effects of anthelmintic treatment on pre-treatment FECs.

Ivermectin was the only drug to which no parasite resistance was found with 54% of the of the fenced commercial and unfenced farms carrying strains of parasites resistant to either Fenbendazole, Levamisole or a combination of both Levamisole and Fenbendazole (Banks, Singh and Pratap, 1987).

5.2 Seasonal Fluctuations of Larvae on Pasture

The research trial investigated the survival of *H. contortus* and *T. colubriformis* on pasture (Banks, Singh, Barger, Pratap and Le Jambre, 1990). The research was carried out at two sites (wet zone and dry zone) to determine the seasonal pattern of egg hatching and larval survival on pasture. Each month a separate pasture plot at each site was contaminated with 2 million eggs in 4 weekly applications in the faeces of naturally infected goats with known proportions of *H. contortus* and *T. colubriformis* eggs. Pasture plots were then sampled at regular intervals and the infective larvae identified and counted.

The results of the trials showed that infective larvae numbers on pasture were highest 7 days after the last contamination with eggs. The results also showed considerable seasonal variation in the survival of larvae on pastures. In the wet zone larval survival on pasture was shorter in the wet season (5 – 9 weeks) than the dry season (13-17 weeks).

Larval survival on pasture on the dry zone plots was found to be much more variable. *T. colubriformis* larvae were found on pasture in all months except the two driest months of the year (August and September). *H. contortus* larval survival on pasture appeared to be more sporadic in nature possibly in response to changes in available moisture.

5.3 The Natural History of Trichostrongylidosis in Small Ruminants

The experiment investigated seasonal patterns of worm burdens and the effects of physiological status in grazing goats in the wet and dry zones of Fiji over a 12 month period. Groups of 20 does were set stocked on paddocks in the dry (5 does/acre) and wet (10 does/acre) zones of Fiji and drenched at 6 and 4 weekly intervals respectively to maintain health. Every 2 months, 4 young worm free tracer animals were introduced to herds for 2 months and then slaughtered. In May and June worm free dry (4) and lactating (4) does were introduced into the herds for 2 months and also slaughtered.

H. contortus and *T .colubriformis* were the dominant parasite species though *O. coulumbianum* and *T. ovis* were also found on occasion. Tracers became infected throughout the year though worm burdens were higher in the wet zone. Mean worm counts varied considerably from month to month at both sites and no reliable pattern of infection was detected, though it appeared that *H. contortus* and *T. colubriformis* burdens were highest during the cool months (July/August) in the dry zone. Worm counts of mature dry does appeared to be similar to those of young growing animals indicating that there was little development of age resistance. Differences in worm counts between lactating and dry does were small which was indicative of an absence of immunity. There was no evidence of arrested development in *H. contortus* indicating that development to adult stages occurred throughout the year (ACIAR, 1994)

<u>5.4 Testing Potential Control Measures – Phase 1</u>

Trials were carried out in the wet and dry zones to compare three treatment regimes. Normal (NORM) control measures of 4 weekly (wet zone) and 6 weekly (dry zone) drenching in set stocked goats. A 2 paddock rotation (RG) in which animals grazed a paddock for period (4 weeks Wet Zone, 6 weeks. Dry Zone) before being drenched and moved to the second paddock while the first paddock was spelled for an equivalent period of time (4 weeks wet zone and 6 weeks dry zone). A strategically drenched group (SD) that received 6 fortnightly drenches of Ivermectin with a dose of Closantel being given with the last dose of Ivermectin.

In the wet zone, FECs and larval cultures showed no differences between the RG and NORM treatments, larval cultures indicated that *H. contortus* and *T. colubriformis* were present. FECs of animals in the SD were low (never falling to zero) during the drenching period, and increased as soon as drenching had ceased necessitating the termination of the SD treatment 7 months later.

In the dry zone both the NORM and RG treatments had low FECs over the duration of the trial, this may have been due to low levels of pasture contamination as a result of the drought prior to the start of the experiment. There were no differences between either NORM and RG treatments in FECs, though live weight gains were slightly lower in the RG group (ACIAR, 1988).

5.5 Sustained Release Capsule for Worm Control in Goats

2 groups of 10 does were grazed on pastures naturally infected with *H. contortus* and *T. colubriformis.* 5 does in one group received ewe strength Albendazole capsules containing 3.85 g. of Albendazole (ET) and five were maintained as controls (EC). 5 does in the second group received lamb strength capsules containing 2.1 g of Albendazole (LT) and 5 does were maintained as controls (LC). The capsules were designed to release the anthelmintic over a period of 3 months. 48 hours after capsules were inserted all does drenched with a double dose of Ivermectin (400ug/kg) to remove adult worms.

The use of both lamb and ewe Albendazole capsules appeared to delay the establishment of patent infections by 2 weeks in comparison to controls, however, after 6 weeks the FECs of treated animals were equal to or greater than those control animals. The experiment was terminated after 8 weeks as the capsules were clearly unsuitable for use in goats (ACIAR, 1988).

5.6 Sustained Release Capsule for Worm Control in Sheep.

40 ewe hoggets naturally infected with *H. contortus* and *T. colubriformis* were drenched with a Ivermectin and allocated to one of 2 paddocks. One group of 20 ewes received ewe strength Albendazole capsules containing 3.83 g of Albendazole (ET). The other group acted as a control and was drenched every 8 weeks.

The Albendazole capsules totally suppressed the production of parasite eggs in the faeces of treated animals for a period of 120 days after the capsules were given. This suppression occurred in spite of the fact that capsules used were “90 day” capsules (ACIAR, 1990).

5.7 Transmission and Identification of *Mecistocirrus digitatus.*

Mecistocirrus digitatus had previously been identified in cattle in Fiji but not in goats. Eggs were recovered from female worms recovered from the abomasum cattle at slaughter and incubated or 8 days in a sterile culture medium. Infective larvae were recovered and used to infect 2 goats (200 larvae/goat).

The *M. digitatus* larvae exhibited only a low ability to establish in goats (ACIAR, 1990).

5.8 Nightyard Trial

60 mature does were drenched with a double dose of Ivermectin (400 ug/kg) at the beginning of the dry season and allocated to one of two treatment groups night yarding (N) or shedding (S) at night. The does grazed the same pastures but separated at night when does were either locked in a shed (S) or nightyard (N).

Does in the both treatments had similar worm burden, despite the fact that infective larvae numbers were much higher in the night yard than on pastures (ACIAR, 1988).

5.9 Effect of Season on Egg Hatching and Appearance of Larvae on Pasture.

Investigations were carried out into the development of GIP eggs and larvae on pasture. Pasture plots were contaminated with known numbers of parasite eggs in the faecal pellets of naturally infected does. Recovery of eggs and larvae from faecal pellets on pasture at 12 hour intervals was carried out at 4 periods (July, October, January and April).

By 72 hours after the commencement of infection 97% of eggs had developed to the first larval stage, with the first third stage larvae (L_3) appearing by 96 hours after contamination. Development to the L_3 appeared to occur more rapidly in January and April (96 hrs.) than in July and October (144 and 108 hours respectively) (ACIAR, 1990a)

5.10 Development of a Simulation Model of Parasites on Pasture.

Data collected from the epidemiological studies was used to develop a simulation model of parasites on pasture.

The development of the simulation model was then continued in an ensuing project ACIAR 8913. (ACIAR, 1988).

5.11 Heritability Pilot Study

A pilot study was carried out estimate the heritability of FEC in goats. Blood and faecal samples were taken from 129 3-4 month old kids sired by 6 bucks on a government goat station six weeks after they had been drenched with Ivermectin.

Significant effects of sire were seen on FEC, Hb, but not PCV. The heritability of FEC was estimated at 0.45. Investigations into the heritability of FEC were continued in ACIAR Project 8913 (ACIAR,1988).

5.12 Testing Potential Control Measures – Phase 2

Trials were carried out in the wet and dry zones to compare three treatment regimes. Normal (NORM) control measures of 4 weekly (wet zone) and 6 weekly (dry zone) drenching in set stocked goats. A 4 day, 8 paddock rotation (RRG) in which animals grazed a paddock for period 4 days which was then rested for 28 days. Drenching of individual animals was done when their individual FECs exceeded 1,000 epg. A strategically drenched group (SD) that received 6 fortnightly drenches of Ivermectin with a dose of Closantel being given with the last dose of Ivermectin.

In the wet zone FECs of NORM animals exceeded 1,000 epg 3 and 5 times respectively in the two replicates. In the dry zone animals in the NORM replicates required 10 and 7 drenches respectively. FECs of SD animals remained low until 25 weeks after the start of the trial (13 wks after the last Closantel dose), they then rose to levels similar to those in the NORM group. Animals in the RRG group required less frequent drenching than the NORM animals with replicates in the dry zone requiring 4 and 6 treatments, replicates in the wet zone, required 2 and Nil treatments respectively (ACIAR, 1990a).

<u>5.13 Age Resistance to Internal Parasites of Sheep</u>

20 4-Month old weaner lambs, 20 dry ewes and 20 lactating ewes were drenched with Ivermectin and grazed together on a 15 Ha. Paddock naturally infected with *H. contortus* and *T. colubriformis*. 10 dry ewes, 10 wet ewes, 10 dry ewes and 10 weaners were slaughtered after 2 months for worm counts. After slaughter 10 additional weaners were added to the group (lactating ewes had since dried of) leaving the group composition as 20 dry ewes and 20 weaner and FECs monitored.

At slaughter total worm counts for weaners differed significantly from those of dry ewes. FECs of weaners gradually decreased over time. At the termination of the experiment at weaner FECs had not yet fallen to the same levels as those of the ewes. By this time weaners were 14 months old indicating that age resistance had not yet developed (ACIAR, 1990a).

5.14 Minimal Drenching Programme for Sheep

The entire sheep flock at the Nawaicoba Station was converted to a minimal drenching programme. This involved drenching lactating ewes 3 times during lactation, drenching lambs and hoggets monthly and drenching dry ewes demonstrating signs of infection. At the completion of one year only 19 of the 600 ewes had required anthelmintic treatment over and above the treatments allocated to lactating ewes (ACIAR, 1990a).

6.0 ACIAR Project 8523 Self Medication of Ruminants in Tethered Husbandry Systems.

A number of experiments were carried out in both goats and sheep over the duration of the project, which investigated the use of urea molasses blocks as a delivery mechanism for Fenbendazole in small ruminants. As resistance to Fenbendazole had already been detected on a number of goat farms in Fiji, the research programme hoped to increase the efficacy of the Fenbendazole by delivering it in a feed block. This was seen as a potential method of maintaining high blood levels of Fenbendazole metabolites to increase its effectiveness against GIPs that had already developed some levels of resistance to the drug.

6.1 Research in Goats

6.1.1 Fenbendazole Dose Rate Trial in Goats at Sigatoka, Fiji (K21/E5)

The initial trial carried out during the programme was aimed at determining appropriate daily Fenbendazole (FBZ) dose rates to control the GIPs in goats as a simulation of the delivery of FBZ using a medicated block. The trial was carried out using dry adult does (mean liveweight 35 kg) which were divided into four groups of 5, 5, 5 and 4 animals and treated daily with doses of 0, 0.75, 1.5 or 5 mg/kg liveweight of FBZ respectively for a period of 6 weeks. FECs were monitored weekly group larval cultures carried out to determine the species composition. The results indicated that at the dose rate of 3.0

mg/kg FBZ was able to reduce FECs and the production of viable larvae to zero (ACIAR, 1990b)

On the basis of the dose rate trial Urea Molasses Blocks were formulated and FBZ powder incorporated at a rate of 0.75 g/kg of block. The blocks were then used in field trials in goats and sheep to test their efficacy.

6.1.2 Field Trial of Fenbendazole Medicated Blocks in Goats at Sigatoka, Fiji (K21/E6)

An experiment in goats was carried out over a period of 36 weeks and involved comparisons between three groups of 20 animals each. Group 1 was given unrestricted access to FBZ medicated Urea Molasses Blocks (FBZ-UMB). Group 2 was given unrestricted access to unmedicated urea molasses blocks (UMB). Group 3 was managed under normal station management (NORM) which included supplementation with 250 g/hd/day of a 50:50 coconut meal, mill mix ration. Individual animals whose FECs exceeded 1000 eggs per gram of faeces (epg) were drenched to maintain health.

Results indicated that the FBZ-UMB was efficacious in controlling FECs, animals in the FBZ-UMB group required only 1.9 treatments per animal to maintain health as compared to the UMB (7.25) and NORM (7.35) groups. Animals in the FBZ-UMB and NORM groups exhibited similar liveweight gains over the period of the trial which were both significantly higher than those of the UMB group. In the case of the NORM group this is thought to an effect of the nutritional supplementation, which was sufficient to compensate for the losses in liveweight seen in the UMB treatment group. Analysis of plasma Fenbendazole levels in the FBZ-UMB varied between individual animals, this was indicative of variations in block intakes (ACIAR, 1991).

6.1.3 Alternate Strategies for the Use of Medicated Blocks in Goats (K21/E14)

60 yearling does from the previous experiment (K21/E6) were dosed with Ivermectin and allocated to one of three treatment groups (2 replicates/treatment), FBZ-UMBAUR, FBZ1-UMB2 and FBZ1-UMB3. FBZ-UMBUR had unrestricted access to a FBZ-UMB, FBZ1-UMB2 had access to a FBZ-UMB block for a period of 1 week, followed by a UMB for 2 weeks. FBZ1-UMB3 had access to FBZ-UMB for a period of 1 week followed by a UMB for 3 weeks. Individual animals were drenched when their FECs exceeded 1,000 epg.

FBZ-UMBUR animals had lower FECs than other animals on most occasions. Numbers of animals requiring drenching over the 22 weeks of the trial were 12, 36 and 26 respectively. Average body weight gains for the period were 6.3 kg, 5.0 kg, and 4.5 kg respectively for the FBZ-UMBUR, FBZ1-MB2 and FBZ1-UMB3 treatments respectively. Average medicated block intakes were 4.0 g/hd/day, 31.9 g/hd/day, and 13.4 g/hd/day respectively for the FBZ-UMBUR, FBZ1-MB2 and FBZ1-UMB3 treatments respectively. Low consumption of FBZ-UMB in the FBZ-UMB treatment early in the trial resulted in elevated FECs (ACIAR, 1992).

6.1.4 Alternate Strategies for the Use of Medicated Blocks in goats (K21/E14b)

The experiment was similar in design to the previous experiment (K21/E14a), though a fourth group managed as per normal station management (4-6 weekly drenching and daily supplementation 150 g/hd/day of a 50:50 Coconut meal: Mill mix mixture) was included (NORM). Does used for the experiment were approximately 10 months of age at the start of the trial. Individual animals whose FEC exceeded 1,000 epg were drenched to maintain health.

FBZ-UMBUR, FBZ1-MB2 and FBZ1-UMB3 treatments had lower FECs than the NORM treatment throughout the trial. Drenching of animals was done on 30, 24, and 26 occasions for the FBZ-UMBUR, FBZ1-MB2 and FBZ1-UMB3 treatments as compared to 81 for the NORM treatment. *H. contortus* and *T. colubriformis* were dominated larval cultures. Body weight gains were 3.0 kg, 3.1 kg, 3.6 kg and 6.6 kg respectively for the FBZ-UMBUR, FBZ1-MB2, FBZ1-UMB3 and NORM treatments (ACIAR, 1992).

6.1.5 The Use of Medicated Blocks in Periparturient Goats (K21/E17)

64 pregnant does were divided into 2 even groups and allocated to separate7 Ha. Pasture plots. Does were expected to kid in the last week of June, the experiment began mid-may. One group FBZ-UMB were given access to a UMB until one month before expected kidding date, when they were drenched with Ivermectin and their blocks were changed to FBZ-UMBs, no animals were drenched unless they showed clinical signs of infection. The second group was subjected to normal station management including regular treatments (NORM).

FECs of the FBZ-UMB group were lower than those of the NORM group on all occasions, they also required fewer drenches than the NORM group (25 and 78 resoectively). *H.contortus* and *T. colubriformis* dominated larval cultures. Average doe liveweights and kid birthweights similar in the two treatments. Weaning weights of the NORM group were higher as a result of their access to coconut meal supplements from birth, kids of the FBZ-UMB group were not supplemented over the period of the trial (ACIAR, 1992).

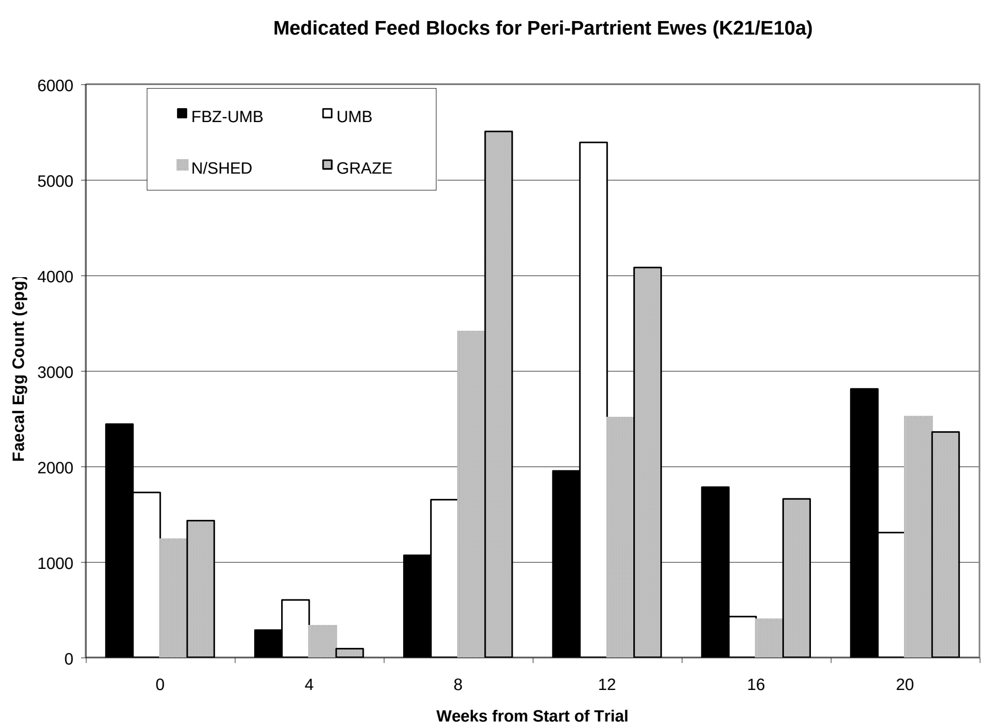
6.2 Research in Sheep

Similar, field trials were carried out in sheep to investigate the efficacy of the FBZ-UMB in peri-parturient ewes.

6.2.1 Field Trial of Medicated Feed Supplement Blocks in Peri-parturient Sheep (K21/E10a)

60 pregnant female sheep were allocated to three groups FBZ-UMB, FBZ and no blocks (CON). All animals were grazed during the day and housed at night when the FBZ-UMB and UMB groups were given access to their blocks. A fourth group was later selected from the general herd for comparison, these animals were not housed at all but subjected to normal station management (NORM). The trial was run for a period of 18 weeks.

Animals in the FBZ-UMB group tended to have lower FECs throughout the trial (see figure below). The UMB group had lower egg counts than the CON and NORM, though it was necessary to drench all UMB animals in week 12 to prevent mortalities.



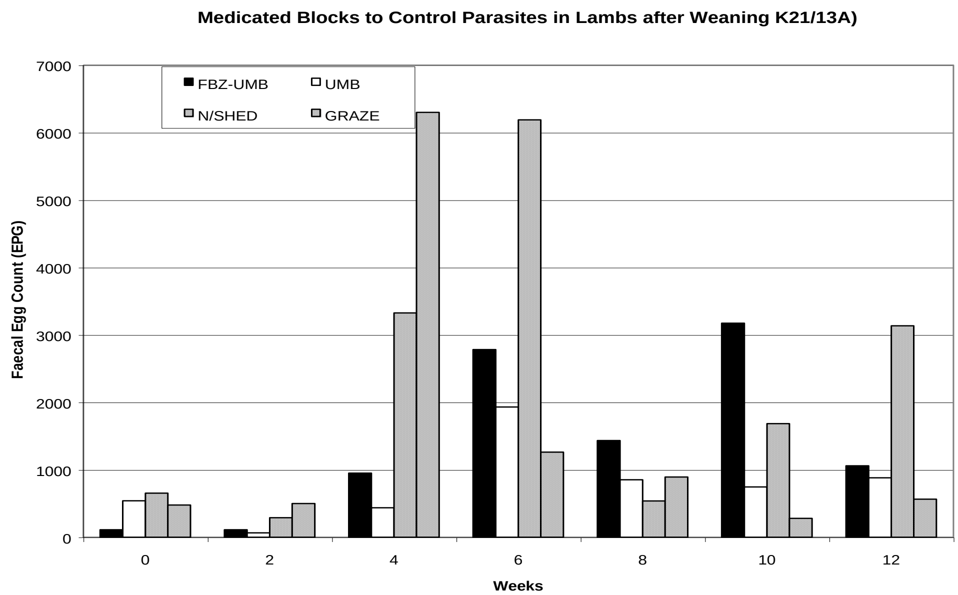
Block intakes in the UMB group over the duration of the trial were much higher than in the FBZ-UMB groups. There was no significant effect of treatment on ewe body weights, but there was a major difference in the weight of lambs at weaning. Lambs of the UMB group were 5 kg heavier than those of the FBZ-UMB and CON groups. The weaning weights of the lambs of the NORM group were a further 2 kg behind the FBZ-UMB and CON groups. There appeared to be a benefit from improved nutrition in both FECs and weaning weights in the UMB treatment. Low block consumption appears to have limited the effectiveness of the FBZ-UMB in this trial.

At weaning the ewes were removed from the trial and the lambs retained in their treatment groups for experimentation (ACIAR, 1991).

6.2.2 The Use of Medicated Blocks to Control Nematode Parasites in Lambs after Weaning (K21/E13a)

Lambs weaned from ewes in the previous experiment (K21/E10a) remained in their respective treatment groups (FBZ-UMB, UMB, CON and NORM), where group sizes were not even additional lambs of similar weights and ages were added. Animals not receiving blocks were supplemented with a 50.50 coconut meal mill mix ration as per normal station management.

Animals in the NORM treatment exhibited very high FECs and needed to be drenched on a monthly basis (see figure below).

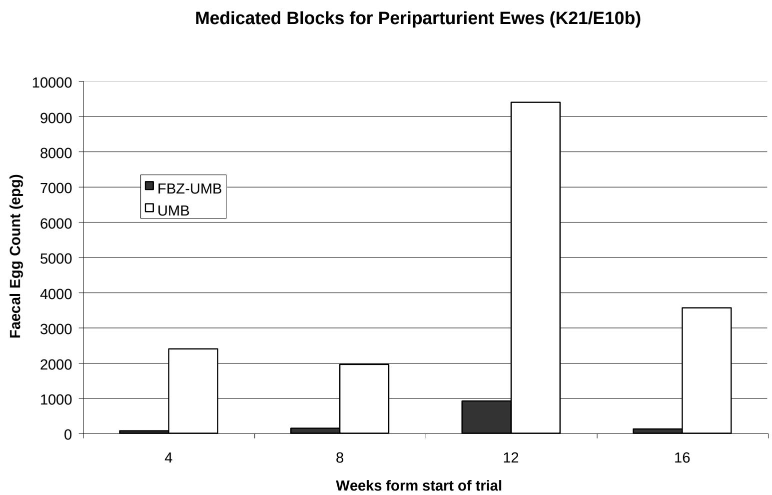


Over the trial period FECs were lowest in the UMB followed by the FBZ-UMB, CON and NORM treatments. The lower FECs in the UMB group appear to be the result of improved nutrition as a result of access to the blocks. During the trial block intakes in the UMB group were much higher than the FBZ-UMB group. Liveweight of UMB lambs was higher than those of other groups at the completion of the trial, appeared to be due to their higher initial liveweights (ACIAR, 1992).

6.2.3 Field Trial of Medicated Feed Block Supplement in Periparturient Sheep (K21/E10b)

60 pregnant ewes were dosed with Ivomec and then allocated to one of two treatment groups and grazed in separate 2 ha. paddocks. One group had access to a FBZ-UMB in its night shed, the other had access to a UMB.

FECs were significantly lower in the FBZ-UMB on all occasions, it was not necessary to treat any of the ewes, and the FBZ-UMB effectively suppressed the periparturient rise in FEC (see figure below).



Ewes in the UMB group all required treatment in the third month of the trial. FBZ-UMB block intakes were higher than the UMB (38.8 g/hd/day vs. 1.4 g/hd/day). *H. contortus* and *T. colubriformis* dominated larval cultures, *Oesphagostomum spp*. was also present in small numbers.

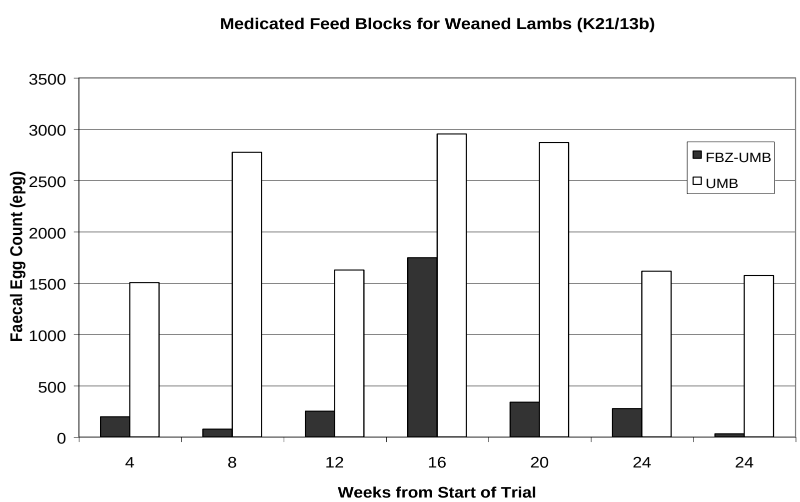
Ewe liveweights and lamb birth weights were not significantly affected by treatment, but lamb weaning weight at 3 months of age was significantly heavier in the FBZ-UMB treatment than the UMB treatment (17.2 kg vs. 14.6 kg).

At weaning the ewes were removed from the trial and the lambs retained in their treatment groups for experimentation (ACIAR, 1992).

6.2.4 The Use of Medicated Blocks to Control Nematode Parasites in Lambs after Weaning (K21/13b)

Lambs born in the previous experiment (K21/E10b) were retained in their respective treatment groups. (FBZ-UMB and UMB), where group sizes were not even additional lambs of similar weights and ages were added. All animals were drenched with Ivermectin at the start of the trial. Individual animals whose FECs exceeded 4,000 epg received salvage treatments. A breakdown of the block mixer meant that blocks were not available for the FBZ-UMB and UMB groups for 55 and 38 days respectively though average daily block consumption was similar for both treatments (40.3 g/hd/day and 47.4 g/hd/day).

FECs were significantly lower in the FBZ-UMB group than the UMB group (see figure below)



H. contortus and *T. colubriformis* dominated larval cultures. At the completion of the trial the initial 2.6 kg weaning weight advantage of the FBZ-UMB group had increased to 4.3 kg with the FBZ-UMB group weighing 30.1 kg and the UMB group weighing 25.8 kg (ACIAR, 1993).

7.0 ACIAR PN 8913: Ecological and Host-Genetic Control of Internal Parasites of Small Ruminants in the Pacific Islands.

Project 8913 was designed to build on the results of the epidemiological studies obtained from ACIAR project 8418. In addition the project investigated the heritability of FEC in goat and sheep populations in Fiji to examine the feasibility of breeding for parasite resistance.

7.1 Ecological Control of Internal Parasites of Small Ruminants

7.1.2 Pharmacokinetics of Albendazole in Goats and Sheep

6 goats and 6 sheep were maintained under controlled conditions and fed a compete ration for a period of 2 weeks. Each animal received a single intra-ruminal doses of 7.5 mg/kg Albendazole directly into the rumen and 10 ml blood samples were collected at 0, 2, 4, 8, 12, 24, 30, 36, 48, 72, 96 and 120 hours after dosing. Two of the sheep were not included in the analysis as no anthelminitic was detectable in their plasma samples. The systemic availability of Albendazole metabolites was the same in both goats and sheep. Peak Albendazle sulphone levels occurred earlier and fell off faster in goats than in sheep indicative of a faster rate Albendazole of metabolism in goats (ACIAR, 1994).

7.2 Host Genetic Control of Internal Parasites of Small Ruminants

The results of the investigations into the host genetic controls, have previously been published in the scientific literature (Woolaston, Manueli, Singh, Tabunakawai and Le Jambre, 1995; Woolaston, Manueli, Eady, Barger, Le Jambre, Banks and Windon, 1996 and Woolaston, Singh, Tabunakawai, Le Jambre, Banks and Barger, 1992) and so will be discussed in brief.

7.2.1 Research in Goats

FEC data were collected from 1513 weaner (< 365 days old) and 951 adult (>365 days old) goats on government research stations in the period 1988 to 1992. During 1988 and 1989 animals were carrying naturally acquired mixed parasite infections, but in 1991 and 1992 animals had been treated with Closantel one month prior to sampling. Treatment was done to remove *H. contortus* from their worm burdens in an attempt to minimise between animal variation in the ratios of *H. contortus* and *T. colubriformis*.

Analysis of the data revealed that there appeared to be an effect of age on FECs (Adult: 508 epg, Weaner: 1385 epg) indicative of a possible age acquired immunity to parasites. Birth status appeared to have an effect on FEC with twins and triplets having higher FECs than singles. Heritability estimates of FEC obtained in both weaners and adult goats did not differ significantly from 0.0.

Haematological data collected in 1988 and 1989 when *H. contortus* was present in the worm burden indicated that neither Packed Cell Volume (PCV) or Haemoglobin (HB) measures were of use as indicators for resistance. From the results of the experimentation it was concluded that there was very little scope for within herd genetic improvement.

7.2.2 Research in Sheep.

Studies with sheep were carried out over the period 1988 to 1993. FEC data were collected from a total of 1826 weaner sheep. During 1988 and 1989 animals were carrying naturally acquired mixed parasite infections, but in 1991 to 1993 *H. contortus* was removed by drenching with Closantel 4-6 weeks prior to sampling.

Analysis of the data indicated that there were effects of age (younger<older), sex (female<male) and year on FEC. Heritability estimates for the pooled data were 0.23 ± 0.07. These results indicated that there was a good possibility to carry out selection for

reduced FEC. This has since been implemented with FEC being one of the criteria for the selection of replacement rams on government sheep stations.

Haematological data from the 1988 and 1989 samplings showed that the “Fiji Sheep” had higher PCV values than pure bred Barbados Blackbelly sheep, but there were no breed effects on Hb values or FECs.

Haematological data from the 1991-1993 weaners showed significant sex (male>female) and age (older>younger) effects on circulating eosinophil counts but, neither breed or sire effects could be detected. There was a negative phenotypic correlation between FEC and eosinophil count suggesting that eosinophil counts would be of little value as indicators of resistance.

8.0 ACIAR PN9132: Nutritional and Chemotherapeutic Strategies for Sustainable Control of Gastrointestinal Parasites of Ruminants.

Project 9132 was an extension of project 8523 brought about because of the good results achieved during project 8523.

8.1 Research in Goats

Only one trial was carried out in goats over the project period. This was aimed at investigating the possibilities for the use of the FBZ-UMB and UMB to control GIPs in goats managed in a RRG programme.

8.1.1 The Use of Medicated Blocks in Conjunction with RRG (K21/E9)

The experiment was designed to test strategies for the use of FBZ-UMBs in conjunction with rapid rotational grazing (RRG) in a 10 paddock, 35 day rotation. 60 pregnant does were allocated to one of 3 treatment groups each with two replicates of 10 does per group. Treatments applied were rotational grazing with FBZ-UMB for the first cycle of rotation (FBZ-UMB35), rotational grazing with FBZ-UMB for the first 2 cycles of the rotation (FBZ-UMB70) and rotational grazing with ad. lib. access to a UMB. A separate group of 20 does maintained under normal station management (NORM) were kept nearby. NORM does were fed a ration of 250 g/hd/day of a 50:50 coconut meal mill mix ration for a period from 28 days prior to their expected kidding date, until the end of the trial which ran for a total of 30 weeks. Animals whose FECs exceeded 1000 epg were drenched to maintain health.

Does in the FBZ-UMB70 treatment had significantly lower FECs over the period of the trial. During periods when the FBZ-UMB70 and FBZ-UMB35 treatments had access to FBZ-UMBs no parasite eggs were detected in their faeces. Goats in the NORM treatment had the highest FECs at all times, followed by the UMB treatment. Numbers of animals requiring anthelmintic treatment to maintain health were 6, 25, 38, and 25 for treatment groups FBZ-UMB70, FBZ-UMB35, UMB and NORM respectively. Doe liveweights at the completion of the trial in the FBZ-UMB70, FBZ-UMB35 and NORM treatments were similar, liveweights of does in the UMB treatment were lowest. A similar pattern was seen in the liveweights of the kids at weaning with the mean liveweights kids born in the UMB treatment group being lighter.

It would appear that the nutritional supplementation given to the NORM treatment was sufficient to help compensate for the losses in production seen in the UMB treatment. This resulted in final doe liveweights, and mean kid weaning weights being similar to those of the FBZ-UMB70 and FBZ-UMB35 treatments.

8.2 Research in Sheep

During the course of project 9132 there were 3 experiments carried out viz.

> 9132A. 1993 - 1994 ' The Effect of Parasite Control and Nutrition on Development of Young Ewes'.

9132B. 1995 - 'The Effect of Parasite Control and Nutrition on the Lambing Performance of Maiden Ewes'.

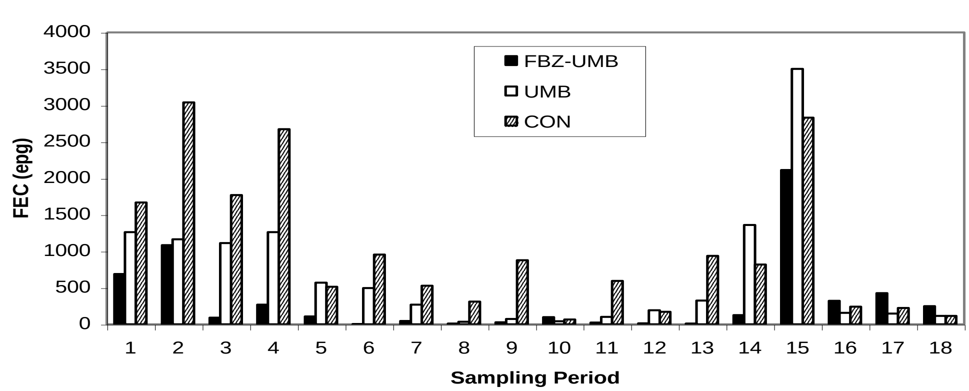
9132C. 1996 - An Investigation of the Effects of Parasite Control and Nutrition on the Lactation Performance of Maiden Ewes.

The results of the various experimental programmes are presented below:

8.2.1 9132A. 1993 - 1994 ' The Effect of Parasite Control and Nutrition of the Development of Young Ewes'.

Manueli, Knox and Mohammed (1995) investigated the effects of parasites and nutrition on young Fiji sheep at pasture. Six groups of thirty 11 month old ewes were each placed into 2 ha. paddocks. Two groups were allowed unlimited access to FBZ-UMB (0.75g FBZ/kg), two groups had unlimited access to UMB and two groups received no supplementation (NB). Animals whose FECs exceeded 3,000 epg were drenched with anthelmintic to avoid unnecessary mortalities. FECs were lowest for the FBZ-UMB group, highest for the NB group while the UMB group was intermediate (see figure 1 below).

Figure 1. Trends in Faecal Egg Counts 9132A



During the experiment it was necessary to salvage treat FBZ-UMB, UMB and NB ewes 13, 55 and 92 times respectively. Larval cultures indicated that *Haemonchus spp*. and *Trichostrongylus spp*. were dominant, *Oesophagostomum spp*. was also present but in low numbers. At mating after 7 months of experimentation, the FBZ-UMB and UMB) groups had gained more weight than the NB group (10.5kg, 10.0 kg, and 5.8 kg respectively). Ewe conception rates, lambing percentages and total weight of lamb weaned were increased by FBZ-UMB and UMB with the former providing the greatest increase. The benefits in reproductive performance are thought to be the result of the higher mating liveweights of the FBZ-UMB and UMB groups. The large benefits in total weights of lambs weaned per treatment are the result of inclusion of the nutritional benefits of the UMB and the benefits of parasite control and nutrition in the FBZ-UMB treatment. (see table 3 below). Weight of lambs weaned per treatment was increased by 82% and 138% respectively for the UMB and FBZ-UMB treatments in comparison to the unsupplemented controls.

Table 3 Effects of Treatments on Reproductive and Lambing Performance

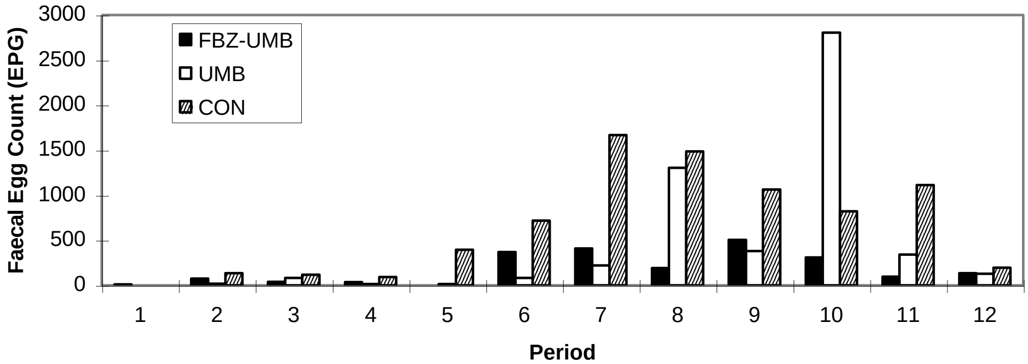
	FBZ-UMB	UMB	NB
Ewes Lambing	40	34	22
Lambs Born	44	40	24
Total Wt Born (kg)	144	126	66
Lambs weaned	40	39	20
Lamb Weaning Wt (kg)	13.2	10.4	11.1
Total Wt Weaned (kg)	528	405	222

At the completion of the trial the ewes were returned to the main flock and subjected to normal station management. An investigation of their performance in the 1995 lambing season reveals no significant differences in premating liveweights or their subsequent reproductive performance, indicating that there is no carry over effect of early suppressive anthelmintic control (FBZ-UMB) or nutritional supplementation (UMB) on ewe reproductive performance.

8.2.2 9132B. 1995 - 'The Effect of Parasite Control and Nutrition on the Lambing Performance of Maiden Ewes'.

The results of 9132A had demonstrated the benefit of the continuous use of the FBZ-UMB. A second trial was designed to investigate the effects of strategic use of the FBZ-UMB to reduce the usage of FBZ, reduce costs and avoid possible problems of anthelmintic resistance that could develop given the extended use of the FBZ-UMB. Manueli, Knox and Mohammed (unpublished) tested a programme of short term usage of FBZ-UMB in conjunction with UMB to determine the optimal time for their prophylactic use. One hundred and fifty 15 month old ewes were divided into 6 even groups on the basis of bodyweight and allocated to 2 ha. paddocks. Two groups were allowed unlimited access to UMB for 8 weeks when FBZ-UMB (0.75g FBZ/kg) was substituted for UMB for 4 weeks prior to and 7 weeks during mating. These groups were then returned to UMB until 4 weeks prior to parturition when FBZ-UMB were then again introduced and remained available up until the lambs were weaned Two groups had unlimited access to UMB and two groups received no supplementation (NB). Animals whose FECs exceeded 3,000 epg were drenched with anthelmintic to avoid unnecessary mortalities. FECs were lowest for the FBZ-UMB group, highest for the NB group while the UMB group was intermediate (see figure 2 below).

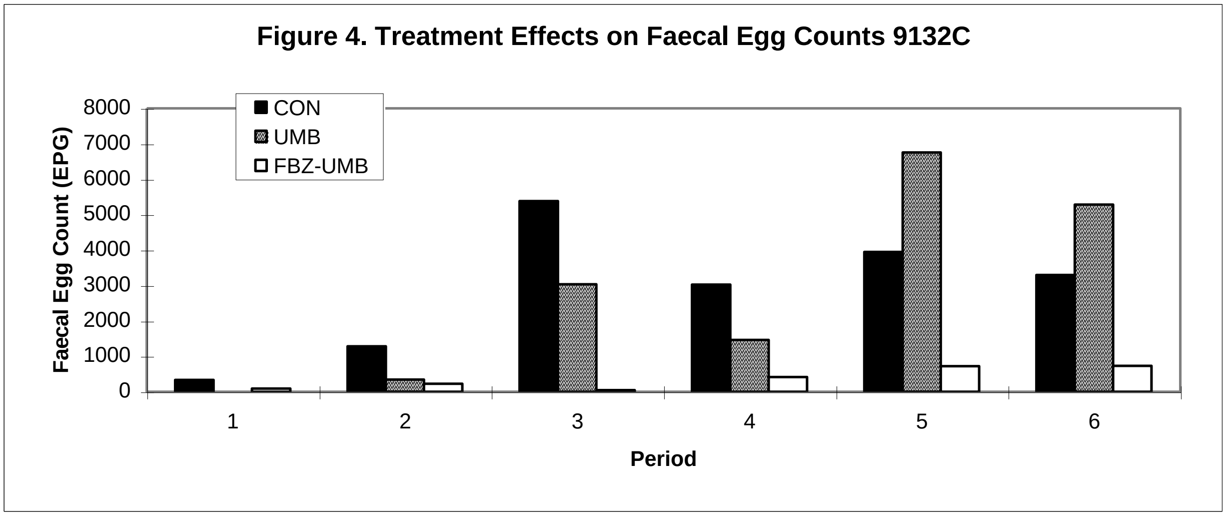
Figure 2. Treatment Effects on Faecal Egg Counts 9132B



During the experiment it was necessary to salvage treat individual FBZ-UMB, UMB and NB ewes 4, 14 and 32 times respectively. larval cultures indicated that *Haemonchus spp*. and *Trichostrongylus spp*. were dominant and that *Oesophagostomum spp*. was also present but in low numbers. Treatment differences in ewe reproductive performances and liveweights during the experiment were not significant. Treatment had a substantial effect on numbers of lambs weaned and the total weight of lambs weaned which was lowest in the NB treatment, 85% higher in the UMB treatment and 160% higher in the FBZ-UMB treatment. (see table 4 below).

Table 4. Effects of Treatment on Lambing Performance

	FBZ-UMB	UMB	NB
Lambs Born	46	43	41
Total Wt Born (kg)	173	146	134
Lambs weaned	36	31	19
Total Wt Weaned (kg)	537	382	206



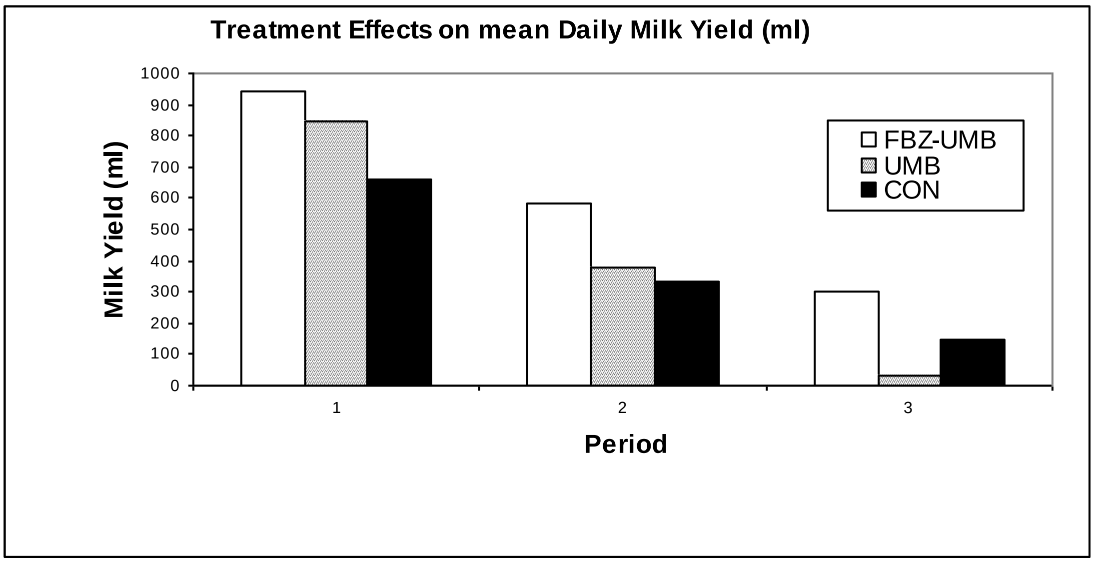
6.3 9132C. 1996 - An Investigation of the Effects of Parasite Control and Nutrition on the Performance of Peri-parturient Maiden Ewes.

The results of trials 9132A and 9132B demonstrated clear benefits in terms of weights of lambed weaned from the use of FBZ-UMB and UMB in comparison to unsupplemented controls. However, the experiments failed to clearly identify the mechanisms by which the benefits accrued. In an attempt to identify the mechanism by which this occurred, Manueli, Knox and Mohammed (unpublished) investigated the effects of FBZ-UMB on the growth of lambs and the milk production of ewes. Seventy two pregnant 21 month old Fiji ewes were divided into six even groups on the basis of bodyweight and allocated to 1 ha. paddocks. Two groups were allowed unlimited access to FBZ-UMB (0.75g FBZ/kg), two groups had unlimited access to UMB and two groups received no supplementation (NB). Animals whose FECs exceeded 3,000 epg were drenched with anthelmintic to avoid unnecessary mortalities. Ewe milk production was estimated at three, monthly intervals using the oxytocin injection (1 ml oxytocin) and hand milking method and milk fat, milk protein determined. Mean 63 day milk yield was estimated by multiplying mean daily milk yield by the number of days between the 3 milk production estimates.

Log transformed (Log(FEC+1)) FECs were lowest for the FBZ-UMB group (370 ± 288 epg), highest for the NB group (2878 ± 290) while the UMB group (2790 ± 291) was intermediate (see figure 4 below).

Despite the use of salvage treatments a number of ewes died (FBZ-UMB:2, UMB: 6, NB: 10) due to an outbreak of haemonchosis during the latter part of the trial. Ewes that died were replaced with animals that had been drenched before entering the trial, which may have affected mean treatment egg counts and milk yields. Salvage treatments required were 4, 12 and 39 respectively for the FBZ-UMB, UMB and Control groups.

The mean daily milk production of ewes from the FBZ-UMB group was significantly higher than those from the UMB and NB groups (see figure below).



Milk composition (as a percentage) was not affected by treatment however, there was a significant effect of treatment on mean daily milk yield, mean daily milk fat production and mean daily milk protein production (see table 5 below).

Table 5. Effects of Treatment on Ewe Milk Production

	NB	UMB	FBZ-UMB
Mean Daily Milk Yield (ml/day)	381	418	607
se ±	50.5	46.8	45.4
Mean Daily Milk Fat Prod.	17.59	21.4	29.8
se ±	3.2	2.8	2.7
Mean Daily Milk Protein Prod.	25.4	29.1	44.2
se ±	5.6	5.2	5.1
63 day milk yield (l)	24.0	26.3	38.2

The differences in milk production were reflected in numbers of lambs weaned and total weights of lambs weaned in the various treatments groups being highest in the FBZ-UMB treatment, intermediate in the UMB treatment and lowest in the Control treatment (see table 6 below).

Table 6. Effects of Treatment on Lambing Performance

	CON	UMB	FBZ-UMB
Total Ewes	24	24	24
Ewes Lambing	21	23	22
Lambs Born	21	24	23
Total Wt Born	62	76	78
Lambs Weaned	8	15	18
Total Wt Weaned	118	196	318

Total weights of lambs weaned were increased by 66% and 169% respectively for the UMB and FBZ-UMB treatments in comparison with the unsupplemented controls.

6.4 Research the Biological Control of Gastro-Intestinal Parasites In Fiji.

Research into the use of nematophagous fungi to control GIPS in Fiji began in 1996. The first investigations in conjunction with the CSIRO under the aegis of ACIAR involved conducting a survey to try to collect the nemtophagous fungus *Duddungtonia flagrans* from local small ruminant farms (Manueli, Waller, Faedo and Mohammed, 1999).

This involved the collection and culturing of some 2,712 faecal samples from a total of 26 sheep and goats farms in Fiji. The research programme yielded a total of 23 isolations of nematphagous fungi of which 11 were lost and a further 12 were identified belonging to one of 4 species of the genus *Arthrobotrys*.

Subsequently, an isolate of *D flagrans* was imported from CSIRO in Australia and a series of pen and field trials conducted. Trials involved the feeding of *D flagrans* chlamydospores to animals carrying naturally acquired worm infections, and monitoring changes in the percentage of their FECs that were recovered as infective larvae.

Results of pen trials show that *D flagrans* was effective in trapping infective larvae in faecal cultures at a range of dose rates (Manueli unpublished data). The trapping of infective larvae has resulted in reductions of up to 90% in the numbers of larvae recovered from larval cultures. Replicated field trials aimed at investigating the use *of D. flagrans* under grazing conditions are on going. Initial results are variable with larval recoveries from grazing animals fed *D. flagrans* daily ranging from by 0-60% in comparison to control animals who do not have access to *D. flagrans*.

7.0 CONCLUSIONS

The two major parasites of importance are *H. contortus* and *T. colubriformis*.

M. digitatus does not readily infect goats

Rotational grazing 28 days with 8 paddocks or 35 days with 10 paddocks can be effective for the control of GIPs in small ruminants.

Reducing the number of paddocks in a 28 day rotational grazing system makes it ineffective

Larvae survive on pastures all year round

Infective larval stages are generally available on pasture by 4 days after faecal contamination with parasite eggs.

Evidence for the development of age immunity in goats is equivocal. Epidemiological studies indicate that little age resistance occurs, though the genetics studies found evidence of an age effect.

There is no hypoiosis in *H. contortus*

It is not necessary to drench young stock fortnightly

Anthelmintic resistance means that it is necessary to develop sustainable parasite control measures.

Albendazole sustained release capsules are not effective in goats but are extremely effective in sheep.

Albendazole is metabolized faster in goats than it is in sheep

FBZ administered at a dose rate of 3.0 g/kg liveweight can reduce egg counts and larval hatch rates to zero.

FBZ-UMBs can be used to control GIPs in sheep and goats provided block intakes are adequate.

There is a lot of variation within flocks and herds in FBZ-UMB intakes.

FBZ-UMBs can reduce the need for drenching in small ruminants.

The strategic use of FBZ-UMBs in conjunction with UMBs can be effective in controlling GIPs in small ruminants.

FBZ-UMBs can be used in conjunction with RRG to control GIP infections in small ruminants.

Improved nutrition can be beneficial in helping GIP infected small ruminants overcome/with stand the effects of infection.

There is no effect of night yarding on FECs in goats.

In young ewes GIPs can affect reproduction by delaying the attainment of oestrous resulting in fewer lambs being born. This is exacerbated by sub-optimal nutrition. This effect does not carry over.

These effects on reproduction do not occur in well grown ewe hoggets.

GIPs affect the growth rates of lambs from birth to weaning.

GIPs cause reductions in ewe total milk yields, total fat yields and total protein yields.

Nematophagous fungi surveys were unable to identify *D. flagrans* in Fiji.

D. flagrans pen trials have been successful though results in field trials have been very variable.

FEC is not heritable in goats in Fiji

FEC is heritable in sheep and can therefore be used in selection programmes

Eosiniphil count is not a good predictor of FEC count in sheep.

Biliogical control using *D. flagrans* has potential but problems of delivery and fungal culture methods need to be addressed.

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