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Options for the control of parasites in the Australian Goat Industry

A situational analysis of parasites and parasite control

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Contents

List of Tables

1 Executive Summary

Goatmeat is the most widely consumed meat in the world and Australia is one of the major exporters. The goat industry has been growing rapidly to capitalise on this market and in 2005-2006 this sector was valued at A$97.7 million. The industry also includes smaller fibre and dairy sectors valued at about A$5 million which often also sell into the goatmeat market. As with most livestock industries, parasites increase costs of production and can cause significant production losses if not properly controlled. Although growing rapidly, the goat industry is still small relative to the more mainstream livestock industries and has a limited number of effective parasiticides available for control.

Objectives of this review were to: (i) provide an assessment of key parasites, their impact in the Australian goat industry and current control practices; (ii) develop guidelines to maximise and preserve the efficacy of currently registered products; (iii) identify currently unavailable parasiticides that would be beneficial to the goat industry and define the processes required to make them legally available and, (iv) identify alternative non-chemical measures that could be used to reduce reliance on chemical parasiticides.

A survey addressing the extent of problems from endo and ectoparasites, and control practices was circulated to 1500 producers. Useable responses were returned from 195. Gastrointestinal parasites were always or mostly a problem on 26% of properties and sometimes a problem on 59% whereas lice were always or mostly a problem for 9% of respondents and sometimes a problem for 53%. Coccidiosis was sometimes a problem for 31% of respondents. Eighty-eight percent of respondents used drenches to control worms, whereas 56% treated for lice and 28% percent treated for coccidiosis. The limited availability of effective goat parasiticides meant that products registered for control of similar parasites in other livestock species were often used. A range of non chemical parasite management techniques were also employed.

Gastrointestinal parasites present little problem to goats run on extensive rangeland properties. However, these animals often require treatment when inducted into depots. Registration of an injectable formulation is considered desirable as rangeland goats are not accustomed to close handling and oral dosing is often inefficient and puts both goats and operator at risk of injury.

For goats grazed on grass and improved pastures in the higher rainfall zones, parasitism is a frequent occurrence with severe outbreaks of disease linked to rainfall events. Use of chemical anthelmintics mostly registered for sheep and often administered at doses above the recommended ovine rate is common. The effects of the higher dose rates, administration of repeat doses within a 12–36 hour period and feed withdrawal, which are practices commonly used to increase efficacy, on the export slaughter interval are not well defined.

Currently there are three drench actives registered for the broad-spectrum control of nematodes in goats: certain benzimidazoles, morantel citrate and abamectin (macrocyclic lactone) as well as a minor use permit for trichlorfon to control *Haemonchus contortus* valid until 2009. In registration trials, the newly registered abamectin anthelmintic, Caprimec® was effective at the sheep dose rates but nematodes carrying resistance to this product are known to be present on some properties. The frequency and extent of drench resistance is unknown. Registration of products from further chemical groups is required to provide realistic options for control and flexibility in control programs and to enable the development of resistance management programs.

New registrations should focus on short acting compounds, such as levamisole, as they select less strongly for resistance, have short withholding periods and are less likely to lead to residue violations. However, consideration should also be given to supporting registration of a multi-active formulation for goats. This would provide goat owners with an option for quarantine drenching to prevent the importation of resistant worms. It is desirable that levamisole is a component of this formulation, but that moxidectin is not.

Adoption of integrated approaches to control that incorporate the use of non chemical methods are critical to minimise further resistance development. Pasture rotation and management to provide uncontaminated pastures have been shown to be effective and should be a key component of any well planned helminth control program. The provision of browse and some species of bioactive forages have also been shown to reduce helminth burdens in goats and could also be incorporated into an integrated program. Strategic supplementation of susceptible stock can reduce the effects of worms and selection of stock for improved immunity or resilience using worm counts or the FAMACHA® and BODCON technologies has been effective overseas and may be applicable in some Australian production systems. Administration of bioactive fungal treatments and copper oxide wire particles have promise but Australian Pesticides and Veterinary Medicines Authority (APVMA) registration will be necessary.

For external parasites, lice are the major problem and by far the major reason for the topical application of chemical treatments to goats. Lice treatments are not used in all herds, but where they are used, often multiple treatments are applied and there is substantial use of unregistered product. Except for management to prevent new infestations there are currently few practical options for controlling lice that do not rely on insecticidal treatments. However, given the limited economic and animal welfare impact of lice in most situations there appears to be an opportunity for a more strategic approach to chemical use.

Backline treatments are convenient, offer significant practical advantages and are used widely by goat owners but only one product, a synthetic pyrethroid, is currently registered. Resistance to synthetic pyrethroids in goat lice has occurred overseas but whether it is also present and compromises the effectiveness of control in Australia has not been investigated. The restricted choice of chemicals available for lice control in goats limits options for the implementation of resistance management programs to preserve the efficacy of currently available products.

Registration of a new chemical group, probably an insect growth regulator (IGR) for administration by backline application for control of lice in goats would be beneficial. Good resistance management recommendations should accompany this registration. In contrast to many helminth parasites, goat lice are specific to goats. Therefore, registration of new chemical groups for lice control in goats would not jeopardise the efficacy of similar products in other more lucrative animal health markets.

Some organic compounds and biopesticides show promise for use against lice on other animal species. However, the relatively small market represented by the goat industry and a general requirement for a similar level of safety and efficacy testing as for chemical therapeutics may be a barrier to their future registration for use on goats.

The economic and animal welfare impact of other ectoparasite species in the Australian goat industry is small, although localised problems may occur intermittently. Products are currently registered for the control of ticks and treatment of strike in goats and where treatments for mite infestations or nasal bot are required they are most likely to be administered under veterinary supervision. The potential for residues from individual animal or localised therapeutic treatments to impact on goatmeat and milk markets needs to be kept in mind.

Coccidiosis is mainly a problem in young goats under intensive management or in stressed condition. Monensin is currently registered for treatment and prevention of coccidiosis in goats and appears effective in most circumstances.

A step by step guide to securing a minor use permit and a detailed outline for the process involved in seeking registration of a chemical are presented. It should be noted that products requiring registration are not confined to those made from ‘synthetic chemicals’. In Australia, biological, homeopathic, herbal, other natural medicines and nutritional products require registration if they contain nutrients at levels considered to have therapeutic benefits rather than just nutritional. A major barrier is the lack of data on maximum residue limits specific to goats. Testing under rigorous scientific protocols is mandatory for the provision of acceptable data. The high costs involved for a relatively small market is a major impediment to chemical companies pursuing registration of new compounds. Only the registrant of an existing registered product can submit further applications to vary that existing registration. Thus, an application to extend the registration of a product registered in cattle, for example, to include its use in goats has to come from the chemical company which registered that product in the first place. Concerns that resistance originating in the goat industry is transferred to the sheep industry and reduces the economic longevity of these treatments in the much larger sheep anthelmintic markets is also a major disincentive for the registration of new goat products.

2 Definition of Terms

Active constituent

An active constituent, in relation to a proposed or existing agricultural chemical product or veterinary chemical product, means the substance that is, or one of the substances that together are, primarily responsible for the biological or other effect identifying the product as an agricultural or veterinary chemical product.

APVMA

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is an Australian government authority responsible for the independent scientific assessment and registration of pesticides and veterinary medicines and for their regulation up to and including the point of retail sale.

Codex

The Codex Alimentarius Commission was created in 1963 by the Food and Agricultural Organisation (FAO) and the World Health Organisation (WHO) to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme. The main purposes of this Programme are protecting health of the consumers and ensuring fair trade practices in the food trade, and promoting coordination of all food standards work undertaken by international governmental and non-governmental organisations.

Biotic Potential

Biotic potential is the maximum reproductive capacity of a population under optimum environmental conditions. For example, female worms of *Haemonchus contortus* are prolific egg producers and lay from 5,000 to 10,000 eggs per female worm per day. Even moderate infections (up to 2,000 worms) may result in counts of 2,000 epg (eggs per gram of faeces) or ten million eggs per day passed with the dung onto pasture.

BODCON

Body condition scoring (BODCON) is a field based method of scoring the tissue over the lumbar vertebrae of goats. The winter scour worms such as *Trichostrongylus* spp. and *Teladorsagia* sp. cause reduced appetite, scouring and rapid weight that is easily detected by this method. Scour worms do not cause anaemia.

Codex Committee on Pesticide Residues

The Codex Committee on Pesticide Residues establishes standards for allowable concentrations of pesticide residues in food commodities moving in international trade.

Ectoparasitism

A parasite that lives or feeds on the external body surfaces of its host.

Export Slaughter Interval

An Export Slaughter Interval (ESI) is the time that should elapse between administration of a veterinary chemical to animals and their slaughter for export. ESIs manage differences between Maximum Residue Limits allowed for chemicals in Australia and its trading partners. ESI advice is particularly important for quality assurance schemes, and especially for producers filling out the National Vendor Declaration (NVD) forms as part of the whole-of-chain management of exported product. ESIs have been agreed to by the industry and the registrant of the veterinary chemical.

Endoparasitism

An endoparasite is a parasite that lives within the body of a host and is dependent on at least one gene or its product from that host to complete its own life-cycle. Endoparasitism in this context refers to the helminth parasites such as the nematodes (roundworms), trematodes (liver fluke) and the cestodes (tapeworms) that mostly inhabit the gastrointestinal tract but sometimes the liver and bile ducts, and lungs. The gastrointestinal tract is also a predilection site for the protozoan infections such as coccidia.

FAMACHA©

FAMACHA is a field based method of scoring the colour of the conjunctiva (the lower inner eyelid) of individual goats against a simple colour chart to grade the degree of anaemia. Anaemia is associated with blood sucking nematodes such as *Haemonchus contortus* (barber’s pole worm) but also has other causes. This method is used to detect affected sheep and goats for treatment and culling.

Legal use

Users of agricultural and veterinary chemical products are required by law to use them according to the instructions on the approved label which show the crop, animal or situation for which the product can be used and the pests and diseases that can be controlled. Chemicals may also be legally used in animals if approval has been granted under an APVMA permit or if the use is stipulated in a regulation.

Material Safety Data Sheet

A Material Safety Data Sheet (MSDS) means a document that describes the properties and uses of a material, that is, identity, chemical and physical properties, health hazard information, precautions for use and safe handling information. A Material Safety Data Sheet (MSDS) should be supplied by the supplier of a chemical and users of the chemical should follow the instructions in the MSDS carefully when applying, handling or storing products.

Maximum residue limit

The maximum residue limit (MRL) is defined as the maximum concentration of a residue, resulting from the registered use of an agricultural or veterinary chemical that is legally permitted in or on a food, agricultural commodity, or animal feed. The concentration is expressed in milligrams per kilogram of the commodity (or milligrams per litre in the case of a liquid commodity).

Minor use

Under the Agricultural and Veterinary Code Regulations 1995, a minor use "in relation to a chemical product or an active constituent, means a use of the product or constituent that would not produce sufficient economic return to an applicant for registration of the product to meet cost of registration of the product, or the cost of registration of the product for that use, as the case requires (including, in particular, the cost of providing the data required for that purpose)”.

Minor Use Permit

Applications under Category 21 for a minor use permit (MUP) from APVMA can include one of the following: the ‘off-label’ use of an existing registered veterinary product; the use of an unregistered veterinary product; or the use of an autogenous vaccine.

Misuse of a chemical

Misuse of a chemical is the use of a chemical in ways not allowed under legislation. Examples are: use by a veterinary surgeon of an unregistered chemical in more than one single trade species animal where no APVMA permit has been granted or any use of unregistered chemical by a non veterinary surgeon; use of a registered veterinary chemical in a trade species animal for which the product is not registered and where there are no written instructions from a veterinarian nor an APVMA permit. When an MRL is exceeded, it usually indicates a chemical is being misused, rather than a public health or safety concern because MRLs have been set with large safety factors taken into account to ensure safety of the chemical for humans.

Off-label use

An off-label use of a chemical product is use of the product in a way that is not covered by an instruction on the label approved by APVMA for the product registered in Australia.

Off-label Permit

An off-label permit (OLP) allows registered agricultural or veterinary chemical products to be used for a purpose or in a manner that is not included on the approved Australian label for the product.

Permit

A permit, in respect of an active constituent or a chemical product, is issued by APVMA to allow persons covered by the permit to do or omit to do any thing stated in the permit which would otherwise be an offence under the legislation, if the permit did not exist. A permit from APVMA is legally required before using a registered agricultural or veterinary chemical product for an off-label use; using an agricultural or veterinary chemical product that is not registered; or carrying out research trials with agricultural or veterinary chemical products to generate data for registration or other scientific purposes.

Refugia

Refugia is the name given to that proportion of a given parasite population that escapes exposure to an anthelmintic and allows the survival of anthelmintic-susceptible parasites. This part of the parasite population is usually the free living stages on pasture but can also be worms in untreated animals or even inhibited larvae within the host.

There are 2 sub-populations that constitute the parasite population at any one time. One sub-population is in the host as developing and mature adult worms and the other subpopulation is on pasture as eggs, larvae and free living infective larvae. During hot dry summers, the numbers of free living stages on pasture (refugia) may be very low with most of the parasite population in the host. The reverse is true of wet summers, especially for barber’s pole worm with most of the parasite population as larvae on pasture.

Drenching when very few worms are in refugia (the timing of this will vary with the type of climate, whether Mediterranean, winter rainfall or summer rainfall) will heavily select for drench resistance.

The progeny of survivors of the drench will have little competition from the few larvae on pasture. When numbers in refugia are high, the progeny of the survivors of the drench will often be swamped by the high numbers of larvae on pasture and selection for resistance will take longer to occur.

Registered chemical

Before agricultural and veterinary chemical products can be sold, supplied, distributed or used in Australia, they should be registered by the APVMA. The registration process is governed by Commonwealth legislation and each chemical product undergoes rigorous scientific assessment before its registration can be approved. The APVMA allocates a unique registration number which is printed on the bottom of the product label.

Targeted Selective Treatments

Targeted selective treatments aim to identify and treat those goats in a herd most severely affected by nematodes. Conventional chemical treatment methods treat all of the animals in a herd many of which may not be carrying a heavy burden. FAMACHA and BODCON are two methods used to identify and select out animals for treatment.

Under the care of

For an animal to be 'under the care of' a veterinary surgeon, a distinct veterinarian – patient/client relationship must exist, with the veterinary surgeon assuming real responsibility for the animal's health and welfare.

Unregistered chemical

An unregistered chemical active constituent or chemical product is one that has not been assessed and registered in Australia by APVMA.

Veterinary surgeons' prescribing rights

Under state legislation, registered veterinary surgeons may use, supply, prescribe or recommend the use of registered veterinary chemicals contrary to label instructions ('off-label' use) for animals under their care. Veterinary surgeon's have fewer rights in relation to unregistered chemicals and can only use, supply or recommend them on one single trade species animal.

Withholding period

The withholding period (WHP) is the minimum period which must elapse between last administration or application of a veterinary chemical product, including treated feed, and the slaughter, collection, harvesting or use of the animal commodity for human consumption. WHPs are mandatory for domestic slaughter and on the label of every registered product.

3 Terms of Reference

Objective

To provide a clear situational analysis of parasite control methods currently available to the Australian goat industry

To provide clear recommendations to support the sustainable development of the industry

Issues to be addressed

1. A detailed situational analysis of parasites and parasite control in the Australian goat industry is required. This analysis should include, but not be limited to:
   - An assessment of key parasites and their prevalence in each production system and land class (to include coccidiosis)
   - Current chemical usage; registered and non-registered, and administration practices.
   - Current non-chemical remedies and their reputed efficacy in various production system and land class.
   - A clear definition of the process to be followed for the off-label use of a chemical.
   - A definitive list of all internal and external parasite controls relevant to the goat industry in clear tabular form. This should include all parasiticides registered for use on goats in Australia and those not registered but relevant.

     Example: Active constituent (molecule)
Brand name
Registered (yes/no)

2. A comprehensive review of all major national and international non-chemical parasite control alternatives currently available to goat producers including grazing management and herbal and mineral supplements and drenches. Identification of the relative benefits and risks associated with these options from a legal, food safety and animal welfare perspective.

3. A clear explanation of the situation regarding the registration of additional chemicals is required. This should include, but not be limited to:
   - A clear description of the registration process and the role of the chemical company and regulatory organisations in this process.
   - The time required and cost associated with the registration of any one chemical from the expression of interest from the company to commercial release (estimated).
   - The commercial drivers (or lack thereof) for a chemical company to pursue the registration of a chemical for use on goats.
   - Other factors that may influence this decision.
   - Any potential or likely interest from chemical companies in registering a particular chemical for use on goats.
   - What benefit and risks (such as resistance) would such a registration pose to the industry?

4. Realistic recommendations for chemical usage are required. This may include substantiated and realistic recommendations for the industry to pursue the registration of one or more parasiticides for use on goats and industry programs to support the sustainable development of the industry.

4 Introduction

The national goat herd is estimated to number about three million on approximately 7000 Livestock Production Assurance registered properties in three main product sectors. The largest is the thriving meat and live export sector which supplies product mainly from rangeland goats into both the domestic and export markets. In 2005-2006 this sector was valued at A$97.7 million. The industry also includes fibre and dairy sectors which supply small amounts of product to the meat sector (P. Schuster, Meat and Livestock Australia MLA).

Approximately ninety percent of meat goats are supplied from the rangeland zones of northern Australia extending into the more southern drier pastoral zones where annual rainfall is less than 380 mm per year. These enterprises are based on the opportunistic capture of rangeland goats and increasingly on extensively managed herds infused with Boer genetics. Endo- and ectoparasitoses are either not a problem in this sector or only intermittently so. Rarely do infections require chemical treatments. However, goats waiting consignment are usually sold to regional depots or aggregators, some of whom quarantine drench on arrival.

Parasitism is a constraint to the profitability of the remaining enterprises based in the higher rainfall agricultural zones. These holdings produce meat and fibre for the domestic and export markets and milk for the domestic market. Goat rearing may be carried out together with other enterprises such as cropping, sheep and cattle production. Intensification of the industry within these sectors has resulted in increased productivity but also increased dependence on efficacious chemotherapy for parasite control. Repeated treatments are often applied at very short intervals and often with products not registered for goats and resistance has developed to many of the parasiticides used.

While product from the rangeland, pastoral and agricultural zones supplies most of the meat export and domestic markets, cast-for-age animals and culls from the fibre and dairy sectors may also enter these markets. The risk of chemical residues in such product is high particularly in seasons suitable for the proliferation of parasites.

Most testing authorities now have very sensitive testing methods and are increasingly able to detect extremely low levels of residues in animal tissues. Detection of residues that violate the MRLs of importing countries could jeopardise expanding goatmeat markets while detection of residues that violate domestic MRL standards could lead to prosecution.

Continued growth of an efficient and profitable goat industry clearly requires the availability of effective parasite control methods which do not jeopardize access to key markets. This review summarises the key parasites of goats in Australia and their impact on profitable goat production. Available chemical and non-chemical control options are considered and recommendations for best practice parasite control programs in the Australian context provided. In addition, the practicality and desirability of registration of new chemical groups of parasiticides for use in goats and the feasibility of development of new non-chemical controls is assessed.

5 Key parasites and their prevalence

Most serious diseases and deaths in goats are the result of infection with endo- or internal parasites (See 3 Definition of Terms). Ecto- or external parasites can cause significant economic losses but rarely result in deaths.

5.1 Internal Parasites

In general, internal parasites are most common in those districts that receive more than 380 mm of rain annually. Rangelands goats, extensively managed and largely feeding on browse (leaves and twigs of trees and shrubs) and woody perennial plants, are relatively free of parasitic infections whereas in goats grazed on grass and improved pastures in the higher rainfall zones, parasitism occurs frequently and can be severe. The main endoparasite problems include a variety of nematode (roundworm) and trematode (fluke) parasites and occasionally protozoan infections such as coccidia. Cestodes (tapeworm) are not generally considered to be of great importance.

5.1.1 Nematodes

Superficially, parasitism in goats is similar to that in sheep. Goats share the same main nematode genera as sheep but when run with sheep in mixed grazing situations, goats tend to carry heavier worm burdens and suffer more pathology than sheep (Sangster 1990). The heavier nematode burdens of goats compared with sheep when grazed together are due in part to greater rates of infection consequent on different grazing patterns as well as susceptibility (Jallow *et al.* 1994). Like sheep, goats have three or four nematode genera that predominate and are of overwhelming economic importance particularly in the higher rainfall zones.

The major nematode parasites of concern are *Haemonchus contortus* (barber's pole worm) and *Teladorsagia* [*Ostertagia*] *circumcincta* (small brown stomach worm) that parasitise the abomasum, *Trichostrongylus* spp. (black scour worms) in the small intestine and *Oesophagostomum columbianum* (nodule worm) mainly in the large intestine (Table1). *Oes. columbianum* is of most concern in districts experiencing warm, moist summers. It was detected in samples from an abattoir survey in Queensland (McKenzie *et al.* 1979) and is still present in goats in central and western Queensland and in areas of the Northern Territory (Small 2004a). *Strongyloides papillosus* (thread worm) and *Nematodirus* spp. (small necked intestinal worms) are also resident in the small intestine. *Chabertia ovina* (large-mouthed bowel worm) and *Oesophagostomum venulosum* (small bowel worm) inhabit the large intestine but are of lesser concern. The immatures of *Nematodirus* spp. in the small intestine may cause sporadic disease when in large numbers. *Muellerius capillaris* (the small lungworm) is common in higher rainfall areas and *Dictyocaulus filaria* (lungworm) is occasionally found in goats pastured in cooler climates (Sangster 1990).

The effects of nematodes on the host depend on the genera of infecting parasite. Immature *H. contortus* are blood suckers in the abomasum and animals infected with large numbers may suffer anaemia and weakness on exertion and often die before the parasites mature and eggs are detected in the dung. In the more chronic form of the disease, goats may develop anaemia and in severe cases a condition commonly referred to as bottle jaw. This condition is due to protein loss, the result of the parasite's blood feeding activities. *Trichostrongylus* spp. and *Teladorsagia* sp. (collectively referred to as the winter scour worms) infect the small intestine and can produce damaging outbreaks with sudden losses in body condition, poor appetite and diarrhoea. Recovery leaves the animal with an ill-thrift syndrome from scarring of the intestinal wall and consequent poor absorption of nutrients. Mortalities are less commonly seen with infections of these worms than with infections of *H. contortus*. Scour worms are relatively poor egg layers and infections build-up slowly allowing adequate time for treatment interventions.

While some breeds of goat have shown a remarkable lack of susceptibility to cattle parasites (Bisset 1980) Angoras are an exception and may become infested with the cattle parasite, *Ostertagia ostertagi* (Le Jambre 1978). *Trichostrongylus axei* is also shared with sheep and cattle (Sangster 1990).

Chevis (1980) and Sangster (1990) have listed the full range of genera found in goats in Australia together with summaries of their life cycles and pathogenesis.

Table 1 Key endoparasites of goats in Australia

Key Parasite Genera	Common name	Predilection Site	Effect on host	Comments
Haemonchus contortus	Barber's pole worm	abomasum	Blood sucking resulting in anaemia Soft swelling under jaw "bottle jaw" and abdomen Weakness on exertion No weight gain	Prefers warm, moist weather Infections build up rapidly with outbreaks of sudden deaths High biotic potential See Table 2
Teladorsagia circumcincta	Small brown stomach worm	abomasum	Mucosal damage Diarrhoea Weight loss	Survives well in weather too cool for *H. contortus*. Often insidious onset and may have only vague signs of ill thrift before onset of diarrhoea
Trichostrongylus colubriformis	Scour worm	small intestine	Mucosal damage Diarrhoea Weight loss	As for *Teladorsagia* sp. although present in low numbers along with *H. contortus* in tropical and subtropical regions See Table 2
Trichostrongylus vitrinus	Scour worm	small intestine	Mucosal damage Diarrhoea Weight loss	As for *Teladorsagia* sp.
Oesophagostomum columbianum	Nodule worm	large intestine	Mucosal damage Dark green diarrhoea with mucous Nodules on walls of large intestine	Prefers warm moist weather Survives on pasture for about 10 weeks
Muellerius capillaris	Small lung worm	lungs	Large numbers of nodules in lungs Reduced weight Cough and pant Deaths not uncommon if	Higher rainfall zones Land snails and slugs are intermediate hosts

Key Parasite Genera	Common name	Predilection Site	Effect on host	Comments
			left untreated	
Eimeria spp	Coccidia	small and large intestine	Mucosal damage Dark brown diarrhoea	Moist weather and crowding of young stock Acute onset due to high stocking rates and heavy intake of sporulated oocysts
Fasciola hepatica	Liver fluke	bile ducts	Anaemia Submandibular oedema Damage to liver during migration from the small intestine to the bile ducts	Prevalent in cooler, high rainfall and irrigation zones suitable for the aquatic snail host Rapid loss of condition, depending on the size of the infection Exotic snails may extend prevalence into coastal tropical and subtropical zones

5.1.1.1 Prevalence and economic importance

The prevalence of nematodes in production systems is generally limited by low rainfall while genera abundance in the higher rainfall zones depends on temperature and the timing of the rainfall events. The attributes and risks for nematode worm control in each land class and production system are listed in Table 2.

Abattoir surveys of goats sourced from the low rainfall pastoral zones in south-western Queensland and from five different regions in South Australia identified moderate to heavy worm burdens in some animals (McKenzie *et al.* 1979; Beveridge *et al.* 1987). Twenty rangeland goats were sampled from each of two consignments of >1000 goats from the Aramac and the Charleville-Quilpie areas in Queensland. All nematodes found in the survey had been recorded in sheep and goats previously. *H. contortus, Skrjabinema* sp. and *Trichostrongylus* spp. were the dominant genera. *Oes. columbianum* was mostly found in goats from the Charleville-Quilpie area with only one worm found in the consignment from the Aramac region. Average worm egg counts were 1200 (<100-5400) eggs per gram(epg) from the Aramac region and 1900 (100-8400)epg from the Charleville-Quilpie region. In South Australia, 328 rangeland goats were examined with 18 nematode genera recovered. Regional differences in worm burdens generally followed the same pattern as that in sheep. *Trichostrongylus rugatus* was the dominant species in the pastoral zone with *H. contortus*, *C. ovina*, *M. capillaris*, *Nematodirus filicollis* and *Oes. venulosum* and *Trichuris skrjabini* found predominantly in the high rainfall zone but absent from the pastoral zone. In addition, nematodes of camel origin were found in goats, a legacy of the extensive use of camels in that region between 1860 and 1910. *Camelostrongylus mentulatus* also occurs in sheep but *Nematodirus dromedarii* was not found in sheep from the same area. *Oes. columbianum*, *Trichostrongylus probolurus* and *Trichuris ovis* seen in the Queensland survey were not found in South Australia.

Patterns of disease closely follow larval availability on pasture. Much of the following is based on Coop et al. (2002). For a review of the ecology of the free-living stages of nematode parasites see O'Connor et al. (2006).

In tropical and subtropical production systems, *H. contortus* is the predominant parasite species becoming less common towards the temperate zone where *T. colubriformis* is more prevalent. *Oes. columbianum* is common in high temperature zones but its longer development cycle is adversely affected by dry, cool conditions of winter and administration of anthelmintic treatments active against inhibited larvae in the gastrointestinal wall. Where rainfall is not a limiting factor goats are raised in an environment of high and persistent larval challenge. Although worm egg hatching and larval development is rapid and continuous throughout the year, the resulting infective larvae on pasture have very short life expectancies (Barger 1994). Where rainfall is a limiting factor, outbreaks of disease are linked to the rainfall events. Larvae on pasture die off during the dry season and at the start of the next wet season persistent adult worms and hypobiotic larvae in the abomasal wall of the host resume their parasitic activity.

In temperate production systems the more cold-tolerant scour worms such as *Trichostrongylus* spp., *Teladorsagia* sp. and *Nematodirus* spp. tend to dominate with sporadic outbreaks of haemonchosis during wet summers in some districts. Temperate scour worm infective larvae are better able to withstand desiccation than *H. contortus* infective larvae. They are also able to develop at lower temperatures. Where rainfall is non-seasonal or has summer prevalence, large numbers of infective larvae become available on pasture from mid-summer onwards, usually reaching a peak in autumn/early winter. In some temperate areas larval populations tend to remain relatively steady throughout winter (E. Hall 2007 *pers. comm.*) while in other areas pasture larval numbers tend to decline over the winter months as temperatures become too low for development. In the more arid temperate regions where drought is a regular occurrence, the spikes in disease prevalence shift towards the wetter periods in autumn and/or winter months. In the winter rainfall temperate zones larval survival on pasture is relatively long compared with those in subtropical and tropical production systems.

In Mediterranean production systems of southern Australia, winters are relatively mild and wet followed by hot, dry summers lethal to free-living nematode larvae on pasture. Following the first rains in autumn, the adult worms quiescent in the host during the hostile summer months recommence egg laying. This gives rise to infective larvae which reach a seasonal peak in late winter or early spring.

The increasing incidence of dry weather in most production systems, increasing temperatures, irregular rainfall patterns and escalating drench resistance may change the prevalence and incidence of nematode genera locally and within regions.

The host's ability to acquire immunity to nematode infection and limit worm egg output is critical to determining levels of pasture contamination and the incidence of parasitism in higher rainfall production systems. Immunity to nematodes in goats is slow to develop and is often incomplete so that even mature goats are at considerable risk (Kaplan 2006). However, there are well documented reports from Australia of within-in breed variations in ability to withstand nematode infection (Thompson and Bisset 1990). (See 8.1.2.4 Genetics).

The economic damage caused by these parasites is a function of their pathogenicity due to the relative destructiveness of their feeding habits and the numbers present. In pen trials with Kacang cross Etawah goats, weight gain penalties due to *T. colubriformis* were 17.5% and 32.2% for *H. contortus* (Beriajaya and Copeman 2006). Losses due to haemonchosis alone in Kenya in 1992 were estimated to be approximately US $31 million (m) annually (Upton and Gathuma 1992 cited by Odoi *et al*. 2007). McLeod (2004) recently estimated annual costs due to *H. contortus* alone in the humid tropics/subtropics to be $26m, $46m and $103m for Kenya, South Africa and India respectively. During outbreaks of haemonchosis in higher rainfall zones in Australia mortalities of up to 15% of a herd can occur (Lyndal-Murphy unpublished data).

Economic valuations of the effects of these key nematodes on goats are not available, but in sheep McLeod (1995) estimated that the cost of internal parasitism was in the order of A$222m, the sum of control costs (A$81m), losses of wool and meat production (A$100m) and mortalities (A$41m). He considered that nematode parasitism was the greatest constraint on the Australian grazing industry. Sackett *et al*. (2006) calculated that losses due to endoparasitism in sheep pastured in the summer rainfall dominant zone were $4.13 per head under good management and $7.13 per head under poor management. Additional costs of $5.93 per head from reduced income and increased costs of treatments were also incurred. In contrast, there were no losses due to parasitism in the pastoral zone providing additional support to the suitability of the rangeland/pastoral zones for large scale goat enterprises. Also in support of enterprises in rangeland/pastoral zones Alexandre and Mandonnet (2005) observed that goats are efficient producers of meat under such harsh conditions.

Table 2 Land class / Production Systems; attributes and risks for nematode worm control

Land Class/ Production System	Attributes of the production system	Risks in the production system
Rangeland & **Pastoral zones** Tropical /subtropical	Low risk of worm infestations Extensively managed Low stocking rates Browse available Short larval survival time on pasture due to extreme temperatures and low rainfall	In a high rainfall event acute infections of *H. contortus* may occur
Rangeland & pastoral zones Managed Tropical / subtropical	Low risk of worm infestations Extensively managed or managed behind “wire” Low–medium stocking rates Browse available Short larval survival time on pasture due to extreme temperatures and low rainfall	Increased stocking rates could increase the risk of sporadic outbreaks of acute infection of *H. contortus* in the wet season
Rangeland & pastoral zones Depot or aggregators	Quarantine drench most likely effective Low risk of worm infestations Moderate–high stocking rates Supplementary feeding to improve resilience and growth rates Short larval survival time on pasture due to extreme temperatures and low rainfall	In a high rainfall event acute outbreaks of *H. contortus* may occur *Risk of importing drench resistant* worm burdens in goats collected from higher rainfall agricultural zones Increased stocking rates could present opportunities for sporadic outbreaks of disease in the wet season Leaky water troughs and grazing along bore lines will provide a moist habitat for infective larvae
Agricultural zones Tropical / subtropical	Moderate stocking rates Cropping iterations for grazing rotations Ability to grow browse and leguminous crops High growth rates Larval survival on pasture short during summer	Set–stock grazing Very high risk of *H. contortus* infections following rainfall events *T. colubriformis* also present in some regions *Anthelmintic resistance prevalent and escalating*

Agricultural zones temperate	Moderate stocking rates Cropping iterations for grazing rotations Ability to grow browse and leguminous crops Very high growth rates	Set–stock grazing Very high risk of worm infections following rainfall events Larval survival on pasture about 60 days in wet seasons *T. colubriformis* and *T. vitrinus* also present *Anthelmintic resistance prevalent and escalating* Sporadic outbreaks of *H. contortus* after rain in summer
Agricultural zones Mediterranean	Moderate stocking rates Cropping iterations for grazing rotations Ability to grow browse and leguminous crops Very high growth rates in late winter to spring	Set–stock grazing Very high risk of worm infections following rainfall events Larval survival on pasture about 60 days in wet seasons *T. colubriformis* and *T. vitrinus* also present *Anthelmintic resistance prevalent and escalating* Sporadic outbreaks of *H. contortus* after rain in summer in some zones
Agricultural zone Feed lot or aggregators	Quarantine drench most likely partially effective Cropping iterations for grazing rotations Ability to grow browse and leguminous crops Very high growth rates in late winter to spring	High stocking rates High risk of worm infections after rainfall events Temperatures will affect types of worms present. *H. contortus* will build-up quickly in subtropical zones after rain with *T. colubriformis* and *T. vitrinus* in temperate zones Larval survival dependent on rainfall and temperature. *Anthelmintic treatments may be ineffective* with productivity losses
Metropolitan zones Tropical / subtropical	Close to domestic markets Provide high genetic improvements for the industry	Large numbers of small holdings High risk of worm infections related to rainfall patterns

	Maximise liveweight gains High management inputs Ability to provide browse Feed in raised toughs	High stocking rates Graze grass *H. contortus* predominant with black scour becoming important in late summer *Anthelmintic resistance most likely severe* Leaky water troughs provide habitats for infective larvae and coccidia
Metropolitan zones temperate	Close to domestic markets Provide high genetic improvements for the industry Maximise liveweight gains High management inputs Ability to provide browse Feed in raised toughs	Large numbers of small holdings High risk of worm infections linked to rainfall events High stocking rates Graze grass Temperate scour worms, sporadic outbreaks of *H. contortus* after rain in summer *Anthelmintic resistance most likely severe* Leaky water troughs provide habitats for infective larvae and coccidia

5.1.2 Liver fluke

Fasciola hepatica (liver fluke) adults live in the bile ducts of goats and produce eggs into the gastrointestinal tract which are then passed out with the dung of the host. Further development of the non-parasitic stages occurs in the partner aquatic snail, *Austropeplea tomentosa*. After two to three months depending on temperature, the snail releases tiny swimming larvae that encyst on pasture near the edge of water. Encysted stages are subsequently eaten with the vegetation.

The distribution of fluke is dependent on the habitat of its partner snail. *A. tomentosa* is present in elevated higher rainfall and irrigation zones of New South Wales, Victoria and Tasmania and restricted small areas in Queensland and South Australia. More recently exotic snails, *Pseudosuccinea columella* and *Austropeplea viridis*, more tolerant of higher temperatures than *A. tomentosa,* have been introduced with the aquarium trade and have the potential to increase the spread of fluke to some metropolitan districts particularly along the northern edge of its distribution in south-east Queensland (P. Green 2006 *pers. comm.*; Molloy and Anderson 2006).

While fluke in goats is relatively uncommon, infections do cause significant damage to the liver with deaths in untreated cases. In chronic infections, adult fluke cause anaemia. The onset of dry seasonal conditions forces goats to graze close to swampy areas where vegetation carries encysted immature fluke. In fluke endemic areas in the higher rainfall zones clinical infection occurs from mid-summer through to autumn with eggs produced in the dung 10-12 weeks later.

5.1.3 Coccidia

Coccidial infection of the small intestine is caused by the unicellular parasite *Eimeria* spp. Mixed infections usually occur in young animals less than six months of age and each may exert pathogenic effects. While small numbers of oocysts are present in healthy animals, heavy burdens can cause ill thrift, severe diarrhoea, weight loss and sometimes death within 24 hours. Young or naive goats are very susceptible especially during times of stress such as weaning or transport between properties. The degree of damage depends on the number of oocysts ingested. Feedlot coccidiosis manifests itself in a sudden outbreak of acute disease in a large number of kids within a week or two of their entering the feedlot.

O'Callaghan (1989) detected oocysts of *Eimeria* species in 97% (n=497) of domestic goats and 3% (n=318) of rangeland goats examined. The species of *Eimeria* identified from domestic goats (and their prevalences) were *E. hirci* (82%), *E. arloingi* (81%), *E. ninakohlyakimovae* (51%), *E. alijevi* (49%), *E. caprina* (32%), *E. christenseni* (29%), *E. caprovina* (12%), *E. jolchijevi* (9%) and *E. apsheronica* (6%). Two of these species, *E. caprina* and *E. jolchijevi,* were not found in the rangeland goats. *E. christenseni*, *E. caprovina* and *E. jolchijevi* were more prevalent in domestic goats less than 12 months old than in adults.

If exposure to oocysts is controlled, the infection becomes self limiting. Food and water contaminated with faecal material is often the trigger for infection particularly when it coincides with periods of nutritional stress and crowding onto unhygienic conditions during showery weather (Howe 1980). Management to prevent contamination is a key element in preventing disease.

5.1.4 Tapeworm and larval tapeworms

Infection with tapeworm (*Moniezia* spp.) is usually restricted to kids up to six months of age. Some carry large burdens that may reduce growth and have the potential to cause intestinal blockage (Sangster 1990). Discarded segments with the appearance of white grains of rice are easily seen in dung and producers often find them a cause for concern. There are only a few reports in the literature indicating that tapeworm is of economic significance. Southworth et al. (1996) treated 100 lambs with two praziquantel-levamisole treatments four weeks apart. Lambs gained significantly more weight ($P<0.001$) than did either the levamisole or the untreated control groups of 100 lambs. Praziquantel is a tapeworm drench and levamisole controls nematodes but not tapeworm. Rickard (1990) also reported that heavy burdens of tapeworm in kids can sometimes cause pathological changes.

Cysticercus ovis (sheep measles) and *Cysticercus tenuicollis* are larval stages of the tapeworms *Taenia ovis* and *Taenia hydatigena* respectively that are resident in the small intestine of dogs. *C. ovis* is found in heart and musculature while C. *tenuicollis* is usually seen as pendulous cysts hanging from the peritoneal cavity. *C. tenuicollis* may cause acute disease during its migration through the liver (Sangster 1990). Cysts of *Echinococcus granulosus* (hydatids) adults also resident in dogs are commonly found in the liver but also lungs and other tissues. Control is affected by eliminating adult tapeworms in dogs with anthelmintic treatments and by not feeding offal. McKenzie et al. (1979) found *C. tenuicollis* migration tracts in the liver from 53 lesions collected from consignments in an abattoir survey in south-western Queensland. Hein and Cargill (1981) also reported larval cestodes in rangeland goats from South Australia with mature cysts detected in 52 (1.4%) of 3720 goats examined.

5.2 External Parasites

A number of ectoparasites infest goats in Australia (Table 3). Of these the most important and by far the major reason for the application of insecticides are lice. Ticks can be a problem in some areas and there are intermittent problems with opportunistic blood feeding parasites, myiasis flies and nuisance flies. A number of species of mites also regularly infest goats but their economic importance is usually small and therapeutics are seldom applied to control them.

5.2.1 Lice

Four species of lice are found on goats in Australia. Two species, *Bovicola caprae* and *Bovicola limbatus,* are chewing lice that feed mainly on skin scurf and superficial skin cells. *B. caprae* is widespread on most goat species whereas *B limbatus*, the Angora goat biting louse, is restricted mainly to Angora goats (Price and Graham 1997). Chewing lice exert economic effects by irritating the host and stimulating pruritic behaviour.

The goat sucking louse (*Linognathus stenopsis*) and African blue louse (*Linognathus africanus)* are blood-feeding lice which feed by penetrating capillaries with finely adapted mouthparts and sucking blood. Sucking lice are larger in size than the chewing lice and appear bluish in colour. *L. stenopsis* is found on most goat species and often occurs in mixed infestations with *Bovicola* spp. *L. africanus* was first identified in Australia in 1988 from a herd of Anglo Nubian goats from Alice Springs and subsequently identified following collection from a goat during post-mortem at Naracoorte in South Australia (O'Callaghan et al. 1989). As it is very close to *L. stenopsis* in appearance it could easily have been misdiagnosed previously. The authors note that more extensive surveys are required to determine the distribution of *L. africanus* in Australia.

Price and Graham (1997) indicate a larger yellow hairy goat louse, *Bovicola crassipes,* as having a worldwide distribution, mainly on Angora goats. However, this species has not been recorded in Australia. Sheep lice (*Bovicola ovis*) have been shown to transfer to and breed on Angora cross goats held in close contact with infected sheep (Hallam 1985). However, this seldom occurs in the field and sheep lice are not a significant pest of goats under practical conditions.

Goat lice are generally specific to goats and are unlikely to breed on other hosts. Hallam (1985) found that *B. caprae* did not transfer from goats to sheep held in close contact for eight weeks and O'Callaghan *et al.* (1989) reported that although both *B. caprae* and *L. stenopsis* transferred from goats to lambs run with them, they did not persist on the lambs beyond 12 days. L. stenopsis has also been reported from sheep overseas (Price and Graham 1997). Although *L. africanus* has been recorded overseas from a wider range of hosts including sheep (Kemper and Hindman 1950) cattle (Rao *et al*. 1977) and deer (Brunetti and Cribbs (1971), it appears that this species is not widespread in Australia.

5.2.1.1 Prevalence and economic importance

There is little data available on the prevalence of the different lice species on goats or their economic impact in Australia. McKenzie *et al.* (1979) examined goat hides collected in an abattoir survey of rangeland goats from the Aramac region in Queensland and indicated that they were infested with *B. caprae* and *L. stenopsis,* but did not provide data on the level of infestation. Hein and Cargill (1981) indicated lice were "regularly encountered" in an abattoir survey of rangeland goats from the pastoral areas of north western New South Wales and South Australia.

They noted that the degree of infestation varied markedly among individual goats and between separate consignments, but remarked that the lice appeared to be causing little ill effect. They noted however, the potential for transfer to mohair flocks where considerable economic loss could result.

Rubbing and scratching to relieve irritation from lice is particularly damaging in Angora goats where significant fleece damage can be caused. Roberts (1952) notes that chewing lice are able to bite through mohair fibres with their mandibles and Price and Graham (1997) note that both *B. crassipes* and *L. africanus* may pull several fibres together for oviposition and cause matting of mohair by this means. Price *et al.* (1967) considered that chewing lice reduced the clip of mohair by as much as 10 to 25% and Babcock and Cushing (1942) suggested reductions of 230 g per head from the effects of lice. Thorold (1963) noted that heavy louse infestations caused staining and reduction in the lustre of mohair, weakening and breaking of the fibres and significantly reduced market value.

Table 3 Key ectoparasites of goats in Australia

Parasite group	Species	Prevalence	Predilection sites	Economic impact
Lice				
Chewing	*Bovicola caprae*	Widespread	Whole body	Reduction in mohair cut and quality Reduction in skin quality
	Bovicola limbatus	Mainly angoras	Whole body	
Sucking	*Linognathus stenopsis*	Widespread	Whole body	Anaemia, reduction in growth rates and possible death in heavy infestations (sucking lice)
	Linognathus africanus	Uncertain probably rare	Whole body	
Mites	*Psoroptes cuniculi*	Uncertain	Ears	Major impact is on skin quality in severe infestations
	Raillietia caprae,	Uncertain	Ears	Spread of mycoplasmas by ear mites?
	Chorioptes bovis	Uncertain	Feet, legs, scrotum	
Ticks	*Demodex caprae*	Uncertain	Hair follicles	
	Ixodes holocyclus	Localised significance		Paralysis (*Ixodes*)
	Rhipecephalus sanguineus *Rhipicepalus microplus*			Skin quality and weight gain in heavy infestations
Fleas	*Ctenocephalides spp*	Rare		
Flies				
Nasal bot	*Oestrus ovis*	Uncertain	Nasal passages	Uncertain
Blood feeding and nuisance flies	Stable flies, March flies, mosquitoes, sand flies, midges, bush flies, houseflies	Significant problems intermittent and local	Various	Irritation, disease transmission in some instances

Even heavy infestations of *B. ovis* do not appear to reduce growth rates or bodyweight in sheep (Wilkinson *et al*. 1982; Niven and Pritchard 1985) and it is likely that there is similarly little effect on growth rates from chewing lice in goats. Blood feeding lice can be more debilitating than chewing lice when present in high numbers and can cause anaemia and the formation of scabby bleeding areas in heavy infestations (Roberts 1952). Van Tonder (1975) indicated sucking lice to be the most troublesome species in Angora goats in South Africa and Thorold (1963) stated that massive infestations of *L. africanus* could cause anaemia, oedema of the legs, stunting of newly weaned goats and occasionally resulted in the death of heavily infested animals, particularly kids. Fajimi et al. (2003) reported improvements in weight gains of up to 100 g/day from the treatment of heavy infestations of *L. stenopsis* in West African dwarf goats.

Bayou (1998) noted that 56% of rejections of goat skins in Ethiopia were due to defects associated with ectoparasite infestation.

These rejections were due to cockle like disease and associated scratching and scarring of the skins. An investigation by Sertse and Wossene (2007) found that most damage was associated with sarcoptic mange (which is not known to be present in goats in Australia) and did not appear to be associated with *Linognathus* spp*.* Infestations of *B. ovis* are known to cause a skin defect known as cockle in sheep skins, which can lead to downgrading of affected skins and significant reduction in hide value (Heath *et al*. 1995a). It is likely that ectoparasite infestation and associated rubbing and scratching also affects the quality of goat skins but there are no estimates of the impact on Australian goat skin values.

Yadav *et al*. (2004) note occasional self inflicted injuries leading to myiasis and hairball formation in the gastrointestinal tract as a further source of loss from lice in goats in India. Screwworm is not present in Australia and although species of calliphorid flies occasionally cause strike in goats (King 1980a) this is unlikely to be a common occurrence in Australian goat herds.

5.2.2 Ticks

A number of species of ticks are found on goats although they are seldom a major problem. The main species in Australia include the paralysis tick *Ixodes holocyclus* (also commonly called the scrub tick or dog tick), the 'Australian' cattle tick (*Rhipicephalus* [*Boophilus*] *microplus)* and the New Zealand cattle tick (*Haemaphysalis longicornis*). The brown dog tick *Rhipicephalus sanguineus* and various other species of native ticks are also occasionally recovered from goats.

I. holocyclus is the main species of concern as it may cause posterior paralysis in young goats. However, affected goats usually recover (Knott 1961). Paralysis is caused by secretion of a neurotoxin, mainly by the engorging female. Larvae and nymphs also secrete the toxin but in smaller amounts so that quite heavy infestations of these stages are required to cause paralysis. Infested animals often develop keratitis and an ocular discharge in association with paralysis (Knott 1961). *I. holocyclus* is usually restricted to bush and scrub areas and is limited in its distribution by its need for a humid climate. It is found along the east coast from northern Queensland to Bairnsdale in Victoria. In Queensland it has been found inland as far as Warwick, but in New South Wales and Victoria it is seldom found more than 16 km from the coast (Arundel and Sutherland 1988).

The New Zealand cattle tick (*Haemaphysalis longicornis*) has a wide host range and also infests goats. Its effects in goats have not been documented, but Heath (1985) indicates that an infestation of sheep with an average of 28 ticks per animal significantly reduced blood haemoglobin levels and packed cell volume and reduced bodyweight by up to 1.6 kg per head. The 'Australian' cattle tick, *R. microplus* is reported as rarely found on goats in Australia (Arundel and Sutherland 1988) although this species is known to breed on goats in Brazil. Studies in Brazil showed that *R. microplus* with goats as hosts reproduced as successfully as with cattle as hosts (Prata *et al.* 1999) and these authors suggest that goats might be alternative hosts for *R. microplus* and a source of pasture contamination. Callow (1965) also reports a study in Australia in which *R. microplus* larvae fed on a goat subsequently produced viable progeny.

In addition to paralysis caused by *I. holocyclus* and reduction in weight gains, tick infestation is known to be a significant cause of downgrading of animal skins (Everett *et al.* 1977; Heath 1994). Hein and Cargill (1981) report a high prevalence of Q fever in rangeland goats (51.5 % showed positive serological reactions) and it is known that ticks can transmit this disease so the potential for transmission to humans by multi-host ticks such as *I. holocyclus* or *H. longicornis* that have become infected from goats should be borne in mind.

5.2.3 Mites

A number of species of mites are known to infest goats in Australia and some of these appear to be present at relatively high prevalence. The species found include the ear mites *Psoroptes cuniculi* and *Raillietia caprae*, the follicle mite *Demodex caprae* and the chorioptic mange mite *Chorioptes bovis*. There is now compelling evidence that *P. cuniculi* and *P. ovis*, the causal agent of sheep scab which was eradicated from Australia in 1896, are actually strains or ecotypes of the same species (Mullen and O'Connor 2002). *Sarcoptes scabiei* does not appear to infest goats in Australia although it causes serious defects in goat skin in other countries (Sertse and Wossene 2007) and in severe infestations may result in the death of goats (Manning *et al.* 1985).

Psoroptes ovis has been reported from the ears of goats in Victoria, Queensland and New South Wales. Cook (1981) found that 21% of 185 goats and 22% of 23 herds of domesticated goats examined on the North Coast of NSW were infested with *P. ovis*. In one herd mites were detected on swabs from 19 of 31 goats tested. In New Zealand (Heath et al. 1983) recorded an overall prevalence of infestation of 10.8% with a peak of 41.7% in winter. McKenzie *et al.* (1979) found only one infested ear in a survey of rangeland goats in outback Queensland and Hein and Cargill (1981) found only two infested goats amongst samples examined from the Broken Hill area. Goats with dependent ears (such as Anglo Nubian) appear more susceptible than goats with erect ears (Bates 1991*)*. Cook (1981) notes from a comparison of swabs and examination following autopsy that the swabbing technique could underestimate mite prevalence.

Lesions can range from a dry crusty scale on the external ear canal with no clinical symptoms sometimes extending onto the face (Roberts 1952) to severe lesions covering much of the body and causing death (Littlejohn 1968; Munro and Munro 1980). Spread outside of the ears is most commonly seen in old or debilitated goats (Bates 1991). In severe cases the poll may be affected and scabs may be found on the pasterns. Examination of the ear will often show a marked accumulation of wax at the base of the ear canal, sometimes completely blocking it.

Raillietia caprae also occurs in the ears of goats and Cook (1981) found *Raillietia* mites in 13% of 185 goats and 74% of 23 herds examined in New South Wales. Mites were identified prior to autopsy in only two of 18 infested goats, again suggesting that inspection of ears probably significantly underestimates the prevalence of infestation.

Ear twitching and scratching of the ears is commonly observed in goats infested by both species but in most cases clinical symptoms are not obvious. Cottew and Yeats (1982) isolated seven species of *Mycoplasma*, four known to cause disease in goats, from *R. caprae* and *P. cuniculi*. The authors note the possible role of *P. cuniculi* and *R. caprae* in spreading mycoplasmas requires further investigation.

Chorioptes bovis is a surface dwelling mite which also infests sheep, cattle, horses and a range of other animals. It appears to cause lesions through stimulating an immune reaction manifest as crusts or 'scabs' of yellowish exudate that can range in thickness from a few millimetres to several centimetres in thickness. Chorioptic mange mites are found most commonly on the coronet, udder, scrotum and limbs of goats although in severe infestations lesions can extend to most body areas (Manning *et al*.1985). Babcock and Hardy (1960) reported severe hair loss in goats caused by *C. bovis* infestation. There is little information available in Australia but in New Zealand Heath *et al.* (1983) examined 368 rangeland goats and found an overall prevalence of 59% which ranged from 27% in summer to 100% in winter. Although infestation was relatively common, the occurrence of clinical symptoms was rare.

Demodex caprae belongs to a highly specialised genus of mites that live in the follicles and sebaceous glands of a wide range of wild and domestic animals. *D. caprae* usually causes few ill effects but can sometimes form papules or nodules on the head, neck, shoulders and flanks of goats. Infestations with clinical symptoms have been reported in Queensland (King 1980b) and in Victoria in Saanen goats (Seddon 1968) where it caused crusty scabs which when removed left raw lesions. Seddon (1968) notes when severe in goats, it can spread rapidly and potentially cause death. Much higher prevalences have been recorded in other countries (Manning *et al*.1985). The main effect is on skin quality and infestations of the goat follicle mite were reported as a cause of downgrading of skins in Africa (Bwangamoi 1969) and as causing holes and white spots in leather from goats in India (Bhaskaran *et al.* 1968).

5.2.4 Nasal bot

The nasal bot fly (*Oestrus ovis*) is a worldwide pest of sheep and goats. The fly deposits newly hatched larvae, about 1 mm long, in the nostrils of the host. The larvae move into the nasal passages and attach there for various periods of time before moving to the frontal sinuses where they complete their development. They do not move into the brain as is commonly suggested. Once mature, the third stage larvae which may be up to 2 cm in length move back to the nostrils and are expelled, usually by the goat sneezing, and pupate in the soil.

The flies are most active in the warmer months and may disturb sheep or goats in their efforts to deposit their larvae. This can interfere with grazing and animals under attack are often seen bunched together with their heads pushed into the flanks of other animals or close to the ground. The mouth hooks and spines on the larvae irritate the mucus membranes of infected animals, often leading to a mucopurulent discharge and sneezing. There is only limited information available on extent of infestation of sheep in Australia and no information in goats. Roberts (1940) reported *O. ovis* as widespread in sheep in Queensland and D. Scobie *pers. comm.* (1985) recorded an infestation rate of 28% in an investigation of 600 sheep heads collected from June to August in South Australia. This was lower than in many overseas studies with sheep (Meleney 1962; Horak 1977; Rogers and Knapp 1977). Arundel and Sutherland (1988) are of the opinion that the widespread use of anthelmintics and organophosphate insecticides, some of which also have activity against nasal bots, has probably considerably reduced the prevalence of *O. ovis*.

Dorchies *et al.* (2000) in France notes that the prevalence and numbers of *O. oestrus* in goats are generally less than in sheep. They found larvae in 28% of 672 goats examined and the prevalence rate varied from 6% in September to 47% in April. Other overseas studies with goats include that of Biu and Nwosu (1999) in Nigeria who reported that 53.8% of Borno-White Sahel goats were parasitised by *O. ovis* larvae, Unsworth (1948) also in Nigeria, who found that 19% and 68% of goats from two locations were infested, Pathak (1992) in northern India who reported a prevalence of 53.4%, Martinez et al. (1992) in Mexico who found a prevalence of 31.3%, Vassiliades (1989) in Senegal who found that approximately 50% of goat heads examined were infected, Yepez and Gallardo (1974) in Venezuela who found *O. ovis* in 13 of 27 goats examined in an abattoir survey and Ranatunga and Rajamahendran (1972) in Sri Lanka who found larvae in the nostrils of 30% of Jamnapari goats and 16% of South Indian goats.

The economic impact of *O. ovis* in sheep is the subject of some debate and there appear to be no reported studies of economic effects on goats. In sheep, Arundel and Sutherland (1988) indicate most infestations are probably benign and American studies with lambs found no difference in weight gains or carcase evaluations between infested animals and those cleared of *O. ovis*

(Buchanan *et al.* 1969). However, Horak and Snijders (1974) showed that treatment of Merino lambs increased their growth rate and almost eliminated the 'tail' in a group routinely treated for internal parasites. Two Russian studies both showed that treatment for *O. ovis* increased weight gains and wool cut (Ponomorev 1976 cited by Drummond et al. 1988; Bukshtynov 1980). Wall and Shearer (2001) note that infestation with *O. ovis* has been associated with reductions of 1-4.5 kg in weight gain, 200-500 g in wool production and 10% in milk production in sheep.

Dorchies *et al*. (2000) noted that in countries with a hot dry climate, infection can severely impair health when nasal discharge becomes caked with dust. Some sheep and goats develop mouth breathing which interferes with grazing and rumination, can induce lung abscesses and emaciation and can ultimately lead to death. Zumpt (1965) notes that the larvae can sometimes also lead to secondary infections and Ranatunga and Rajamahendran (1972) found a significantly higher incidence of pleuropneumonia in goats infested with *O. ovis.*

5.2.5 Myiasis, biting and nuisance flies and fleas

There are a number of species of nuisance and biting flies that may affect goats. These include stable flies, bush flies, mosquitoes, biting midges, March flies, sand flies, black flies and buffalo flies. Goats can occasionally also become flystruck in wounds, particularly fighting wounds in bucks, and where they become fouled with urine or faeces (King 1980a). Feeding by stable flies (*Stomoxys calcitrans*) can produce large sores on the legs, face, ears udder and scrotum of goats and has been associated with reductions in weight gains in cattle (Campbell *et al*. 1993). Bush flies (*Musca vetustissima*) can annoy goats by feeding around the eyes and are known to transmit eye diseases such as pink eye in other species. Mosquitoes have been shown to produce economic loss in growth rate in cattle when in high numbers (Steelman *et al*. 1972) and the same may be so of goats. Biting midges (*Culicoides* spp.) are mainly of concern as they can transmit bluetongue, an exotic disease of considerable concern in sheep and goats. Sheep keds can also infest goats (Coles 1997), but keds are now never reported from sheep flocks and it is likely that they may have been eradicated from Australia.

Fleas can also infest goats (Manning *et al*.1985). These authors note cat fleas *Ctenocephalides felis* and sticktight fleas *Echinophaga gallinacea* as the main species but King (1980a) notes infestation with dog fleas *Ctenocephalides canis* in Australia and Christadoulopolous *et al.* (2006) in a study of 64 dairy goat herds with a history of flea infestation in Greece, found that the major flea species involved was *Pulex irritans*. This species has been found infesting pigs on straw in Australia (I. Beveridge *pers. comm.*) and could potentially also infest goats. Flea infestation is most likely to occur in housed goats and is unlikely to be a problem in paddock run animals.

Although fleas and biting, nuisance and myiasis flies can occasionally be a problem it is unlikely that they are a significant reason for the application of chemicals to goats in Australia.

6 Chemical control of parasites

6.1 Internal Parasites

6.1.1 Current chemical use practices

Information used in this section was sourced mainly from the responses to a national mail and email survey of the industry conducted from March 1 to June 30 2007 and also from semi structured phone interviews with industry magazine staff, goat producers and aggregators, abattoir owners, industry magazine articles and scientific publications. Of the 1,500 surveys distributed 195 replies were received achieving a response rate of 13%.

Eighty-one per cent of respondents ran either intensively managed (54%) or moderate input grazing enterprises (27%). The remaining 19% were from respondents who ran extensive rangeland enterprises (6%), were aggregators (2%), or who formed part of the education or hobby sectors (11%). Forty-five percent of producers ran up to 100 goats, 36% ran 100–500 goats and 13% ran 500–1,000 goats. Four per cent of producers ran enterprises carrying 1,000–10,000 goats and 2% of producers ran 10,000 or more goats. Eighty-five percent of goat numbers (n=142,227) in the survey were run on 20% of holdings. Eighty percent of producers with smaller enterprises ran on average 140 head.

While there is a bias in favour of the intensively managed and moderate input sectors, it is these sectors most likely to be heavy users of chemical treatments for parasites both internal and external. Many of the respondents also ran other enterprises such as farming, cattle, poultry and plant nurseries. Control of internal parasites of goats has in the last 20 years been almost completely reliant on chemical treatments used in a set-stocked regimen most likely because anthelmintic treatment has been easy, safe, effective and relatively cheap (See Appendix 2 Results of the survey).

6.1.1.1 Nematodes

Producers indicated that they used products registered for use in goats but also a range of products not registered for goats but available to the sheep, equine, poultry and small companion sectors and also from human medicine (Table 4).

Eighty-eight percent of respondents used drenches to control worms. On average, these producers drenched 4.5 times (range 0–14) in the last two years and of these, nine respondents (5%) drenched 10 or more times in the last two years. Of those producers who used drenches, 51% indicated that they used the Macrocyclic Lactone (ML) drenches, 22% indicated that they used the Benzimidazole (BZ) drenches, 12% used various combinations of drench actives available as commercial multi-active products, 7% used closantel (CLOS), 6% used Levamisole (LEV), and 2% used the organophosphate (OP-NAP and OP-TRI) based drenches. Of the producers who drenched, 18% drenched for internal parasites within six weeks of sale.

Table 4 Products used for the control of nematodes and liver fluke as indicated in the survey of goat owners

Active group	Brand names nominated as used in the past 2 years	Formulation type
BZ	Alben, Panacur, Valbazen, Farma Worma Drench	oral
BZ	Captec Extender, adult and weaner	***capsule***
BZ-triclabendazole	Fasinex, Tremicide, FlukareC	oral
LEV	Big L, Levamisole, Nilverm, Rycozole, Levamisole Gold	oral
Pyrantel/morantel	Combantrin for humans	oral
ML-Moxidectin(ML-Mox)	Cydectin, Eweguard, Weanerguard, Cydectin LA injection Cydectin Pour-on (dairy goats)	oral ***injectio****n* ***pour-on***
ML-Abamectin(ML-Aba)	Abamectin, Virbamec, Promectin for horses First Mectin (praziquantel for tape) Genesis injection	oral ***injection***
ML–Ivermectin(ML-Iver)	Ivomec, Noromectin, Equest Paste for horses	oral
ML-Iver	Ivomec Maximiser, adult and weaner	***capsule***
ML-Iver	Ivomec plus for cattle	***injection***
OP–naphthalophos (OP-NAP)	Rametin	oral
OP–trichlorfon (OP-TRI)	Neguvon	oral
CLOSANTEL(CLOS)	Closantel, Closicare, Razar, Seponver or Sustain,	oral
BZ+LEV	Combi, Duocare, Scanda	oral
BZ+LEV+ML-Iver	Triton	oral
BZ+LEV+ML-Aba	Hatrick	oral
BZ+LEV+ML-Aba+CLOS	Q-drench	oral
ML-Mox+praziquantel	Equest Plus tape gel for horses	oral
ML-Aba+praziquantel	Virbamec First Drench Genesis Tape	oral
OP-NAP+BZ+LEV	Rametin Combo	oral
CLOS+BZ	Closal or Closicomb	oral
CLOS(increased dose)+ML-Aba	Genesis Xtra	oral

Formulations

A variety of formulations such as oral, topical and injectable were stated as being used. Producers operating in extensive production systems used injectable formulations for the quarantine drench as rangeland goats unused to being restrained endangered operator's safety during dosing of oral chemical treatments.

Use of goat-specific dose rates for oral products

Most respondents to the survey and those who participated in informal interviews understood from industry advisers that goats are considered to be metabolically different from sheep as drenches are metabolised faster, drench products are not as bioavailable and ovine dose rates are suboptimal.

The differences are considered to be due to different drug pharmacokinetics in goats and the greater degree of rumen bypass leading to underdosing (Rickard 1990; Hennessey *et al*. 1993). Underdosing has been identified as one of the main reasons that drench resistance developed in goats before sheep (Thompson and Bisset 1990).

Many industry advisers have tried to establish goat-specific dose rates. For instance, Jackson and Bartley of the Moredun Research Institute in Scotland cited by Smith (2007) in The Australian Goat World Magazine recommend that BZ drenches be dosed at twice the recommended ovine dose rate i.e. 10 mg/kg and the LEV drench at one and a half times i.e. 7.5mg/kg for goats. Sangster (1990) recommended a higher dose rate for LEV of 12 mg/kg as the action of LEV is related to peak concentration. Double the ovine dose rate for LEV is approaching the level that could cause toxicity in some of the more susceptible breeds such as Angoras (Cawley *et al.* 1993). Smith and Bell (1971) determined that a dose of 8 mg/kg was safe for Angora goats but higher doses up to 32 mg/kg caused transitory head shaking, episodes of teeth grinding, facial twitching, incoordination, general muscular tremor and dyspnoea. Affected goats returned to normal and resumed eating three to five hours after treatment ceased. Kaplan (2006) recommends double the ovine dose rate for the ML oral drenches for goats in southern and central United States of America.

Reducing feed intake before drenching

Reducing feed intake by yarding goats for 24 hours before and 12 hours after drenching can extend the plasma profile of the BZ and ML drenches with a concomitant increase in efficacy against resistant strains of worms (Ali and Hennessey 1995; Ali *et al*. 1995). Reduction of feed intake before oral anthelmintic treatment slows the ruminant digesta flow, prolongs and extends the availability and therefore increased efficacy, of the BZ and ML-abamectin compounds. This is a cost effective option that not only increases efficacy of 'older' compounds, but will prolong the useful life of the 'newer' drugs (Hennessey 1994a; 1994b). Feed withdrawal is not recommended for dairy goats. Withdrawal of feed prior to drenching is also not recommended for the LEV, CLOS or organophosphate groups due to toxicity concerns and different pharmacokinetics. Gill *et al*. (1999) identified optic abnormalities in sheep and goats from closantel toxicity.

Repeat dosing

In Australia, producers are advised to administer two or three treatments separated by a period of 12 hours (BZ) or 36–48 hours (ML) as a mechanism to manage resistance (Small 2004b). Efficacy of 'repeat' treatments of a single dose is substantially better than a single treatment at double or treble the recommended dose rate. Based on the modes of action of these antiparasitic drugs, maximum activity requires exposure of the parasite to 'toxic' concentrations for as long as possible. Exposure to sub-lethal concentrations therefore has significant potential to promote the development of resistance. The greater hepatic activity of goats speeds drug elimination and increases the potential for generation of drench resistance in parasites of goats as compared to sheep (Hennessey 1997).

Use of multi-active products

Current recommendations for the management of drench resistance in the sheep industry encourage the use of multi-active products except in very dry seasons when larval numbers in refugia (See 3 Definition of Terms) are low (R. Dobson *pers. comm.*). It is suggested that this strategy protects the drench active to which there is less resistance (E. Hall *pers. comm.*). However, Bath *et al*. (2005) do not support this approach as use of such products will mask increasing resistance to all the individual actives in the product. Worms with resistance to each of the drench actives will survive and pass their genetic characteristics to their progeny, with the progressive development of strong resistance to all drench actives (Craig 2006).

Triton, a multi-active sheep product combining a single dose of each of the BZ, LEV and ML-iver actives, was nominated as an often-used quarantine drench.

Use of laboratory testing of drenches for efficacy
Laboratory testing services can provide two tests of importance to goat producers. The most commonly used test is the worm egg count test to determine if goats need to be drenched and the other is based on the worm egg count test but identifies resistance in worms to drenches – the Faecal Worm Egg Count Reduction Test (FECRT) (Coles *et al*. 2006).

Forty-one percent of respondents to the survey indicated that they used laboratory testing and that drench decisions were based on worm egg count test results. Drench resistance testing was not nominated as a management practice and no respondents indicated that they had conducted a drench resistance test. One respondent (<1%) used a post-drench screen to gauge if drenches were achieving good control.

Anthelmintic resistance
There are now no treatments that are able to claim a 100% kill of worms, 100% of the time, in 100% of animals managed in small ruminant production systems (Waller 2006a). Widespread resistance to all drench actives in most key genera of nematodes has been detected in Australia. Rolfe *et al*. (1995) performed FECRTs on 21 dairy goat farms in NSW. Resistance to ML-Iver was found on two farms, but only in*Teladorsagia* sp.. Resistance to the BZ albendazole was found on 13 of 15 farms. LEV resistance was found on 10 of 12 farms. CLOS (active against *Haemonchus* sp.) resistance was detected on one of the 21 farms. Since then resistance to most drench actives in all key genera of worms of goats has become more widespread. Veale (2002) detected resistance in *Teladorsagia sp*. to a number of anthelmintic actives including ML-Mox. Le Jambre *et al*. (2005) also detected resistance in *H. contortus* and *T. colubriformis* to a number of drench actives including ML-Mox but not to OP-NAP. ML-Mox when dosed at twice the sheep dose rate failed to control either of these strains of nematodes after passage into sheep. West *et al*. (2004) reported multiple resistances in *Trichostrongylus* spp. and *Teladorsagia* sp. in goats to the BZ oxfendazole, LEV and ML-Mox, and lack of efficacy of OP-TRI (only registered for *H. contortus* control) against these parasites. The prevalence and incidence of resistance will vary between regions but resistance is most likely present to some extent on all goat rearing properties in the agricultural and metropolitan zones.

The prevalence of drench resistance is not known as resistance testing is not a strategy adopted by the goat industry. In the absence of testing, resistance only becomes obvious when the product has an efficacy of about 50% (van Wyk 2006). If efficacy can be restored to about 80% or better through feed withdrawal, goat-specific dose rates and repeat drenching there may be no production penalties but the system is likely to be unsustainable without integration with non-chemical strategies (Barger 1995).

Long-acting oral and injectable products based on CLOS and ML-Mox, slow release preparations such as capsules, and long-acting injections with extremely long residual actions select heavily for resistance particularly in drier seasons when few larvae are in refugia. Widespread resistance due to overuse and incorrect use of chemical treatments especially without due regard to the concept of refugia has rendered many drench actives ineffective for worm control (van Wyk 2001; 2006).

Anthelmintic resistance to an increasing number of drench actives in key internal parasites of goats and sheep is also prevalent in Europe (Artho *et al.* 2007), south-eastern and south central United States of America (Kaplan *et al.* 2005), South Africa (van Wyk *et al.* 1997), Malaysia

(Chandrawathani *et al*. 1999; Chandrawathani *et al*. 2004b), New Zealand (West *et al.* 2004) and Australia (Besier and Love 2003).

However, resistance to the ML group of actives in Australia is already widespread in parasites of goats. Resistance to ML-Mox, the most potent of the ML group indicates that resistance is already present to ML-Aba. It is therefore unlikely that chemical treatments on their own will be able to provide adequate control of nematodes across the industry (van Wyk 2006).

6.1.1.2 Coccidia

Sixty-seven percent of producers responding to the survey indicated that coccidiosis was never a problem while 29% sometimes had a problem, 2% mostly had problems and 2% always had problems. Sixty-eight percent of producers treated coccidiosis outbreaks with the chemicals listed in Table 5, while 21% used feed additives such as Rumensin as a preventative, 6 % used minerals and the remainder used non-chemical treatments.

Table 5 Products used for the control of coccidia as indicated in the survey of goat owners

Active	Brand names nominated as used in the last 2 years	Administration type
Toltrazuril	**Baycox**	oral solution
Amprolium & Ethopabate	**Keystat**	oral solution
Sulfadimidine	**SD333**	injection
Oxytetracycline	**Oxytet**	in feed
Monensin	**Rumensin**	in pellets
Sulphur		in feed
Sulphonamides & other antibiotics	**Scourban**	liquid

6.1.2 List of registered products to control internal parasites of goats

Lists of registered products for use in goats are tabulated in Tables 6, 7 and 8. These products are commercially available. The tables have been developed from the APVMA website, the Department of Primary Industries and Fisheries Infopest data base (See 3 Definition of Terms) and through consultation with relevant chemical companies.

Certain BZ products, morantel citrate and the ML abamectin (Caprimec®) are registered for use in goats to control nematodes. Some of these products also control tapeworm. Trichlorfon (Neguvon®) has an off-label permit for use in goats against *H. contortus*. The permit (PER9864) is current to 1 April 2009.

The **Withholding period (WHP)** is the minimum period which must elapse between the last administration or application of a veterinary chemical, including treated feed, and the slaughter, collection, harvesting or use of the animal commodity for human consumption. [1]

It is mandatory to abide by WHPs for animals slaughtered within Australia.

[1] Export Slaughter Intervals and Withholding Periods of Chemicals. (http://www.apvma.gov.au/residues/ESI.shtml)

An **Export Slaughter Interval (ESI)** is the time that should elapse between administration of a veterinary chemical to animals and their slaughter for export.[1]

ESIs manage differences between the Maximum Residue Limits allowed for chemicals in Australia and those of its trading partners. ESI advice is particularly important for quality assurance schemes, and especially for producers filling out the National Vendor Declaration (NVD) forms as part of the whole-of-chain management of exported product. ESIs are subject to change due to alterations in overseas requirements, and ongoing review and consultation with industry. Updates to ESIs are available on the APVMA website for sheep and cattle but at this stage APVMA have not established a list of ESIs for goats on their web-site. The only ESI for goats that has been established on the basis of data actually produced in goats is the ESI for the newly registered product Caprimec®, which was launched in early August 2007. A number of other products registered in goats have labels from which it can be inferred that the goat ESI is the same as the sheep ESI. These ESIs were established prior to the APVMA assuming responsibility for ESIs in 2005 so were not developed using current APVMA techniques. It is expected the inferred goat ESIs were extrapolated from sheep and APVMA cannot be confident of the basis for establishing the sheep ESIs. Additionally, it may be that major importing countries have a defined numerical value for the sheep MRL for a particular chemical yet have no MRL for goat commodities. Therefore, the residues in goats of that chemical would have to be nil so the associated ESI would need to be lengthened to achieve this (by comparison with the sheep ESI). Advice from the Australian Quarantine and Inspection Service (AQIS) and from the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) is that Taiwan, for example, requires that all residues have to be at non-detectable levels.

ESIs, unlike WHPs, are currently optional on labels and do not have the legal standing of a WHP. They can be regarded as risk mitigation strategies. APVMA does require some form of trade advice to appear on labels. This may take the form of an advisory statement indicating that the chemical company should be contacted in relation to export issues prior to using the chemical.

6.1.2.1 Nematodes

Table 6 Anthelmintics registered for nematode control in goats and commercially available

Active group	Constituent	Brand name	Manufacturer	WHP meat (days)	ESI (days)
BZ*	albendazole†(19g/L)	**Alben**	Virbac	10	10 (inferred)
BZ*	albendazole†(19g/L)	**Albendazole (Sheep, Lamb & Goat)**	WSD	10	Not set
BZ*	albendazole†(19mg/mL)	**Valbazen Sheep Lamb & Goat Drench**	Coopers	10	Not set
BZ*	fenbendazole‡ (25g/L)	**Fenbendazole**	4Farmers	14	Not set
BZ*	fenbendazole‡ (25g/L)	**Fenbendazole**	WSD	14	Not set
BZ*	fenbendazole‡ (25g/L)	**Panacur 25**	Virbac	14	Not set
BZ*	oxfendazole† (45.3g/L)	**Oxfen LV**	Virbac	10	14 (inferred)
Morantel citrate	morantel citrate† (30mg/mL)	**Oraljject Goat & Sheep Wormer**	Virbac	7	Not set
organophos phate	trichlorfon§ 800mg/kg	**Neguvon**	APVMA permit PER9864	7	Not set
ML-Aba	abamectin‖ (0.8mg/mL)	**Caprimec**	Virbac	14	28

*BZ drenches give control of tapeworm
†Not to be used in animals producing milk for human consumption
‡Fenbendazole is registered for use in lactating does whose milk is to be used for human consumption. Milk withholding period is 24 hours.
§Not to be milked for at least 28 days after treatment
‖ Caprimec is registered as of August 2007. The withholding period for milk is four days.

6.1.2.2 Liver fluke

Table 7 Anthelmintics registered for liver fluke control in goats and commercially available

Active Group	Constituent	Brand name	Manufacturer	WHP meat (days)	ESI (days)
BZ*	albendazole(19g/L)	**Alben**	Virbac	10	10 (inferred)
BZ*	albendazole(19g/L)	**Albendazole (Sheep, Lamb & Goat)**	WSD	10	Not set
BZ*	albendazole(19mg/mL)	**Valbazen Sheep Lamb & Goat Drench**	Coopers	10	Not set
BZ*†	triclabendazole(100g/L)	**Exifluke Oral Flukicide**	Bomac	21	Not set
BZ*†	triclabendazole(100g/L)	**Fasinex 100 Oral**	Novartis	21	Not set
BZ*†	triclabendazole(100g/L)	**LV Triclabendazole Flukicide**	WSD	21	Not set
BZ*†	triclabendazole(50g/L)	**Flukguard S**	Norbrook	21	Not set
BZ*†	triclabendazole(50g/L)	**Tricla 50**	Youngs	21	Not set
BZ*†	triclabendazole(50g/L)+Se as sod.selenate(0.5g/L)	**Flukare S With Selenium**	Virbac	21	63 (inferred)

*Not to be used in goats producing milk for human consumption or processing
†Kids fed this milk should not be slaughtered for human consumption within seven days

6.1.2.3 Coccidia

Table 8 Products registered for the treatment and prevention of coccidiosis in goats and commercially available

Constituent	Brand Name	Manufacturer	WHP meat (days)	ESI (days)
monensin* as sodium(100g/kg)	**Moneco 100**	IAHP	nil	Not set
monensin* as sodium(100g/kg)	**Monendox 100 BMP**	Doxal	nil	Not set
monensin* as sodium(100g/kg)	**Monensin Premix**	CCD	nil	Not set
Monensin* as sodium(100g/kg)	**Rumensin 100**	Elanco	nil	Not set
Monensin* as sodium(100g/kg)	**Phibromensin 100**	Phibro	nil	Not set
Monensin*† as sodium (200g/kg)	**Rumensin 200**	Elanco	nil	Not set
Monensin*† as sodium(200g/kg)	**Moneco 200**	Eco Animal Health	nil	Not set
Monensin*† as sodium(200g/kg)	**Monendox 200 BMP**	Dox-AL	nil	Not set
Monensin*† as sodium(200g/kg)	**Phibromonensin 200**	Phibro	nil	Not set
Monensin*† as sodium(210m†g/g)	**Rumensin Granular**	Elanco	nil	Not set
Monensin*† as sodium(400g/kg)	**Phibromonensin 400**	Phibro	nil	Not set
Monensin*† as sodium(800mg/g)	**Rumensin Technical**	Elanco	nil	Not set

*Monensin is not to be used in goats producing milk for human consumption
†S4 products requiring veterinary prescription

6.1.3 List of anthelmintics registered for control of internal parasites of other small ruminants (sheep)

6.1.3.1 Nematodes

The drench actives listed in Table 9 are registered for nematode, tapeworm and liver fluke control in the sheep industry. There are three broad-spectrum anthelmintic groups (Coles *et al*. 2006).

These are:
Group 1 benzimidazoles (BZ)
Group 2 imidazothiazoles (levamisole LEV) and the hydropyrimidines (pyrantel/mortanel) and
Group 3 macrocyclic lactones (avermectins and milbemycins, ML drenches)

In Australia, a mid-spectrum and a narrow-spectrum group are also registered for use in sheep.
Group 4 mid-spectrum naphthalophos (NAP) and
Group 5 narrow-spectrum closantel (CLOS) drenches for *H. contortus*

Table 9 Anthelmintics registered for nematode control in sheep with possible application to goats

Drench actives	Common names	Constituent	Actives sold under brand names such as
Single-active products			
BZ	white	***Certain BZs and morantel citrate are registered for goats See Table 6***	
			Combat White,
LEV	yellow	levamisole	**Big L, Levamisole, Combat Clear or Nilverm**
ML-Mox	clear	moxidectin	**Cydectin**
ML-Mox		moxidectin i**njection**	**Cydectin LA injection**
		moxidectin + 6in1 vaccine+ **injection**	**Eweguard and Weanerguard**
ML-Aba	clear	abamectin	**Genesis Tape** **Rycomectin** **Virbamec**
M-Aba		abamectin **injection**	**Genesis Injection**
ML-Iver	clear	ivermectin	**Ivomec, Genesis+Selenium Noromectin or Paramax**
ML-Iver		ivermectin **capsule**	**Ivomec Maximiser**
OP-NAP powder	powder	napthalophos	**Rametin or Combat**
CLOS	green	closantel	**Closantel, Closicare, Seponver or Sustain**
Multi-active products			
BZ+LEV		Multi-active	**Combi, Duocare, Combat Duo or Scanda**
BZ+Iver		Multi-active **capsule**	**Optamax**
BZ+LEV+Iver	pink	Multi-active	**Triton**
BZ+LEV+Aba		Multi-active	**Hatrick**
BZ+LEV+Aba+CLOS		Multi-active	**Q-drench**
OP-NAP powder+BZ		Multi-active	**Rametin+BZ**
OP-NAP powder+LEV		Multi-active	**Rametin+LEV**
OP-NAP powder+BZ+LEV		Multi-active	**Rametin Combo**
OP-NAP powder+Aba		Multi-active	**Rametin ML**
CLOS+BZ		Multi-active	**Closal or Closicomb**
CLOS (increased dose)+Aba		Multi-active	**Genesis Xtra**

6.2 External Parasites

6.2.1 Current chemical use practices

Control of arthropod parasites in the goat industry relies almost exclusively on the use of chemical parasiticides, although some organic and nutritional supplementation methods are also employed. Active ingredients registered for application to goats for ectoparasite control include the organophosphates (OPs) diazinon and chlorfenvinphos, the synthetic pyrethroids (SPs) deltamethrin and cypermethrin, the botanicals rotenone and pyrethrins, inorganic sulphur and the formamidine acaricide amitraz (Table 10). Chlorfenvinphos and cypermethrin are only available in combination formulations as Barricade S and Blockade S and sulphur and rotenone in combination as Pestene Insect Powder. Notably, none of the insect growth regulator (IGR) insecticides which command the majority of the ectoparasite market for sheep, or the systemic anthelmintics which also have activity against blood feeding and invasive ectoparasites (eg macrocyclic lactones (MLs), closantel, some organophosphates), are registered for application to goats. This will change with the registration of abamectin for control of helminths in goats, although there will be no claim for effect against external parasites (P. Martin *pers. comm.*). Most chemicals are registered for application as sprays or dips (diazinon, amitraz and chlorfenvinphos/cypermethrin) with deltamethrin registered for application as a backline (Clout S) and sulphur/rotenone as a dust (Pestene Insect Powder).There is also extensive use in the goat industry of products not registered for use in goats (Table 11) but registered for the control of similar ectoparasites in other animal species (Table 12).

Table 10 Insecticides and acaracides registered for ectoparasite control in goats

Parasite	Active group	Constituent	Brand name	Manufacturer	WHP meat	ESI
Lice	SP	Deltamethrin	Clout-S*	Coopers	3 days	Not set
	OP	Diazinon	Nucidol 200EC	Novartis	14 days	Not set
	OP	Diazinon	Di-Jet†	Coopers	14 days	Not set
	OP	Diazinon	WSD Diazinon‡	WSD	14 days	Not set
	Botanical / inorganic	Rotenone & sulphur	Inca Pestene Insect Powder§	INCA	1 day	Not set
Ticks	OP/SP	Cypermethrin & chlorfenvinphos	Blockade S*	Coopers	8 days	Not set
	OP/SP	Cypermethrin & chlorfenvinphos	Barricade S*	Fort Dodge	Not set	Not set
	Formamidine	Amitraz	Tacktic EC‖	Intervet	Nil	Not set
	Formamidine	Amitraz	Tacktic WP‖#	Intervet	Nil	Nil (inferred)
	Formamidine	Amitraz	Amitik#	Coopers	Nil	Not set
	Formamidine	Amitraz	Amitik EC#	Coopers	Nil	Not set
Mites			Nil			
Nasal bot			Nil			
Flystrike	OP/pyrethrins	Diazinon & pyrethrins & PBO	WSD Flystrike* Powder	WSD	14 days	Not set
	OP/pyrethrins	Diazinon & pyrethrins & PBO	WSD Mulesing* powder	WSD	14 days	Not set
	OP/pyrethrins	Diazinon & pyrethrins & PBO	Flystrike powder	Coopers	14 days	Not set
Buffalo flies	OP/SP	Cypermethrin & chlorfenvinphos	Barricade S*	Fort Dodge	8 days	Not set
	OP/SP	Cypermethrin & chlorfenvinphos	Blockade*	Coopers	8 days	Not set
Fleas			Nil			

*Do not use on female goats which are producing or may in the future produce milk or milk products for human consumption.
†Milk taken from goats within 48 hours following treatment must not be used for human consumption or processing.
‡Milk collected from does within 48 hours following treatment must not be used for human consumption or processing. This milk should not be fed to kids.
§Do not use on lactating does where milk or milk products may be used for human consumption.
‖NSW only; however, a permit currently exists for use in Qld but only under the supervision of DPI&F.
Milk WHP nil.

6.2.1.1 Lice

Control of lice is by far the major reason for the application of ectoparasiticides to goats. Fifty seven percent of respondents to the survey indicated that they had treated for lice in the last two years. Most producers indicated that they treated once per year but 36% indicated that they treated more than once per year and some indicated that they treated three times. Taken overall, where a product could be identified, 36 % used registered products and 64% applied products not registered for use on goats.

Table 10 lists the products currently registered for control of lice in goats. The active constituents in these products are diazinon, deltamethrin and sulphur/rotenone in combination. The recent review of diazinon by the APVMA has suspended diazinon for application to sheep by dipping and jetting (Ashton 2007). Diazinon based products registered for lice control on goats (DiJet, Nucidol 200ED and WSD Diazinon) can still be used as a spray. However, as the sheep market is the major market for these products, their future availability is uncertain.

Non-registered chemicals currently being used include the IGRs diflubenzuron and triflumuron (37%), cydectin, eprinomectin and other MLs (8%), spinosad (2%) and cypermethrin (2%). Diflubenzuron and triflumuron are registered for louse control in sheep and account for approximately 72% of this market (Walkden-Brown et al. 2006). Macrocyclic lactones are used in both sheep and cattle for internal parasite control, but often also have claims for control of sucking lice and nose bot fly. Eprinomectin is registered for use in cattle but not sheep. Spinosad is a low residue chemical recently registered for control of lice and flystrike in sheep. Cypermethrin is an SP contained in backline products for lice control in sheep while fipronil (Frontline), which was used by one producer, is registered for use on cats and dogs, but not for application to food animals.

Many other chemicals have also been shown to be effective against goat lice and a much larger range of chemicals is registered for use overseas. Drummond *et al*. (1988) give an excellent summary of those chemicals tested against goat lice historically. Some early technologies included hand applications of dusts containing naphthalene and pyrethrins, washes of sodium fluoride, which were said to control biting lice only, and dipping in arsenic, coal tar creosote and nicotine. Drummond *et al.* (1988) noted that two dippings were necessary to eradicate lice with most of these chemicals. DDT and a range of other organochlorine chemicals were also shown to control lice (Brown 1947), although resistance of *B. caprae* and *B. limbatus* to the organochlorine (OC) toxaphene was reported from Texas in 1959 (Moore *et al.* 1959). A range of OPs have also been tested and shown to give varying degrees of efficiency against goat lice. Of those tested by Medley and Drummond (1963), crufomate, chlorfenvinphos and dichlofenthion were most effective. Diazinon also shown to have good effect by these authors and has been used widely throughout the world to control goat lice.

Table 11 Products used for lice control as indicated in the survey of goat owners

Active Group	Active Ingredient	Brand names	Percent owners using	Registered for goats	Application
Insect Growth Regulator (IGR)	Triflumuron	Zapp/Triffik	29.7	No	Backline
	Diflubenzuron	Magnum	7.0	No	Backline
Synthetic Pyrethroid (SP)	Deltamethrin	Clout S	19.5	Yes	Backline
	Cypermethrin	Cypercare	2.3	No	Backline
Macrocyclic lactone	Moxidectin	Cydectin	4.7	No	Injection
	Eprinomectin	Eprinox	1.6	No	Pour-on
Organophosphate (OP)	Diazinon	Di-Jet	1.6	Yes	Spray/dip
		Jet Dip	1.6	Yes	Spray/dip
		Nucidol for dogs	5.5	Yes	Spray/dip
Spinosad	Spinosad	Extinosad	2.3	No	Jetting, dressing
Inorganic	sulphur		6.3		Dust
Botanical Inorganic	Rotenone & sulphur	Pestene	0.8	Yes	Dust
Phenylpyrazole	Fipronil	Frontline	0.8	No	Spot-on

A number of insect growth regulators have also been tested against goat lice with encouraging results. These include synthetic juvenile hormone which, with two sprays controlled chewing lice on goats, two commercial insect growth regulators which caused a slow decline in louse populations and diflubenzuron which brought about a rapid decline in lice numbers (Chamberlain and Hopkins 1971; Chamberlain *et al*. 1976). Fourie *et al*. (1994) demonstrated that a single dipping of Angora goats in 1000 ppm diflubenzuron 14 days after shearing eradicated *B. limbatus* and provided protection against reinfestation for up to four to five months. It should be noted that the concentration they used (625 ppm) is significantly higher than similar formulations registered for control of sheep lice in Australia (100 ppm or 375 ppm depending on product).

Miller *et al.* (1985) compared the efficacy of a range of compounds and application methods against *B. limbatus* in Angora goats six weeks after shearing. Diflubenzuron fenvalerate and phenthoate pour-ons, (30 ml of 2% a.i.) were all 100% effective. Fenvalerate administered as a spot-on did not give effective control and ivermectin applied as an injection at 200 µg/kg bodyweight appeared to have no effect at all on chewing lice. Fenvalerate applied in a neckband with 8% active ingredient (ai) gave 100% control after 18 weeks, but took the full 18 weeks to achieve this level of control. These figures are similar to Darrow *et al*. 1973 who found complete control of chewing lice from resin collars impregnated with 5%, 10% and 20% dichlorvos. Fuchs and Shelton (1985) also compared a range of treatments and application methods including fenthion and chlorpyrifos as spot ons, permethrin, fenvalerate and famphur as pour-ons and malathion and fenvalerate as sprays on Angora goats that had not been recently shorn. All gave a level of control, but none gave eradication. This suggests that Angora goats need to be shorn before treatment to maximise likelihood of eradicating lice, as is also the case with sheep.

Flumethrin, a chemical not registered for use in sheep in Australia but registered for tick control in cattle, was shown to reduce lice (*B. caprae*) on Barberi goats in India to non detectable levels up to 42 days post-treatment when applied as a pour-on at the rate of 1 mg/kg bodyweight (Garg *et al*. 1998). Yadav *et al*. (2004) who assessed lice numbers by examination of the numbers present in a one inch square area of the sacrum, found moxidectin and flumethrin as 1 mg/10 kg pour-ons and ivermectin as a 0.2 mg/kg subcutaneous injection as 100% effective against sucking lice (*L. stenopsis*) up to 30 days post treatment. No information is provided in this study on the degree of lice survival at sites more distant from the application strip.

Table 12 Insecticides registered[1] for lice control in sheep with possible application to goats

Active	Constituent	Brand name	Method of application
Organophosphate	Diazinon	Eureka gold	Backline,
		Coopers 4in1, Di-jet, JetDip[2]	Dip/shower,
	Temephos	Assassin	Jetting
Synthetic pyrethroids	Cypermethrin	Cypercare, Spurt Cypermethrin 25	Backline
	Alphacypermethrin	Duracide Vanquish	
Insect growth regulators	Triflumuron	Cannon, Clipguard, Command, Epic, Exilice, Exit, Triffik, Virbac IGR pour-on, Zapp	Backline
	Diflubenzuron	Diflu, Magik, Magnum, Stampede, Zenith	Backline
		Crusader, Fleececare, Strike, Virbac Duodip	Dip/shower
Spinosyn	Spinosad	Extinosad	Backline, Dip/shower
Macrocyclic lactone	Ivermectin	Jetamec, Paramax	Jetting
Other	Magnesium fluorosilicate+ rotenone+ sulphur	Flockmaster Mk2 X-lice Washdown	Dip/shower

[1] Not all registered products listed are currently available
[2] Registration of these three products suspended for dipping and jetting; existing stocks may be used

Method of application

The method and thoroughness of application is a critical consideration in determining the effectiveness of chemical treatment. Ecto-parasiticides can be administered as sprays, dips, backliners, dusts or sometimes systemically as drenches, injectables, bolus formulations, or capsules. By far the major method of application indicated in the survey was by backline pour-on used by 66% of those treating for lice. Other methods of application included spraying (11%), dipping (12%), dust (6%) and injectable or oral (5%). No ecto-parasiticides are currently registered for use in goats by the last two methods.

Backline application has significant practical advantages for goat owners including ease of use, low labour input, less stress for goats in that animals don't have to be immersed in a dip vat or sprayed with fluid, particularly in cold climates, low environmental contamination and little capital expenditure. These reasons no doubt account for the widespread use of this method. Deltamethrin, is currently the only chemical registered for application by this method although the IGRs, diflubenzuron and triflumuron are widely used. Backline applications rely on applying a high concentration of chemical along the backline which then moves over the body surface in diminishing concentration. Thorough application is required to ensure that active concentrations of chemical reach all sites on the body. Poor application of backliners has been associated with the development of resistance in sheep (Levot 2000). This is thought to be because of the potential for providing exposure of lice to sub-lethal concentrations of chemical and because of the concentration gradients left in the fleece.

Backline application, where spread is mainly over the surface of the body, is distinct from spot-on or pour-on formulations that rely primarily on systemic dispersal. Chemicals with systemic activity can also be applied orally, by injection or in bolus formulations and capsules. Systemically delivered parasiticides are often effective against sucking lice but seldom very effective against chewing species. No chemicals with systemic action against lice are currently registered for use on goats. Abamectin, which now is registered for internal parasite control in goats, would be expected to also have some effect against sucking lice, but will not be registered with a claim to this effect. When sucking lice are present, it is most often in mixed infestations with chewing lice. Therefore in most practical circumstances topical treatment will be a more realistic option than systemic treatment anyway.

The importance of complete coverage with active concentrations of pesticide has been demonstrated regularly as being critical to achieving eradication of lice in sheep. Good wetting from spraying or dipping would be expected to be similarly important with goats. Drummond *et al*. (1988) note that sprays do not effectively penetrate the hair cover in densely haired goats and this could significantly compromise the success of treatments. The temperament of goats can make dipping a trying and sometimes hazardous method of application and for this reason backline application is the method favoured by managers in most cases.

Dusts have the advantage that the animals do not have to be wet at treatment particularly in cold weather. The effectiveness of dust formulations is not well recorded, but could be expected to also be strongly influenced by the thoroughness of application. Even though there is no good information available of the effectiveness of the rotenone/sulphur formulation it represents a group with another mode of action that could be helpful in resistance management. Rotenone generally has low persistence and a second application two to three weeks after the first treatment to kill hatching nymphs will be important to achieving good control. This formulation, available in small quantities, may be the only realistic registered option for lice control for owners with only a few goats.

A novel method of application shown to be effective in a number of cases is resin collars impregnated with insecticide. Formulations shown to be effective include 5%, 10% and 20% dichlorvos (Darrow 1973) and 8% fenvalerate (Miller *et al*. 1985). In both studies it took a significant period of time for the level of control to reach 100%. This was considered due to the amount of time required for chemical to diffuse out of the neckbands and build up to active levels on the integument of goats. Miller *et al.* (1985) suggested the possibility of using an initial treatment to control lice together with neck bands to provide prolonged protection against reinfestation. Insecticide impregnated ear tags, which use similar technology to the resin collars, have been implicated in the development of widespread chemical resistance in horn flies and buffalo flies (Sparks *et al.* 1985) and there is the likelihood of similar selection for resistance in lice.

The possibility of failure of eradication because of reinfestation from eggs hatching after treatment needs to be considered. Most ectoparasiticides do not have ovicidal action and eradication from one application depends on the chemical persisting long enough to kill hatching nymphs. In sheep, the abundant wool yolk present in the fleece provides a reservoir of chemical that persists long enough to kill nymphs. However, chemicals often do not persist nearly as long in the hair coat of goats (Clear *et al*. 1982). Persistence will depend on a range of factors including the type of chemical, concentration of chemical applied, application method, environmental factors and animal characteristics. As the incubation period of the eggs of goat lice species is between seven and 14 days (Price and Graham 1997) a second treatment two to three weeks after the first may be necessary to provide confidence of eradication in goats.

Resistance

With the limited number of chemical groups registered for lice control in goats and reluctance of companies to incur the costs to register new compounds for a relatively small market, retaining the effectiveness of available products is a key consideration. The frequent number of treatments applied to goats in some herds (up to six times over two years) is of concern in terms of the selection pressure it exerts for resistance development. As previously noted, backline applications may add to the likelihood of resistance development if good resistance management programs are not put in place. Resistance to SPs has been recognised in goat lice in England (Coleshaw *et al*. 1992) and to OPs in South Africa (Baker 1969). Thorold (1963) indicated the development of resistance to rotenone and some organochlorine pesticides from widespread use on farms in South Africa, and resistance to organochlorine pesticides was found in goat lice in Texas (Moore *et al.* 1959). To our knowledge no tests have been conducted to determine if resistance is present in any Australian populations of goat lice.

The backline method of application has significant management and economic advantages for goat owners. The availability of only one registered backline formulation, a synthetic pyrethroid, could be expected to exert significant pressure for the selection of resistance and the use of unregistered compounds places goat owners at risk of prosecution. Registration of a second chemical group that could be applied as a backline formulation is desirable to provide goat owners with a second practically realistic and registered option for lice control and to enable them to better develop resistance management strategies. This need is especially acute with uncertain future availability of diazinon based products. It should be noted that, in contrast to helminth parasites, lice infesting goats are host specific and different to those on sheep. Therefore use of products in goats would not be expected to contribute to selection for resistance in sheep lice or lice breeding on other livestock species.

6.2.1.2 Ticks

Ticks were not commonly listed as a problem in the survey of goat owners and are probably not a major reason for the application of chemicals to goats in Australia. However, applications may be required from time to time in some areas. There are two major groups of product registered for control of ticks in goats. These are formulations containing 25 g/L cypermethrin and 13 g/L chlorfenvinfos in combination (Barricade S Blockade S) and amitraz registered as formulations containing 500 g/kg wettable powder and 125 g/L emulsifiable concentrate (Amitik, Taktic). Amitraz is registered for application to goats in NSW, but with permits for use on goats in Queensland. Both of these groups of products were also indicated in the survey as occasionally being used to treat lice. This is probably not surprising as both Barricade S and Blockade S are registered for the control of lice on cattle.

6.2.1.3 Mites

Mite infestation is not a significant reason for the application of chemicals to goats and unless clinical symptoms are acute, mite infestations are seldom treated. Where treatments are applied this generally involves individual severely affected or high value animals rather than whole herd treatments. No products are registered for the control of mites in goats in Australia, although Pestene Insect Powder, registered for the control of lice, has claims for the control of *Chorioptes* mites on horses.

Smith (1981) suggests that a mixture of one part rotenone in three parts oil is effective against *P. cuniculi* ear mites in goats and Bates (1991) lists ear drops containing 0.1% malathion, 0.03% and 0.1% benzene hexachloride (BHC)as effective with repeated applications. Arundel and Sutherland (1988) note that ears should be cleaned of all wax before treatment and suggest a range of possible treatments including BHC, phoxim, (neither of these compounds are registered for animal use in Australia) diazinon, propetamphos, ivermectin and amitraz based on the effectiveness of these compounds against the closely related sheep scab mite (*P. ovis*). Bates (1991) indicated successful eradication of *P. cuniculi* from goats by subcutaneous injection of 200 µg/kg ivermectin. It is notable that ivermectin does not appear to be effective against *C. bovis* (Lloyd and Jackson 1983), possibly because of the superficial habit of this mite. Bates (1991) noted the need for care in observing milk withholding periods when milk goats are treated with ivermectin. Manning et al.(1985) caution that susceptibility of *Raillietina* mites to chemicals has not been documented and this probably also applies to some of the chemicals listed by Arundel and Sutherland (1988) for potential use against *P. cuniculi*.

Treatment protocols reported in the literature for the control of *Demodex* mites in goats include rotenone and a ronnel (fenchlorphos) dip regimen often used with dogs (Manning *et al.*1985; Coles 1997). Wall and Shearer (2001) also indicated weekly topical washes with malathion, trichlorfon and amitraz. Arundel and Sutherland (1988) indicate that while the mites are susceptible to treatment with acaricidal compounds, reaching them in hair follicles can be difficult and thorough cleansing of the area and application of the active ingredient in a fat solvent such as isopropyl alcohol or propylene glycol is necessary for good effect.

Any use of chemicals for the treatment of mites in goats would be an off-label use and should only be administered under veterinary supervision. Although chemicals are rarely used to treat mite infestations the potential for treatments used close to slaughter or in lactating animals to leave residues needs to be considered.

6.2.1.4 Nasal bot

There are no products currently registered for the control of nasal bots in goats or compounds currently registered for other uses that could be expected to have effect against nose bot. In most cases specific treatments for *O. ovis* will probably not be warranted. Early control for nose bot included injecting a range of materials directly into the nasal sinuses and smearing repellents around the nasal openings to repel the flies (Drummond *et al*. 1988). A range of systemic chemicals including the organophosphates ronnel, dimethoate, trichlorfon, crufomate, famphur and fenthion and phosmet have been shown to have effect. In addition a range of anthelmintics including rafoxanide, nitroxynil, closantel and ivermectin have been shown to give control (Drummond *et al.* 1988). Arundel and Sutherland (1988) indicate that insecticides such as trichlorfon and dichlorvos given as aerosols are also effective.

A number of anthelmintics are registered for use in sheep with claims for control of *O. ovis*. The active ingredients in these compounds include closantel, ivermectin, abamectin and moxidectin. None of the anthelmintics currently registered for use in goats has a claim for use against *O. ovis* although trichlorfon, the active ingredient in Neguvon, for which there is an off-label permit for use in goats to control *Haemonchus contortus*, is known to have effect against nose bot (Stampa 1959; Ranatunga and Weilgama 1972). Abamectin, the active compound in Caprimec also has activity against nasal bot in sheep, but is not registered with this claim in goats.

6.2.1.5 Myiasis, biting and nuisance flies and fleas.

Flystrike can occasionally occur in goats in wounds, particularly in fighting lesions in bucks, footrot lesions, or where the hair has become fouled. Three products containing diazinon and synergised pyrethrins are registered for treatment of strikes in goats (Table 10). Blockade S and Barricade S, containing chlorphenvinphos and cypermethrin are registered for application to goats for the control of buffalo flies. Although there are products registered for repelling other flies and controlling fleas in other animal species, none of these are registered for application to goats. A range of compounds are registered as premise treatments for the control of nuisance and biting flies and application of these products around sheds and bedding areas will help reduce the level of attack in housed or penned goats.

6.3 Off-label use of a chemical

The Australian Pesticides and Veterinary Medicines Authority (APVMA) in Canberra is the Australian government authority responsible for the assessment and registration of pesticides and veterinary medicines and for their regulation up to and including the point of retail sale. The APVMA administers the National Registration Scheme for Agricultural and Veterinary Chemicals (NRS) in partnership with the States and Territories and with the active involvement of other agencies such as the Australian Government Department of the Environment and Water Resources and the Office of Chemical Safety within the Australian Government Department of Health and Ageing. The APVMA's role is to independently assess whether a chemical product that has been submitted for registration by a chemical company will be effective; will be safe for people, animals and the environment; and will not present a risk to trade. State and territory governments regulate the use of agricultural and veterinary chemicals after they have been sold. This State-based legislation is termed Control of Use legislation.

Legislation

In 1999 national agreement was reached on recommended control principles governing the use of veterinary chemicals. All States and Territories subsequently introduced new control of use legislation, with some minor differences existing between States. It is important that the local department of primary industries, agriculture or health should be contacted to clarify any issues relating to legislation concerning use of veterinary chemicals in a particular State or Territory and suitability of products from the animals as food.

The restrictions on the use of veterinary chemical products that were introduced aim to reduce the potential risks to trade arising from residues in food and fibre products obtained from animals treated with veterinary chemical products that are either not registered or that have been used in ways that have not been approved under permit by APVMA.

All persons, including veterinary surgeons, must use registered veterinary chemical products to treat animals according to the instructions on the approved label for the product. However, under the veterinary control principles, there are a number of authorised ways for a veterinary surgeon to use, prescribe, supply or recommend veterinary chemicals, for uses that differ from the instructions on the approved product label (i.e. 'off-label' uses). For instance, veterinary surgeons may treat trade species animals (such as goats) which are under their care with registered veterinary chemical products 'off-label'. This does not apply to uses which are specifically prohibited on the registered label (restraints) nor does it allow use by injection unless the label already covers use by injection.

In the major trade species animals (cattle, sheep, pigs and chickens in most States), veterinary surgeons can only use registered veterinary chemical products off-label on a single animal (individual animal) unless there are already instructions for use in a different major trade species on the label. The restriction of treatment to a single animal is meant to severely curtail the use of the chemical. It is important to note that, in New South Wales, goats are regarded as a major trade species animal under legislation but this is not the case presently in other States.

The allowances for off-label use of veterinary chemicals by veterinary surgeons have often been referred to as 'veterinary surgeons' prescribing rights'. These prescribing rights provide animal owners with access to off-label treatments when required. It is important to note that veterinary surgeons can only use, supply, prescribe or recommend chemicals for animals under their care. The determination of whether or not the animals are under the veterinary surgeon's care is left to the professional judgement of the veterinary surgeon in each particular case.

A definition of 'under the care of' can be found in the *Guide to Professional Conduct 2000* issued by the Royal College of Veterinary Surgeons, namely:

(a) the veterinary surgeon must have been given responsibility for the health of the animal or herd in question by the owner or the owner's agent

(b) that responsibility must be real and not nominal

(c) the animal or herd must have been seen immediately before prescription and supply or

(d) recently enough or often enough for the veterinary surgeon to have personal knowledge of the condition of the animal or current health status of the herd or flock to make a diagnosis and prescribe

(e) the veterinary surgeon must maintain clinical records of that herd/flock/individual. What amounts to "recent enough" must be a matter for the professional judgement of the veterinary surgeon in the individual case.

For non-veterinary surgeons the methods available for using any registered veterinary chemical products off-label are:

- under a veterinary surgeon's written instructions. These must be comprehensive and include the length of the withholding period that has to be observed. An actual prescription from the veterinary surgeon is required in the case of Schedule four (prescription only) drugs;
- under a minor use permit granted by the APVMA (see later);
- under a research permit granted by the APVMA for a properly conducted research trial; or
- under an emergency use permit granted by APVMA (see later).

As will be discussed in more detail later, off-label permits may be sought for chemical uses which the veterinary prescribing rights cannot cover. In such cases, the APVMA will, in consultation with the states, consider granting an off-label permit for the treatment of a number of food-producing animals for a specified purpose.

If the veterinary chemical product is unregistered (i.e. not registered with APVMA), even veterinary surgeons cannot use it to treat more than one trade species animal (such as one goat). The same strict interpretation of one animal applies here, as was described earlier in relation to treating only one major trade species animal with a product that is not registered in any major trade species. Under legislation, permits could be granted by APVMA for use of unregistered products in more than one animal but this approval would depend on provision of appropriate data.

Recommendations of a veterinary surgeon
Although veterinary surgeons may use, prescribe, supply or recommend registered veterinary chemical products 'off-label' in goats which are under their care, in practice they could be reluctant to recommend such use. Veterinary surgeons should give full and appropriate instructions. Hence, in trade species animals (including goats), the veterinary surgeon would need to consider the fate of residues and assume responsibility for any issues arising in relation to the off-label use that has been recommended. In order to demonstrate due care in providing advice, the veterinary surgeon would have to obtain residue advice from APVMA or from the chemical company or international sources. This may be difficult because the available residue data are usually confidential commercial information. More often, in practice, there is a lack of suitable data to support recommendations, particularly in terms of a withholding period.

In general terms, datasets should already be available for many products already registered in species such as sheep and cattle because these data would have been required by the APVMA for setting maximum residue limits (MRLs) in those species. Where there is no existing MRL that would cover goats, the only way to avoid potential risks to trade is for the recommended withholding period to be long enough to allow for the residue levels to decline below the Limit of Quantitation (i.e. the lowest level of the chemical which the laboratory can report with confidence). As indicated above, whenever a trading partner does not have an MRL for a particular veterinary chemical, it is essential that no detectable residues of that chemical be found in the exported product.

Unfortunately, it has long been recognised that it is not generally appropriate to extrapolate data from registered uses in sheep directly to goats. Many anthelmintics appear less effective in goats than sheep against the same nematode genera. It is important to note that, if higher dose rates are used, it is generally expected that the residues would be higher. Unfortunately, the relationship between dose and the withholding period is complex; therefore, it is inappropriate simply to double the withholding period when the dose is doubled. There are no simple rules of thumb, according to the APVMA Veterinary Residues Section. The different behaviour of drugs and the typically faster metabolism of goats compared to sheep have been referred to in an earlier section. In recognition of this, APVMA has advised that they would generally require residue decline data to support registrations or permits allowing use of veterinary chemicals in goats.

Example
Under the veterinary control principles in most States, a veterinary surgeon could recommend giving goats an oral drench of a chemical product containing levamisole which is registered as an a oral drench for sheep. There would have to be no restraint on the approved label stating that the product should not be used in goats. In this scenario, there are existing Australian MRLs which could be interpreted as covering levamisole use in goats. However, there are no levamisole containing products currently registered for goats in Australia. The APVMA Veterinary Residues Section has advised that these goat MRLs for levamisole were set around 1980. The National Registration Scheme was not established until 1993. The APVMA has noted that the use pattern and data on which the goat MRLs were set is not known and, therefore, even dosing goats at the same dose rate as sheep does not guarantee that there would be no residue issues in goats. This is compounded by the fact that goatmeat is frequently exported. Depending on the trading partner, there may be a requirement for goat products to contain no levamisole residues at all. Therefore, unless the veterinary surgeon has access to relevant data that would satisfy contemporary standards of assessment, it would be unwise to recommend this off-label use in goats.

Off-label permits
In the light of the difficulties faced by veterinary surgeons when prescribing off-label use of veterinary chemicals in goats, the preferred approach would be the submission of off-label permit applications to APVMA and, even better, urging chemical companies to proceed with full registration of veterinary chemicals in goats. In this way, thorough scientific assessment of available data can be undertaken.

As stated above, the term ‘off-label use’ refers to use of a chemical product other than in a way stated in the instructions on the approved label for the product. The approved label is the label that has been approved by APVMA for a product it has registered in Australia. Chemical products that are imported into Australia cannot have an approved label until they have been registered by APVMA. Until such time, use of such products is regarded as use of an unregistered product and cannot be regarded as an off-label use.

As indicated earlier, this concept is reflected in the very limited veterinary prescribing rights for unregistered products – that is, a veterinary surgeon can use, prescribe, supply or recommend an unregistered chemical treatment on no more than one individual trade species animal. Thus, if use of an unregistered chemical on more than one trade species animal is sought, a minor use permit application must be submitted to the APVMA so that the proposed use can be scientifically assessed.

7 Non-chemical control of parasites

7.1 Internal Parasites

7.1.1 Current non-chemical use practices

7.1.1.1 Nematodes

From the survey responses and discussions with producers (See 7.1.1 Current chemical use practices) current non-chemical control practices fall into two main categories: those directed against the infrapopulation in the goat and those directed against the suprapopulation on the pasture (Jackson and Miller 2006). See Table 13.

Table 13 Products used for the non-chemical control of nematodes as indicated in the survey of goat owners

Worm population targeted	Remedy employed
Suprapopulation (nematode populations on pasture)	Grazing rotations Providing browse such as leaves of gum trees, walnut, pine, bauhinia acacia and leucaena Lime spread over pastures
Infrapopulation (nematode populations in the host)	Herbs including garlic, slippery elm and plantain Minerals including copper, dolomite and seaweed meal Homeopathic remedies

Grazing rotations with browse

The majority of producers who responded to the survey ran enterprises in pasture based systems and were very aware of the need for grazing rotations and the provision of browse as a component of the diet. Grazing rotations when used in combination with nutritional supplements and bioactive tanniferous forages will provide sustainable nematode control (See 8.1.2.5 Bioactive forages).

Tree forages are a good source of nutrition when both the quantity and quality of pasture is limited. Leaves or foliage often contain varying amounts of tannins (Nguyen *et al.* 2005) and goats selectively graze them to avoid any antinutritional effects (Silanikove *et al*. 1996; Silanikove 2000). Browse leaves from acacias (wattle) have the potential to provide crude protein and are moderately antiparasitic (Kahiya *et al*. 2003) while those of *Eucalyptus grandis* (flooded or rose gum) were demonstrated to be very active against *H. contortus* adults (Bennet-Jenkins and Bryant 1996). *Leucaena leucocephala* was nominated as a browse plant. When supplied at 20% dry matter (DM), *Acacia polyacantha* leaves fed to seven to nine month old South African male goats overcame weight losses associated with poor nutrition during the dry season (Rubanza *et al*. 2007). Bakshi and Wadhwa (2007) reported that leaves of *Melia azedarach*, *Morus alba* or *L. leucocephala,* when supplemented with mineral mixture and common salt, would serve as an excellent complete feed for small ruminants.

Partial replacement of dietary protein by a leaf meal mixture was shown to contribute up to 36% of total DM in does (Patra *et al*. 2006). Wirth (1980) encouraged the daily habit of feeding branches to goats to maintain health and vitality. He nominated leaves of deciduous trees such as oak, elm, poplar as well as eucalypts, acacias and willow as suitable.

Dry feed should be offered before green feed. Crops suitable for goats include kale, oats, peas, lucerne, millet, chicory, cabbage, broad beans and beetroot tops to nominate a few. Leaves and bark of the bauhinia tree *Bauhinia variegata* were also nominated as browse. In Nepalese traditional medicine the dried buds of *B. purpurea* are used in the treatment of worms. They do however contain an antinutritional component, ricin (Kumar and D'Mello 1997 cited by Nguyen *et al*. 2005). Crude extracts of *Mimosa pudica* and *Tinosphora rumphii* both of which contain condensed tannins were highly effective against *Haemonchus* worm egg counts and worm numbers in experimental trials (See 8.1.2.5 Bioactive forages).

Lime over pastures

Applications of lime spread over pasture were used by one producer as a method to control nematode larvae on pasture. Cabaret and Mangeon (1994) tested the efficacy of several lime fertilizers against infective larvae of *Tel. circumcincta* under experimental plot conditions in France. The fertilizer, which supplied N, P, K as well as lime, did not reliably reduce infestations of goats. In contrast however, the fertilizer did reduce the levels of lungworm and tapeworm infections by killing their snail and slug intermediate hosts respectively, thus breaking the life cycle. Nitrogen fertilizing of pastures in North America demonstrated a slight reduction in levels of infective larvae (Miller and Waller 2004).

Herbs

Phytomedicine has been used down through the centuries by farmers and traditional healers to treat parasitism and improve performance of livestock. To date however, scientific validation of the anti-parasitic efficacy and potential toxicity of most plants is limited despite their widespread use in ethno-veterinary medicine. Under scientific controlled trials antiparasitic activity is often lacking or of limited effect particularly when extracts are tested. Githiori *et al. (*2006) suggest that evaluation of traditional remedies should be conducted under controlled protocols that are consistent with traditional use such as daily dosing over a number of days.

Garlic has reputed efficacy against the human pin worm *Enterobius vermicularis* and tapeworm *Hymenolepis nana* but efficacy against gastrointestinal nematodes of goats has not been tested under scientific *in vivo* trials. Furthermore, treatment of dairy goats with garlic leaves the milk with an unpleasant taint. Trengove (2001) reported no effect against *Trichostrongylus* spp. or *Teladorsagia* sp*.* when sheep were dosed with 2ml of garlic concentrate mixed with Benefit®.

Slippery elm and plantain are mucilaginous herbs and may have beneficial activity on the digestive system but are not considered antiparasitic in scientific literature or in herbal medicine (Hoffman 1997).

Extracts of black hulls of walnut are reputedly antiparasitic in herbal medicine (Hoffman 1997). It is possible that some of the active is also found in the leaves. Efficacy in monogastric animals such as humans often does not translate into efficacy in small ruminants because of their different digestive systems.

Minerals

Many producers currently use copper sulphate as a drench or administer it at the rate of 1 teaspoon per animal in feed once a week. Copper has proven efficacy of about 80% against *H. contortus* in sheep but not against other abomasal or intestinal nematodes. Copper oxide wire particles are a safer form of copper supplementation (See 8.1.2.6 Copper oxide wire particles). Trengove (2001) examined the impact of commercially available multi-mineral mixes on worm burdens and found no effect against *Trichostrongylus* spp. or *Teladorsagia* sp. in sheep although long-term studies are now being considered as more appropriate to better assess the nutritional effects of minerals.

Diatomaceous earth
This product is being extensively used by producers in Australia and the United States. In trials conducted to date no effect on resident nematodes has been detected (Miller and Waller 2004).

Homeopathic treatments
Many European dairy cattle are treated homoeopathically for nematode infections but strong evidence for the efficacy of this modality is lacking (P. Waller *pers. comm.*). Da Rocha *et al.* (2006) treated sheep with Fator Vermes according to manufacturer's directions for 2 periods of 3 months each and were not able to substantiate the product's prophylactic benefits against gastrointestinal nematode infections.

Genetics
Producers who responded to the survey nominated genetics and selecting animals well suited to their environment as part of their non-chemical control methods for nematode parasites (See 8.1.2.4 Genetics). Exploiting the genetic immunity of livestock to disease in general, and to parasites in particular, represents the ultimate approach towards sustainable parasite control (Krecek and Waller 2006)

7.1.1.2 Coccidia

Survey responses indicated that producers were well aware of the hygiene requirements for the control of coccidiosis. Preventing excessive faecal contamination of food and water is essential for intensively managed young stock. Feed and water troughs should be raised above the ground and not leaking as oocysts will survive in moist conditions. Immunity to this disease develops by about 6 months of age but can break down during stress. Good management practices that prevent stress can reduce the likelihood of outbreaks (Spence 2004). One producer used lime in the sheds as a dehydrating agent to kill oocysts while another moved goats to a less contaminated area on the property as a standard control measure.

7.1.2 Non-chemical control options

Non-chemical control practices generally seek to maintain parasite infections below an economic threshold and are most often used as part of a multifaceted integrated approach to control. This is in contrast to anthelmintic and ectoparasiticide treatments which are often used as stand alone parasite controls and generally aim to reduce parasite numbers to undetectable levels (Ketzis *et al*. 2006). Practically speaking the most efficient and sustainable approach is likely to be an integrated program that uses a mix of non-chemical methods together with strategic use of chemicals. As indicated by Krecek and Waller (2006) 'best practice' approaches must be practical, affordable and appropriate and it is unlikely that any one approach, chemical or non-chemical, will be sustainable if used in isolation (Waller 2006a).

7.1.2.1 Grazing management

Browse
Goats evolved to browse on leaves and twigs of tall plants rather than graze on short grasses. During their evolutionary history, browsing goats have had little exposure to parasitic nematodes and consequently selection for innate immunity to infection has not occurred (Thompson and Bisset 1990). Sheep, on the other hand, have evolved under constant and often very heavy parasite challenge from the pasture and selection of individuals for better growth and production would have also included some measure of selection for parasite immunity (Chevis 1980).

Goats are also better able to digest tannin-containing browse plants to ameliorate their negative effects (Silanikove *et al*. 1996) and are better adapted to rangeland conditions than sheep (Wirth 1980). Browse in the form of heather supplementation proved to be a sustainable method to control gastrointestinal nematode infections in a pasture based production system of perennial ryegrass-white clover pastures in Spain (Osoro *et al*. 2007b). Browsing behaviour is usually associated with lower levels of nematode infections due to a combination of lower stocking rates characteristic of extensive grazing conditions and feeding on plant material free of nematode larvae.

Recent evidence suggests that the condensed tannins in browse may also often contribute a moderate antiparasitic effect (See 8.1.2.5 Bioactive forages). Browse, leguminous crops and stubble or tall grasses that encourage grazing at least 10 cm above the ground provide a good mechanical separation of the food source from the infection lower to the ground. Goats do not perform well if forced to graze below 4 cm (Thompson and Bisset 1990).

Appropriate stocking rates
Extensively grazed goats run at low stocking rates nearly always carry much lower nematode burdens than more intensively grazed animals (Coles 2002). Conversely, overstocking or overgrazing will quickly lead to rapid infections by creating large reservoirs of infective larvae on any remaining pasture especially around watering points. Goats when grazed at high stocking rates are more sensitive to infections with *H. contortus* and *Tel. circumcincta* than sheep (Le Jambre 1984). Overstocking of pastures also results in depleted feed levels. For the practical calculation of feed days see the Resource Consulting Services website. http://www.rcs.au.com/matching-stock-rate.htm To minimise internal parasitism McGregor (2007) recommends that goats be grazed at carrying capacities no greater than 8 Dry Sheep Equivalents (DSE)/hectare and that any additional grazing capacity on property be taken up with adult dry sheep managed separately from goats, or cattle. However, if goats obtain a significant proportion of their diet from woody "weeds" the stock unit system is most likely ineffective. If browse plants are available, the topography variable and the stocking rate low, inclusion of goats may have little effect on the performance of any other animal species. In contrast, on a flat, intensively grazed site with a botanically simple pasture, goats will compete directly with other livestock, and the livestock equivalence system will be more applicable (Lambert 1990). In poor seasons, increased stocking rates need to be accompanied by the provision of more feed in the form of protein, energy and minerals to ensure goats remain productive (See 8.1.2.3 Immunonutrition).

Rotations
The size of a helminth burden will depend on the number of parasites present in the goat at the start of the grazing period, the number of eggs deposited on pasture and their survival rate, the subsequent ingestion of larvae and the length of time that goats graze the pasture as it becomes increasingly infective. Grazing rotations aim to move goats to less contaminated pasture before high levels of infective larvae accumulate on the pasture being grazed.

Earl and Jones (1996) compared cell grazing with continuous grazing on 3 properties in the New England district and found that the percentage ground cover was significantly higher after two years of cell grazing than under continuous grazing. In addition the palatable species at each site were found to remain constant or to increase under cell grazing, while they declined significantly under continuous stocking.

Concurrent or sequential grazing of susceptible stock such as young goats and late pregnant and lactating female goats ahead of wethers that have acquired some natural immunity to infection, or ahead of a larger population of animals more resistant to parasites such as adult cattle will assist in lowering infection levels on pasture. Sale of young susceptible livestock will also reduce pasture contamination and remove one of the most nematode-susceptible groups (Waller 2006a). Shade trees in pasture based systems by their nature encourage parasitism. They protect both eggs in dung and larvae on grass from excessive temperatures and dehydration and encourage goats to congregate. Increased numbers of pellets on the ground leads to increased numbers of available infective larvae. As the vegetation becomes progressively more closely cropped, worm larvae are more easily picked-up and passed between hosts.

In wet tropical production systems, the free living stages of parasites are generally short-lived. Infective larvae of *H. contortus* and *T. colubriformis* are present on pasture about 4 days after egg deposition and fall to barely detectable levels within four to six weeks. A grazing system utilizing 10 paddocks, each one grazed for 3.5 days and then spelled for 31.5 days, reduced egg counts of goats to less than half those of similar goats set–stocked on an adjacent area. The rotation cycle was 35 days (Barger 1994).

In temperate production systems long grazing interchanges of between two to six months are more appropriate to the longer survival times of nematode larvae on pasture. Goat and cattle interchanges are based on host specificity. Parasites pathogenic in one host either don't infect the alternative host, or are less pathogenic and prolific. Increasing the ratio of cattle to goats will result in a reduction in the number of homologous nematodes to which goats are exposed (Thompson and Bisset 1990). Effective rotations under New Zealand conditions involved alternation of calves and kids (Bisset 1988) and adult cattle and goats (Kettle *et al*. 1983).

Adult cattle are normally recommended for rotations as animals younger than 24 months can carry worms such as *O. ostertagi* which can infect Angora goats in particular and cause clinical disease (Le Jambre 1978) (See 6.1.1 Nematodes). *H. contortus* from goats is also able to infect young calves but to a limited extent. Under long rotation systems sporadic outbreaks of *H. contortus* can occur in some districts during wet summers.

As the length of the grazing interval varies with the climatic region producers need to have a good understanding of the local epidemiological factors that control infectivity on pasture on a daily and weekly basis (O'Connor *et al*. 2006).

7.1.2.2 Predaceous fungi

The predaceous fungi *Duddingtonia flagrans* has proven efficacy to control nematodes on pastures (Waller 2006a). *D.flagrans* spores when dosed to goats pass intact through the digestive tract without any effect on the resident population of worms. Once deposited in the faeces, the spores germinate and grow rapidly to trap and destroy actively moving worm larvae (for a review see Larsen 2006). Efficacy of *D. flagrans* is determined by demonstrating either a decrease in infective larvae recovered from faeces or around faecal pellets in plot studies (for animals on pasture or in controlled laboratory studies) or by a decrease in the intensity of infections in tracer animals (placed on pastures previously grazed by *D. flagrans* fed animals). Efficacies of >90% have been recorded for cattle parasites and >70% for sheep parasites (Ketzis *et al*. 2006).

In coproculture, Paraud et al. (2006) observed reductions of 62.8% to 99.5% in the numbers of larvae in faeces of goats due to *D. flagrans* feeding compared to controls. They also identified that trapping activity was temperature dependent with more larvae trapped at 21°C than at 28°C. Trapping was also exposure dependent with more larvae trapped after 7, 10 and 14 days exposure than after four days. Additionally, trapping activity was nematode genera dependent with

Haemonchus larvae trapped more frequently than *Teladorsagia* larvae. Kahn et al. (2007) incubated faeces from a sheep dosed with *D. flagrans* spores at temperature ranges of 14–34^{0}C and 14–39^{0}C over a 24 hour period to mimic normal diurnal air temperature variation in Australia. A mean trapping efficacy of 96.4% was achieved indicating that typical Australian lambing temperatures should not be a barrier to the use of *D. flagrans* as an effective control agent against *H. contortus.* However, temperatures in faeces on pasture under summer conditions are significantly higher than ambient temperatures. For example, in the microclimate of the grass tuft, temperatures in faecal pellets were measured to range from 6^{o}C to 55^{o}C when the ambient temperatures were between 6^{o}C and 16^{o}C (Barger 1999).

Terrill et al. (2004) investigated the duration and dose of *D. flagrans* required to control mixed infections of key nematodes in coproculture. Daily fungal spore feeding at a dose rate of 2.5×10^5 of *D. flagrans* spores /kg BW/day provided a more consistent reduction in larval numbers than feeding spores every second or third day. The mean reduction in larval numbers started at day two of the treatment period and lasted until the day after treatment stopped. Reductions of 93.6%, 80.2%, 84.1% and 60.8% for animals dosed with 5×10^5, 2.5×10^5, 10^5, and 5×10^4 spores /kg BW/day respectively were reported. Within 3–6 days after fungal spore feedings ceased, reductions in larval development were no longer apparent. Waghorn et al. (2003) noted a dose rate effect with doses of 5×10^5 spores /kg BW/day required for activity against *Tel. circumcincta* whereas doses of 2.5×10^5 spores /kg BW/day were effective against *H. contortus* and *T. colubriformis.* Average efficacy of *D. flagrans* against key parasites was 78% with group means ranging from 40% to 93%. Furthermore, no host effect was observed. *D. flagrans* spores were equally effective against the three key parasites in both sheep and goats.

Faessler et al. (2007) recently reported greater efficacy of the fungus in coproculture than on pasture on 3 farms running dairy sheep in Switzerland. *D. flagrans* did not have a significant effect on larval numbers on pasture but, in faecal cultures, mean suppressions of 82%, 89% and 93% respectively were obtained during the fungus-feeding period.

In pasture trials, Wright et al. (2003) were able to demonstrate a significant reduction in the number of abomasal worms establishing in tracer kids grazed on pasture pre-grazed with kids dosed with *D. flagrans* spores. A total reduction in worm burdens of 53.5% (P=0.008) was reported, with individual reductions in burdens of *Tel. circumcincta* (mean of 54.8%) and *H. contortus* (mean of 85%). Paraud et al. (2007b) dosed kids with *D. flagrans* spores at the rate of 10^6 spores /kg BW/day during the grazing season in France. Kids fed spores showed lower faecal egg counts and higher growth rates at the end of the second grazing season compared to kids not receiving spores.

Synergistic opportunities for better nematode control have been demonstrated by combining a number of non-chemical control alternatives. For instance, additional benefits were observed when the fungus was dosed in combination with a fast rotational grazing system (See 8.1.2.1 Grazing management *Rotations)* in sheep managed in the tropics (Chandrawathani *et al*. 2004a). Gomez-Rincon *et al.* (2007) identified enhanced effects from the combination of *D. flagrans* with a nutritional supplement of 100 g barley grain per kid per day. The effects were greater and of a longer duration than would be expected from use of *D. flagrans* alone, with a 65% reduction in *T. colubriformis* burdens (See 8.1.2.3 Immunonutrition).

Most trials have concentrated on the effects of *D. flagrans* on the key nematodes of goats. Against nematodes of lesser importance, *D. flagrans* controlled the larvae of *Nematodirus* spp. of sheep (Githigia *et al*. 1997) and significantly reduced ($P<0.05$) larvae of *Strongyloides papilliosus* in goats (de Araujo *et al.* 2006) but did not control the slower moving larvae of *M. capillaris* of goats (Paraud *et al*. 2005).

The barrier to wider practical adoption of *D. flagrans* is the requirement for daily dosing of individual goats for a prolonged period. The recommended dosing schedule will most likely be between 2.5 to $5x10^5$ spores /kg BW/day for a period of two cycles of eight weeks each to coincide with kidding and weaning times when nematode infections are most likely to cause productivity losses and deaths (Ketzis *et al.* 2006). Long-term delivery devices such as fungal feed blocks and fungal controlled release devices have to date failed to produce effective and sustained parasite control (Larsen 2006). An application for this technology in the goat industry may be in intensive systems where goats are fed individually.

Environmental studies conducted in Australia and in France have shown no detectable detrimental effects on soil nematode populations or other microfauna (Knox *et al*. 2002; Paraud *et al*. 2007a). Concurrent anthelmintic treatment using a registered BZ product, thiabendazole, which has high antifungal activity, did not affect germination of the fungus (Paraud *et al*. 2004).

Duddingtonia flagrans oral treatments would require registration by APVMA.

7.1.2.3 Immunonutrition

In general, the primary effect of nematode infections on goat health is malnutrition. The pathophysiological processes causing this are reduced appetite and feed intake, decreased digestibility of food, protein loss into the gastrointestinal tract and diversion of nutrients away from growth and into repair of tissues damaged by parasites (for review see Hoste *et al.* 2005b).

Coop and Kyriazakis (1999) developed a compartmentalised theory of protein use in sheep that is relevant for goats but needs further validation. Nutrients are prioritised and allocated to different bodily functions; the higher the priority of the function, the less likely nutrient scarcity will affect that function. For instance, available protein is firstly used for maintenance activities such as respiration and digestion as this ensures the animal's survival in the short-term, followed by growth and reproduction to ensure preservation of the animal's genetics in the long-term. After these two functions have been satisfied, available protein is then allocated to immune activities such as throwing off a worm burden. The final function with least priority is fat deposition.

In general, determining the level of required supplements is complex. Requirements will differ between localities for different breed of host, at different stages of growth and reproduction, with differing seasonal availability of forage, with different genera of nematodes and different levels of established infections and exposure to infective stages on pasture (Knox *et al.* 2006). Disturbances in absorption and retention of minerals especially of phosphorus and molybdenum are also particularly significant in parasitic infections (McClure 2003).

Improved nutrition has been associated with improved resilience and immune functions. Resilience is the host's ability to cope with the adverse consequences of parasitism and to continue to gain bodyweight, produce fibre or increase milk supply despite carrying a parasite burden. In young parasite-naive goats whose immune systems have not matured, the pathophysiological effects of parasitism are more marked than in older goats. Protein supplementation has produced greater improvements in this age group than in any other age group (Coop and Kyriazakis 2001).

In contrast, immunity is the host's ability to contain and expel a worm burden and is most often expressed in terms of low worm egg counts and worm burdens. In young goats, immunity may not be fully developed until 12-18 months of age (Vlassoff *et al*. 1999). When protein is scarce, immunity has a higher priority than growth to ensure the animal reaches reproductive maturity. However, in the adult reproductive animal, immune functions are relaxed during the peri-parturient period. Protein is allocated for maintenance, reproduction and milk production at the expense of immunity to nematodes to ensure the animal's genetics are passed onto the next generation.

The rise in worm egg counts during parturition is well documented (Faye *et al.* 2003) and effects are especially marked in young does and does with multiple kids. Kids from dams with high worm egg counts of for example, >600epg had a 17% lower average daily weight gain 30 and 70 days post-partum and were approximately 1 kg lighter at weaning than kids from dams with lower worm burdens (Mandonnet *et al.* 2005). In experimentally infected dairy does carrying *T. colubriformis*, supplementation with 130% of protein requirements resulted in better immunity (lower faecal worm egg counts at parturition) and increased resilience (better milk yields) particularly in the 'high' producing does (Etter *et al*. 2000). Similarly, Chartier *et al. (*2000b) identified high milk producing dairy goats as less immune to nematode infection under natural conditions.

The extra nutrient requirements for accelerated growth during weaning coincide with a susceptibility to worms that also exacerbates the need for additional nutrition. In feeding trials, urea blocks supplemented with 100 g/day of cotton seed meal produced beneficial weight gains and reduced worm egg counts (Knox and Steel 1996). Improved immunity to *H. contortus* and enhanced growth was achieved when young weaner goats grazed in tropical zones were supplemented with urea plus molasses blocks at 95.0 g/head/day for 3 months (Waruiru *et al.* 2004). Fernandes *et al.* (2007) reported a requirement of 2.44+/-0.4 g of net protein/kg (0.75) of empty body weight (EBW) for daily maintenance. Net energy requirements for growth ranged from 2.55 to 3.0 Mega (M) cal/kg of EBW gain for Boer x Saanen crossbred male goats weighing 20 and 35 kg. Net protein requirements for growth ranged from 178.8 g/kg to 185.2 g/kg of EBW gain. These requirements exceed those established for dairy goats that are used as a guide for maintenance and growth requirements. Odoi *et al.* (2007) calculated that a small ruminant with, for example, a worm egg count of 100 epg higher than a contemporary of same age and sex would gain 41 g/day less weight than its contemporary under the same conditions of management. This decreased weight gain is thought to be a direct result of decreased feed intake and digestive disturbances due to worms.

Torres-Ascosta et al. (2004) demonstrated that a supplement of 100 g/day of 74% sorghum and 26% soybean meal mix improved the growth rates and decreased the pathophysiological effects of parasitism in browsing kids in tropical regions during a period of high larval challenge in the wet season. During the dry season, however, nutrient insufficiency became a greater threat to productivity than parasites (Torres-Ascosta *et al*. 2006). Despite the benefits of supplementation for improvements of resilience and immunity of kids against natural nematode infections animals kept free of nematodes had higher live weight gains compared to infected animals irrespective of the supplementation strategy (Gutierrez *et al*. 2003).

There is some evidence that nematodes under threat of nutrient scarcity can reduce their own activities and minimize their effects on the host (Blackburn *et al.* 1991). Perhaps this is an adaptation to ensure their host's survival. When conditions become favourable again worms resume their own development.

Among the alternative methods to anthelmintics currently available, manipulation of host nutrition to improve host immunity and/or resilience to parasitic infections is a most promising short-term option to reduce the dependence on conventional chemotherapy (Hoste *et al*. 2005b). Some indications of the long-term benefits from short-term supplementation have also been reported. Short term feeding of a higher protein diet for nine weeks to weaner sheep at five to seven months of age demonstrated beneficial effects up to 69 weeks (Datta *et al.* 1999).

7.1.2.4 Genetics

Potential for selection for immunity against nematodes is not as strong in goats as it is in sheep (Le Jambre and Royal 1976; Bishop and Morris 2007). Nevertheless, between-breed differences have been reported on a number of occasions (Pralomkarn *et al*. 1997; Baker *et al.* 1998) as have within-breed differences (Patterson *et al*. 1996; Vlassoff *et al.* 1999; Pepper *et al.* 2003; Fakae *et al*. 2004; Behnke *et al*. 2006) as judged by faecal worm egg counts.

Under Australian conditions, heritability of faecal worm egg count in fibre producing goats was found to vary with age and type of infection but was highest (0.22±0.13) at five months during natural challenge with *T. colubriformis* (Walkden-Brown *et al*. 2004; Walkden-Brown *et al.* 2007). This was slightly higher than the heritability estimate (0.17±0.02) reported in Scottish Cashmere goats (Vagenas *et al*. 2002). In sheep, selection of lines with increased immunity to nematodes resulted in animals carrying worm burdens around 10-20% of those in unselected mobs (Barger 1985; 1989). A recommendation from the Bushley MLA sponsored Producer Initiated Research and Development (PIRD) trial – 'Boers in pastoral country' is that Boer goat studs aim to breed goats that are more resistant to worms and to mineral and other deficiencies (Atkinson *et al.* 2007).

Benefits from genetically improving immunity to nematodes include, most importantly, decreased anthelmintic requirements and reduced pasture contamination leading to decreased larval challenge. However, selection for improved immunity also reduces selection pressure that can be placed on other economically important traits and this needs to be considered as part of any decision to select for increased immunity to worms. In meat goats, possible benefits from scientific advances made in genetics, nutrition and husbandry have not yet been realised to the same extent as in other livestock and poultry species (Shrestha and Fahmy 2005).

7.1.2.5 Bioactive forages

Throughout history, plants have been utilised as antiparasitics in most agricultural regions of the world. The condensed tannins (CT) complex in plants is presumed responsible for this activity. CT have a high affinity for proteins (Hoste *et al*. 2006) and their actions are thought to be a combination of direct anthelmintic-like and indirect nutritional effects. Direct anthelmintic-like effects are thought to be targeted against the proteins in the cuticle and digestive tract of worms thereby disabling them. Indirect effects are most likely mediated through protection of dietary proteins from microbial degradation in the rumen with their subsequent release into the small intestine for improved nutritional support of immune function. Improved mineral and trace element status may also be involved (Min and Hart 2003).

The effects against nematodes seem to vary with the concentration of the CT in the plant material. Forages containing about 30 to 40 g CT/kg DM, are considered optimal for antiparasitic effects. Forages low in CTs (20–45 g CT/kg DM) produce variable antiparasitic effects while forages high in CTs (>55g CT/kg DM) produce adverse effects such as reduced voluntary feed intake and digestibilities, and depressed rates of body growth (Min *et al*. 2003). While many rangeland plants contain high levels of CTs, browsing goats generally consume a wide variety of tannin-containing trees of varying concentrations and types to counter their negative effects (Osoro *et al.* 2007b).

The effects also seem to vary with the host. In sheep, consumption of CTs has been associated with modest activity against intestinal nematodes, whereas in goats, effects have been reported against both abomasal and intestinal nematodes (Ketzis *et al.* 2006).

The most common effect against adult worms is reduced fecundity (Paolini and Hoste 2006). Reductions in egg output of adult worms were obtained when goats were fed extracts of *Schinopsis* spp. (quebracho). Reductions were in the order of 64% for *H. contortus*, and 50% each for *Tel. circumcincta* and *T. colubriformis*. The effect on fecundity lasted only 15 days after tannin administration ceased. Also observed was that establishment of new infections was decreased by 33% for *H. contortus*, 70% for *Tel. circumcincta* and 66% for *T. colubriformis*.

The effects against adult worms seem to vary with the length of exposure to the CT-containing forage. Pomroy and Adlington (2006) fed the temperate forage legume *Hedysarum coronarium* (Sulla) containing low concentrations of CTs to young kids (<6 months of age) carrying naturally acquired mixed infections of scour worms for 10 days. No antiparasitic activity was observed. By comparison, significant reductions in egg hatch and larval development of *H. contortus* were reported when the tropical forage *Serecia lespedeza* (also containing low concentrations of CTs) was fed to goats for 15 days. The percentage of eggs developing to infective larvae in culture was reduced from 99% to 58.2% (P<0.01). The effects however, did not persist, indicating activity was against worm fecundity rather than the worms themselves (Min *et al*. 2004).

Longer periods of exposure to CT-containing forages seem to produce better activity against adult worms. Kabasa *et al*. (2004) noted apparent cumulative effects in improvement of postpartum performance of does and kids after browsing on rangeland plants for 77 days. Min and Hart (2003) observed reductions in numbers of *Haemonchus* (94%) and *Teladordagia* sp. (100%) in the abomasum and *Trichostrongylus* (45%) in the small intestine with an overall reduction in adult worm burdens of 76% when tracer wether goats were grazed on *S. lespedeza* for 81 days.

Processing of forage legumes into hay did not reduce the antiparasitic activity of the CTs. Feeding *S. lespedeza* hay to goats for 35 days produced an anthelmintic-like effect and significantly (*P*<0.01) reduced both faecal worm egg counts and numbers of abomasal *(H. contortus* and *Tel. circumcincta*) and small intestinal (*T. colubriformis*) nematodes in comparison to control goats fed bermuda grass (Shaik *et al.* 2006). Processing *S. lespedeza* into pellets not only retained but enhanced antiparasitic effects against nematodes primarily *H. contortus* and confirmed previous reports on the anthelmintic efficacy of this forage when fed as either long or ground hay. The reductions in faecal worm egg counts relative to the controls were 77% and 54% for goats fed pellets and ground *S. lespedeza* rations, respectively (Terrill *et al.* 2007).

No reductions in the milk production of dairy goats fed on average 1.36 kg of *Onobrychis viciifoliae* (Sainfoin) hay for 10 days of each month over a 9-month grazing period were identified, supporting the palatability of the product (Hoste *et al.* 2005a).

Other forms of CTs, particularly those of indigenous tropical or subtropical plants, are also reputedly antiparasitic. Kahiya *et al. (*2003) reported a 34% reduction in *H. contortus* burdens when Boer goats were fed *Acacia karoo* leaves high in CTs as 40% DM in the diet. Fresh heather offered *ad libitum* to cashmere does every third day during a 6-month period significantly (*P*<0.001) reduced live weight loss and faecal worm egg count (*P*<0.05) (Osoro *et al.* 2007a).

Fresh *Eucalyptus grandis* leaves (as whole branches) when fed to 10 rangeland goats as whole of diet for seven days reduced *H. contortus* adult worm burdens by 91%. There was no significant effect on the *Teladorsagia* sp. burdens. Extracts of leaves identified Mannich bases as a potential source of compounds for parasite control (Bennet-Jenkins and Bryant 1996). *E. grandis* has a wide distribution in Australia and can be grown under coppiced cultivation (Australian Forest Plantations, *pers. comm.*).

Overall, the beneficial effects of tannins are most likely due to their protein-binding ability improving protein supply for immune system activity (Hoste *et al*. 2006). Many CT-containing plants and forages also offer a higher plane of nutrition and their taller growth habit encourages browsing rather than grazing. A period of long-term feeding on browse with antiparasitic properties while the immune system is slowly maturing should protect goats from serious infection (Pomroy 2006).

7.1.2.6 Copper oxide wire particles

In the 1950's copper sulphate, despite its toxicity, was used as a treatment for haemonchosis. It was administered either as a drench or mixed into the drinking water, by itself or in combination with other products such as nicotine sulphate. With the advent of much safer modern anthelmintics the use of copper sulphate as an anti-parasitic declined. Today, however, many producers still mix copper sulphate with other drenches to control haemonchosis of sheep and many goat producers dose copper sulphate with feed.

Ruminal boluses of copper oxide wire particles (COWP) are a much safer form of copper supplementation. COWPs are registered as Coopers Permatrace® for nutritional deficiencies of goats. Restrictions on the label state that this product should be administered only once a year. The boluses when dosed into the rumen lodge within the folds and release needle-like particles of copper oxide that move with the ingesta to the abomasum. The low pH of the abomasum assists with the release of soluble copper (Bang 1990).

COWPs are currently being assessed for their potential anti-parasitic properties. Chartier *et al. (*2000a) achieved good activity against *H. contortus* in dairy goats using a 4 g capsule. Worm burdens were reduced by 75% and new infections were reduced by about 40% (range 37–95%) over several weeks. No antiparasitic activity was demonstrated against *Teladorsagia, Trichostrongylus* or *Oesophagostomum* infections. A recent study in semi-arid Kenya demonstrated that goats given 2 g copper oxide wire capsules had 75% less *H. contortus* eggs and worms than controls for up to eight weeks following treatment (Waruiru *et al.* 2004 cited by Krecek and Waller 2006). In Australia, a four to six week suppression period of worm egg counts was reported for an MLA sponsored (PIRD) trial that examined the impact of copper oxide capsules on worm burdens (Niven *et al*. 2000 cited by Trengove 2001).

In an attempt to provide longer and safer treatment during high infection risk periods a sustained release multi-trace element/vitamin ruminal bolus containing copper (80 mg) along with cobalt and selenium was administered to yearling/mature does during late gestation. Worm egg counts were reduced by 80% in does prior to breeding and 60% when dosed six weeks prior to kidding. The effects were apparent within seven days of treatment but did not persist more than 28 days after treatment (Burke and Miller 2006).

COWPs when used sequentially or concurrently with other non-chemical strategies have the potential to provide useful broad-spectrum control. For example, COWPs markedly reduced *H. contortus* infections and had no adverse effect on *D. flagrans* trapping ability when dosed to lambs. This observation has prompted a recommendation for lambs of sequential dosing of COWPs followed by *D. flagrans* treatments four weeks later (Burke *et al*. 2005). This recommendation may also have relevance for goats. De Montellano *et al*. (2007) used a combination of COWPs and nutritional supplementation (100 g of feed/day of 74% sorghum: 26% soybean meal) to give control of both abomasal and intestinal parasites of kids during a period of high larval challenge. Kids receiving nutritional support improved their live weight gain (LWG) and haemoglobin (Hb) levels to the level of control goats kept parasite free by suppressive anthelmintic treatment. The COWPs only treatment group did not improve LWG or Hb levels. The levels of the naturally acquired *Haemonchus* infections were low and most parasitism was due to *T. colubriformis*.

Toxicity levels have not been determined for copper in goats. Glennon *et al*. (2004) observed increased liver copper concentrations in test goats dosed with either 5 g or 10 g boluses compared to controls not receiving the copper boluses. Solaiman *et al.* (2007) demonstrated that copper, supplemented as copper (Cu) sulphate at the rate of 100 mg/day, in addition to 14 ppm of Cu in the basal diet, improved LWG and enhanced the immune response in kids. The overall average daily DM intake of these goats was reduced (linear, $P < 0.05$) with higher levels of Cu intake but the average daily weight gain was most improved (quadratic, $P = 0.05$) with 100 mg/day Cu supplementation. The availability of plants containing pyrrolizidine alkaloids such as Patterson's curse and heliotrope in the grazing environment need to be assessed before copper therapy is commenced. These plants place an added burden on liver function and the combination in lambs has been fatal (Seaman 1987; Walker 2004). Trials in south-east Queensland are being conducted on 7-month-old Boer goats to ascertain dose rates, efficacy and toxicity of 1.25 g, 2.5 g and 5 g COWPs dosed 42 days apart against artificial and natural infections of *H. contortus* (J. Cawdell-Smith *pers. comm.*).

Since *H. contortus* is considered to be the most pathogenic parasite of small ruminants on a worm-for-worm basis (Krecek and Waller 2006) control of established infections by COWPs could provide a useful alternative to chemical treatments for young goats pastured in *H. contortus* endemic tropical and subtropical agricultural and metropolitan zones.

COWPs are not registered for use as an antiparasitic product and the restriction on the label states that dosing should be once a year.

7.1.2.7 Targeted selective treatments

Targeted selective treatments aim to identify and treat only those animals in a herd most severely affected by nematodes. This is in contrast to conventional drench practices which treat the whole herd even though some animals may not be affected. The principle behind this concept is the gross over-dispersion of nematode burdens within a herd with the majority of the worms being carried by a small percentage of goats (Barger 1989; Vlassoff *et al.* 1999; van Wyk *et al*. 2006). Treatments targeted at selected animals will reduce chemical usage in the herd, decrease selection for immunity and increase the numbers of the worm population in refugia (See 3 Definition of Terms). Goats identified as more susceptible to worms should be excluded from breeding programs. These methods are labour-intensive and time-intensive when conducted on a weekly basis and are best suited to properties carrying fewer than 200 goats.

FAMACHA© and BODCON (Body condition Scoring) are management tools to identify nematode affected sheep and goats. FAMACHA scoring is used to detect anaemia induced by haematophagous (blood sucking) nematodes (Vatta et al. 2001).

BODCON will detect sheep and goats affected by non-haematophagous worms which reduce appetite and cause digestive disturbances resulting in observable weight loss (Ketzis *et al.* 2006).

FAMACHA
The signs of anaemia are most easily seen in the colour of the inner lower eyelid. This method matches the colour of the conjunctiva of an individual goat to a simple colour chart to grade the anaemia and determine the need to treat. FAMACHA has been trialled successfully in the southern United States. Kaplan *et al*. (2004) found that the predictive value of a positive test was low and that many non-anaemic animals would also be treated. However, this was far fewer than treating all animals in the herd and would still achieve the goal of leaving a large proportion of animals untreated. Burke *et al*. (2007) determined that the predictive value of a negative test was greater than 90% for all anaemia and eye score categories for sheep and goats. In Guadeloupe, Mahieu et al. (2007) tested the FAMACHA method as a decision aid for culling management. They estimated the repeatability of the need for drenching an individual doe was 41%. Older goats or the goats in poorer body condition at kidding needed more drenching than younger goats or goats in good body condition. Use of the FAMACHA method dramatically decreased anthelmintic use during the peri-parturient period. The FAMACHA group was drenched 0.57 of an individual dose compared with three doses for the control group. The proportion of the nematode population on the pasture not derived from previously-treated goats was estimated to about 79% (65–90%) of the pasture contamination derived from the FAMACHA-scored group while treated goats should pass very few eggs if dosed with an effective anthelmintic.

H. contortus is probably the only nematode parasite of sheep and goats that can be accurately diagnosed without the aid of specific laboratory testing (Waller 2006b). Anaemia is also indicative of a number of other conditions such as liver fluke and *Mycoplasma ovis* infections and copper and molybdenum deficiencies. Awareness of other local causes of anaemia is important when using FAMACHA to make a diagnosis (Wolstenholme *et al*. 2004).

BODCON
This is a practical method of clinical evaluation for non-haematophagous worm species, such as *Trichostrongylus* spp., *Teladorsagia* sp. and *Oes. columbianum.* It is a simple, clinical scoring of the tissue over the lumbar vertebrae and has shown high genetic correlation with FAMACHA scores, haematocrit values and worm egg counts on one sheep farm in South Africa (Bath *et al*. 2005). In Western Australia, treatment of only a proportion of a sheep flock using short-interval weight change as a treatment index did not result in significant production loss compared to traditional strategies (Besier 2007).

Clearly, in the future, improvements in resilience criteria such as live weight gains, FAMACHA indexes and BODCON scoring of breeding stock would favour selection of those animals more resilient and better adapted to local conditions rather than using faecal worm egg counts or other parameters of immunity measurement (Hoste *et al*. 2005b).

7.1.2.8 Importance of an integrated approach

Regulation of the suprapopulation is most appropriately achieved by decreasing the degree of exposure to infecting parasites during feeding. The provision of browse or browse paddocks may be one of the most readily achievable options for control of nematodes of goats. Predacious fungi may also have a role in decreasing levels of contamination and infection on pastures but at present the product is not available commercially. Both grazing strategies and predaceous fungi have proven effectiveness.

The infrapopulation can be regulated by adequate nutrition to support resilience to nematodes, by genetically selecting goats with greater immunity to parasites and by the use of anthelmintic alternatives such as bioactive forages and copper oxide wire particles. Use of targeted selective treatments such as FAMACHA and BODCON to identify goats at risk of clinical disease may be possible on smaller holdings or in small feedlots. See Table 14.

Even if anthelmintic-free production systems were successful, it is possible that nematodes may still be selected for attributes that may ultimately render these control procedures ineffective. For instance, in mixed-host grazing systems increased numbers of parasite species could be able to infect both host species. Similarly, rotational grazing systems could be subverted by selection for enhanced larval survival or faster development from egg to infective larva. Nevertheless, it is hoped that selection for such fundamental changes as those presumably required to affect survival, development or host specificity will be slower than selection for anthelmintic resistance (Barger and Michel 1997).

However, despite this possibility, an integrated approach as promulgated at an international level will reduce the need for repeated chemical treatments, assist to preserve the efficacy of available chemical treatments and lower the risk of residue in product.

The risk of using non-chemical parasite control alternatives lies in not being able to predict the level at which goats will begin to experience an impact on productivity particularly when acute infection demands fast and efficient control.

Table 14 Non-chemical alternative management methods to control nematodes

Non-chemical strategy	Target nematode population	Benefit	Action for Immediate adoption	Barriers to adoption
Browse	on pasture	Feed free of larval nematode contamination Antiparasitic properties in plants Extra nutrition	Grow browse paddocks or access browse vegetation	Economic cost-benefit analysis
Bioactive forage crops	on pasture	As above	Crop suitable country	Economic cost-benefit analysis
Stocking rates and grazing rotations	on pasture	More available feed Stocking rates appropriate to available feed in all seasons Control nematode levels on pasture	Calculate speed of rotations on available feed, height of pasture, temperature and rainfall patterns and parasite epidemiology Calculate feed days	Strong knowledge of parasite epidemiology on property Availability of paddocks for rotations
Nutrition	in host	Immune system requires protein, energy and minerals	Supply nutritional needs of weaners and peri-parturient does	Economic cost-benefit analysis
Immunity	in host	Goats carry fewer nematodes Less contamination onto pasture	Identify more immune breeding stock when 5 months on a faecal worm egg count test	This trait has low-moderate heritability and will take time to develop an immune herd Small advances will have a

Non-chemical strategy	Target nematode population	Benefit	Action for Immediate adoption	Barriers to adoption
		Less selection for drench resistance		positive effect on pasture contamination and infectivity
Resilience	in host	Goats carry some nematodes but productivity doesn't suffer Removes the need to drench the whole mob – *use this strategy with caution* Identifies animals to be culled or removed from breeding programs Less selection for drench resistance Suitable for smaller holdings	Use FAMACHA and BONCON to evaluate hardiness to property conditions	Role of worm egg counts in resilience need to be clarified Large extensive properties
Bioactive fungi	in dung	Expect a 50-97% broadspectrum control of infection Takes up to two days for effects to become obvious Effects stop when dosing ceases Suitable for production systems in higher rainfall zones		Daily individual feeding Efficacy needs to be tested in goats under Australian Not registered for use in Australia
Copper oxide wire	in host	Expect a 70-90% reduction in		Best practice use and dose

Non-chemical strategy	Target nematode population	Benefit	Action for Immediate adoption	Barriers to adoption
particles (COWP)		*H. contortus* nematode egg counts and adult worms Best suited to *H. contortus* endemic zones Takes from 7 to 21 days for reductions in worm egg counts to become evident May provide up to six weeks protection		rates still to be determined in goats under Australian conditions Not registered for use as an antiparasitic Not to be administered more than once a year

7.2 External Parasites

There has been very little in the way of investigation of non-chemical control of goat ectoparasites, particularly those of concern in an Australian context. This section draws mainly from information available on similar parasites of other livestock species.

7.2.1 Lice

As noted earlier, control of goat lice currently relies almost exclusively on the application of insecticidal treatments. Other methods are limited primarily to cultural methods such as the prevention of new infestations.

Prevention of new infestations:
Most new infestations will result from contact with other infested goats, although often a supposed new infestation will have come from failure to eradicate lice at a previous treatment. Goats carrying lice can come from three main sources, newly purchased animals, feral or stray goats, either other people's strays, or a goat from the home herd straying, coming into contact with infested goats and returning to the herd, and goats that were missed at the last muster and not treated. Infections beginning from contact with other infested goats at shows or field days have also been reported. Invoking strategies to prevent new infestations from these sources will do much to prevent losses from lice and the need for treatment.

Although spread of lice is predominantly by contact between goats some stages can survive away from the host for short periods of time. It is possible that infestations could begin from handling facilities recently occupied by lousy goats. Heath (1973) indicated that 14 days exclusion of goats should be sufficient to confidently remove the risk of any viable forms of *B. caprae* and Ramchurn (1980) found that *L. stenopsis* could survive 19 days in the absence of hosts, suggesting a slightly longer period may be required with sucking lice infestations. Disinfection of pens could be an important part of eliminating infestations in closely managed or housed goats.

As already noted, goat lice are generally specific to goats and other species of livestock are unlikely to provide a significant source for new infestations. However, sheep and other livestock running in close proximity with goats could harbour viable goat lice for short periods of time and should be either removed from the goat herd when lice treatments are applied or treated at the same time.

Nutrition
Although food supplements with particular micronutrients are sometimes recommended as aiding parasite control, in most instances there is little information to verify these claims. For example, Babcock and Boughton (1943) found that daily oral administration of sulphur in capsules had no effect on biting or sucking lice. However, there is a general belief that animals with poor nutrition or in poor health are more susceptible to lice and often support higher louse burdens than well nourished healthy animals. Evidence supporting this in sheep and cattle was reviewed by James (1999).

Host susceptibility
In most animal populations there are some animals that carry a disproportionate proportion of the louse population (James *et al.* 1998; James *et al*. 2002). It will be harder to eradicate lice from these animals and they probably often act as a source for reinfestation of other animals in the herd when the seasonal build up in lice commences. Culling such animals should be considered as part of an integrated approach to control.

Strategic shearing (Angoras)
Most resident ectoparasites, such as lice have well defined seasonal cycles in abundance, increasing through autumn winter and into spring and then falling away in summer. Shearing directly removes a high proportion of lice and many more are subsequently killed from exposure to environmental elements. Strategic timing of shearing to maximise exposure of lice to unfavourable environmental influences such as high temperatures and high levels of solar radiation could be expected to increase mortality of lice from shearing and enhance the effect of any insecticidal treatments applied.

Biopesticides and plant extracts
With increased sensitivity to the use of chemicals there has been growing interest in alternative treatments such as the use of biopesticides and organic treatments. There have been few studies with goat lice although Gingrich *et al.* (1974) demonstrated that *Bacillus thuringiensis* (Bt) was effective against *B. limbatus* and *B. crassipes* in laboratory trials. No animal studies with goats have been reported but tests against *B. ovis* on sheep gave up to 97% reduction in louse numbers (Pinnock 1994). Briggs *et al.* (2006) demonstrated high levels of infection of the cattle louse *B. bovis* in arena studies on cattle following application of the fungal pathogen *Metarhizium anisopliae* and
D. Leemon 2006 *pers. comm.* found that the fungal pathogens *Metarrhizium anisopliae* and *Beauvaria bassiana* were effective against sheep lice (*B. ovis*) in both laboratory and animal studies. A number of Australian strains of these fungi have been screened for activity against *B. ovis* and work is proceeding towards development of a commercial product for control of sheep lice. James 2006 (unpublished data) demonstrated that a number of species of entomopathogenic nematodes could invade and kill *B. ovis* in both laboratory studies and when applied to sheep, but effect against goat lice was not tested.

A range of plant extracts or derivatives have been tested against lice, in particular human head lice. Eucalyptus oil was shown many years ago to be toxic to human head lice and dog lice (Sergent and Foley 1915). More recently, Yang *et al*. (2004) tested 54 plant essential oils against head lice and found activity comparable with commercial pediculicides in at least 11 of them. Toloza et al. (2006) described fumigant and repellent activity against head lice from 16 native and exotic Argentinean plants. With sheep lice, Heath *et al.* (1995b) found that dipping in a neem formulation gave a reduction in louse score of 85% to 100%. Guerinni (2000) reduced lice by 98 to 100% by spraying sheep with 80 to 1280 ppm of neem amd Dimri and Sharma (2003) reported that dusting sheep with 25% neem powder and 75% sulphur removed 51% of lice (James *et al.* 2006 unpublished data) showed that a range of plant extracts including essential oils from eucalyptus, lemon scented myrtle, and tea tree and various neem extracts all had effect against sheep lice in laboratory studies.

There appears to be potential for use of a number of biopesticides and plant extracts in the control of lice on goats. However, both biopesticides and plant extracts would require registration with the APVMA for application to goats (with the exception of entomopathogenic nematodes which are specifically exempt) and studies with goat lice would be needed to demonstrate effectiveness. As with chemical parasiticides, the cost involved in testing and registration for a relatively small market may be a barrier to future availability.

7.2.2 Ticks

There has been widespread investigation of alternatives to chemical pesticides for controlling ticks because of their importance as medical and veterinary pests and vectors of pathogenic diseases.

These include cultural methods such as pasture spelling (Wilkinson 1964), breed selection and selection within breeds for more resistant hosts (Frisch *et al.* 2000), tick vaccines (Willadsen 2006), biological controls (Samish *et al.* 2004) and plant extracts (Chagas *et al*. 2002). In addition, anti-*I. holocyclus* paralysis serum is available under prescription as Purified Anti-tick Serum (Summerland Serums Pty Ltd, Alstonville NSW) and is registered for treating *I. holocyclus* induced paralysis in goats.

As problems from ticks in goats are limited to localised areas in Australia and tick infestation is a minor reason for the application of pesticides to goats, a full consideration of alternative methods for tick control is beyond the scope of this review. The reader is referred to the above publications for further information.

7.2.3 Mites

Mite infestation is generally only a problem in a small proportion of the herd, although as detailed earlier, in some instances the infestation may become severe. Treatment will normally be by the use of chemical therapeutics and under veterinary supervision. Nevertheless, because of the economic importance of *Psoroptes* mites in causing sheep scab, now eradicated from Australia, and *Sarcoptes* in a range of species, there has been some investigation of alternative methods of control, such as vaccination, biological controls and the use of plant extracts. The potential and progress in development of a vaccine for *Sarcoptes* and *Psoroptes* mites has recently been reviewed by Nisbet and Huntley (2006). Although significant advances have been made and the rapid advances currently occurring in molecular technology offer exciting possibilities for the future, the likelihood of a practical vaccine for use in goats is low.

Smith *et al.* (2000) report the possibility of using entomopathogenic fungi for controlling parasitic mites. Perrucci *et al*. (1997) found that 5% linalool, a naturally-occurring terpene alcohol found naturally in many flowers and spice plants eliminated infections of *P. cuniculi* from goats and the results of Das *et al*. (1994) and Magi *et al.* (2006) with *Sarcoptes* mites on goats and pigs respectively also indicate the future possibility of using plant extracts for control of some mite species in goats.

7.2.4 Myiasis, biting and nuisance flies and fleas

Repellents have occasionally been smeared on the nostrils of sheep and goats to deter sheep bot flies from depositing larvae, but there appears to have been little investigation of other methods of control, possibly because of the cryptic location of sheep bot fly maggots in the nasal passages and sinuses of their hosts. A wide range of cultural, biological, immunological and genetic means have been tested for control of biting, nuisance and other myiasis flies, but given their generally low impact in the goat industry a full consideration is beyond the scope of this review. The reviews of Hall and Wall (1995) for myiasis flies, and the relevant chapters in the books by Wall and Shearer (2001) and Mullen and Durden (2002) for nuisance flies, biting flies, myiasis flies and fleas provide further information.

8 Registration of a chemical

8.1 The registration process

As discussed earlier, the Commonwealth and State and Territory governments are all partners in the National Registration Scheme. The Australian Pesticides and Veterinary Medicines Authority (APVMA) comes under the portfolio of the Australian Government Minister for Agriculture, Fisheries and Forestry and is responsible for the registration of pesticides and veterinary medicines prior to sale and their regulation up to and including the point of retail sale. The States and Territories are then responsible for the control of use of those products.

The Commonwealth's *Agricultural and Veterinary Chemicals Code Act 1994* contains a schedule, the 'Agvet Code', which has detailed provisions under which the APVMA evaluates submissions from chemical companies for approval of active constituents and registrations of agricultural and veterinary chemical products (and approves their associated labels). APVMA also reviews existing approved active constituents and registered products; licences the manufacturers of chemical products; and issues permits.

The Agvet Code defines a veterinary chemical product as follows:
'A veterinary chemical product is a substance or mixture of substances for administration or application to an animal by any means, or consumption by an animal, as a way of directly or indirectly:

- (a) preventing, diagnosing, curing or alleviating a disease or condition in the animal or an infestation of the animal by a pest; or
- (b) curing or alleviating an injury suffered by the animal; or
- (c) modifying the physiology of the animal:
  - (i) so as to alter its natural development, productivity, quality or reproductive capacity; or
  - (ii) so as to make it more manageable; or
- (d) modifying the effect of another veterinary chemical product.'

Products requiring registration
Advice on determining whether or not a particular product requires registration is available on the APVMA web-site: http://www.apvma.gov.au/registration/vet_reg.rtf
Essentially, a product requires registration if it makes a claim that fits the definition of a veterinary chemical product, or it contains ingredients that are used for a purpose that fits the definition of a veterinary chemical product, or both. Thus the APVMA considers that a product is likely to require registration if any claim is made on a label, advertisement or website that the product is intended to modify the health, production, performance or behaviour of animals.

In general terms, it is most likely that a veterinary chemical product will require registration if it contains:

- active constituents already approved by the APVMA; or
- chemicals which in the opinion of the APVMA are normally used as veterinary chemical products (such as antibiotics or anaesthetics); or
- chemicals or chemical products declared by the Regulations to the Agvet Code to require registration. These include: allergenic substances supplied for administration or consumption by an animal; medicated licks or blocks; enzymes supplied or used for administration or consumption by an animal; direct fed microbial products (such as *Duddingtonia flagrans*); sheep branding substances; stockfeed non-active constituents unless those non-active constituents are

included in an Order ('The Stockfood Non-active Constituents Order') in the Regulations to the Agvet Code.

It is important to note that products requiring registration are not confined to those made from 'synthetic chemicals'. In Australia, biological, homeopathic, herbal and other natural medicines require registration. Some nutritional products also require registration if they contain some nutrients at levels considered to have therapeutic benefits rather than just nutritional.

Where there is any doubt on registration requirements, it is best to seek specific advice on the chemical product from APVMA. It will be necessary to provide a copy of the intended market label and a copy of any advertising claims from printed or website material, plus a copy of the full formulation. Any material submitted will be treated by APVMA as Confidential Commercial Information.

Registration process

During the APVMA's evaluation process, each product is subjected to rigorous scientific assessment before it can be approved for registration. The APVMA must be satisfied that the use of the product would not cause an undue hazard to the general public or to those who have to handle it; nor should it cause unintended harmful effects on the environment, animals or plants or prejudice Australia's trade with other nations. It is also important that the product should be effective when used according to the instructions for use on the approved label.

As suggested by the above list, it is usual for any submission for approval of an active constituent or registration of a product to contain extensive scientific data in order to satisfy all the above criteria. While any person who owns data can apply to APVMA for approval of a new active constituent, registration of a new chemical product and approval of a label, only the registrant of an existing registered product (the chemical company) can submit further applications to vary that existing registration. Thus, an application to extend the registration of a product registered in cattle, for example, to include its use in goats has to come from the chemical company which registered that product in the first place (i.e. the product registrant). If an animal industry would like a particular product to be registered for use in a particular animal species, it is possible for industry representatives to interact with the registrant of that product and to support trials on that product. Such support might be financial or might involve provision of trial sites and animals for conduct of field trials by the company, for example.

In the course of evaluating a submission for registration of a chemical product, the APVMA seeks expert advice from other agencies, particularly the Office of Chemical Safety (within the Australian Government Department of Health and Ageing) and the Australian Government Department of Environment and Water Resources. APVMA may also contact Food Standards Australia and New Zealand (FSANZ), the Office of the Gene Technology Regulator (OGTR), the Expert Advisory Group on Antimicrobial Resistance (EAGAR) and the Australian Quarantine Inspection Service (AQIS). Specialists within the States and Territories or external consultants are called upon to evaluate whether the submitted data demonstrate that the product will work effectively for the intended purpose and will also be safe to target and non-target species.

The APVMA provides considerable guidance on its web-site with respect to the comprehensive data package required for registration. The data package needs to include chemistry and manufacture, toxicology, metabolism and toxicokinetics, residues and implications for overseas trade, efficacy, occupational health and safety and environmental effects. All the data submitted must have been generated according to accepted scientific principles.

Table 15 contains a summary of specific data requirements as discussed on the APVMA web-site (refer http://www.apvma.gov.au/registration/data2_new.shtml).

Table 15 Summary of data required for registration

Part 1 Application Overview
A brief overview of the entire application.

Part 2 Chemistry and Manufacture
Active Constituent: data to identify the active constituent (common name, chemical name, CAS registry number, manufacturer's code number, molecular formula, molecular weight and structural formula/diagram), its manufacturer and manufacturing site address, manufacturing process and quality control, specifications, batch analysis, analytical methods and validation data.
Product: data to clearly identify the product, formulator, formulation type, composition and manufacturing process, physical and chemical properties, product specifications, batch analysis, stability data, analytical methods and validation data and packaging.

Part 3 Toxicology
Results of toxicity studies (acute, short-term and long-term); reproduction studies; developmental studies; genotoxicity studies; and studies of the toxicity of metabolites and impurities, other adverse effects and toxicology of mixtures. Data on human toxicology, the no observable effect level, acceptable daily intake (for humans), and proposed first aid and safety directions.

Part 4 Metabolism and Toxicokinetics
Results of metabolic studies in target crops and animals. Metabolic and toxicokinetic studies in laboratory animals. Database of all metabolic studies considered.

Part 5a Residues
Complete, detailed proposed use-pattern for the product, including dose rate and regime and proposed withholding period. Data showing the nature, level and safety of residues and metabolites resulting from the proposed use-pattern of the product and the effect of any major variables. Included should be residues in crops, livestock, poultry, eggs, milk and (if applicable) wool. Fate of residues during storage, processing and cooking. A proposed maximum residue limit (MRL) and data on MRLs in Australia, other countries and Codex.

Part 5b Overseas Trade Aspects of Residues in Food
Information about the overseas registration status of the product/active constituent, use patterns and MRLs overseas, export intervals, labelling, compliance with overseas MRLs, authorities and growers' views on use as proposed, and gazettal/trade advice notices.

Part 6 Occupational Health and Safety
Data on potential occupational exposure of workers to the active constituent, end-use product and residues. Health conditions contraindicating use of the product. Occupational health monitoring, including atmospheric and biological monitoring (as applicable). Safety information to be provided on the label, Material Safety Data Sheets and through education/training.

Part 7 Environmental Studies
An assessment of the extent of, and potential for, environmental exposure during manufacture, use, disposal and through accident. Results of laboratory studies on the degradation of the chemical in water and by light; the metabolism of the chemical (both aerobic and anaerobic); bioaccumulation in fish, aquatic organisms and other species; and mobility in soil. Results of field studies to determine degradation (persistence) and leachability. Ecotoxicity studies of birds, mammals and other vertebrates; aquatic organisms and non-target invertebrates and native vegetation.

Part 8 Efficacy and Safety Comprehensive data from laboratory and field trials which show that the product is effective for the purposes claimed and safe for the intended crops (or species) and non-target crops, plants and animals. **Part 9 Other Trade Aspects** Data on the trade aspects of a product relating to matters other than residues in food; eg. environmental concerns about residues in wool. **Part 10 Special Data Requirements**

The APVMA provides specific explanation of its data requirements in the Manual of Requirements and Guidelines (MORAG) available on-line. The Veterinary MORAG is located at: http://www.apvma.gov.au/MORAG_vet/MORAG_vet_home.shtml

The critical residues study that will underpin the registration must be performed according to Good Laboratory Practice and will be costly. There could be significant time savings overall if an acceptable trial is conducted at the outset to generate the required residues data. Some detailed information on residues follows.

Minor Use Permits Process

A minor use is defined as the use of a chemical product that would not produce sufficient economic to the applicant company to meet the costs of registration, including the costs of generating the required data submission. The term 'minor use' therefore is not interchangeable with the term, 'off-label use'.

There are Guidelines for making Veterinary Minor Use applications on the APVMA web-site under Category 21 of Volume 2 of the Veterinary Requirements and Guidelines – Vet MORAG (http://www.apvma.gov.au/MORAG_vet/MORAG_vet_home.shtml)

Category 21 Minor Use applications can include:

- the 'off-label' use of an existing registered veterinary product
- the use of an unregistered veterinary product
- the use of an autogenous vaccine.

The APVMA will consider applications for minor use permits where the permit is for off-label use in a minor food-producing (trade) species, such as goats. In general, the recognised major trade species are cattle, sheep, pigs and chickens; minor use permits can also be issued for quite limited off-label uses within these major trade species. Alternatively, an application for a minor use permit could be considered if the applicant could provide evidence that the economic return from sales of the product would not meet the costs of registration.

As indicated, minor use permits can also be issued to allow the use of unregistered veterinary chemical products if the required data are supplied and considered suitable to support a permit. Use of autogenous vaccines specifically prepared for use on a particular property from disease causing organisms isolated from animals on that property must also be covered by minor use permits. In both these instances the use, although minor, is not an off-label use because there is no registered product label. See Table 16.

Table 16 A step-wise procedure for submitting Minor Use Permit applications to APVMA

1. Identify the parasite(s) causing the problem.

2. Have the identity of the parasite(s) confirmed (eg. by government or private veterinarian, scientist from department of primary industries/agriculture or CSIRO, etc).

3. List the veterinary chemicals already registered or approved under permit (if any) for control of these parasites. If the use of an alternative chemical is required, provide advice on why these currently registered or approved chemicals are not suitable. After consulting with advisers (as above), choose the most appropriate chemical and use pattern. Complete the APVMA off-label minor use permit application form, available on the APVMA web-site (http://www.apvma.gov.au) under Industry – MORAG – Vet MORAG. In the Vet MORAG section, a copy of the permit application form is available under Vet MORAG under Application Forms on the left hand side of the bottom tool bar. Under Chapter 2, Category 21 Requirements and Guidelines, there is helpful information for making an Application for a Minor Use Permit (Veterinary).

4. The APVMA prefers a peak industry body to be the permit holder where possible.

5. Submit the completed signed permit application to the APVMA with appropriate fee:

Address to: Application Management and Enquiries
Australian Pesticides & Veterinary Medicines Authority
PO Box E240
KINGSTON ACT 2604
Fax: 02 6210 4721
Contact Officer, Veterinary Medicines Program, Ph: 02 6210 4726

The APVMA fee for a minor use permit application is $320. An individual or a peak industry body may submit the permit application to APVMA. If required, assistance with completing the permit application form could be sought from consultants, officers of the State primary industries/agriculture department or private veterinarians.

It is important that a permit application for use of a veterinary chemical is prepared thoroughly. The applicant should gather as much supporting data or argument as possible. Literature searches may yield scientific papers supporting efficacy of a chemical use or containing residues data. In doing this, data gaps and the resulting need for research trials may be identified.

Permit applicants should ensure both the background to the problem and a clear justification for the chemical use are provided. Section 2.5 of the Category 21 Guidelines states that applicants must demonstrate that a genuine need exists for an alternative in cases where there are already registered products or products.

The Application Overview section of the permit application form may appear lengthy but Section 4.1.3 of the Category 21 Guidelines outlines a number of data exemptions if off-label use of an already registered product is requested. In such cases, it is not usually necessary to provide data on Chemistry and Manufacture (1.2), Toxicology (1.3) and Metabolism and Kinetics (1.4).

Where the proposed use regime is similar to an existing registered use, it is likely that APVMA will also not require data on Occupational Health and Safety (1.6) or on Environmental Safety (1.7) as these data will usually have already been assessed.

However, Section 4.1.3 of the Category 21 Guidelines does not indicate any likely exemption from the need to provide data or argument concerning (1.5) Residues and trade considerations (food-producing animals only). Residues data are required to support both permit applications and registrations. In the case of registrations, the critical study underpinning the registration of a particular chemical must be done according to Good Laboratory Practice (GLP) (see later). Hence, it is worth considering undertaking residue trials according to GLP to support permit applications so that the data could be used for subsequent registration purposes.

Section 4.2.2 states that significantly more data will be required in support of applications for minor use permits if the product in question is unregistered. The APVMA regards an unregistered product as a product not currently registered by APVMA. This may include a product which contains an active constituent that has not been previously assessed in Australia and therefore does not have any regulatory standards established. Alternatively, an unregistered product may contain an active constituent that has undergone previous assessment in Australia and may even be present in a different existing registered product.

Emergency Use Permits

An emergency use is defined in the Agvet Code Regulations as:

> '…a use of the product or constituent arising from an emergency in which there is a genuinely believed need for the use of the product or constituent.'

Emergency uses may involve either:

- the use of an existing registered veterinary product off-label; or
- the use of an unregistered veterinary product.

Emergency uses are situations where the proposed use is generally unforeseen (not seasonal, annual or on another regular basis), such as the outbreak of an exotic disease or the incursion of an endemic disease at a significantly higher rate or level than normal. Commonly, applications for a Category 22 emergency use permit are submitted by the relevant government authority for control of emergency animal diseases.

Minor Use Permits vs. Registration

From the sections on endo and ectoparasites it is apparent that the goat industry would benefit from additional chemical products to treat these pests. This report has described two processes (minor use permits and registration) by which legal access to additional chemical controls could be furthered.

It is therefore important to consider what is the optimal process for the goat industry. In reality, there are pros and cons for each and the relative benefits for each are dependent on the type of active constituent for which access is sought. Both processes potentially allow legal access to new chemical products. However, for an industry such as the goat meat industry where product is sold to predominately export markets this is only part of the solution. The ability to trade goat products containing the residues resulting from the treatments must also be considered.

There are several strategies to avoid producing residues in traded goat products, namely:

1. prevent the residues from being above the MRLs and tolerances set by our trading partners by allowing sufficient time after treatment for the concentration of the residues to decline to below the tolerances of our trading partners. This is normally done through an ESI.
2. influence trading partner MRLs and tolerances such that the use of treatments in goats in Australia have appropriate MRLs and tolerances in the importing countries or through Codex.

The first strategy is applicable to both registration and minor use permits as an ESI can be set by the APVMA provided there is enough data. However, this is a short term strategy where there are no limits sets in importing countries. The problem is the detection limits for the analytical methods progressively get lower forcing the required ESI to be longer (longer time since treatment). Furthermore, for some active constituents the ESI may be unmanageably long for normal animal production systems.

The second strategy is only applicable to the registration process because a Codex MRL can only be set if the use is registered and it is highly probable that it would be difficult to influence our trading partners' MRLs and tolerances based on a use that was only allowed under a minor use permit. This strategy is more beneficial in the longer term. If our major trading partners had MRLs or tolerances consistent with the Australian use, there would not be a need to observe ESIs. The downside to the second strategy is that it takes considerable time to achieve.

The minor use permit process will be both quicker and cheaper in terms of both APVMA fees and the costs of generating data to support the application. It should be noted that data supporting minor use permits does not need to be GLP compliant. The process therefore appears an attractive proposition; however, it is a short term strategy that is not suitable for all active constituents. This process will be most effective for active constituents that are short acting and there are MRL or tolerances set above the analytical method detection limit in importing countries.

There is also an unexpected hurdle to the process in that it will be more difficult to obtain chemical industry support because the company would not get data protection for a minor use permit.

By contrast, the registration process is slower and more costly but it has the advantage of being able to take advantage of the second type of 'residue in trade' strategy. To a certain extent, it would benefit the goat industry to conduct any necessary trials according to GLP requirements to they take advantage of the second strategy. However, by doing so, the benefits of seeking a minor use permit are eroded. The longer term strategies also have to be weighed against the expected life of the product, given that resistance issues may shorten the effective time a chemical treatment can be used.

Residue considerations

<u>Residue trials</u>

One of the most constraining factors affecting the registration of appropriate chemicals for the goat industry is the absence of residue data on goats.

In order to understand what residue data are required for a particular use it is necessary to have a basic understanding of the process of setting MRLs including performing dietary risk assessments. The APVMA sets MRLs for agricultural and veterinary chemicals in agricultural produce, particularly produce entering the food chain. These MRLs are set at levels which are not likely to be exceeded if the agricultural or veterinary chemicals are used in accordance with approved label instructions.

At the time that the MRLs are set, the APVMA undertakes a dietary exposure evaluation to ensure that the levels do not pose an undue hazard to human health. When an MRL is exceeded, it usually indicates a chemical is being misused, rather than a public health or safety concern. The APVMA and Food Standards Australia New Zealand (FSANZ) work together to ensure that the use of chemical products and the level of any residues in food are safe. When a new MRL is set by the APVMA, it notifies FSANZ so that it can be considered for listing in the Food Standards Code. When incorporated into the Food Standards Code, the MRL is the highest concentration of a chemical residue that is legally permitted in a food.

The APVMA website at http://www.apvma.gov.au/guidelines/residueguidelines.shtml sets out many relevant guidelines for conducting residue trials.

Residues in Australian goatmeat, milk and fibre have the potential to prejudice the trade of these commodities in international markets. There is a complex interplay between residues and trade. This interplay dictates the trade considerations that need to be thoroughly evaluated as part of the residue trial design process.

When considering undertaking residue trials the industry needs to be clear as to which markets its produce will be sent. From a Queensland government news release ‘Export demand buoys rangeland goat industry future’, it would appear that 95% of goatmeat is exported, with 58% going to the US and 26% going to Taiwan. For the residue data to be suitable for getting an import tolerance from countries like the US, it has to be generated according to Good Laboratory Practice (GLP).

GLP is defined[2] as ‘a quality system concerned with the organisational process and the conditions under which studies are planned, performed, monitored, recorded, reported and archived’. Essentially, this may be translated as the residue trials must be performed by a laboratory and field entities accredited under GLP whereby the documentation requirements are set down by the GLP quality assurance practices. Note, only three laboratories in Australia have GLP accreditation as at August 2007.

When considering the trade implications of any proposed use, it is also important to consider the MRLs or tolerances (US) that are set by overseas countries and internationally (Codex). MRLs are only set on food commodities; however, there are also trade consequences associated with fibre products from goats.

Table 17 outlines the US tolerances and Table 18 outlines the Codex MRLs that are relevant to some pesticides and veterinary drugs proposed to be used on goats.

Table 17 Some US tolerances on goats

Goats	Muscle (ppm)	Kidney (ppm)	Liver (ppm)	Milk (ppm)	Residue Definition
fenbendazole	0.4	ns	0.8	ns	fenbendazole
albendazole	ns				albendazole 2-aminosulfone
monensin	Edible tissues. 0.05			ns	monensin
morantel tartrate*	ns	ns	0.3	nr	*N*-methyl-1,3-propanediamine
triclabendazole	ns				ns
eprinomectin	ns				eprinomectin B1a
levamisole hydrochloride	ns				levamisole hydrochloride

[2] OECD Principles of Good Laboratory Practice GLP 7 4.2

ivermectin	ns	22,23-dihydroavermectin B1a
moxidectin	ns	moxidectin

ns =not set, nr = not required, *Australian use is citrate

Data retrieved from US Federal Register
http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?CFRPart=556

Table 18 Some Codex MRLs on goats

Goats	Meat (mg/kg)	Kidney (mg/kg)	Liver (mg/kg)	Milk (mg/kg)	Residue Definition
Abamectin[#]	*0.1	Edible Offal 0.1		*0.005	Sum of avermectin B1a and 8,9-Z-avermectin B1a.*
Febantel/ Fenbendazole/ Oxfendazole	0.1 (muscle)	0.1	0.5	ns	Febantel/ Fenbendazole/ Oxfendazole

pesticide use – may not cover treatments to animals, ns =not set, * animal commodity residue definition

When examining the MRLs and tolerances of Codex and overseas countries, it should be established whether a use on animals has generated the MRL or whether the MRL has arisen because of the transfer of residues from treated crops eaten by the animals. It should not be assumed that, because there is an MRL overseas, it relates to use on animals or that the use pattern in that country will be the same as the use proposed for Australia. It is also possible that differences between countries exist with respect to the residue definition used (refer http://www.apvma.gov.au/guidelines/guidln6.shtml).

> 'The residue is defined as the chemical, its metabolites and related compounds to which the MRL applies.
>
> The inclusion of specific metabolites or degradation products in the expression of a residue depends on their toxicology profile and the extent to which they occur.'

For the direct treatment of animals, there are generally two main types of data required for setting an MRL for a particular use. Firstly, metabolism data is used to identify the components of the residue and their relative magnitudes in various tissues such as fat, muscle, liver and kidney; and milk. These studies are performed using a radiolabelled version of the veterinary drug.

The second main type of data is a treatment study whereby a group of animals is treated at the maximum dose rate and minimum treatment interval for the proposed use. These studies are used to estimate the median and highest residue (defined from the metabolism studies) from the proposed treatment. The highest residue is used to set the MRL and the median and highest residue, along with information about how much goat commodity is consumed in Australia both per day and on average throughout the lifetime of a person, is used to perform dietary risk estimations.

Other required data may include storage stability of residues in animal commodities, trial analytical methods and regulatory analytical methods.

Metabolism data can be used to get an indication of the likelihood of residues from a proposed use exceeding an overseas MRL. Such considerations determine whether to collect data to support an Export Slaughter Interval (ESI). ESIs manage differences between the MRLs allowed for chemicals in Australia and the MRLs of its trading partners (refer http://www.apvma.gov.au/residues/ESI.shtml).

It is fortunate that radiolabelled metabolism data on lactating goats is generally one of the basis for determining residue definitions and kinetic profiles when setting MRLs on other species for a range of pesticides and veterinary drugs. However, it should be noted that the processes for setting MRLs for veterinary drugs are different from those used for setting pesticide MRLs. This is further complicated by the fact that Codex treats ectoparasiticides as pesticides whereas APVMA treats ectoparasiticides as veterinary drugs.

The data requirements are different for pesticides compared to veterinary drugs, which means that the types of data available for ectoparasiticides are generally different from endoparasiticides.

When considering a new use on goats, it is essential that the metabolism data meets the majority of contemporary data requirements. Metabolism data is expensive to produce and would be beyond the means of a small industry to generate. This would also be a deterrent to chemical companies so it is important that only compounds with suitable metabolism data are considered. It should not be assumed because a pesticide or veterinary drug is registered for other species in Australia that the data that supports those other uses is of suitable quality.

When proposing the use of a pesticide or veterinary drug in goats, it is paramount that the compounds chosen are not under regulatory reconsideration in Australia or other countries. For instance, it would be unwise to seek to register diazinon for external use on goats when the APVMA intends to severely limit the use of diazinon externally on sheep. Another example pertains to the use of some coccidiostats over which there is international concern and a move towards regulatory action to deregister them. Pioneer manufacturers and overseas authorities are a useful source of information on regulatory concerns.

The scientific literature, chemical manufacturers, the APVMA and Joint FAO/WHO Meeting on Pesticide Residues (JMPR) and Joint FAO/WHO Expert Committee on Food Additives (veterinary drugs) (JECFA) are valuable sources of metabolism data. Both JMPR and JECFA provide summarised data so the owner of the data should be contacted regarding the use of the data during the consideration of a registration.

Once the suitability of metabolism data for the proposed use has been established, it will be necessary to determine if suitable field residue trials on goats are available. The scientific literature should be searched for relevant trial data; however, generally residue trials in goats will not be available because of the limited registrations on goats in any jurisdiction.

Before conducting a residue trial it is necessary to get an idea of the approximate WHP that will meet the requirements of Good Veterinary Practice, trade and food safety perspectives. The following procedure details the process the APVMA follows to set veterinary MRLs[3]:

1. A marker residue and target tissue are identified by assessment of total residue ratios from the results of the metabolism and radiolabelled veterinary chemical depletion study;

2. MRLs are estimated for the animal tissues from the Acceptable Daily Intake (ADI) of the veterinary chemical, JECFA food factors and percentage marker residue in the total residue at a practical withdrawal time that is compatible with Good Veterinary Practice;

3. A withholding period is estimated where residues would not be expected to exceed the MRLs. The estimate would rely on marker residue levels occurring in tissues taken from animals slaughtered at intervals after treatment in trials representative of commercial practice;
   (*Note: With respect to commercial practice: The APVMA Residue Guideline No. 27 - Ectoparasiticide residues in sheep tissues*, available at http://www.apvma.gov.au/guidelines/guidln27.shtml, states that the 'objective … is to ensure the data generated are adequate for the purpose of establishing Maximum Residue Limits (MRLs) and Withholding Periods (WHPs) without conducting more trials or sacrificing more animals than

[3] Denis Hamilton, Rick Webster, Wayne Thompson (2004) Review Of Residue Processes (Confidential)

necessary'. It is recognised that it is impractical to address all combinations of variables such as 'application technique, wool length at the time of pesticide application, animal type and environmental conditions. …..Therefore…. this objective is attained by ensuring that the trials result in tissue residues as high as could be expected when the product is used according to label directions (the *maximum residue scenario*)'.

4. The residue levels found in the trials are used in conjunction with Australian dietary information for estimation of dietary intake and public health risk assessment.

The ADI, which is the starting point for the MRL calculation, may not always be based on toxicity, eg. for antibiotics it could relate to the no-effect-level (NOEL) for effects on human gut flora.

It is apparent that the planning and conduct of residue trials in animals are complex and require a sound knowledge of the factors affecting any proposed use. It is suggested that chemical manufacturers have personnel who are familiar with APVMA requirements and would routinely plan residue trials.

Export considerations
If it is necessary either because of differences in MRLs between Australia and its trading partners or because of the complete lack of an MRL in an importing country, an ESI can usually be established by the APVMA when it approves a permit or grants a registration for a veterinary chemical. There are some limitations with the ESI approach alone. With a chemical for which trading partners have no MRL, the ESI has to be sufficiently long to allow for the residues to decline below the Limit of Quantitation (LOQ), as discussed earlier. With the residue decline curve associated with the uses of some chemicals, this time period could be impossibly long. In addition, as laboratory analytical methods continue to improve, ever lower LOQs can be set. Trading partners which have no MRL for a particular chemical set the default MRL at the LOQ to ensure there are no detectable residues in imported commodities. Europe has already lowered its default MRLs by a ten-fold factor. This lowering of the default MRL therefore means an increased ESI will be required for those chemicals which have no MRLs in the importing country.

A long-term approach should also be adopted. It is recommended that, once an agvet chemical product for treating goats is registered, the relevant residue data should be sent to Codex (JECFA) so that a Codex MRL can be established. The establishment of a Codex MRL would facilitate trade with countries that accept Codex MRLs. Furthermore, establishment of a Codex MRL would be based on the data for the Australian use pattern; therefore, an ESI would not be required to protect market access to countries which accept Codex MRLs. It should be noted that the process of establishment of a Codex MRL takes a number of years.

Not all countries accept Codex MRLs. There is a third approach available (also longer term) when importing countries lack a relevant MRL. The Unites States does not accept Codex MRLs but it could take a Codex MRL into consideration when setting its own import tolerance for a particular chemical.

When deciding between generating residues data to support a minor use permit or residues data to support a registration, it is important to consider export. An importing country such as the US would be far more likely to consider an approach from the Australian government regarding setting a US import tolerance for a particular chemical in goats if that chemical was actually registered in Australia in goats rather than just approved under a minor use permit. It is suspected the US would, even then, require the chemical to have had some level of assessment in the US and a toxicology package to be available.

Another issue that may be of interest to a chemical company is that of data protection. It should be noted that, currently, data protection doesn't apply to data submitted in relation to a permit application. Therefore, prior to submitting a minor use permit application, the applicant should contact the APVMA for advice on the most appropriate way to use the data to support the permit application without compromising any future use of the data to support registration.

8.2 The time and costs associated with the registration process

Should the decision be made to progress a minor use permit application or to interact with a particular chemical company in relation to pursuing registration of a particular chemical, the APVMA could be contacted at an early stage. They could ascertain whether some suitable residues data already exist for a particular chemical and also ensure that the available information on that chemical does not suggest that an application to APVMA in relation to that particular chemical would be unlikely to succeed.

Apart from the considerable costs incurred by the applicant in generating the data required to support registration, the APVMA also has fees for registration which will depend on the category of the application. An application to extend the use of a veterinary chemical product registered in sheep to goats would be eligible under category 14 as it comes under a 'variation to the label claims of a product (including new pests, diseases or target animal species)'. The application would have to be made by the registrant of the existing sheep product. Category 14 is a modular category which means that the fees payable to APVMA and the timeframe for registration will depend on how many of the modules (Parts 1 to 10) will require assessment. An idea of the time required at APVMA and the fees to register a product can be gauged by referring to the APVMA web-site:
http://www.apvma.gov.au/registration/time.shtml
http://www.apvma.gov.au/MORAG_vet/table_of_categories.pdf

In the case of an application for registration in goats of a veterinary chemical product already registered in sheep, it is estimated that the fees could be in the range of
$7,500–$11,000 and the timeframe between 8 to 14 months.

A new product containing an existing active would come under category 10 or, if it was a brand new active, under category two. Both of these categories are modular. In the unlikely event of a new active/new product being launched in goats, the registration fees would be probably at the most just less than $50,000 with a timeframe of 15 months once it was accepted into evaluation following screening of the application.

Screening time depends on the quality of the submitted dossier and whether there are deficiencies that need to be addressed before it can be accepted into evaluation.

The evaluation timeframe is based on the time the APVMA has responsibility for any action on the application and the 'clock' is turned off while any response is being generated by the applicant. Elapsed time may therefore cause significant delays and is dependent on the time taken by the applicant to provide a response to a requirement.

8.3 Commercial drivers for a chemical company to pursue the registration

Antiparasitic drug discovery in more recent times has been targeted to the most lucrative market segments such as the pet medicine market. The apparent lack of resistance in important animal parasites has also reduced the industrial motivation to invest in parasitology (Geary and Thompson 2003). Estimates in 1997 of the costs for a company to develop a new anthelmintic product for the veterinary industry were between US$100m–US$200m and the time for such a product to reach the market was in the order of 10 years (Hennessey 1997).

A survey of members of the Animal Health Alliance (Australia) Ltd and informal discussions with representatives of the smaller drug companies revealed close agreement in attitudes to the registration of products for the goat industry. Most indicated that the potential size of the goat market both locally and globally was too small to recoup developmental costs. If they did have a new molecule all stated that they would be unlikely to seek registration for use in the goats. The reason cited was the rapid development of resistance in goats that could jeopardise the longevity of such a product in the more lucrative sheep and cattle markets. Most companies also stated that they would be unwilling to fund a minor use permit application.

One company however, indicated a willingness to consider product registration if the goat industry was prepared to partially fund the process. Estimated costs of such an activity would largely depend on the type of registration being sought and the requirements of the APVMA with respect to safety, field efficacy, confirmatory and residues data. In general, for a product with registration in the sheep industry to gain registration in the goat industry, the costs could be in the order of A$600,000 whereas for a minor use permit the costs may be closer to A$200,000. For a product already registered in the goat industry to gain approval to be used at increased dose rates, residues data and field efficacy studies costs could be in the order of A$120,000 (B. Chick 2007 *pers. comm.*).

Interest was also expressed in terms of a permit being the mechanism by which to address the lack of products for the treatment of ectoparasites and coccidiosis.

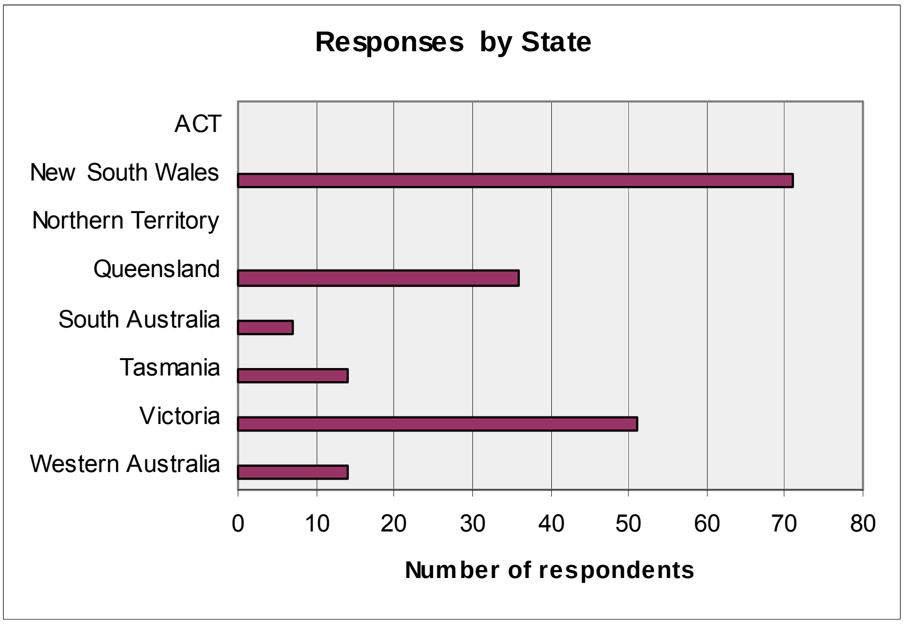
9 Appendix

Appendix 1 - Results of the survey of practices used by goat owners

A summary of the results of the survey completed online and in hard copy form as of 30 June 2007 is provided below.

Property profile of respondents

- Of the 195 respondents who completed the survey 37% were from New South Wales (NSW), 26% from Victoria (Vic), 19% from Queensland (Qld) with fourteen responses (7%) received from Tasmania (Tas), and Western Australia (WA), 7 (4%) from South Australia (SA) and none from the Australian Capital Territory (ACT) or the Northern Territory(NT).

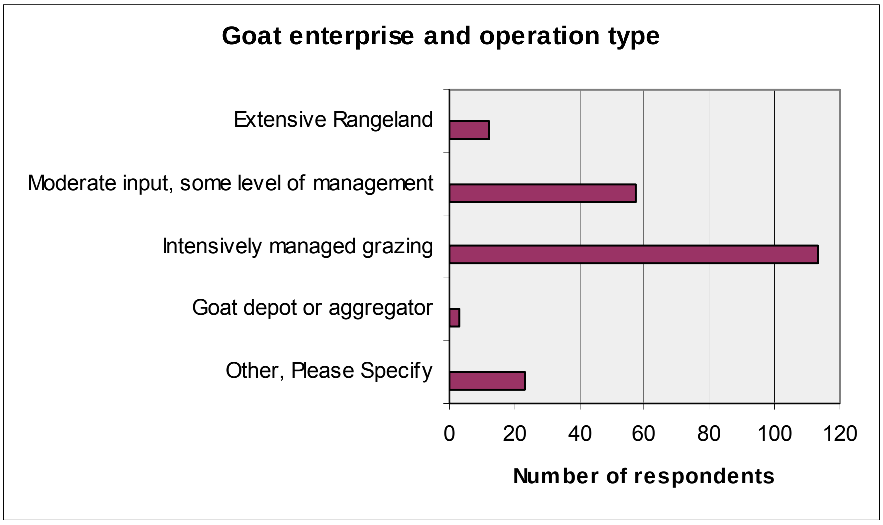


- The 81% of responses were from producers who ran either an intensively managed grazing type enterprise (54%) or enterprises with moderate inputs with some level of management (27%).

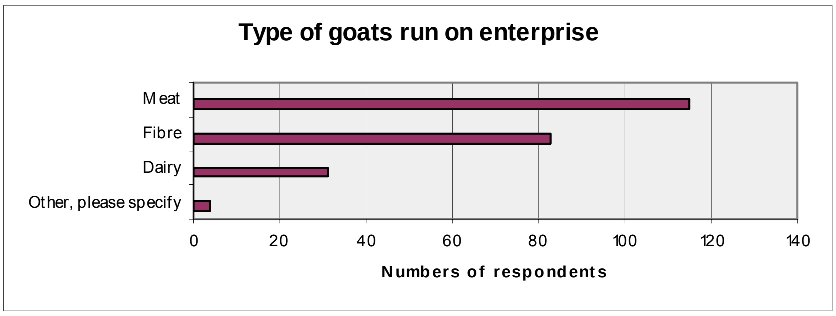
- Six per cent of responses were received from extensive rangeland enterprises. Of these thirty-four percent were from NSW, 25% each from WA and Vic, 8% each from Qld and Tas. No responses were received from SA.

- Two percent of the overall responses were from aggregators. Of these, two were from Qld and one from WA.

- The remaining 11% were from the education and hobby sectors.



- Most responses were from meat and fibre producing enterprises (49% and 36% respectively) with 13% from dairy and 2% other.

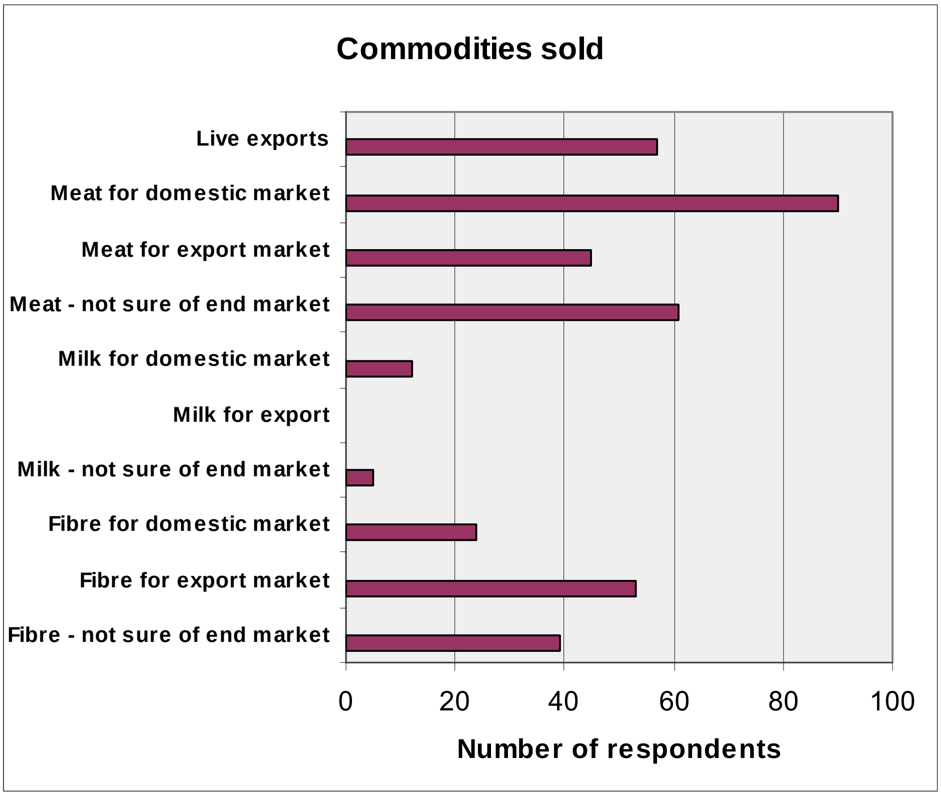


- Of the commodities sold, 15% of respondents produced goats for the live export market. Of these, 37% were from NSW, 25% from Qld, 21% from Vic and 12% from WA. Two respondents from Tas and one from SA also sold into the live export markets.

- Fifty-one per cent of respondents produced goats for the goatmeat market. Of these 23% sold into the domestic market, 12 % into the meat export market and 16% not sure of the final market. Most of the respondents who sold goatmeat were from NSW (41%) followed by Vic (23%), Qld (21%) and WA (8%) with 4% from Tas and 3% from SA.

- Thirty per cent of respondents produced fibre for the fibre market with 6% going into the domestic market, 14% to the export market and 10% not sure of the final market.

- Eleven respondents produced milk for the domestic market. Another five respondents were not sure of the end market.

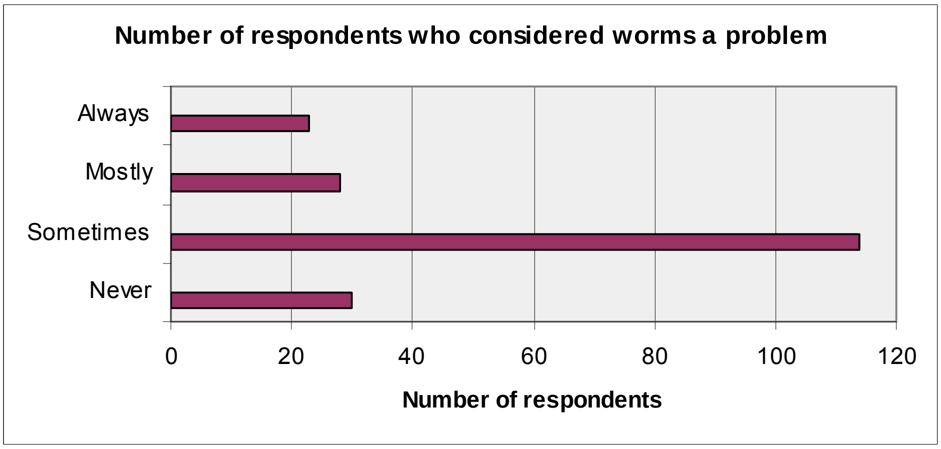


Nematodes parasites

- Nematode parasites were always or mostly a problem on 26% of respondent's properties, 59% had worm problems sometimes and 15% never experienced a worm problem.

- Of those enterprises that sometimes had a problem, 3% were extensive rangeland, 28% moderate inputs, 63% intensive and 0.9% depots while seven respondents were in the education and hobby sectors.

- Of the 15% of producers who never had a problem with worms 28% ran an extensive rangeland type enterprise, 25% a moderate inputs enterprise and 32% ran intensive type enterprise. Three per cent were depots and 12% belonged to the education and hobby sectors.

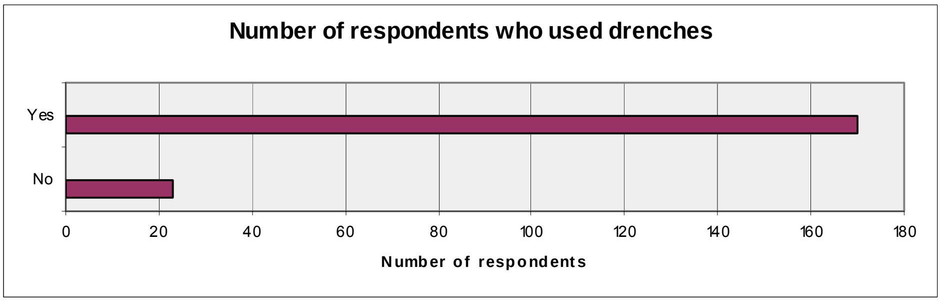


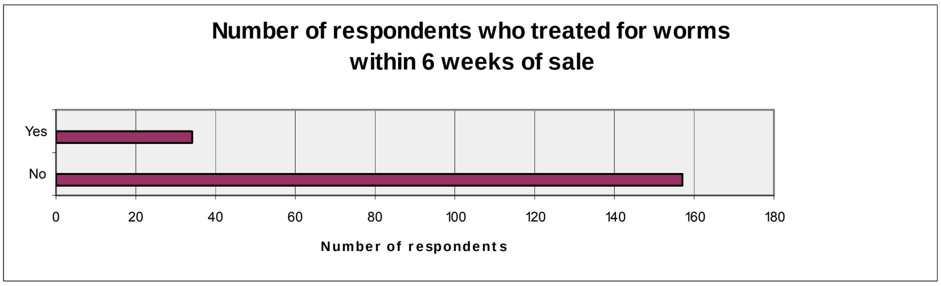
- Eighty-eight per cent of respondents used drenches to control worms and 18% had treated goats for worms within six weeks of sale of produce.

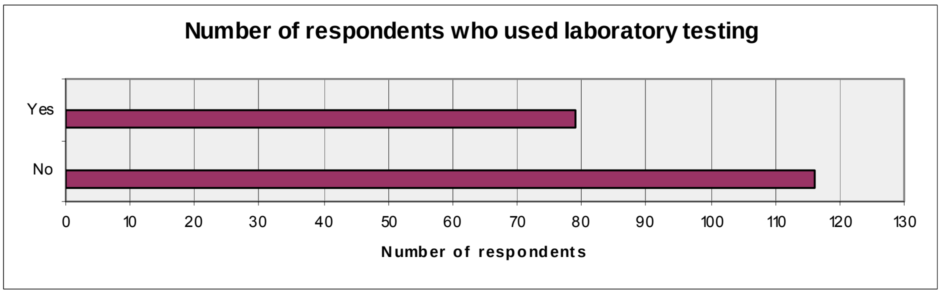
- Of the 12% of respondents who did not use drenches to control worms 41% ran extensive type enterprises, 36% enterprises with moderate inputs, 18% intensive type grazing enterprise while the remaining 5% were from the education and hobby sectors.

- Of the 18% who had treated for worms within six weeks of sale of produce, 30% each were from NSW and Vic, 19% from Qld and 7% each from WA, SA and Tas.

- Forty-one per cent of respondents used laboratory testing to determine when to drench.



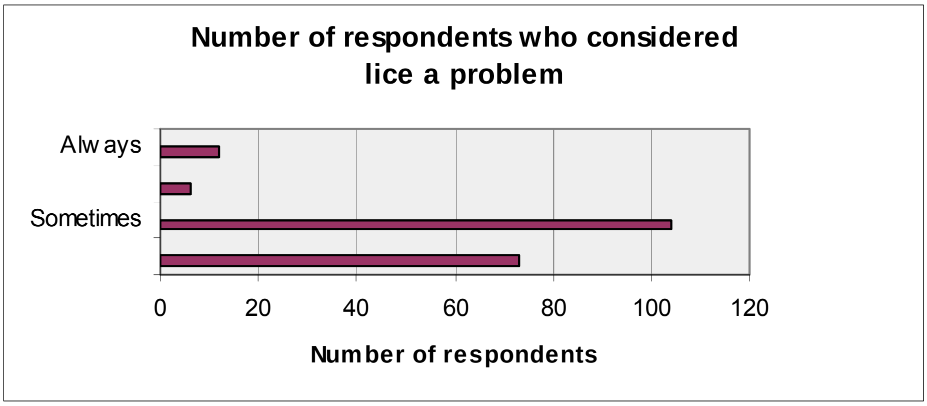


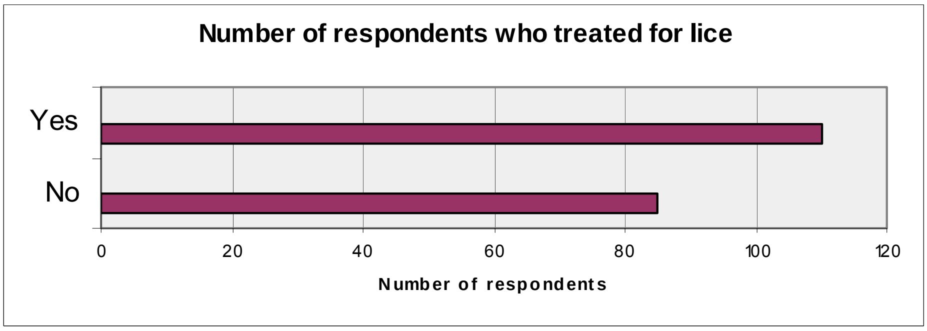


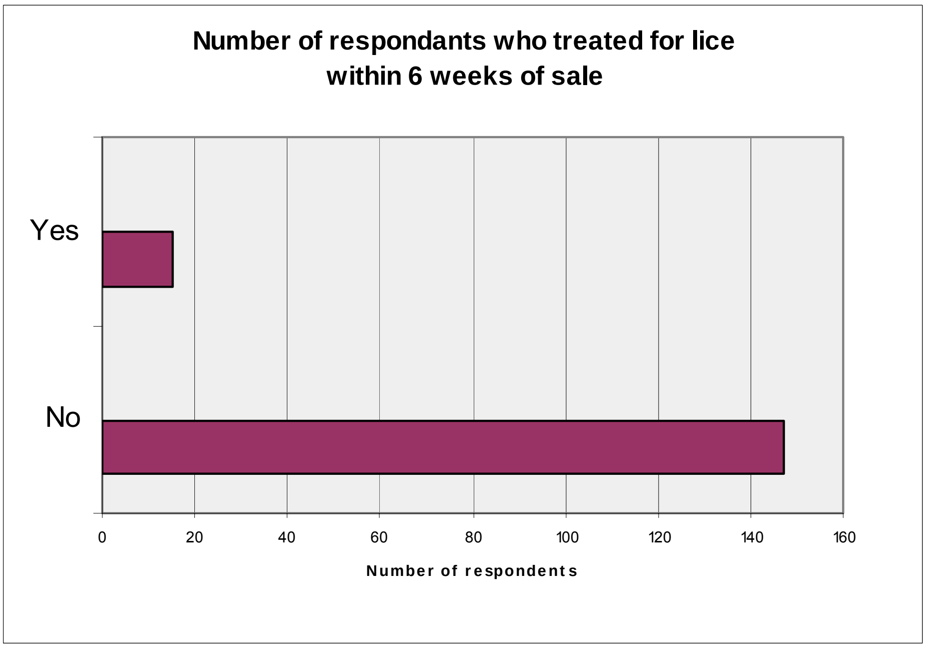
Lice

- Lice were always or mostly a problem for 9% of producers, sometimes a problem for 53% and never a problem for 37% of respondents. However, 56% of producers treated for lice and 9% of respondents had needed to treat for lice within six weeks of sale.

- Where a product could be identified, 36% were registered for use on goats and 64% registered for other species. By far, the largest group of unregistered products used was IGR backliners.

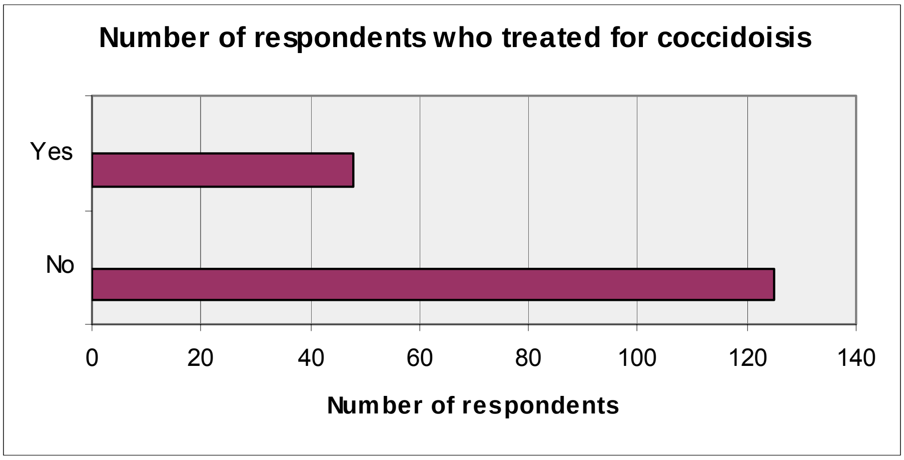






Coccidiosis

- Coccidiosis was never a problem on 64% of respondent's properties with 31% nominating coccidiosis as a problem sometimes. Only 28% of respondents treated for coccidiosis.


Number of respondents who treated for coccidoisis
Yes
No
0
20
40
60
80
100
120
140
Number of respondents

10 References

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