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PLANT DEWORMERS AND BREED RESISTANCE TO REDUCE INTERNAL PARASITE INFECTIONS IN SMALL RUMINANTS

By

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Dedication

I want to dedicate my thesis to my parents, Mrs. Dorothea Matthews and Mr. Talbot Matthews, for their unconditional love and support. I am forever grateful to you for everything you have done for me.

"I can do all things through Christ who strengthens me"

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PLANT DEWORMERS AND BREED RESISTANCE TO REDUCE INTERNAL PARASITE INFECTIONS IN SMALL RUMINANTS

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ABSTRACT

With worldwide reports of an increase in gastrointestinal nematode (GIN) resistance to chemical anthelmintics, producers are seeking effective alternative means of parasite control. The use of natural dewormers, such as pumpkin seeds and ginger, and the selection of breeds or individual hosts with resistance to parasites offer promising alternatives for integrated parasite management. Therefore, it was the objective of four experiments (Exp) to test the efficacy of natural dewormers in reducing fecal egg counts (FEC) in goats (pumpkin seed oil and drench, and ginger) and sheep (pumpkin seed oil) and to evaluate parasite resistance and resilience traits in three different breeds of goats (Kiko, crossbred Savanna, and Boer) with the goal of using genetics to combat the issues of parasitism in the goat industry. In Exp 1, 22 naturally-infected Boer crossbred kids were used to determine the effect of ginger and a pumpkin seed drench on GIN indicators. In Exp 2, 26 artificially-infected Katahdin lambs (mixed sex) were used to determine the effect of a pumpkin seed oil drench on GIN indicators. In Exp 3, 24 naturally-infected mixed sex Boer crossbred meat goat kids were used to determine the effect of a pumpkin seed oil drench on GIN indicators. In the final experiment, Exp 4, 31 Boer (n = 10), Kiko (n = 12), and crossbred Savanna (n = 9) meat goat kids were used in a preliminary study to evaluate the goal of using genetics to combat GIN infections. In

Exp 1, 2, and 3, animals were placed in individual pens and received pre-weighed rations of a commercially pelleted meat goat or sheep diet daily for 42 (Exp 1), 28 (Exp 2) or 35 d (Exp 3). In Exp 1, kids were orally drenched with water (CON; n = 7), 5 g pumpkin seed/kg BW (PUM; n = 10) or 3 g ginger/kg BW (GIR; n = 5) every other day for 42 d. In Exp 2, lambs were orally drenched with water (CON; n = 10), 2.0 ml/kg BW pumpkin seed oil once every week (7 d; PUM1; n = 9), or 2.0 ml/kg BW pumpkin seed oil divided equally over 3 doses in one week (3 out of 7 d; PUM2; n = 7) for 28 d. In Exp 3, kids were orally drenched with water (Control; CON; n = 13), or 2.0 ml/kg BW pumpkin seed oil (PUM; n = 11) every other day for 35 d. In Exp 4, goats grazed on three Kentucky 31 tall fescue paddocks in a 21 d rotation for 198 d. For all experiments, BW and fecal samples were collected weekly. However, blood samples for packed cell volume (PCV) was collected in Exp 1, 2 and 3 while FAMACHA© scores were measured and recorded in Exp 4. Fecal samples were collected to determine fecal egg counts (FEC) using the modified McMaster's technique (reported as eggs per gram; epg) while blood samples for PCV and FAMACHA© scores were measured to determine the degree of anemia in individual animals. In Exp 1, BW was not influenced by treatment and averaged 18.71 ± 0.23 kg. There was an influence of day ($P < 0.0001$) on FEC with d 0, 7, 14, 21, and 28 (6194 ± 750, 3749 ± 750, 3284 ± 750, 4233 ± 750, and 4344 ± 750 epg, respectively) being similar but greater ($P < 0.01$) than d 35 and 42 (661 ± 750 and 1309 ± 750 epg, respectively). Day 35 FEC was also greater ($P < 0.01$) than d 42 (661 ± 750 and 1309 ± 750 epg, respectively). Packed cell volume had a tendency ($P = 0.06$) for a treatment effect with GIR-treated animals (31.3 ± 2.0%) having a higher ($P < 0.02$) PCV than CON animals (25.1 ± 1.7 %) with PUM-treated animals (27.4 ± 1.4 %) being intermediate. In

Exp 2, BW and PCV were similar among treatments and averaged 33.0 ± 0.5 kg and 31.6 ± 0.3%, respectively. Fecal egg counts was influenced by day ($P < 0.0001$) with FEC significantly decreasing ($P < 0.03$) over time until d 21 and then throughout the rest of the study (1736 ± 212, 692 ± 212, 334 ± 212, 163 ± 212, and 75 ± 212 epg for d 7, 14, 21, and 28, respectively). In Exp 3, there was a treatment by day interaction effect ($P < 0.03$) on BW with CON animals having a greater BW than PUM-treated animals on d 7 only (21.0 ± 0.9 and 18.4 ± 1.0 kg, respectively). Day influenced ($P < 0.0001$) FEC with d 0 FEC (5315 ± 561 epg) greater ($P < 0.0001$) than all other days measured (2394 ± 586, 2151 ± 602, 1835 ± 561, 1665 ± 569, and 1704 ± 589 epg for d 7, 14, 21, 28, and 35, respectively) and d 7 FEC being similar to d 14 but greater ($P < 0.02$) than d 21, 28, and 35 while d 14 FEC was greater ($P < 0.02$) than d 28 but similar to d 21 and 35. There was a treatment by day interaction effect ($P < 0.04$) on PCV with the PUM-treated animals having a greater ($P < 0.05$) PCV than the CON animals on d 7 (30.0 ± 2.0 and 24.6 ± 1.7 %, respectively), 21 (32.7 ± 1.9 and 26.4 ± 1.7 %, respectively), and 35 (30.6 ± 1.9 and 24.7 ± 1.8 %, respectively). In Exp 4, ADG was not influenced by treatment and averaged 0.011 ± 0.003 kg/d. However, there was a treatment by day interaction effect ($P < 0.0001$) on FEC. Boer goats had a higher ($P < 0.0001$) FEC than Kiko and crossbred Savanna goats on d 0 (3038.3 ± 642.2, 18.8 ± 586.2, and 41.7 ± 676.9 epg, respectively) and 23 (4668.5 ± 711.5, 55.6 ± 586.2, and 49.0 ± 676.9 epg, respectively). In addition, Boer goat FEC was greater ($P < 0.04$) than that of Kiko goats on d 198 (659.3 ± 642.2 and 240.97 ± 586.2 epg, respectively). Finally, there was a treatment by day interaction effect ($P = 0.0002$) on FAMACHA© scores with Boer goats having a higher ($P < 0.03$) score than both Kiko and crossbred Savanna goats on d 23 (3.9 ± 0.2, 3.3 ± 0.2, and 3.3 ±

0.2, respectively) and a higher ($P < 0.03$) FAMACHA© score than Kiko goats on d 44 (4.0 ± 0.2 and 3.3 ± 0.2, respectively) and 177 (3.0 ± 0.2 and 2.5 ± 0.2, respectively). Crossbred Savanna goats had lower ($P < 0.005$) FAMACHA© scores than Boer and Kiko goats on d 135 (1.6 ± 0.2, 2.6 ± 0.2, and 2.5 ± 0.2, respectively) and 156 (2.0 ± 0.2, 2.7 ± 0.2, and 2.8 ± 0.2, respectively) but lower ($P < 0.03$) than only Kiko goats on d 198 (2.2 ± 0.2 and 2.8 ± 0.2, respectively). There was a tendency ($P = 0.07$) for a treatment effect on the frequency of goats dewormed, with Boer goats having a higher (48%) deworming frequency than Kiko (28%) and crossbred Savanna goats (24%). Overall, all Boer goats were dewormed while 66.7% of Kiko and 77.8% of crossbred Savanna goats were dewormed at least once throughout the study period. In conclusion, under the conditions of these studies, pumpkin seeds drench, pumpkin seed oil and ginger drench were not effective in reducing FEC and at this time are not recommended as alternative parasite control strategies in sheep and goats. In addition, more data is needed on the influence of breed on GIN indicators for breed selection to be used to combat parasite infections in the goat industry.

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CHAPTER I

Introduction

The demand for small ruminant meat in the United States (U.S.) exceeds its supply (Child *et al.*, 1985; Glimp *et al.*, 1986; Gunderson and Ospina, 1986; Shelton, 1990; Mercado *et al.*, 1991; Knight *et al.*, 2006). Moreover, producers are still struggling to meet this demand for sheep and goat meat even though the increased demand has resulted in a doubling of the supply of domestic production (Coffey, 2006). The increase in small ruminant production is mainly due to immigrants coming into the U.S. from countries that consume sheep and goat meat, there-by introducing a new demand for small ruminant meat and related products (Luginbuhl, 2007). Some of these sheep and goats are used for religious customs or for ritual slaughters (Nettles and Bukenya, 2005). In response to the increased demand for small ruminant products, opportunities have been created for limited-resource farmers to fill the void and enhance their business prospects by integrating sheep and goat production into their farm enterprises (Luginbuhl, 2000).

Goat farming has the potential to be a profitable enterprise due to the high reproductive rates possible (specifically twinning and out of season breeding), low cost of breeding, and the ability of goats to thrive on native pasture (Haenlein, 1992). In addition, sheep and goat farming is a cheaper enterprise than cattle farming, since it requires fewer resource inputs and less money as an initial investment (purchase animals, facilities, etc.; Okpebholo and Kahan, 2007). With the small ruminant industry being so cost effective, small ruminant production may be able to contribute significantly to local economies and to the survival of rural producers in the U.S. (Panin and Mahabile, 1997).

Although there are several benefits to small ruminant production, a major hurdle in the small ruminant industry is animal and production loss due to gastrointestinal nematodes (GIN), particularly the blood sucking abomasal GIN, *Haemonchus contortus* (Miller, 1996). Parasite infections can hinder production by causing disease and mortality, which makes parasites a major health problem in small ruminants (Kaplan, 2004b). Gastrointestinal nematodes commonly affecting small ruminants thrive in warm and humid conditions conducive to the completion of their lifecycle. In the northern region of the U.S., parasite problems occur mainly during the summer months when high temperatures and moisture can contribute to their development on pasture. However, in the southern region of the U.S., parasites can be a problem in spring, summer, and fall due to an extended season of warm and potentially moist weather (Shaik *et al.*, 2006). The most common method used to control GIN infection in the U.S. is anthelmintic drug treatment. However, anthelmintic overuse and misuse has led to an increased prevalence of anthelmintic resistance in sheep and goat GIN (Mortensen *et al.*, 2003; Crook *et al.*, 2010). Anthelmintic resistance is now a global problem (Kaplan *et al.*, 2007; Howell *et al.*, 2008; Crook *et al.*, 2010), and has been reported for all three major classes of anthelmintics (Terrill *et al.*, 2001; Howell *et al.*, 2008; Crook *et al.*, 2010).

As previously stated, increasing anthelmintic resistance may be due to the overuse and/or misuse of these chemicals. The overuse of anthelmintics is the first potential cause of anthelmintic resistance (Miller and Craig, 1996). Producers frequently treat all animals within the herd at the same time without consideration to diagnosis or symptoms of parasites. This practice of overuse has gradually contributed to increased anthelmintic resistance. In addition to the common practice of frequently treating animals,

inappropriately low dosages during treatment of the herd, since animals are often not weighed, also leads to anthelmintic resistance. Under-dosing can promote anthelmintic resistance (Smith *et al.*, 1999) by allowing parasites to survive the drug treatment. Furthermore, goats have a higher level of metabolism than sheep and require a higher anthelmintic dose (Conder and Campbell, 1995). However, goats are often treated based on sheep doses since few drugs are labeled for goats. Resistance to anthelmintics may also result from rotating two different classes of drugs. Despite previous recommendations that prescribed this type of rotation (Kaplan, 2004b; Miller and Horohov, 2006), switching anthelmintics at each dosing is not appropriate and may lead to anthelmintic resistance developing more quickly in the classes of anthelmintics being rotated (Miller and Craig, 1996; Kaplan, 2006). If resistance to specific classes of anthelmintics is known for a farm, the anthelmintic to which there is only low resistance should be used first until it is no longer effective (Kaplan, 2004b). Another method of control may be the use of two effective classes of anthelmintics simultaneously as they have collaborative effect, which increases the efficacy of the treatment when compared to the use of one anthelmintic (Kaplan, 2006). Effective anthelmintics should be reserved for severely anemic or heavily infected animals demonstrating clinical signs of parasitism (Kaplan, 2004b).

Although parasites are becoming resistant to anthelmintics, there are some alternatives to chemical anthelmintics used in small ruminants. For instance, goats are natural browsers. Therefore, incorporating taller browse species into their diet will decrease infections of parasites because larvae are only capable of traveling 0.08 – 0.10 meters up on vegetation (Orlik, 2010). Therefore, if goats are allowed to consume only

forages over 0.15 meters tall, in a controlled grazing system, *H. contortus* infection should be low. This type of grazing is also used as a means of parasite control since rotating the animals through several plots will prevent overgrazing/overstocking the plots. Additional alternatives to chemical control of small ruminant GIN have been under investigation in recent years, including the use of nematode-trapping fungi to destroy parasitic larvae (Larsen, 2000; Terrill *et al.*, 2004), vaccines against *H. contortus* (Knox, 2000; Knox and Smith, 2001), copper oxide wire particles to expel adult worms (Chartier *et al.*, 2000; Burke *et al.*, 2004), and natural plant dewormers (forages with condensed tannins, pumpkin seeds, garlic, ginger, and papaya seeds; Iqbal *et al.*, 2006; Shaik *et al.*, 2006; Burke *et al.*, 2009; O'Brien *et al.*, 2009; Strickland *et al.*, 2009; Worku *et al.*, 2009). Of these alternatives, the use of natural plant products is especially popular with producers due to accessibility of these products.

The use of natural plant dewormers is a promising alternative for the chemical control of GIN when used in an integrated control system and can be used by both conventional and organic farmers. There are several plants with anthelmintic properties that have been used in experiments to control internal parasite infection (Rahmann and Seip, 2006). For instance, the seeds of squash, pumpkins and many other vine crops are believed to contain a deworming compound called cucurbitacin and has been studied in lambs (Waller, 1999; Strickland *et al.*, 2009). Ginger (*Zingiber officinale*) has also been used as an anthelmintic purge for cattle and horses (Duval, 1997) as well as lambs (Iqbal *et al.*, 2006). Though the effectiveness of these natural products is largely anecdotal (Githiori *et al.*, 2006), the increasing incidence of anthelmintic resistance and the popularity of organic or sustainably produced animals, has led to renewed interest

in alternative parasite control strategies. However, there is either limited data available on the efficacy of these natural products, or the information available is anecdotal and needs further verification.

In addition to the use of natural dewormers, selecting parasite resistant breeds can aid in the control of internal parasite infections in small ruminants. There have long been reports of genetic variation for resistance to GIN among goat breeds (Preston and Allonby, 1978; Cabaret and Anjorand, 1984; Shavulimo *et al.*, 1988; Richard *et al.*, 1990; Pralomkarn *et al.*, 1997; Baker *et al.*, 1998; Costa *et al.*, 2000) and there is also now a substantial body of evidence showing that genetic variation for resistance or resilience to GIN occurs in sheep as well (Gray *et al.*, 1995; Woolaston and Baker, 1996). Animals with resistance to GIN are able to reduce the number of GIN reproducing and surviving within their body, while resilient animals are able to produce and perform effectively despite their parasite loads (Gray *et al.*, 1995). More recent studies have also indicated that there is significant variation for resistance within goat breeds (Patterson *et al.*, 1996; Morris *et al.*, 1997; Mandonnet *et al.*, 2001; Vagenas *et al.*, 2000). Goats are considered to be more susceptible to GIN than sheep, because goats are natural browsers and when forced to graze, become easily infected. Due to this, the option of selecting goats resistant to GIN needs to be explored and estimates of the heritability of resistance and the relationship between resistance and production traits need to be investigated (Vagenas *et al.*, 2002).

It has been confirmed in goat studies that an individual's ability to regulate worms is under genetic control and that it is a moderately heritable characteristic (Vagenas *et al.*, 2002). The fact that regulation of worm burden and egg output is under genetic control

has enabled the development of selected lines of goats for research purposes (Bisset *et al.*, 1996; Morris, 1997). The Kiko breed is a composite goat breed that was developed for meat production in New Zealand (Batten, 1987) and preliminary studies have indicated that does of this breed demonstrate hardiness when exposed to conditions conducive to internal parasitism compared to Boer does (Browning *et al.*, 2006). The Boer goat is a breed that was developed in the semi-arid region of South Africa for meat production (Casey and Van Niekerk, 1988) and is the predominant meat goat genotype in the U.S. today (Browning *et al.*, 2006). Though ideal for meat production, Boer goats are generally not considered hardy or possess many parasite resistant traits. In addition to the Kiko breed, the Savanna breed developed in South Africa has been reported to possess parasite resistance traits while having greater muscling than traditional parasite resistant breeds, leading to an increase in the number of purchases of this breed by some producers in the U.S. However, information available on the true status of parasite resistance in these breeds can mostly be found in the popular press or are anecdotal. Therefore, research needs to be conducted to evaluate parasite resistance in these popular breeds of goats as an additional method of combating the impacts of parasitism in the small ruminant industry.

With current research indicating that there is an increase in GIN resistance to chemical anthelmintics, producers are seeking effective alternative means of parasite control. The use of natural dewormers, such as pumpkin seeds and ginger, and the selection of breeds or individual hosts with resistance to parasites may offer the most promising alternatives for integrated parasite management. Therefore, the objectives of this study are to 1) test the efficacy of natural dewormers in reducing fecal egg counts

(FEC) in goats (pumpkin seed oil and drench, and ginger) and sheep (pumpkin seed oil) and to 2) evaluate parasite resistance and resilience traits in three different breeds of goats (Kiko, Savanna, and Boer) with the goal of potentially using genetics to combat the issues of parasitism in the goat industry. The results of this research will be useful in prescribing and promoting a sustainable goat production system in the U.S.

CHAPTER II

Literature Review

Sheep and Goat Industry in the U.S.

Goat numbers in the US increased three to five percent every year through 2007 (NASS, 2007). In 2012, however, the National Agriculture Statistics Service (NASS, 2012) reported a 4% decrease in overall goat production and a 2% decrease in overall sheep production. Although there has been a decrease in the overall production of sheep and goats in the U.S., sheep imports are estimated to increase by 9% in 2012 (Johnson, 2012). This increase is likely due to the high demand for small ruminant meat by immigrants coming into the U.S. from different ethnic groups as well as health conscious customers (Okpebholo and Kahan, 2007; Knight *et al.*, 2006). The high demand for goat meat still surpasses its supply, creating an opportunity for limited-resource farmers in these and neighboring states (Okpebholo and Kahan, 2007). The goat industry is an attractive industry to limited resource farmers as the animals are smaller and easier to handle, they also require less land than larger animals (Tadesse, 2004). Also, goats are capable of converting low quality forages into quality meat and other by-products (Okpebholo and Kahan, 2007). Goat production can be a great asset to small and large scale producers, as it can be a very profitable enterprise (Child *et al.*, 1985; Glimp *et al.*, 1986; Gunderson and Ospina, 1986; Shelton, 1990; Mercado *et al.*, 1991). Despite the apparent profitability and economic viability of the sheep and goat industry, parasitism is a serious constraint affecting production worldwide (Miller and Horohov, 2006), particularly the blood sucking abomasal GIN, *H. contortus* (Miller, 1996).

General GIN Life Cycle

In a GIN typical life cycle, *H. contortus* and *Trichostrongylus* spp. eggs are defecated by grazing sheep and goats onto a pasture, after which it incubates on the pasture. *Haemonchus contortus* and *Trichostrongylus* thrive best in warm, moist and humid conditions. However, *Trichostrongylus* are capable of surviving cooler temperatures as well. In prolonged low temperatures or dry spells, these parasites may delay development or the larvae might die. If the larvae do not die, then the larvae hatches and their development go through many stages. The third stage of development is the infective stage. Third stage larvae gain the ability to move up and down blades of grass within droplets of water and are ingested by grazing small ruminants. The *H. contortus* is a blood-sucking parasite that is found in the abomasum and *T. colubriformis* lay their eggs in the small intestine. The life cycle repeats when eggs laid by the ingested larvae are defecated onto pasture.

Parasite Infections in Small Ruminants

Parasitism is the most serious problem affecting the small ruminant industry across the world (Miller and Horohov, 2006). Gastrointestinal nematodes are the leading cause of losses in the goat industry (Miller, 1996; Kaplan *et al.*, 2004b), commonly affecting small ruminants and they thrive in warm, humid conditions. Parasite infections have been known to hinder goat production by causing disease and mortality, which make parasites a major health problem in small ruminants (Kaplan, 2004b). *Haemonchus contortus* infection causes a severe case of anemia and hypoproteinemia, which leads to depression, loss of condition, reduced productivity, and then death (Kaplan *et al.*, 2004a). Although mature animals can be severely affected by parasites, it is often more severe in

younger animals (Kaplan *et al.*, 2004a). Gastrointestinal nematodes that affect the small intestine and the abomasum of small ruminants can pose the largest concern to producers by damaging the linings of both, affecting digestion and absorption, respectively (Webb *et al.*, 2008). These GIN also cause increased plasma protein leakage, mucus secretion, and epithelial cell replacement within the animals (Sykes and Greer, 2003). Therefore, there will be a great demand for amino acids, protein, and minerals in the gastrointestinal tract and a reduced partitioning of nutrients to the muscle and skin (Roy *et al.*, 2003; McClure, 2003).

In the past, parasite control strategies in sheep and goat herds concentrated on frequent anthelmintic treatment and intensive grazing management (Miller and Horohov, 2006). However, grazing management has not been effective because of its high expense in maintenance and the hardiness of infective larvae on pasture (Miller and Horohov, 2006). The three classes of anthelmintics used as parasite control in the U.S. are benzimidazoles, macrocyclic lactones, and imidazothiazoles. Due to the overuse and/or misuse of chemical anthelmintics, there have been reports of growing anthelmintic resistance. Anthelmintic resistance is a global problem (Kaplan *et al.*, 2007; Howell *et al.*, 2008; Crook *et al.*, 2010), and has been reported in all three major classes of anthelmintics (Terrill *et al.*, 2001). It is now clear that alternative strategies are needed to control internal parasites of sheep and goats. Alternatives to chemical control of small ruminant GIN have been under investigation in recent years, including use of nematode-trapping fungi to destroy parasitic larvae (Larsen, 2000; Terrill *et al.*, 2004), vaccines against *H. contortus* (Knox, 2000; Knox and Smith, 2001), feeding of copper oxide wire particles to expel adult worms (Chartier *et al.*, 2000; Burke *et al.*, 2004), and natural

dewormers (forage with condensed tannins, pumpkin seeds, garlic, ginger, and papaya seeds; Iqbal *et al.*, 2006; Shaik *et al.*, 2006; Burke *et al.*, 2009; O'Brien *et al.*, 2009; Strickland *et al.*, 2009; Worku *et al.*, 2009). In addition, one of the most promising alternatives for integrated parasite management might be the selection of breeds with resistance to parasites.

Common Small Ruminant Internal Parasites

Haemonchus contortus

Haemonchus contortus, also known as the barber pole worm, is a blood-sucking GIN found in the abomasum and is the most prevalent GIN in small ruminants (Kaplan, 2004a). *Haemonchus contortus* causes anemia, reduced production, and in serious cases leads to death (Burke *et al.*, 2007). The genetic diversity of *H. contortus* allows for rapid selection for anthelmintic resistance (Prichard, 2001). Although there has been extensive research conducted on anthelmintic resistance in *H. contortus,* this parasite is still a major concern to the small ruminant industry. In a study done by Howell *et al.* (2008), *H. contortus* was found to be resistant to all three classes of commercially available anthelmintics on 48% of the southern farms tested. The life cycle of *H. contortus* is 17 – 21 days long, with the adult worm being 10 – 30 mm long in the abomasum (Flynn *et al.*, 2007). Female worms may produce 6,000 – 10,000 eggs per day. Animals that are heavily infected may have facial edema (bottle jaw), anemia and will die if not immediately treated with an effective anthelmintic (Flynn *et al.*, 2007). Other clinical signs may include pale mucous membrane and sometimes soft stool.

To diagnose *H. contortus* infection a fecal float is required (Flynn *et al.*, 2007). The eggs of *H. contortus* are similar to other GIN, so a fecal egg count reduction test

(FECRT) in combination with a larval identification (ID) can be done to identify *H. contortus* separately by their body structure. Conducting a necropsy can also reveal adult worm numbers in the abomasum (Foreyt, 2001). All classes of anthelmintics approved for small ruminants have the ability to prevent or treat *H. contortus* (Foreyt, 2001), if the *H. contortus* is not already resistant to the drug.

Trichostrongylus colubriformis

Trichostrongylus colubriformis (hair worm) is a GIN in small ruminants that can be found in the small intestine. *Trichostrongylus colubriformis* has a life cycle of 21 days and when fully grown, the adult is 4.5 – 8.0 mm long in the small intestine (Foreyt, 2001). Infected small ruminants present symptoms such as diarrhea, anorexia, weight loss, dehydration, lethargy, and abdominal pain (Flynn *et al.*, 2007). Dairy goats with a higher milk production history tend to be more susceptible to infection, which results in decreased milk production (Hoste and Chartier, 1993). Even though fecal floatation will show the presence of GIN (Foreyt, 2001), a larval culture for parasite identification needs to be conducted to accurately diagnose *T. colubriformis*. If a necropsy is done on infected animals, the adult *T. colubriformis* will be seen in the small intestine (Foreyt, 2001). All classes of anthelmintics are labeled for treatment of *T. colubriformis* (Flynn *et al.*, 2007).

Trichostrongylus axei

Trichostrongylus axei, also known as the small stomach worm, is a GIN in small ruminants that can be found in the abomasum. Similar to *T. colubriformis*, *T. axei* has a life cycle of 21 days (Foreyt, 2001). Typical *T. axei* egg size is 80 μ x 40 μ in a fecal flotation and a full grown adult is 4.0 – 8.0 mm long (Foreyt, 2001). Infected small ruminants present symptoms such as diarrhea, dehydration, bottle jaw, and emaciation

(Foreyt, 2001). If a necropsy is done on infected animals, the adult *T. axei* will be seen in the abomasum (Foreyt, 2001). An infected animal may be treated with albendazole, doramectin, eprinomectin pour-on, fenbendazole, ivermectin, morantel tartrate and moxidectin pour-on depending on its resistance status (Foreyt, 2001).

Parelaphostrongylus tenuis

Parelaphostrongylus tenuis is a meningeal, or brain worm, that is 10 – 15 cm long as adults, and is known to have a life cycle of up to 90 days (Foreyt, 2001). *Parelaphostrongylus tenuis* is generally yellowish-brown or black in body (Flynn *et al.*, 2007). The white tailed deer is the host of this parasite; however, it can also infect other ruminants such as mule deer, llamas, sheep, goats, and wapiti (Flynn *et al.*, 2007). A snail acts as an intermediate host and if ingested, the larvae in the snails may cause a lethal infection in sheep, goats, moose, caribou, elk, mule deer, exotic deer and llamas (Foreyt, 2001). Larval migration results in lesions in the spinal cord and may cause necrosis, perivascular infiltration, and loss of myelin (Flynn *et al.*, 2007). White tailed deer infected with *P. tenuis* may shorten the life span of sheep and goats (Foreyt, 2001). If a necropsy of the brain is conducted on a white tailed deer, it will show the adult worms, but in sheep and goats, only larvae will be seen (Foreyt, 2001). If the baermann funnel procedure of larval ID is used, the larvae will also be seen in the fecals of sheep and goats (Foreyt, 2001). An infected animal may be treated with 0.2 mg/kg of ivermectin subcutaneously to kill larvae, but not adults (Foreyt, 2001).

Teladorsagia circumcincta

Teladorsagia circumcincta, also known as the brown stomach worm, is found in the abomasum. This GIN enters the gastric glands of the abomasum, causing a complete

loss of proteolytic pepsin, movement of serum protein, and decreased acid production, which leads to diarrhea (Miller and Horohov, 2006). When an animal is infected by *T. circumcincta*, they are usually unable to grow correctly or even maintain themselves very well, and the infected animal is said to have a production disease (Miller and Horohov, 2006). A high infection of *T. circumcincta* may result in death (Miller and Horohov, 2006). Therefore, it is very important to deworm the animal with the correct dosage of anthelmintics, so that this parasite does not become resistant. *Teladorsagia circumcincta* also thrives in cooler wet environments (Miller and Horohov, 2006).

Eimeria Spp.

Eimeria, commonly known as coccidia, are well-known protozoans found in the small intestine of small ruminants (Foreyt, 2001). Coccidia has a prepatent period of 12 to 18 days and a size of 16 – 47 µm x 13 – 32 µm (Foreyt, 2001). There are several species of coccidia that can be found in small ruminants causing coccidiosis (Foreyt, 2001). Coccidia are more severe in young animals than in more mature animals. In young animals, coccidia causes bloody diarrhea and in more severe cases death, while in adults, it causes decreased production and in some cases diarrhea (Foreyt, 2001).

Fecal examination for ocysts is a diagnostic technique used to determine the coccidia status of an animal (Foreyt, 2001). Another diagnostic technique is noting whitish lesions in the small intestine at necropsy (Foreyt, 2001). Following infection, treatments may include 10 mg/kg amprolium orally every 24 hours for 5 – 21 days and 130 mg/kg sulfamethazine orally then at 65 mg/kg every 12 hours for 4 days (Foreyt, 2001). However, it is better to prevent coccidia infestation than to treat it, because if caught late, it may be detrimental to the herd. Methods of prevention include the use of

0.5 mg/kg decoquinate orally every 24 hours for 28 or more days, 1 mg/kg lasalocid orally every 24 hours for 30 or more days, 0.25 mg/kg monensin in feed every 24 hours for 31 days, and sulfaguanidine at 0.2% of feed (Foreyt, 2001).

Chemical Anthelmintics and Anthelmintic Resistance

Classes of chemical anthelmintics used in small ruminants

The primary problem faced by small ruminant producers across the world is parasitism. Parasite infections have been known to reduce small ruminant production by causing disease and death in serious cases. Gastrointestinal nematode infections are commonly controlled by the use of chemical anthelmintics that improve the production and body condition of animals when effective (Orlik, 2010). Although there are several trade names for anthelmintics, there are currently three main classes of anthelmintics used in the U.S. small ruminant industry classified by their mode of action. The three classes include benzimidazoles (BZ), macrocyclic lactones (ML), and imidazothiazoles (Fleming *et al.*, 2006). All three classes of anthelmintics are considered to be broad spectrum anthelmintics effective against all major GIN (Orlik, 2010).

The BZ class was the first modern class of anthelmintic to be developed, and is known as the white drenches. The BZ class of anthelmintics includes thiabendazole (TBZ), fenbendazole (FBZ), albendazole (ABZ), and oxfendazole. Thiabendazole and ABZ are approved by the Food and Drug Administration (FDA) for use in sheep but only FBZ is approved for use in goats. This class of anthelmintic works on parasites by binding to the protein tubulin and preventing the formation of the microtubules needed for the parasite's energy metabolism (Prichard, 2001). This interference of energy metabolism causes starvation of the parasite, resulting in worm death.

Imidazothiazoles, the second class of anthelmintics, are known as the clear dewormers and includes levamisole (LEV), morantel tartrate (MOR), and pyrantel (Orlik, 2010). Levamisole is FDA approved for use in sheep while MOR is approved for use in sheep and goats (Webb, 2004). This class of anthelmintic affects the nerves of the parasite causing muscular contraction which leads to paralysis. The paralysis causes the worms to be unable to eat and they will starve to death (Orlik, 2010).

The macrocyclic lactones are the most recent class of anthelmintics; this class includes ivermectin (IVM), doramectin, and moxidectin (MOX). Moxidectin and IVM are the only two anthelmintics in this class that are FDA approved for use in sheep with none approved for use in goats. These anthelmintics work by interfering with the reproduction of the parasite (Orlik, 2010). Macrocyclic lactones interfere with the gamma aminobutyric acid (GABA) neurotransmission which causes death of the parasite (Arundel, 1985; Holden-dye and Walker, 1990). Unfortunately, recent studies have indicated that there is small ruminant GIN resistance to all three major classes of anthelmintics (Terrill *et al.*, 2001).

Although there are GIN resistant to all three classes of anthelmintic in the U.S., a new anthelmintic, Zolvix®, has been developed from a new classification of anthelmintic termed amino-acetonitrile derivatives (AADs). Zolvix® was developed primarily for use in sheep with a unique mode of action, as it attacks the HCO-MPTL-1 receptor present only in nematodes. This anthelmintic is effective against sheep GIN which are resistant to other drenches. However, this anthelmintic is currently only approved for use in New Zealand, Australia, Europe, UK, and South America.

Anthelmintic Resistance

Gastrointestinal nematode infections are most commonly controlled in herds by the use of frequent administration of chemical anthelmintics. However, this has led to a dramatic increase in the prevalence of anthelmintic resistance in GIN (Mortensen *et al.*, 2003). The overuse and misuse of available dewormers has made anthelmintic resistance a global issue (Jackson, 1993; Zajac and Gipson, 2000; Terrill *et al.*, 2001; Mortensen *et al.*, 2003; Kaplan *et al.*, 2007). Anthelmintic resistance can be caused by several different management practices. The primary cause for anthelmintic resistance is the overuse and/or misuse of the anthelmintics that are available. Overuse is defined as deworming all animals at the same time regardless if they require treatment or not and deworming frequently. Under-dosing individual animals are another practice that has contributed to the development of resistance to an anthelmintic. Giving too low a dose exposes the parasites to a sub-lethal dose of the drug which increases resistance because the parasite does not get a lethal dose (Kaplan, 2006). Under-dosing can also be caused by improper dosing orally. For accurate dosage of anthelmintics, the animals should be weighed individually (Kaplan, 2006) and the anthelmintics should be delivered over the tongue and in the back of mouth, to allow for swallowing.

Anthelmintic resistance is very common in tropical or sub-tropical areas. For instance, Howell *et al.* (2008) conducted a study with forty-six sheep and goat farms in eight southern states, Puerto Rico, St Croix, and the U.S. Virgin Islands. Forty-eight percent of the farms tested in this study (11 sheep, 11 goat) had resistance to all three classes of anthelmintics. Using the Drenchrite® Larval Development Assay (LDA), Howell *et al.* (2008), found that *H. contortus* from 98%, 54%, 76%, and 24% of the farms

tested were resistant to BZ, LEV, IVM, and MOX, respectively. This research also indicated that fourteen of the farms (30%) had *T. colubriformis* and all were resistant to BZ (Howell *et al.*, 2008). For the twelve goat farms with *T. colubriformis*, 100%, 58%, and 41% of farms had resistance to BZ, LEV, and IVM respectively (Howell *et al.*, 2008).

Although resistance has been primarily reported for the southeastern states, evidence of resistance to anthelmintics is increasing for the entire United States. Similar to the work of Howell *et al.* (2008), a recent study conducted in 5 Mid-Atlantic states on 33 farms (13 sheep and 20 goats), indicated that there was 100%, 79%, 48%, and 27% of the farms resistant to BZ, IVM, MOX, and LEV respectively (Crook *et al.*, 2010). The study further showed that goat farms tested (n = 20) had 100%, 95%, 55%, and 35% resistance to BZ, IVM, MOX, and LEV, respectively and four (20%) of the goat farms had resistance to all three classes of anthelmintics (Crook *et al.*, 2010). Therefore, due to increasing anthelmintic resistance throughout the U.S., it is imperative that studies are conducted to determine the efficacy of alternative approaches to chemical control of GIN in small ruminants.

Alternatives to Chemical Control of Gastrointestinal Nematodes

Alternatives to chemical control of GIN are needed because anthelmintic resistance is a global problem and has been reported in all three classes of anthelmintics. Several alternatives that have been studied include the use of copper oxide wire particles, nematode-trapping fungi, vaccines, rotational grazing, and natural plant dewormers (Shaik *et al.*, 2006; Worku *et al.*, 2009; Larsen, 2000; Terrill *et al.*, 2004; Knox, 2000; Knox and Smith, 2001; Chartier *et al.*, 2000; Burke *et al.*, 2004).

Copper Oxide Wire Particles

Copper oxide wire particle (COWP) have been used to control *H. contortus* in both sheep and goats (Burke *et al.*, 2004). Copper oxide wire particles are used as a bolus also known as "needles", and the bolus is generally administered orally (Pollard, 2009). The development of COWP was done originally for the treatment of cattle for copper deficiency; however, it was observed that it had a major effect on abomasal worms as well (Pollard, 2009). Currently, several studies have reported that COWP is effective against the two most prolific parasites in sheep and goats in the U.S. (*H. contortus* and *T. colubriformis*).

In a study conducted using fifty lambs (15 Katahdin, 16 Dorper, and 19 Dorper cross) to determine the effectiveness of 2, 4, and 6 gram doses of COWP, it was found that all three doses of COWP were very effective in controlling *H. contortus* infection (Burke *et al.*, 2004). However, the 4 g and 6 g treatment had a slightly lower FEC than the 2 g treatment (Burke *et al.*, 2004). In a similar study, 0.5 g and 1.0 g of COWP was used in comparison to LEV against *H. contortus* and these treatments worked just as well as LEV without causing copper toxicity (Burke and Miller, 2006). However, sensitivity to copper is different in some sheep breeds, so care must be taken to avoid copper toxicity (Burke and Miller, 2006). Therefore, the use of COWP may require blood testing in a sheep flock before starting to use as an alternative method of GIN control. Due to sensitivity to copper, many sheep producers are hesitant about including this in their parasite control program and are seeking less potentially toxic approaches.

Nematode Trapping Fungus

Nematode trapping fungi have been used for GIN infection control in small ruminants. *Duddingtonia flagrans* is the primary fungus used in nematode trapping fungi research (Pollard, 2009). This fungus is studied because of its ability to produce chlamydospores that are resistant to conditions within the gastrointestinal tract of livestock (Larsen, 2006). So, after feeding they pass through the tract and chlamydospores grow in the feces, forming a network of loops that trap the developing larvae in the L3 stage thus preventing the larvae from getting out of the manure and onto the pasture to cause infection (Larsen, 2006).

Peña and colleagues (2002) conducted a study using eighteen ewes to determine if *D. flagrans* is effective in reducing existing infections. It was found that when fungi were administered daily, the treatment was effective. In addition, after one day, the number of L3 was reduced by 98.5% in all groups with the exception of one that was reduced by 80.9% (Peña *et al.*, 2002). In a similar study in goats, Terrill *et al.* (2004) noted a reduction of L3 infective larvae (70.3% - 93.2%) in all fungi treated groups. Each group in the study was treated with a different dose of spores (5×10^5, 2.5×10^5, 10^5, and 5×10^4 spores/kg body weight) and parasite reduction was dose dependent (Terrill *et al.*, 2004). Even though research results have demonstrated the effectiveness of this treatment, the fungus is not currently available commercially. Therefore, this method of control cannot be recommended for producers.

Vaccines

The use of vaccines to protect small ruminants against parasites can be seen as an alternative control of GIN. Vaccines have been used in two different approaches, natural

and hidden antigens (Orlik, 2010). Natural antigens are also known as conventional antigens; these antigens are recognized by the host during infection while hidden gut antigens are not immunologically recognized by the host at the time of infection (Pollard, 2009). Hidden gut antigen is the most promising vaccine used, and it targets *H. contortus* specifically (Fleming *et al.*, 2006). The antigen used in this vaccine is found in the gut of the worm and when administered produces antibodies to the antigen (Fleming *et al.*, 2006). After the antibodies have been formed in the blood stream and the blood is ingested by the nematodes, they attack the GIN gut cells, causing an interruption in the worms' ability to process nutrients, thus killing them (Fleming *et al.*, 2006).

The most common hidden gut antigen is a membrane glycoprotein taken from the microvilli of *H. contortus* known as H11 (Orlik, 2010). The H11 antigen was reported to be effective after reducing FEC by 90% (Smith and Smith, 1993). In a study conducted by Nayebzadeh *et al.* (2008), vaccination with whole gut homogenate of *H. contortus* was proven to be effective in controlling FEC in all lambs. Although it did not entirely eliminate the parasite loads in vaccinated lambs, the authors suggested that it can be used to reduce pasture contamination and re-infection since it reduced adult larvae (Nayebzadeh *et al.*, 2008). However, this does not prevent parasite infection, it only helps to get rid of the worms they have. More research still needs to be conducted before this mode of parasite control is made commercially available to producers.

Rotational Grazing

Another alternative method to chemical use in parasite control in small ruminants is rotational grazing. The rate at which parasite larvae can be ingested and the amount ingested depends on the management of the pasture (Hale, 2006). Allowing animals to

graze close to the ground increases internal parasite infection rates since larvae migrate 0.08 – 0.10 meters up a blade of grass (Orlik, 2010). Rotational grazing of small ruminants with cattle (mixed species grazing) is also a good way to reduce internal parasites because cattle consume the internal parasite larvae of small ruminants that helps to clean the pasture of internal parasites (Hale, 2006).

In a study conducted by Barger *et al.*, (1994), ten pastures were rotationally grazed by goats. The study found that after moving the animals every 3.5 days, the FEC of the animals were lower than that of the control group which was not rotated. However, in order to successfully rotate animals and help with internal parasite control, it is necessary to have enough pastures so you can give one pasture 2 – 3 months of rest (Fleming *et al.*, 2006). Therefore, rotational grazing is not the best idea as many small ruminant producers do not have enough pasture to rest one pasture for three months. Resting the pasture breaks the parasite life cycle allowing the majority of larvae to die.

Natural Plant Dewormers

Several plants are being tested as alternatives for GIN control that could be used in organic and conventional systems. These plants include wormwood, garlic, black walnut, pumpkin, ginger, mugwort, fennel, hyssop, thyme, and plants containing condensed tannins (Burke *et al.*, 2008). These plants contain a deworming component such as condensed tannins, cucurbitacin, or allicin (Strickland *et al.*, 2009).

It has been shown that plants containing condensed tannins have anthelmintic properties (Burnet *et al.*, 2008). Plants containing condensed tannins include faba beans, birdsfoot trefoil, big trefoil, sainfoin, crown vetch, and sericea lespedeza (Robbins and Morris, 2000). Lange *et al.*, (2006) conducted a study using sericea lespedeza (SL) in

lambs and found that it was effective in reducing FEC compared to the control group. In a similar study using intact Boer bucks, SL was compared to Bermuda grass and the authors found that the SL group had a significantly lower FEC than the BG group (Shaik *et al.*, 2006). Terrill and colleagues (2007) further tested to determine differences between pelleted and non-pelleted SL when used to help control GIN in goats. The researchers found that the highest FEC reduction was in the group fed SL pellets (70%) and both groups had a lower FEC than that of the control group (Terrill *et al.*, 2007). A study examining the effects of different levels of SL on GIN infection in sheep and goats, found that meat goat kids fed 60% SL had lower FEC than the groups fed 0 and 20% SL (Burke *et al.*, 2011). However, there was no difference in treatments when tested on both hair and wool breed lambs in this study (Burke *et al.*, 2011). Despite these results, SL is not the best option in the Northeast U.S. as producers and scientists in this region have reported problems with growing and maintaining this crop (Dr. Niki Whitley, personal communication).

The potential anthelmintic property found in garlic is allicin (Strickland *et al.*, 2009). In a study conducted using garlic and pumpkin seeds to control *H. contortus* in sheep, it was found that both garlic and pumpkin seeds were an effective method of controlling GIN (Strickland *et al.*, 2009). However, in a study conducted by Burke *et al.* (2009), the effectiveness of garlic administered in two different ways as a natural dewormer in goats was examined and garlic was not effective in controlling parasite loads, with only one of ten goats actually showing a decrease in FEC (16759 – 2050 epg), and all the other goats egg counts rising (Burke *et al.*, 2009). In addition to garlic, a few studies have been conducted evaluating the efficacy of pumpkin seeds and ginger in

reducing FEC. However, most of the information available is anecdotal and needs further verification.

Pumpkin Seed

Cucurbitacin is the proposed anthelmintic substance found in pumpkin seeds. Cucurbitacin is an amino acid that makes up one percent of the pumpkin seed kernel (Blumenthal *et al.*, 1998). It is a phytochemical that is thought to be responsible for the anthelmintic properties of pumpkin seeds (Blumenthal *et al.*, 1998). Pumpkin seeds have previously been studied as an alternative control for GIN and were traditionally used to remove tapeworms from the gastrointestinal tract of dogs (Strickland *et al.*, 2009). In addition, Strickland *et al.*, (2009) conducted a study using garlic and pumpkin seed to control *H. contortus* in sheep and found that pumpkin seed was more effective at controlling GIN than garlic or not treating at all. In a similar study conducted comparing pumpkin seed, tobacco, and a control, the pumpkin seed group was the most effective in controlling internal parasites (Exner *et al.*, 2004).

In a preliminary study conducted at Delaware State University in 2007, a single pumpkin seed drench was effective in numerically preventing a rise in FEC. The FEC of the control group increased by 56%, while the treatment group decreased by 11% (O'Brien, 2007; unpublished data). In a second study conducted at Delaware State University (2008) using 22 kids, ground pumpkin seeds were not effective in reducing FEC in meat goat kids. It was noted in this study that the goat kids sorted through the feed. This meant that kids did not adequately consume the pumpkin seeds and only ate the pelleted feed (O'Brien *et al.*, 2009). However, more studies are needed to evaluate the

efficacy of pumpkin seeds in controlling small ruminant GIN through various modes of administration in controlled studies.

Ginger

Ginger (*Zingiber officinale*) has been used as an anthelmintic purge for cattle and horses (Duval, 1997) as well as lambs (Iqbal *et al.*, 2006). Iqbal *et al.* (2006) used 24 mixed sex sheep to examine the efficacy of ginger administered as a drench or a powder and concluded that the drench (3 g/kg BW) was more effective in controlling parasite infections than administering a powder. The 3 g/kg dose drench and powder were able to reduce FEC by 66% and 24%, respectively (Iqbal *et al.*, 2006). As with pumpkin seed, there is limited data available on the efficacy of ginger in reducing FEC. Therefore, more research is needed before any recommendations can be made to the small ruminant community.

Natural Selection and Resistance

Another promising alternative method for GIN control is the selection of resistant breeds or genetic lines of small ruminants. Although there is limited scientific data available on natural parasite resistant breeds of goats, there are reports of genetic variation for resistance to GIN among goat breeds (Preston and Allonby, 1978; Cabaret and Anjorand, 1984; Shavulimo *et al.*, 1988; Richard *et al.*, 1990; Pralomkarn *et al.*, 1997; Baker *et al.*, 1998; Costa *et al.*, 2000). Also, studies have shown that there are some sheep breeds that have resistance to GIN (Stear *et al.*, 2006). Resistance and resilience are the two major concepts relating to the animal's ability to withstand an infection (Vanimisetti, 2003). Resistance to GIN is the ability of animals being able to reduce the number of GIN reproducing and surviving in the body, while resilience is the

animal's ability to perform effectively despite the existing parasite load (Gray *et al.*, 1995). Several factors that may affect animal resistance or resilience include age, sex, nutrition, reproductive status, and their breed (Vanimisetti, 2003). However, because resistance has been shown to be a moderately heritable trait (Woolaston and Piper, 1996; Albers *et al.*, 1987), selecting resistant breeds and/or breeding for resistance is the best way to bring resistance into a flock.

In a study conducted by Vagenas and colleagues (2002) using crossbred cashmere-producing goats, breeding for resistance in goats was noted as a promising alternative for parasite control. However, over a five year period, results for this study indicated that the FEC each year was not significantly different (Vagenas *et al.*, 2002). In another experiment using Galla and Small East African (SEA) goats, there was no significant difference between resistance to GIN. However, both groups maintained a low FEC throughout the 5 years of the study, with the exception of the Galla goats having a significantly lower FEC than the SEA goats in 1995 (Baker *et al.*, 2001).

On the other hand, in a study conducted by Browning *et al.*, (2006), Kiko does demonstrated hardiness when exposed to conditions conducive to internal parasitism when compared to Boer does. Fecal egg counts of the Spanish and Kiko groups were similar but significantly less than the Boer group (Browning *et al.*, 2006). In a similar study comparing the fitness traits of Boer, Kiko, and Spanish meat goats in the Southern U.S., all three breeds had a significantly different FEC (Browning and Leite-Browning, 2009). The Boer group had the highest FEC and the Spanish group had the lowest, however, the Boer goats had approximately 50% higher FEC than the Kiko group (Browning and Leite-Browning, 2009).

In a sheep study comparing crossbred Dorper, St. Croix, and Katahdin ewes, it was concluded that FEC were similar for all groups, with the exception of the St. Croix group having a higher FEC in November and December of that year (Burke and Miller, 2002). In a second experiment in the same study, hair sheep breeds (Katahdin and 7/8 Dorper) were compared to Hampshire sheep and there was no difference in FEC, with the exception of day 28 when the Hampshire group had a higher FEC (Burke and Miller, 2002). However, in a three year study using Dorper crosses, Dorset crosses, and Katahdin, the Katahdin lambs had the lowest FEC in all three years than all other lambs sampled (Vanimisetti *et al.*, 2004). The pure bred Katahdin lambs had a significantly lower mean FEC than the Dorper lambs in all years with the exception of the first year as FEC was low for all groups.

Considering that there is limited scientific data available on parasite resistance and resilience in specific goat breeds, those believed to have these traits need to be evaluated before recommendations can be made to the small ruminant community. Kiko and Savanna goat breeds are considered by many in the industry to be more parasite resistant breeds, resulting in higher prices for their genetics and them being difficult to find. However, the scientific data supporting this is limited and based mostly on observations. The Kiko breed is a composite goat breed that was developed for meat production in New Zealand (Batten, 1987) and preliminary research has indicated that does of this breed demonstrate hardiness when exposed to conditions conducive to internal parasitism (Browning *et al.*, 2006). However, in this study, no data was collected on any of the internal parasite infection indicators. In addition to the Kiko breed, the Savanna breed was developed in South Africa and has been reported to have parasite

resistance traits. Similarly, there is no scientific data in the literature reviewed supporting this statement. On the other hand, the Boer goat is a breed developed in the semi-arid region of South Africa for meat production (Casey & Van Niekerk, 1988) and is the predominant meat goat genotype in the U.S. today (Browning *et al.*, 2006), but is not known for parasite resistance.

It is apparent from this review, that infections with GIN are one of the major problems faced by the small ruminant industry. Due to increasing GIN resistance to available anthelmintics, producers are seeking alternative means of combating this problem. Goat producers are currently purchasing new breeds to incorporate into their herd while other small ruminant producers are utilizing natural products with anecdotal claims of controlling GIN infections. Selection and the use of natural plants dewormers may be effective means of controlling internal parasite infections. However, further research into their efficacy need to be conducted before recommendations can be made.

Objectives

The objectives of this research were 1) to test the efficacy of natural dewormers in sheep (pumpkin seed oil) and goats (pumpkin seed drench and oil, and ginger) and 2) to evaluate parasite resistance traits in three different breeds of goats (Kiko, Savanna, and Boer) with the goal of potentially using genetics to combat the issues of parasitism in the goat industry. The null hypothesis for Objective 1 is that pumpkin seed drench, pumpkin seed oil and ginger will have no effect on reducing internal parasite loads in small ruminants. For Objective 2, the null hypothesis is that goat breed will have no effect on the internal parasite loads in goats.

CHAPTER III

Materials and Methods

Objective 1

Experiment 1: To determine the efficacy of a pumpkin seed and a ginger drench in reducing internal parasite loads in meat goat kids.

Animals and Location

This experiment was conducted on Delaware State University's farm, Hickory Hill, in Dover, Delaware. Twenty-two naturally GIN infected Boer crossbred meat goat kids at approximately 144.4 ± 1.1 days of age were used in this experiment. Goat kids were placed in individual 1.2 m x 1.2 m pens on solid concrete floors with no bedding and placed in one of three treatment groups after accounting for initial body weight (BW), packed cell volume (PCV) and fecal egg counts (FEC). Kids received pre-weighed rations of a commercially pelleted 15% CP meat goat feed (Southern States Inc., Richmond, VA) daily for 42 days at approximately 3% of their body weight and water supplied *ad libitum*. All animal-related procedures were conducted in compliance with Delaware State University Institutional Animal Care and Use Committee guidelines.

Treatments

Treatment consisted of orally administering water (CON; n = 7), a pumpkin seed drench (5 g pumpkin seed/kg BW; PUM; n = 10) or a ginger drench (3 g ginger/kg BW; GIR; n = 5) every other day for 42 days. Pumpkins were purchased from Fifers Orchard in Dover, DE and seeds were removed, rinsed and dried with paper towel for use in this study. The pumpkin seed drench was prepared from a traditional method for the treatment

of GIN in sheep by adding 500 – 600 g of ground pumpkin seeds to 3 L of water, simmering, cooling and removing excess water (Duval, 1997) such that each animal in this treatment received a dosage of approximately 5 g pumpkin seed/kg BW. The ginger drench was prepared by blending 300 - 500 g of ginger in 100 ml of water, sieving and administering orally such that each animal in this treatment received a dosage of approximately 3 g ginger/kg BW. The amount of pumpkin seeds and ginger required was determined weekly based on sampling date BW.

Sampling

Every 7 d for 42 days, goat BW, fecal, and blood samples were collected. Body weight was measured and recorded to monitor growth or body weight maintenance throughout the study. Fecal samples (1 – 4 g) were collected rectally from individual animals and placed in labeled plastic zippered bags, and stored at refrigerated temperature until analysis. Individual fecal samples were analyzed for FEC using the modified McMaster technique (Henricksen and Aagard, 1986) and reported as eggs per gram (epg).

Larval cultures were conducted according to the WAAVP guidelines (Peña *et al.*, 2002; Appendix 3). A minimum of 10 g of pooled fecal sample was collected per treatment group at each sampling and placed in 500 ml beakers and vermiculite was added to the feces at roughly a 1:1 ratio. A small amount of water was used to dilute feces and promote mixing with the vermiculite. The jar was then labeled with a collection/set date, treatment and harvesting date. The harvesting date was 10 days after the set date. Water was added as needed over the 10 day period if the sample became too dry, because parasites favor a moist environment. After 10 days, a base layer of warm

water was poured into a funnel with ¼ inch wire screening in the bottom, and a tube with a clamp attached to the end (Baermann funnel). The funnel was also lined with Kimwipes® (Fisher Scientific, Pittsburg, PA) and a double layer of cheesecloth prior to adding the mixture. After adding the fecal mixture to the funnel, the fecal mixture was soaked to the top of the funnel with warm water. The Kimwipes® and the cheesecloth were then folded over and the mixture allowed to sit for 12 h. The funnel was then drained into two 50 ml centrifuge tubes. The centrifuge tubes were then refrigerated for 3 h to allow larvae to settle after which the supernatant in both tubes was pulled off and the larvae combined in one tube. The centrifuge tubes were then heated at 55° C in a heatblock (VWR Scientific Products Select Heatblock) for 10 – 15 minutes and finally stained with 50% Lugol's iodine to immobilize the larvae. After which the solution containing the larvae was then transferred to a standard slide and counted for differential percentages of GIN species present. One-hundred worms were counted and data were calculated as a percent of each worm species within the sample population on the slide. These procedures were conducted at Louisiana State University.

The blood samples were collected by jugular venipuncture and analyzed for PCV as a measure of anemia by calculating the percentage of red blood cells in the whole sample collected in capillary tubes after centrifugation (red blood cells measured/red blood cells + serum in capillary tubes * 100). If PCV was < 15%, animals were dewormed with moxidectin (0.4 mg/kg) and removed from the study. Three CON and five GIN animals were removed from this experiment because of PCV below <15%.

At the end of the study, animals were harvested at a USDA-inspected abattoir, the abomasum was tied off, collected and bagged in zippered bags for storage on ice until

content collection the same day. Contents were collected into 3000 ml tap water, mixed well and two 150 ml aliquots were collected, mixed with 100 ml of 10% formalin and stored until GIN counting. Abomasal worm counts were conducted according to procedures described by the Manual of Veterinary Parasitological Laboratory Techniques, (1977; Appendix 2). These procedures were conducted at Louisiana State University.

Variables Measured

The following variables were measured every week throughout the experiment: animal BW, FEC, PCV (%), and larval ID. Gastrointestinal worm counts were measured at the end of the study. Body weight was used to monitor the growth of the animals. Fecal egg count is a quantitative measurement of the number of parasite eggs/gram of fecal matter and PCV indicates the level of anemia in an animal, indicative of a probable *H. contortus* infection. Larval ID and GIN counts were conducted to identify the percentage of each worm species within the sample/treatment population.

Experiment 2: To determine the efficacy of pumpkin seed oil as an oral drench to reduce internal parasite loads in crossbred Katahdin lambs.

Animals and Location

This experiment was conducted on Delaware State University's farm, Hickory Hill in Dover, Delaware. Twenty-six crossbred mixed sex Katahdin lambs at approximately 10 months of age were used in this experiment. All lambs used in the study were dewormed with moxidectin (0.2 mg/kg) and levamisole (6 mg/kg). Following a 21 day dewormer withdrawal period, lambs were artificially inoculated twice, two days apart, with a 2 ml larval inoculation containing approximately 750 L3 *H. contortus*. The

FEC was monitored for all lambs and when all FEC were greater than (>) 150 epg, lambs were placed in individual 1.2 m x 1.2 m pens on solid concrete floors and placed in one of three treatment groups with similar means to account for initial BW, PCV and FEC. Lambs were fed a commercially pelleted 16% CP sheep feed (Southern States Inc., Richmond, VA) at approximately 3% of their BW daily for the duration of the study, and water was supplied *ad libitum*. All animal-related procedures were conducted in compliance with Delaware State University Institutional Animal Care and Use Committee guidelines.

Treatments

Treatments consisted of two doses of a commercially available pumpkin seed oil (PUM) and water (CON). Lambs in the PUM1 group were administered the pumpkin seed oil drenched at a rate of 2.0 ml/kg (5 g pumpkin seeds/kg BW; n = 9) once every week (7 d) or water on days when PUM2 lambs were treated. Lambs in the PUM2 group were administered the pumpkin seed oil drenched at the rate of 2.0 ml/kg (5 g pumpkin seeds/kg BW; n = 10) divided equally over 3 doses in one week (3 out of 7 d) such that their total dose was equivalent to the dose that was given in the PUM1 group. In the CON (n = 7) group, lambs were drenched with water on all days that PUM groups were treated.

Sampling

Every 7 d for 28 days, lamb BW, fecal, and blood samples were collected. Body weight was measured and recorded to monitor growth or body weight maintenance on the study. Fecal samples (1 – 4 g) were collected rectally from individual animals and placed in labeled plastic zippered bags, and stored at refrigerated temperature until analysis. Individual fecal samples were analyzed for FEC using the modified McMaster technique

(Henricksen and Aagard, 1986) and reported as eggs per gram (epg). The blood samples were collected by jugular venipuncture and analyzed for PCV as a measure of anemia by calculating the percentage of red blood cells in the whole sample collected in capillary tubes after centrifugation ((red blood cells measured/red blood cells + serum measured in capillary tubes) * 100). If PCV was < 15%, animals were dewormed with moxidectin (0.4 mg/kg) and removed from the study. One lamb from the PUM1 group was found dead on d 3 and one lamb from the PUM2 group was removed from this experiment.

Variables Measured

The following variables were measured every week throughout the experiment: animal BW, FEC, and PCV. Body weight was used to monitor the growth of the animals. Fecal egg count is a quantitative measurement of the number of parasite eggs/gram of fecal matter and PCV indicates the level of anemia in an animal, indicative of a probable *H. contortus* infection.

Experiment 3: To determine the efficacy of pumpkin seed oil as an oral drench to reduce internal parasite loads in crossbred Boer meat goat kids.

Animals and Location

This experiment was conducted on Delaware State University's farm, Hickory Hill in Dover, Delaware. Twenty-four, naturally infected mixed sex Boer crossbred meat goat kids at approximately 166.4 ± 1.0 d of age were used in the experiment. Kids were placed in individual 1.2 m x 1.2 m pens on solid concrete floors and placed in one of two treatments after accounting for initial BW, PCV and FEC. Kids were fed a commercially pelleted 15% CP meat goat feed (Southern States Inc., Richmond, VA) at approximately 3% of their BW daily for the duration of the study, and water was supplied *ad libitum*.

All animal-related procedures were conducted in compliance with Delaware State University Institutional Animal Care and Use Committee guidelines.

Treatments

Treatments consisted of one dose of a commercially available pumpkin seed oil (PUM) or water (CON). Kids in the PUM group were administered the pumpkin seed oil drenched orally at a rate of 2.0 ml/kg (5 g pumpkin seeds/kg BW; n = 11) every other day for 35 days. In the control (Control; CON; n = 13) group, kids were drenched with water on all treatment days.

Sampling

Every 7 d for 35 days, kids BW, fecal, and blood samples were collected. Body weight was measured and recorded to monitor growth or body weight maintenance on the study. Fecal samples (1 – 4 g) were collected rectally from individual animals and placed in labeled plastic zippered bags, and stored at refrigerated temperature until analysis. Individual fecal samples were analyzed for FEC using the modified McMaster technique (Henricksen and Aagard, 1986) and reported as eggs per gram (epg).

Larval cultures were conducted according to the WAAVP guidelines (Peña *et al.*, 2002; Appendix 3). A minimum of 10 g of pooled fecal sample was collected per treatment group at each sampling and placed in 500 ml beakers and vermiculite was added to the feces at roughly a 1:1 ratio. A small amount of water was used to dilute feces and promote mixing with the vermiculite. The jar was then labeled with a collection/set date, treatment and harvesting date. The harvesting date was 10 days after the set date. Water was added as needed over the 10 day period if the sample became too dry, because parasites favor a moist environment.

After 10 days, a base layer of warm water was poured into a funnel with ¼ inch wire screening in the bottom, and a tube with a clamp attached to the end (Baermann funnel). The funnel was also lined with Kimwipes® (Fisher Scientific, Pittsburg, PA) and a double layer of cheesecloth prior to adding the mixture. After adding the fecal mixture to the funnel, the fecal mixture was soaked to the top of the funnel with warm water. The Kimwipes® and the cheesecloth were then folded over and the mixture allowed to sit for 12 h. The funnel was then drained into two 50 ml centrifuge tubes. The centrifuge tubes were then refrigerated for 3 h to allow larvae to settle after which the supernatant in both tubes was pulled off and the larvae combined in one tube. The centrifuge tubes were then heated at 55° C in a heatblock (VWR Scientific Products Select Heatblock) for 10 – 15 minutes and finally stained with 50% Lugol's iodine to immobilize the larvae. After which the solution containing the larvae was then transferred to a standard slide and counted for differential percentages of GIN species present. One-hundred worms were counted and data were calculated as a percent of each worm species within the sample population on the slide. These procedures were conducted at Delaware State University.

The blood samples were collected by jugular venipuncture and analyzed for PCV as a measure of anemia by calculating the percentage of red blood cells in the whole sample collected in capillary tubes after centrifugation ((red blood cells measured/red blood cells + serum measured in capillary tubes) * 100). If PCV was < 15%, animals were dewormed with moxidectin (0.4 mg/kg) and removed from the study. Two meat goat kids from the PUM group were removed from this experiment.

Variables Measured

The following variables were measured every week throughout the experiment: animal BW, FEC, PCV (%), and larval ID. Body weight was used to monitor the growth of the animals. Fecal egg count is a quantitative measurement of the number of parasite eggs/gram of fecal matter and PCV indicates the level of anemia in an animal, indicative of a probable *H. contortus* infection. Larval ID was conducted to identify the percentage of each worm species within the sample population.

Objective 2

Experiment 4: Preliminary study to determine the influence of goat breed on parasite resistance and resilience in Boer, Kiko and crossbred Savanna Doelings.

Animals and Location

The site of the experiment was Delaware State University's farm, Hickory Hill located in Dover, Delaware. A pasture consisting of Kentucky 31 tall fescue was divided into three equal paddocks for rotational grazing. Thirty-one Boer (n = 10), Kiko (n = 12), and Savanna crossbred (n = 9) meat goat kids at approximately 188.3 ± 20.5 d of age were used in the experiment. All kids used in the study were dewormed with moxidectin (0.4 mg/kg) and levamisole (12 mg/kg) prior to the start of the study to ensure low FEC at the start of the study. All animal related procedures were conducted in compliance with Delaware State University Institutional Animal Care and Use Committee guidelines.

Treatments

Treatments consisted of 31 doelings of three breeds (Boer, n = 10; Kiko, n = 12; and crossbred Savannas n = 9) rotationally grazing three paddocks to determine the

influence of breed on specific parasite infection indicators. Forage height was measured and when it was less than 3 – 4 inches, all animals were moved to the next paddock such that goats are never grazing below 3 – 4 inches. Goats grazed in paddock one and were then moved to the second and third paddock subsequently. However, once there was no forage growth observed, animals were no longer rotated and kept on all paddocks opened. Mineral and water were supplied *ad libitum*. Grass hay was also supplemented when there was minimal forage growth observed in paddocks.

Sampling

Every three weeks for the study period of 198 days, BW, fecal and FAMACHA© scores were taken from all animals. Body weight was measured and recorded to monitor growth or body weight maintenance on the study. Fecal samples (1 – 4 g) were collected rectally from individual animals and placed in labeled plastic zippered bags, and stored at refrigerated temperature until analysis. Individual fecal samples were analyzed for FEC using the modified McMaster technique (Henricksen and Aagard, 1986) and reported as eggs per gram (epg).

Larval cultures were conducted according to the WAAVP guidelines (Peña *et al.*, 2002; Appendix 3). A minimum of 10 g of pooled fecal sample was collected per treatment group at each sampling and placed in 500 ml beakers and vermiculite was added to the feces at roughly a 1:1 ratio. A small amount of water was used to dilute feces and promote mixing with the vermiculite. The jar was then labeled with a collection/set date, treatment and harvesting date. The harvesting date was 10 days after the set date. Water was added as needed over the 10 day period if the sample became too dry, because parasites favor a moist environment.

After 10 days, a base layer of warm water was poured into a funnel with ¼ inch wire screening in the bottom, and a tube with a clamp attached to the end (Baermann funnel). The funnel was also lined with Kimwipes® (Fisher Scientific, Pittsburg, PA) and a double layer of cheesecloth prior to adding the mixture. After adding the fecal mixture to the funnel, the fecal mixture was soaked to the top of the funnel with warm water. The Kimwipes® and the cheesecloth were then folded over and the mixture allowed to sit for 12 h. The funnel was then drained into two 50 ml centrifuge tubes. The centrifuge tubes were then refrigerated for 3 h to allow larvae to settle after which the supernatant in both tubes was pulled off and the larvae combined in one tube. The centrifuge tubes were then heated at 55° C in a heatblock (VWR Scientific Products Select Heatblock) for 10 – 15 minutes and finally stained with 50% Lugol's iodine to immobilize the larvae. The solution containing the larvae was then transferred to a standard slide and counted for differential percentages of GIN species present. One-hundred worms were counted and data were calculated as a percent of each worm species within the sample population on the slide. These procedures were conducted at Delaware State University.

FAMACHA© scores were measured to determine anemia indicative of a possible *H. contortus* infection. Goats were dewormed if FAMACHA© scores were 4's and 5's, or 3's with other visual signs of parasitism (diarrhea, weight loss, rough hair coat, bottle jaw, etc.) and the number dewormed per breed was recorded on each collection date.

Variables Measured

The following variables were measured every week throughout the experiment: animal BW, FEC, FAMACHA©, deworming frequency, and larval ID. Body weight was used to monitor the growth of the animals and calculate the average daily gain (ADG) of

animals. Fecal egg count is a quantitative measurement of the number of parasite eggs/gram of fecal matter and FAMACHA© indicates the level of anemia in an animal, indicative of a probable *H. contortus* infection. Larval ID was conducted to identify the percentage of each worm species within the sample population and number of animals dewormed for each breed on sample collection days were recorded to determine deworming frequency.

Statistical Analysis

All animal data were analyzed using the mixed models procedure of SAS for repeated measures to determine effects of treatment on FEC, PCV, FAMACHA© scores and BW over time (SAS Institute, Cary, NC). Prior to analysis, all FEC data were log transformed: Ln (FEC + 1), due to expected lack of normality, and untransformed least square means and standard error were reported in the results. Deworming frequency data were analyzed using the PROC FREQ procedure of SAS (Chi Square analysis) while all correlations were determined using the PROC CORR procedure of SAS (SAS Institute, Cary, NC). Abomasal worm data were analyzed using the PROC ANOVA procedure of SAS (SAS Institute, Cary, NC). All data were reported in least square means ± standard error of the mean (SEM). The significance levels for all data were set at $P < 0.05$.

CHAPTER IV

Results

Experiment 1: Efficacy of a pumpkin seed and a ginger drench in reducing internal parasite loads in meat goat kids.

Body Weight

Kid BW was not influenced by treatment or a treatment by day interaction effect and averaged 18.71 ± 0.23 kg (Figure 1). However, there was a day effect ($P < 0.0001$), with an increase over time such that starting at d 21 (18.6 ± 0.6 kg), BW was greater ($P < 0.02$) than that measured on d 0 (17.7 ± 0.6 kg). In addition, BW on d 42 (20.1 ± 0.6 kg) was greater than ($P < 0.02$) all other days measured (17.7 ± 0.6, 17.8 ± 0.6, 17.9 ± 0.6, 18.6 ± 0.6, 18.8 ± 0.6, and 19.3 ± 0.6 kg for d 0, 7, 14, 21, 28, and 35, respectively) while d 21 BW was less ($P < 0.05$) than d 35 but similar to d 28.

Fecal Egg Count

Fecal egg counts were similar among treatments and averaged 3396 ± 750 epg (Figure 2). However, there was an influence of day ($P < 0.0001$) on FEC, with d 0 (6194 ± 750 epg), 7 (3749 ± 750 epg), 14 (3284 ± 750 epg), 21 (4233 ± 750 epg), and 28 (4344 ± 750 epg) being similar but greater ($P < 0.01$) than d 35 (661 ± 750 epg) and 42 (1309 ± 750 epg). Day 35 FEC was also greater ($P < 0.01$) than d 42.

Larval Identification

The most predominant species of parasite present in the pooled fecal sample collected from CON, GIR-treated, and PUM-treated animals at each sampling was *H. contortus* (Table 1).

Abomasal Worm Count

Abomasal worms identified were *H. contortus*, *T. axei* and *O. circumcincta*. There was a tendency ($P = 0.08$) for CON animals to have a higher total GIN load than GIR-treated animals but PUM-treated animals were intermediate at slaughter (Table 2). There was also a tendency ($0.06 \leq P \leq 0.09$) for CON animals to have a higher population of adult male, adult female, and total *H. contortus* compared to GIR-treated animals with PUM-treated animals being intermediate (Table 2).

Packed Cell Volume

Packed cell volume was not influenced by a day or a treatment by day interaction effect and averaged 27.5 ± 0.6% (Figure 3). There was a tendency ($P = 0.06$) for a treatment effect with GIR-treated animals (31.33 ± 1.98 %) having a higher ($P < 0.02$) PCV than CON animals (25.14 ± 1.68 %) with PUM-treated animals (27.37 ± 1.40 %) being intermediate.

Experiment 2: Efficacy of pumpkin seed oil as an oral drench to reduce internal parasite loads in crossbred Katahdin lambs.

Body Weight

Lamb BW increased over the study period for all groups and was not influenced by a treatment or a treatment by day interaction effect, averaging 33.0 ± 0.5 kg (Figure 4). There was, however, a day effect ($P < 0.0001$) on BW with all days measured being different ($P < 0.01$; 30.0 ± 1.1, 30.9 ± 1.1, 32.6 ± 1.1, 35.4 ± 1.1, and 36.3 ± 1.1 kg for d 0, 7, 14, 21, and 28, respectively).

Fecal Egg Count

There was no treatment or treatment by day interaction effect on FEC (averaged 604 ± 104 epg; Figure 5). There was an influence of day ($P < 0.0001$) with FEC significantly decreasing ($P < 0.03$) over time until d 21 and then throughout the rest of the study (1736 ± 212, 692 ± 212, 334 ± 212, 163 ± 212, and 75 ± 212 epg for d 0, 7, 14, 21, and 28, respectively).

Packed Cell Volume

Lamb PCV was not influenced by a treatment or a treatment by day interaction effect and averaged 31.6 ± 0.3% (Figure 6). However, there was an effect ($P < 0.04$) of day on PCV with d 0 (30.69 ± 0.77 %) being similar to d 7 (30.30 ± 0.77 %), 21 (32.07 ± 0.77 %), and 28 (31.99 ± 0.77 %), and d 14 (33.01 ± 0.77 %) being greater ($P < 0.02$) than d 0 and 7 (Figure 6). In addition, there was also a tendency for d 7 PCV to be lower than d 21 ($P = 0.06$) and 28 ($P = 0.08$).

Experiment 3: Efficacy of pumpkin seed oil as an oral drench to reduce internal parasite loads in crossbred Boer meat goat kids.

Body Weight

There was a treatment by day interaction effect ($P < 0.03$) on BW with CON animals having a greater BW than PUM-treated animals on d 7 only (Figure 7).

Fecal Egg Count

There was no treatment or treatment by day interaction effect on FEC (averaged 2404 ± 246 epg; Figure 8). However, there was a day effect ($P < 0.0001$) on FEC with d 0 (5315 ± 561 epg) FEC being greater ($P < 0.0001$) than all other days measured (2394 ±

586, 2151 ± 602, 1835 ± 561, 1665 ± 569, and 1704 ± 589 epg for d 7, 14, 21, 28 and 35, respectively). In addition, d 7 FEC was similar to d 14 but greater ($P < 0.02$) than d 21, 28, and 35 while d 14 FEC was greater ($P < 0.02$) than d 28 but similar to d 21 and 35.

Larval Identification

The most predominant species of parasite present in the pooled fecal sample collected from CON and PUM-treated animals at each sampling was *H. contortus* (Table 3). The only exception was on d 35, when *T. colubriformis* was the most predominant in the PUM-treated animals only (Table 3).

Packed Cell Volume

There was a treatment by day interaction effect ($P < 0.04$) on PCV with the PUM-treated animals having a greater PCV than the CON animals on d 7, 21, and 35 (Figure 9). In addition, there was a tendency for PCV on d 28 to be greater ($P = 0.05$) for PUM-treated animals (Figure 9).

Experiment 4: Preliminary study to determine the influence of goat breed on parasite resistance and resilience.

Average Daily Gain

There was no treatment or treatment by day interaction effect on average daily gain (ADG; average 0.011 ± 0.003 kg/d; Figure 10). However, there was a day effect ($P < 0.0001$) on ADG with d 0 – 23 ADG (0.037 ± 0.004 kg/d) significantly higher ($P < 0.001$) than all other days measured (0.018 ± 0.004, 0.008 ± 0.004, -0.003 ± 0.004, 0.009 ± 0.004, 0.004 ± 0.004, 0.006 ± 0.004, 0.008 ± 0.004, and 0.012 ± 0.004 kg/d for d 23 – 44, 44 – 65, 65 – 86, 86 – 114, 114 – 135, 135 – 156, 156 – 177, and 177 - 198,

respectively). In addition, d 23 – 44 ADG was similar to d 44 – 65, 86 – 114, 156 – 177, and 177 – 198 but greater ($P < 0.03$) than d 65 – 86, 114 – 135, and 135 – 156, while d 44 – 65 ADG was greater ($P < 0.04$) than d 65 – 86 but similar to d 86 – 114, 114 – 135, 135 – 156, 156 – 177, and 177 – 198. Days 65 – 86 was similar to d 114 – 135 and 135 – 156 but significantly lower ($P < 0.05$) than all other days measured.

Fecal Egg Count

There was a treatment by day interaction effect ($P < 0.0001$) on FEC with Boer goats having a higher ($P < 0.0001$) FEC than Kiko and crossbred Savanna goats on d 0 and 23 (Figure 11). In addition, Boer goat FEC was greater ($P < 0.04$) than that of Kiko goats on d 198 (Figure 11). Goat FEC was significantly correlated with both BW ($P < 0.003$; r = - 0.17) and FAMACHA© scores ($P < 0.0001$; r = 0.27).

Larval Identification

The most predominant species of parasite present in the pooled fecal sample collected from Boer, Kiko, and Savanna goats at each sampling starting d 44 was *H. contortus* (Table 4).

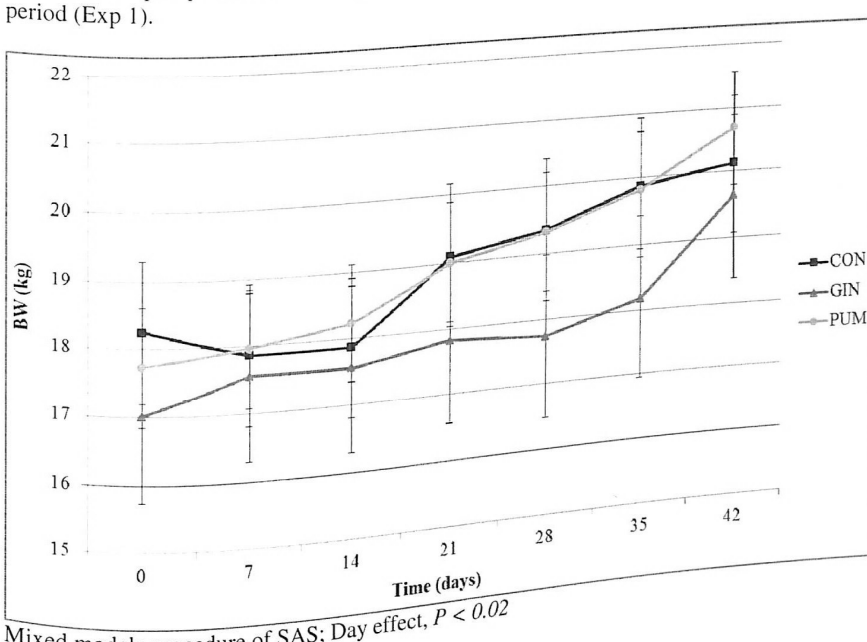
FAMACHA© Scores

There was a treatment by day interaction effect ($P = 0.0002$) on FAMACHA© scores with Boer goats having a higher ($P < 0.03$) score than both Kiko and crossbred Savanna goats on d 23 and a higher ($P < 0.03$) FAMACHA© score than Kiko goats on d 44 and 177 (Figure 12). In addition, crossbred Savanna goats had lower ($P < 0.005$) FAMACHA© scores than Boer and Kiko goats on d 135 and 156 but lower ($P < 0.03$) than only Kiko goats on d 198 (Figure 12).

Deworming Frequency

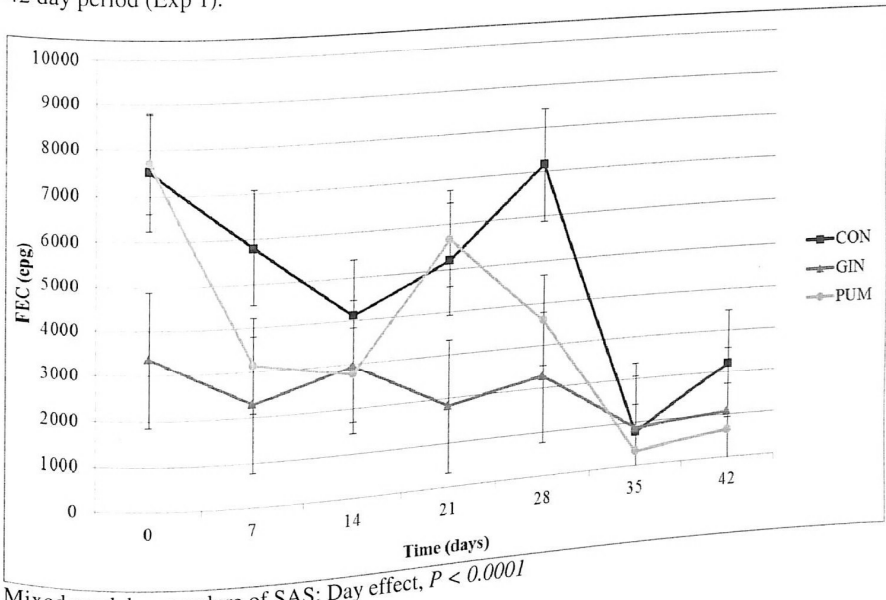
There was a tendency ($P = 0.07$) for a treatment effect on the frequency of goats dewormed. Over the study period there were a total of 42 animals treated, with Boer goats having a higher (48%) deworming frequency than Kiko (28%) and crossbred Savanna goats (24%). Of all the animals dewormed, 15 animals (9/9 Boers, 4/13 Kikos, and 2/10 crossbred Savannas) were dewormed multiple times. Overall, all Boer goats were dewormed while 66.7% of Kiko and 77.8% of the crossbred Savanna goats were dewormed at least once throughout the study period.

Figure 1. Least square means and standard error of body weights (BW) of meat goat kids treated with a pumpkin seed drench, ginger drench or water every other day over a 42 day period (Exp 1).



Mixed models procedure of SAS; Day effect, $P < 0.02$

Figure 2. Least square means and standard error of fecal egg counts (FEC) of meat goat kids treated with a pumpkin seed drench, ginger drench or water every other day over a 42 day period (Exp 1).



Mixed models procedure of SAS; Day effect, $P < 0.0001$

Table 1. Larval Identification of meat goat kids treated with a pumpkin seed drench (PUM), ginger drench (GIR), or water (CON) every other day over a 42 day period (Exp 1).

	PUM		GIR		CON	
Day	*Haemonchus contortus*	*Trichostrongylus colubriformis*	*Haemonchus contortus*	*Trichostrongylus colubriformis*	*Haemonchus contortus*	*Trichostrongylus colubriformis*
14	100%	0%	97%	3%	93%	7%
21	79%	21%	93%	7%	97%	3%
28	75%	25%	93%	7%	71%	29%
35	95%	5%	92%	8%	94%	6%
42	86%	14%	97%	3%	97%	3%

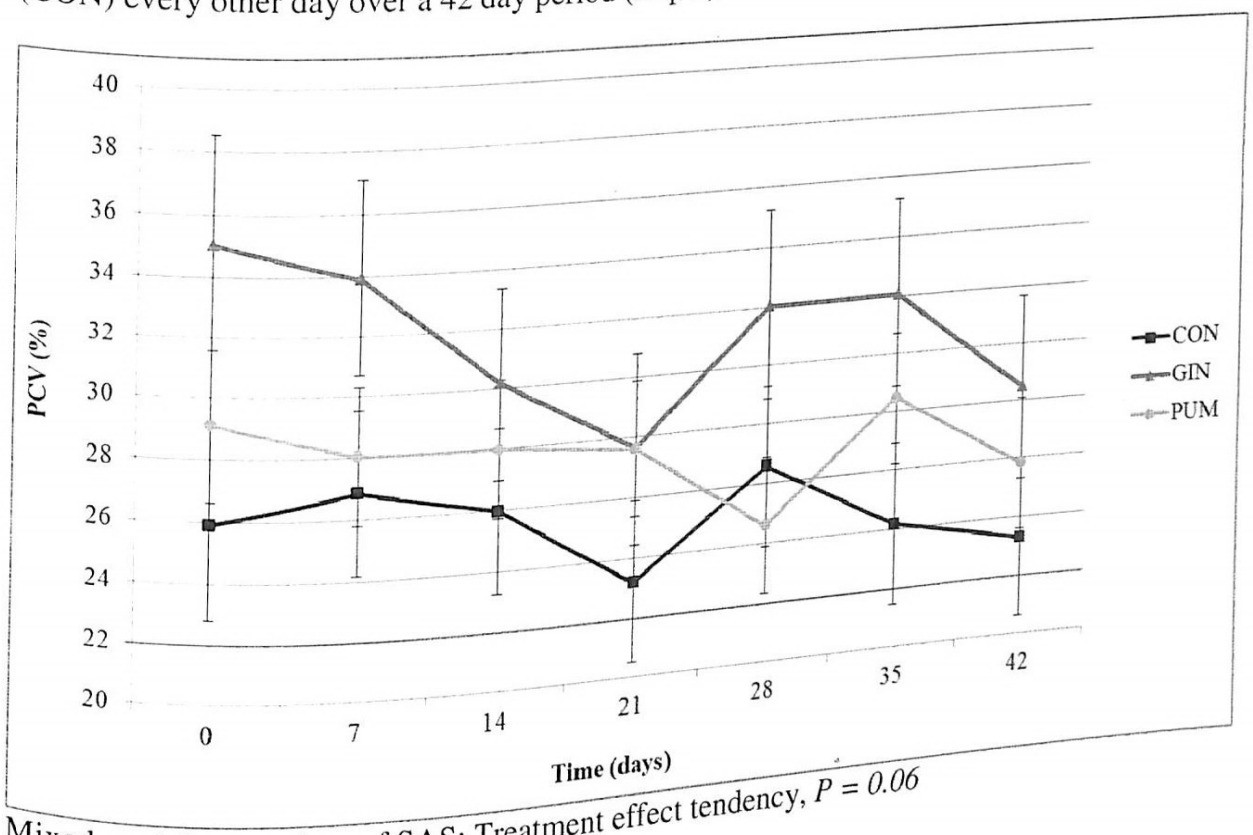
Table 2. Gastrointestinal nematodes recovered from abomasums of meat goat kids treated with a pumpkin seed drench (PUM), ginger drench (GIR) or water (CON) every other day over a 42 day period (Exp 1).

Adult Nematodes	CON	PUM	GIR	S.E.M.
Abomasum total[1]	1857[a]	869[ab]	549[b]	238
H. contortus total	1276[a]	580[ab]	312[b]	166
Adult male	481[a]	176[ab]	123[b]	67
Adult female	665[a]	301[ab]	162[b]	91
L5 male	39	33	6	7
L5 female	28	4	0	7
L4	39	42	12	16
L3	24	24	9	9
T. axei total	509	266	219	65
Adult male	258	123	138	31
Adult female	209	80	60	29
L5 male	13	16	3	4
L5 female	6	6	3	3
L4	15	33	12	8
L3	8	8	3	3
O. circumcincta total	72	23	18	23
Adult male	40	8	18	12
Adult female	32	15	0	11

Proc ANOVA procedure of SAS

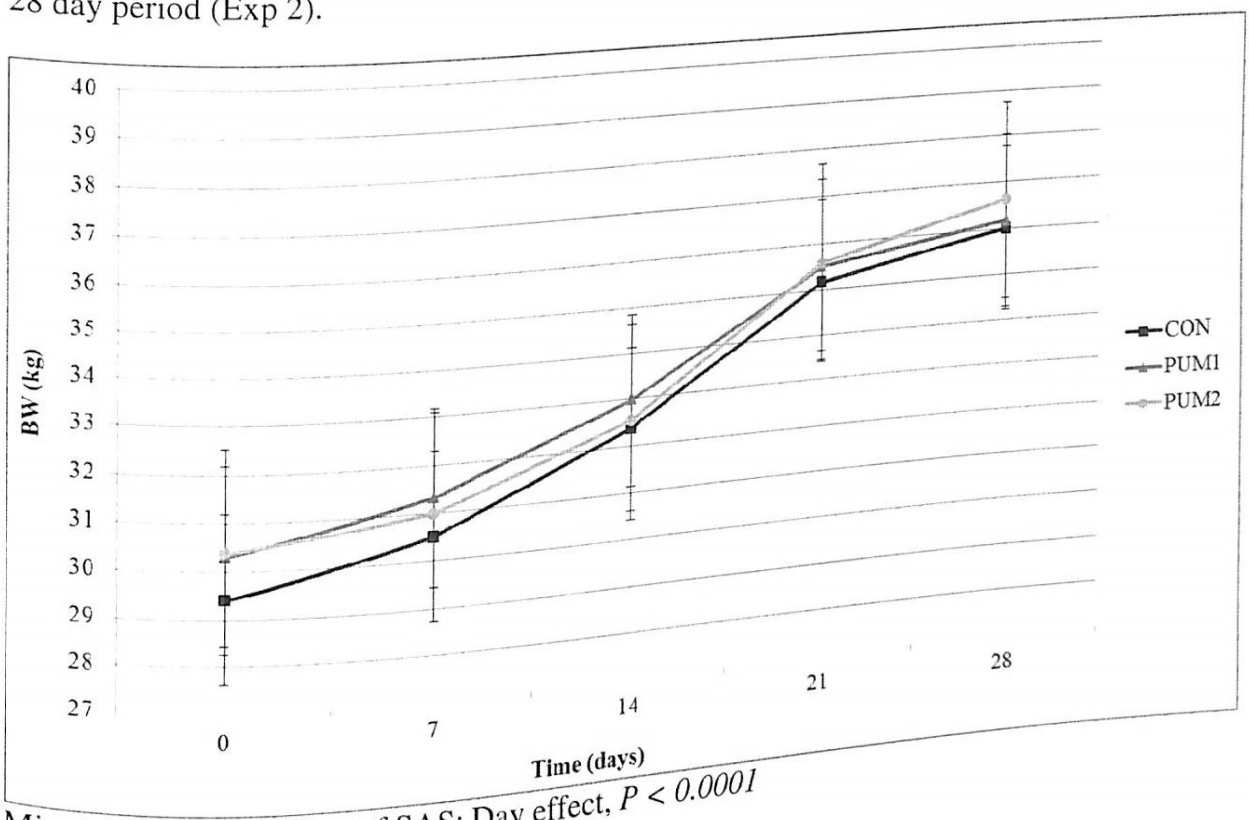
[1] Row means with different superscripts tend to differ at $0.06 < P < 0.09$

Figure 3. Least square means and standard error of packed cell volumes (PCV) of meat goat kids treated with a pumpkin seed drench (PUM), ginger drench (GIR) or water (CON) every other day over a 42 day period (Exp 1).



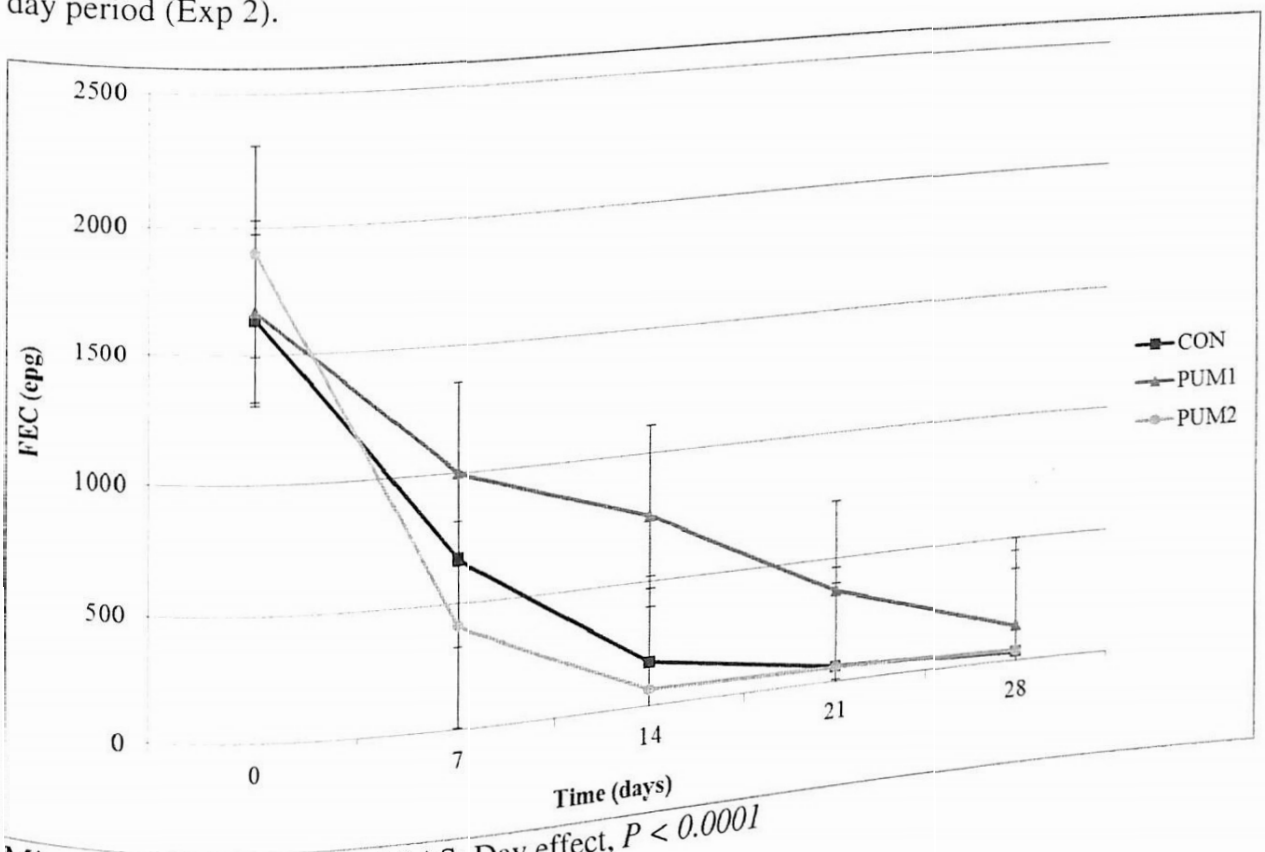
Mixed models procedure of SAS; Treatment effect tendency, $P = 0.06$

Figure 4. Least square means and standard error of body weights (BW) of lambs drenched with pumpkin seed oil once weekly or three times weekly, or with water over a 28 day period (Exp 2).



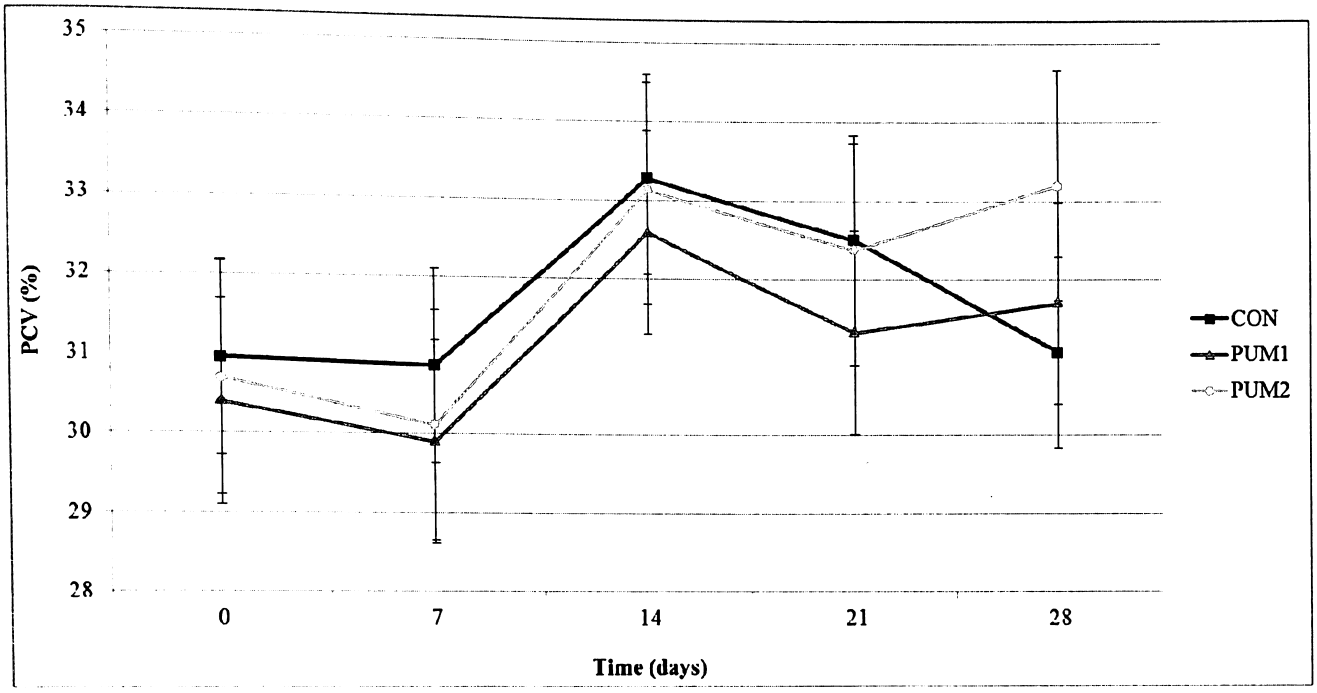
Mixed models procedure of SAS; Day effect, $P < 0.0001$

Figure 5. Least square means and standard error of fecal egg counts (FEC) of lambs drenched with pumpkin seed oil, once weekly or three times weekly, or water over a 28 day period (Exp 2).



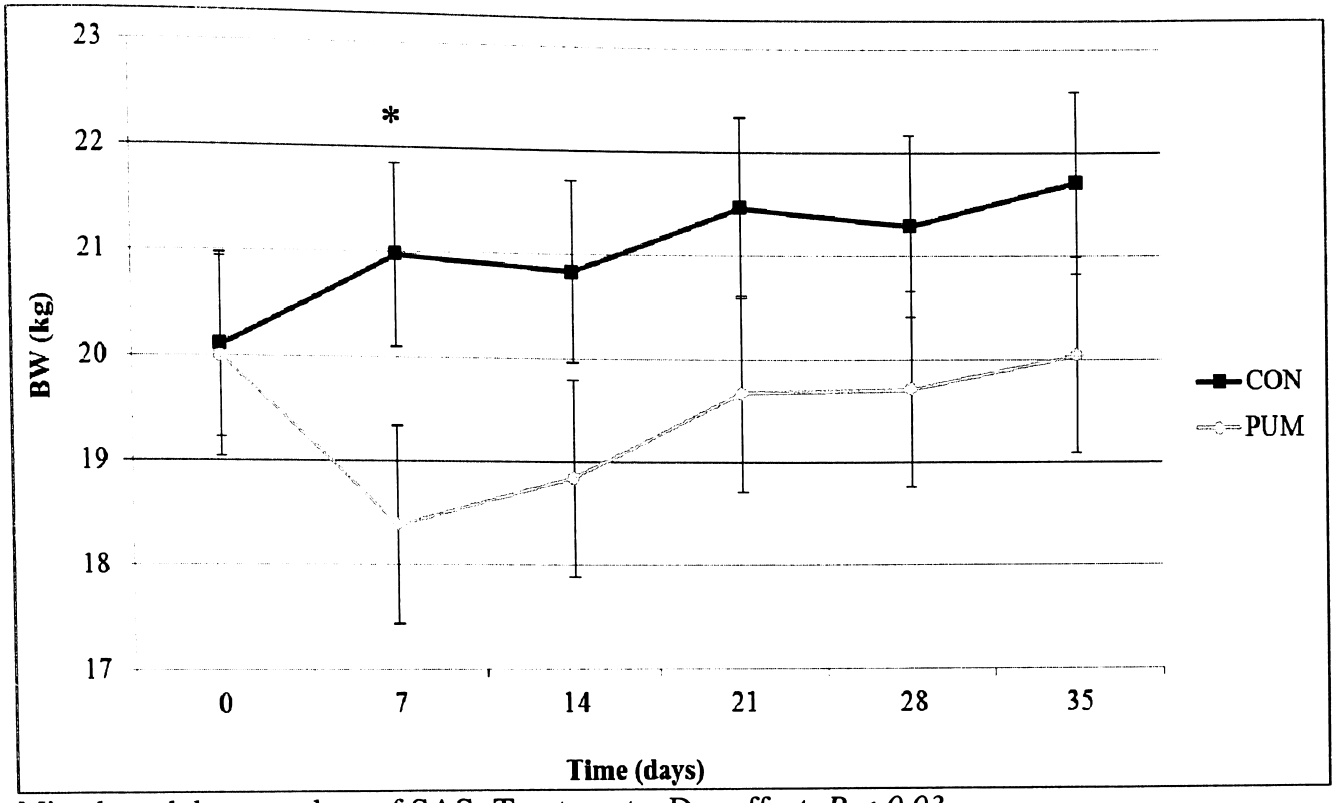
Mixed models procedure of SAS; Day effect, $P < 0.0001$

Figure 6. Least square means and standard error of packed cell volumes (PCV) of lambs drenched with pumpkin seed oil, once weekly or three times weekly, or water over a 28 day period (Exp. 2).



Mixed models procedure of SAS; Day effect, $P < 0.04$

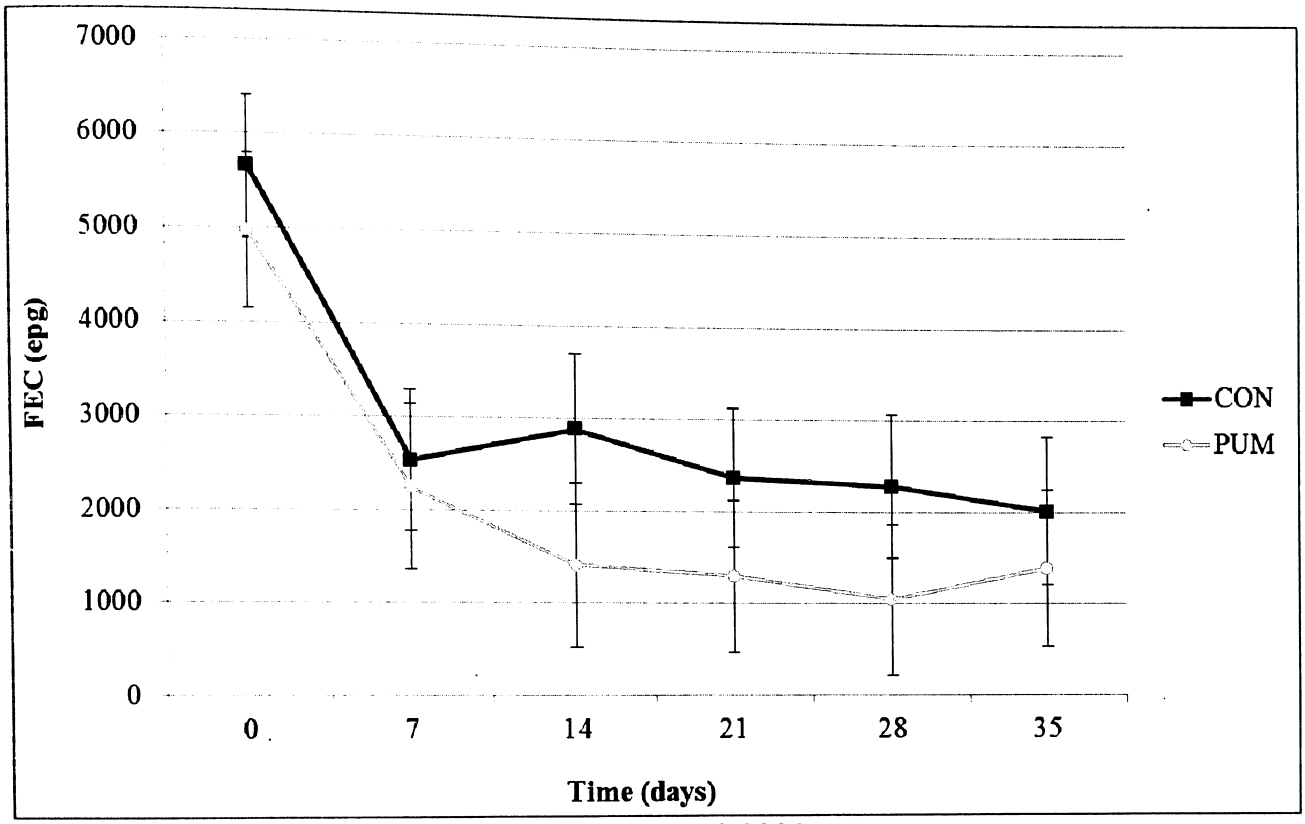
Figure 7. Least square means and standard error of body weights (BW) of meat goat kids drenched with pumpkin seed oil or water every other day over a 35 day period (Exp. 3).



Mixed models procedure of SAS; Treatment x Day effect, $P < 0.03$

* Indicates significance at $P < 0.05$

Figure 8. Least square means and standard error of fecal egg counts (FEC) of meat goat kids drenched with pumpkin seed oil or water every other day over a 35 day period (Exp. 3).

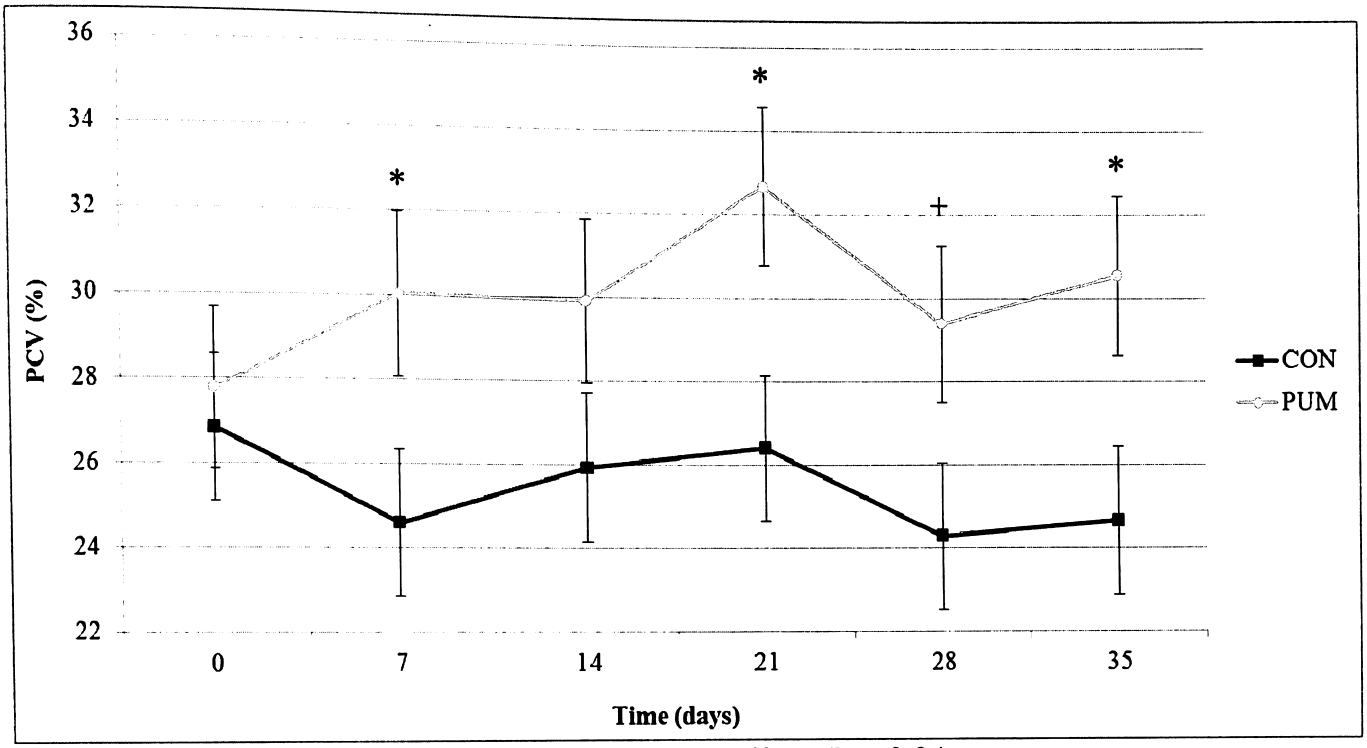


Mixed models procedure of SAS; Day effect, $P < 0.0001$

Table 3. Larval Identification of meat goat kids drenched with pumpkin seed oil (PUM) or water (CON) every other day over a 35 day period (Exp 3).

	CON			PUM		
Day	*Haemonchus contortus*	*Trichostrongylus colubriformis*	Other	*Haemonchus contortus*	*Trichostrongylus colubriformis*	Other
0	81%	14%	5%	62%	7%	31%
7	80%	15%	5%	71%	25%	4%
14	71%	9%	20%	48%	28%	24%
21	73%	10%	17%	57%	25%	18%
28	65%	9%	26%	57%	9%	34%
35	67%	11%	22%	43%	54%	3%

Figure 9. Least square means and standard error of packed cell volumes (PCV) of meat goat kids drenched with pumpkin seed oil or water every other day over a 35 day period (Exp 3).

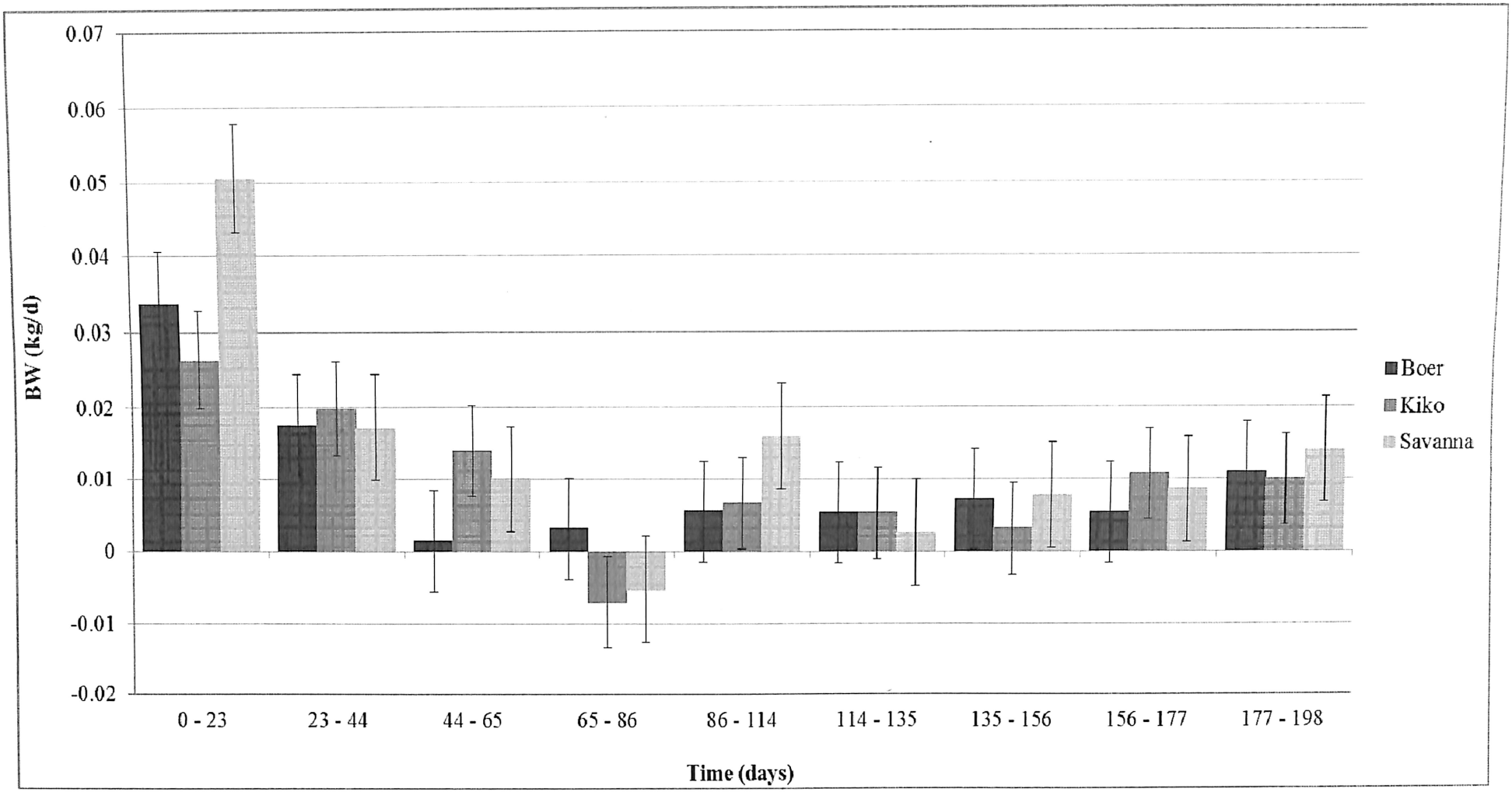


Mixed models procedure of SAS; Treatment x Day effect, $P < 0.04$

* Indicates significance at $P < 0.05$

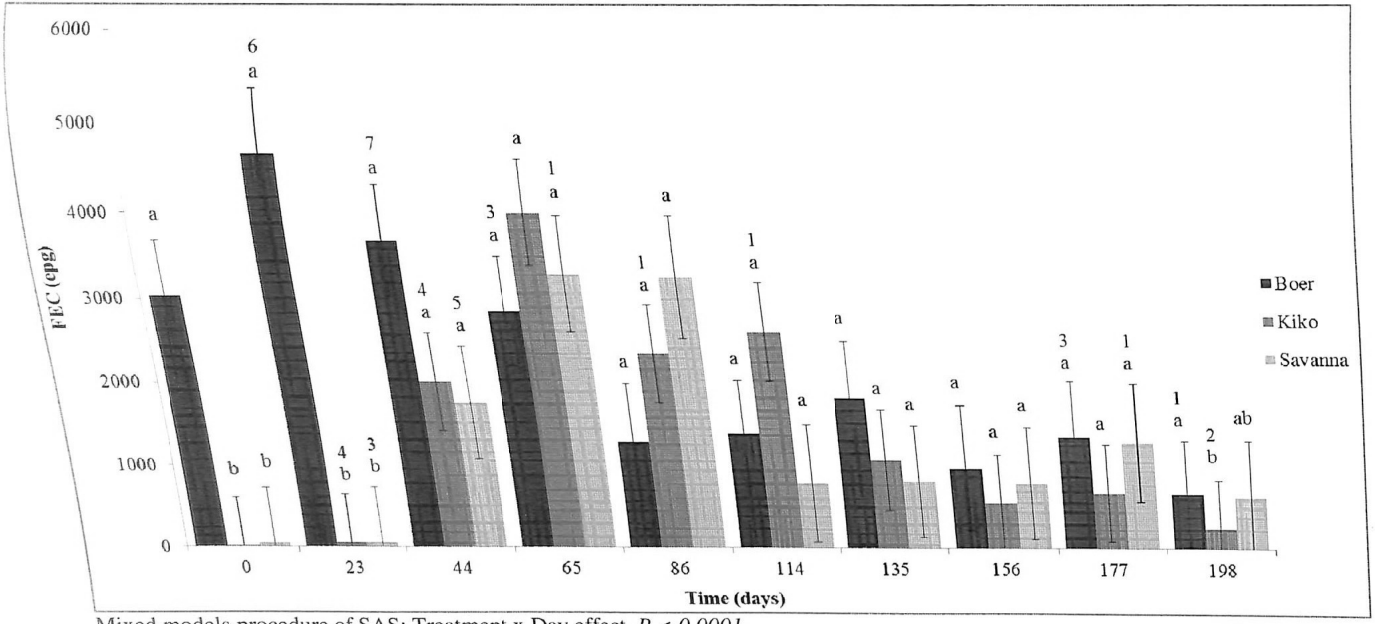
+ Indicates a tendency at $P = 0.05$

Figure 10. Least square means and standard error of average daily gain (ADG) of Boer, Kiko, and crossbred Savanna goats over a 198 day period (Exp 4).



Mixed models procedure of SAS; Day effect, $P < 0.0001$

Figure 11. Least square means and standard error of fecal egg counts (FEC) of Boer, Kiko, and crossbred Savanna goats over a 198 day period (Exp 4).

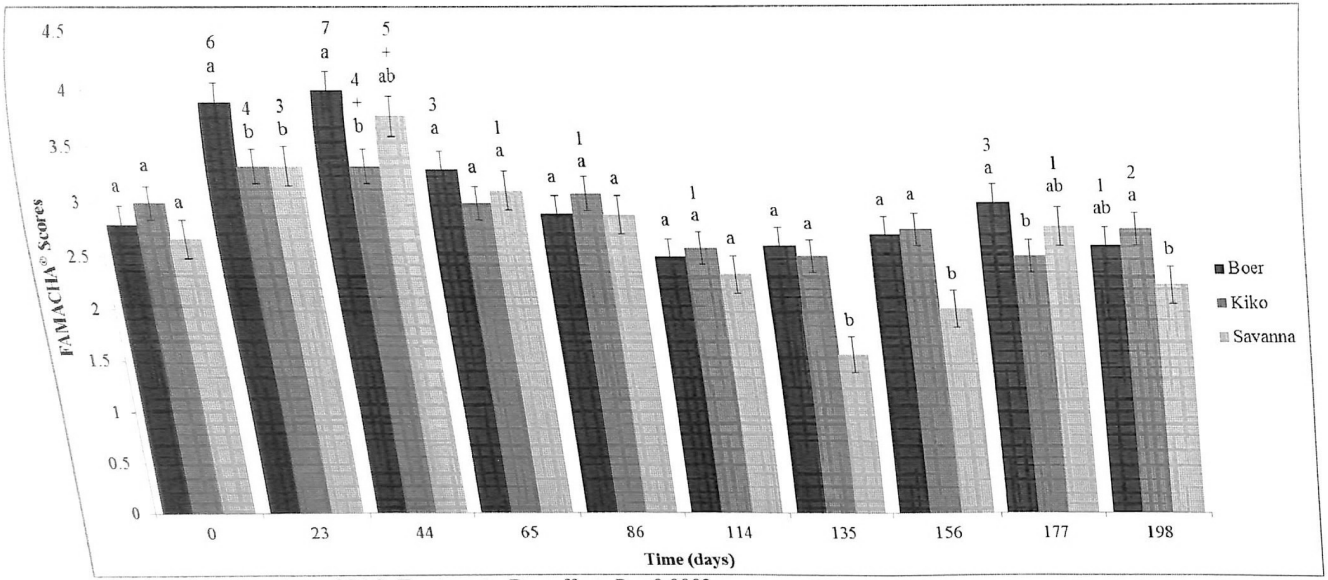


Mixed models procedure of SAS; Treatment x Day effect, $P < 0.0001$
Means with different letters differ ($P < 0.04$)
Numbers above bars indicates number of animals dewormed at that sampling

Table 4. Larval Identification of Boer, Kiko, and crossbred Savanna goat parasites over a 198 day period (Exp 4).

	Boer			Kiko			Savanna		
Day	*Haemonchus contortus*	*Trichostrongylus colubriformis*	Other	*Haemonchus contortus*	*Trichostrongylus colubriformis*	Other	*Haemonchus contortus*	*Trichostrongylus colubriformis*	Other
44	68%	15%	17%	77%	13%	10%	66%	20%	14%
65	72%	13%	15%	68%	6%	26%	78%	13%	9%
86	74%	24%	2%	68%	10%	22%	78%	14%	13%
114	79%	18%	3%	70%	10%	20%	73%	15%	12%
135	66%	25%	9%	70%	25%	5%	63%	24%	13%
156	75%	23%	2%	68%	26%	6%	71%	20%	9%
177	72%	22%	6%	62%	24%	18%	77%	13%	10%
198	54%	33%	13%	64%	28%	8%	74%	15%	11%

Figure 12. Least square means and standard error of FAMACHA© scores of Boer, Kiko, and crossbred Savanna goats over a 198 day period (Exp 4).



Mixed models procedure of SAS; Treatment x Day effect, $P = 0.0002$
Means with different letters differ ($P < 0.03$)
$^{+}$ Indicates a tendency at $P = 0.06$
Numbers above bars indicates number of animals dewormed at that sampling

CHAPTER V

Discussion

The results of experiments 1, 2 and 3 indicated that pumpkin seed administered as a drench or oil under the conditions of these studies were not effective in reducing FEC in meat goat kids and Katahdin lambs. The seed of squash, pumpkins and many other vine crops is believed to contain a potential deworming compound called cucurbitacin and has been studied in goats and lambs (Waller, 1999; Strickland *et al.*, 2009). Cucurbitacin is a phytochemical that is thought to be responsible for the anthelmintic properties of pumpkin seeds (Blumenthal *et al.*, 1998). In a preliminary study conducted at Delaware State University in 2007, a single pumpkin seed drench was effective in numerically preventing a rise in FEC after 7 days. The FEC of the CON animals increased by 56%, while the PUM-treated animals decreased by 11% (O'Brien, 2007; unpublished data). However, in Exp 1 of this study, a similar pumpkin seed drench used was not effective in reducing FEC in meat goat kids. It should be noted that the animals on the O'Brien (2007) study were on pasture and getting re-infected while those in Exp 1 were on concrete. In addition, in Exp 1, no kids in the PUM-treated group were dewormed while 3 kids from the CON group and 5 from the GIR group were dewormed and had to be removed from the study. The PUM-treated animals had FEC as high as those animals in the CON and GIR groups, however, none showed clinical signs of infection and therefore were not dewormed.

Contrary to the results in Exp 1, in a 2001 producer trial in Suffolk lambs, it was found that a single dose of pumpkin seeds (6 oz/75 lbs) appeared to be effective in

controlling parasite loads (Exner *et al.*, 2004). This study was conducted over a 28 d period and FEC began decreasing after 10 d on pumpkin seeds (administered in feed; Exner *et al.*, 2004). In another producer trial conducted in lambs, the pumpkin seed group went from having the highest fecal egg counts on day 21 to having the lowest on day 50 (Exner *et al.*, 2002). In addition, Strickland and colleagues (2009) found pumpkin seeds to be effective in controlling GIN in sheep. Strickland *et al.* (2009) fed pelleted pumpkin seeds, mixed in feed at a rate of 0.33 g/kg BW to lambs for 21 days and found that after two weeks, FEC were significantly lower than the control group. Contrary to this and similar to the results found in Exp 1, a previous study conducted at Delaware State University (O'Brien *et al.*, 2009) found that ground pumpkin seeds mixed in with feed were not effective in reducing FEC in meat goat kids. In that study, however, it was noted that goat kids sorted through the feed and did not consume a consistent amount of pumpkin seeds, mostly eating the pelleted feed (O'Brien *et al.*, 2009). From these results, it was concluded that alternative means of administering the pumpkin seeds might be more effective, so pumpkin seed oil was tested in Katahdin lambs (Exp 2) and meat goat kids (Exp 3) to determine its efficacy in reducing FEC.

Overall, the controlled experiments conducted at DSU indicate that pumpkin seeds, pumpkin seed drench or pumpkin seed oil were not effective in reducing FEC in meat goat kids or Katahdin lambs. The ineffectiveness of these pumpkin seed treatments could be due to the cucurbitacin content, which was not measured in these experiments. Future studies should attempt to measure and record cucurbitacin content in pumpkin treatments in order to effectively make comparisons based on the quantities of this active

ingredient. In addition, more animals should be used per treatment to make the data even more statistically rigorous.

Pumpkin seed treatments had no effect on PCV in Exp 1 and 2. However, there was a treatment by day interaction effect on PCV in Exp 3. Packed cell volume on d 7, 21, and 35 were greater in PUM-treated animals than CON-animals. In addition, there was a tendency for PCV to be greater for PUM-treated animals on d 28. On the contrary, Shaik *et al.* (2006) found that treatment goats with significantly higher PCV in their study had significantly lower FEC as well. Similar to Shaik *et al.* (2006), Terrill and colleagues also found that when PCV increased in goats, there was a decrease in FEC. The most probable-reason for the differences in PCV in Exp 3, even though there were no differences in FEC, may be due to resilience. In addition, pumpkin seeds are known to be rich in protein. Therefore, extra supplementation with pumpkin seeds could have allowed the animals in that treatment to demonstrate less clinical symptoms regardless of their level of infection.

Pumpkin seed administered as a drench in goats (Exp 1) or oil (Exp 2) in lamb had no effect on BW. However, pumpkin seed oil administered in goats had an effect on BW in Exp 3, with CON animals having a greater BW than PUM-treated animals on d 7. This is most likely due to fact that there was no adjustment period to the pumpkin seed oil in this experiment. This had an effect on feed intake in the PUM-treated animals. Even though not reported in the results, PUM-treated animals in this Exp consumed significantly less feed than the CON animals (0.46 kg/d and 0.58 kg/d, respectively). On average, PUM-treated kids were drenched with 41.5 ml of pumpkin seed oil, and even though there no differences in feed intake in lambs in Exp 2, this amount of oil every

other day in kids resulted in reduced feed intake over the study period, which most likely resulted in the significant decrease in body weight from d 0 to 7.

In addition to pumpkin seeds, ginger has been used as an anthelmintic purge for cattle, horses, and lambs (Duval, 1997; Iqbal *et al.*, 2006). Iqbal and colleagues (2006) examined the efficacy of ginger administered as a drench or a powder in lambs and concluded that the drench (3 g/kg BW) was more effective in controlling parasite infections than administering a powder. The 3 g/kg dose drench and powder were able to reduce FEC by 66% and 24%, respectively (Iqbal *et al.*, 2006). However, there is limited data available on the efficacy of ginger and this is why it was included in Exp 1 of the present study. Contrary to the results of Iqbal and colleague (2006), ginger as a drench in Exp 1 was not effective in reducing FEC. The difference in results, however, could be due to differences in preparation of the ginger treatment used in this study. In addition, differences in worm species present could also be a possible reason.

In Exp 1, there was a tendency for GIR-treated animals to have a higher PCV than CON animals but similar to that of PUM-treated animals. As indicated in Table 2, GIR-treated meat goat kids had significantly lower numbers of total worms in the abomasum compared to the CON animals. In addition, even though not significantly different, GIR-treated kids had a numerically lower total number of adult male, adult female, and total *H. contortus* compared to CON kids. This lower number could have resulted in higher PCV since anemia, as indicated by low PCV, is highly correlated with the level of *H. contortus* infection in small ruminants.

The ADG of the goats in Exp 4 was not influenced by treatment or a treatment by day interaction effect. However, there was an influence of day with differences noted

possibly due to the individual age within each breed group and differences in parasite challenges faced. The similarity in ADG for each treatment in this study is most likely due to the similarity in nutrition throughout the study period. Animals in all treatment had ad libitum forage, water, and minerals throughout the study period and grass hay was supplemented when there was minimal forage growth observed in paddocks.

The results of Exp 4 indicated that Boer goats had a higher FEC than Kiko and crossbred Savanna goats on d 0 and 23. Although all animals were dewormed with moxidectin and levamisole prior to the beginning of the study, Boer goats still had a higher FEC on d 0 and 23. This high FEC in Boer goats following deworming could be due to GIN resistance. Crook *et al.* (2010), found incidence of resistance to the three classes of anthelmintics on sheep and goat farms in the mid-Atlantic region of the US. Similar to the current study, however, Browning and Leite-Browning, (2009) found that more Boer does experienced a higher level of internal parasitism (50 ± 5%) than Kiko does (31% and 17%). It was also indicated in a preliminary studies that Kiko does demonstrated hardiness when exposed to conditions conducive to internal parasitism (Browning *et al.*, 2006). Due to the suspected resistance in Boer goats used in this preliminary study as well as low numbers of animals included, no specific conclusions can be made at this time.

There was also a breed by day interaction effect on FAMACHA© scores with Boer goats having a higher score than Kiko and crossbred Savanna goats on d 23 and a higher score than Kiko goats on d 44 and 177. In addition, crossbred Savanna goats had lower FAMACHA© scores than Boer and Kiko goats on d 135 and 156 but lower than only Kiko goats on d 198. Since the primary clinical sign of an infection with *H.*

contortus is anemia, the FAMACHA© system is an effective tool for identifying animals within a herd that require treatment due to haemonchosis (Kaplan *et al.*, 2004a). There was a significant correlation between FEC and FAMACHA© scores in this study, therefore, it is expected that if there were differences in FEC, then there would also be a corresponding difference in FAMACHA© scores. Larval ID data also confirms that the most predominant parasite present in these breeds was *H. contortus*. Similarly, Burke *et al.* (2007) found that FAMACHA© scores were significantly correlated to FEC. Animals in this study were dewormed according to their FAMACHA© scores with Boer goats being dewormed more frequently than Kiko and crossbred Savanna goats. This corresponds to higher FEC and FAMACHA© scores observed in this breed.

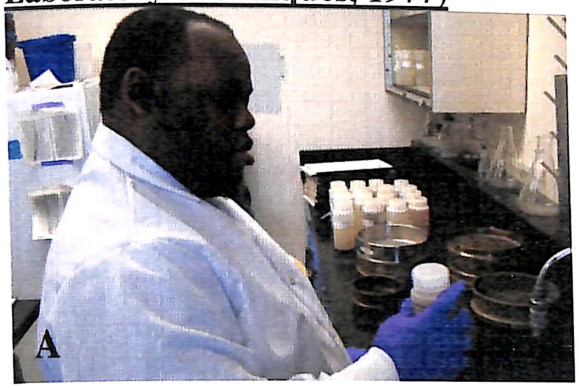
CHAPTER VI

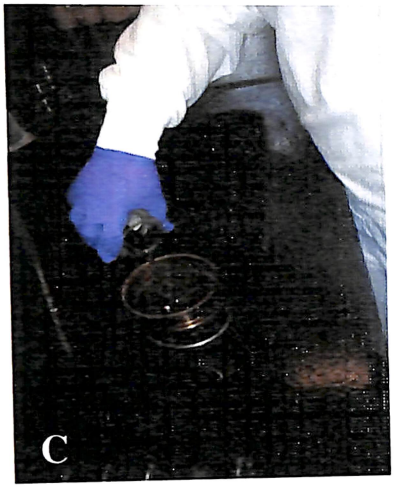
Conclusion and Implication

In conclusion, under the conditions of these experiments, natural dewormers tested were not effective in reducing FEC of goats (pumpkin seed oil and drench, and ginger) and sheep (pumpkin seed oil). As for the influence of goat breed on GIN indicators, no specific conclusions can be made at this time due to limited numbers of each breed type used in the study. However, with current research indicating that there is an increase in GIN resistance to chemical anthelmintics, it is vital for the small ruminant industry that research identifies effective alternative means of parasite control for future recommendations. These experiments indicate that the natural dewormers tested were not effective in causing a significant reduction in FEC, however, these products might still play a role in an integrated management practice where they are combined with other control strategies. In addition, the selection of breeds or individual hosts with resistance to parasites may offer the most promising natural/biological means of parasite control and studies should continue to evaluate breed resistance and resilience to control internal parasite infections in small ruminants.

CHAPTER VII

Appendix 1: Abomasal worm count (Manual of Veterinary Parasitological Laboratory Techniques, 1977)





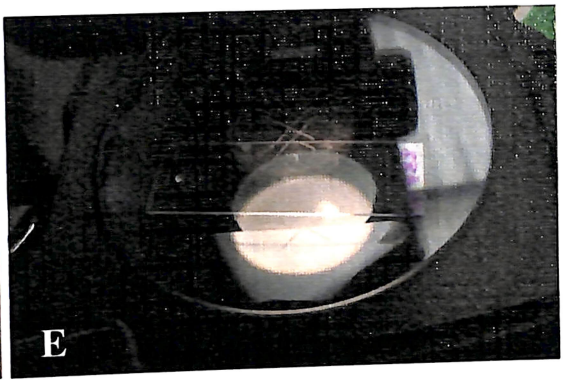
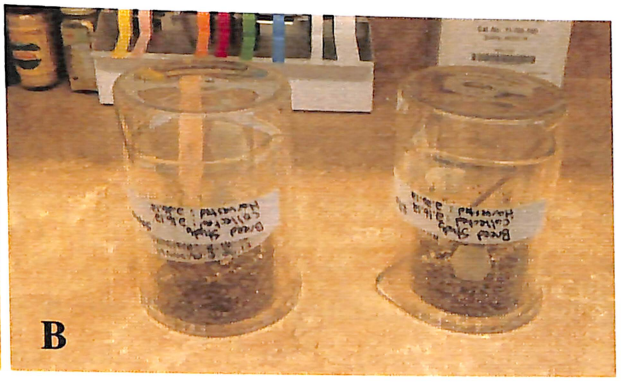


Figure A: Samples were shaken gently about 15 times, to suspend contents evenly.
Figure B: After which, 100 ml was measured from the aliquot in a beaker.
Figure C: The 100ml sample was strained through 75and 100 microns sieve.
Figure D: Sample was washed with a steady stream of tap water until no more food matter passed through both sieves. Using the stream of water on the back of both sieves, nematodes and food material were collected into 2 clean beakers and 2 drops of iodine was added (not pictured).

Figure E: Mixture from the beaker was poured into a petri dish and placed under a dissecting microscope where worms were picked up with a bent tuberculin needle (not pictured). Slides were then labeled and lactophenol was added. After which 10 worms were placed on each slide for differentiation and percentage of each species was calculated.

Appendix 2: Larval Identification (Pena *et al.*, 2002)



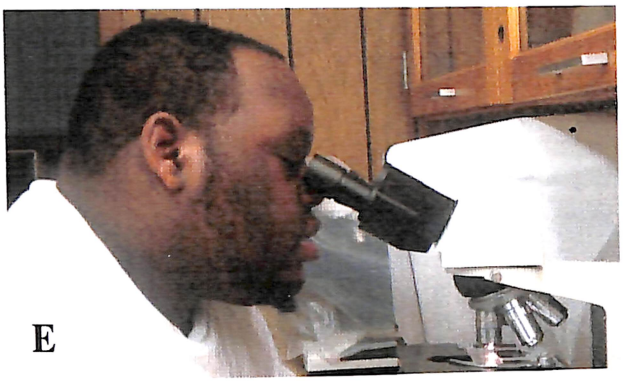


Figure A: Pooled fecal samples were placed in 500 ml beakers and vermiculite was added to the feces at roughly a 1:1 ratio.

Figure B: The jar was then labeled with a collection date and harvesting date, and water was added as needed over a 10 d period if the sample became too dry, giving parasites a favorable moist environment.

Figure C: After 10 d, a base layer of warm water was poured into a funnel with a ¼ inch wire screening, a layer of Kimwipes and a double layer of cheesecloth in the bottom, and a tube with a clamp attached to the end. The fecal mixture was added and soaked to the top of the funnel with warm water and allowed sit for 12 h.

Figure D: 50 ml centrifuge tubes were filled with sample and refrigerated for 3 h to allow larvae to settle after which the supernatant in both tubes was pulled off and the larvae combined in one tube. The centrifuge tubes were then heated at 55° C in a heatblock for 10 – 15 and stained with 50% lugol's iodine (not pictured).

Figure E: After iodine was added, solution containing the larvae was transferred to a standard slide and 100 larvae identified and counted for differential percentages of GIN present.

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A background in animal science with a focus in small ruminants and have 6 published abstracts. Assist in teaching college level students.

EDUCATION

M.S.	05/12 expected	Animal Science: Small Ruminant Parasitology	Delaware State University, Dover, DE
B.S.	12/09	Agriculture Business	Delaware State University, Dover, DE
A.D.	05/07	Business Studies – Computer Major	Moneague Community College, St. Ann, Jamaica

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AWARDS AND SCHOLARSHIPS

- First place poster presentation at Delaware State University Graduate Symposium, 2011
- Full-time Graduate Research Assistantship, 2010-2012
- Dean's List Fall 2008 and Spring 2009
- Outstanding Performance in the Council of Community Colleges of Jamaica Job Placement, 2005-2007

CLUBS AND ACTIVITIES

- American Society of Animal Science (2009 – present)
- Delaware State University Minorities in Agriculture, Natural Resources and Related Sciences (MANRRS), 2007-2009

EXPERIENCE

Graduate Research Assistant, Delaware State University **2010 –2012**
Animal Science Masters Degree Program

Advisor: Dr. Dahlia O'Brien
Thesis title: Plant Dewormer and Breed Resistance to Reduce Internal Parasite Infections in Small Ruminants

Other:

- Use of Goats for Invasive Weed Control
- Use of CIDRS and prostaglandin in synchronizing estrus in meat does and ewes and effect on subsequent fertility, also use of MGA, CIDRs, the buck effect, and PMSG to synchronize estrus in goats

Specific Research Procedures performed –

Fecal egg counts (Modified McMaster's technique)
Larval isolation and identification
Blood/serum collection and processing
Estrus detection in sheep and goats
Management of ewes and does during gestation, parturition and lactation
General daily animal care
Training in cattle and goat artificial insemination

Related Employment and Experiences

Seasonal Technician, Delaware State University **March 2010 – August 2010**
Supervisor: Dr. Dahlia O'Brien
Work closely with Small Ruminant Specialist to facilitate and conduct research.
Assist in developing the Small Ruminant Parasitological lab
Assist in animal care
Basic farm upkeep
Assist with class laboratories

Student Research Assistant, Delaware State University **September 2007 – December 2009**
Supervisor: Dr. Dahlia O'Brien
Assist in the care and treatment of small ruminants (sheep and goats)
Assist with graduate and undergraduate student research

Conducted research using natural dewormers for parasite control in goats (undergraduate student)

PRESENTATIONS

Efficacy of pumpkin seed oil in controlling internal parasites in Katahdin lambs. American Society of Animal Science Southern Section Meeting. February, 2012. Oral Presentation

"Gastrointestinal nematode (GIN) resistance and GIN management on small ruminant farms in the mid-Atlantic U.S." American Society of Animal Science Joint Annual Meeting. July, 2011. Poster Presentation

Estrus, Mating and Fertility Response in Meat Goats Following Estrus Synchronization Protocols. Delaware State University Graduate Research Symposium. April, 2011. Poster Presentation. 1st Place

Estrus, Mating and Fertility Response in Meat Goats Following Estrus Synchronization Protocols. ARD 16th Biennial Research Symposium. April, 2011. Poster Presentation

"Natural plant anthelmintic fails to reduce internal parasites in meat goat kids." American Society of Animal Science Joint Annual Meeting. July, 2009. Poster Presentation

"Natural plant anthelmintic fails to reduce internal parasites in meat goat kids." Delaware State University, Honors Day. April, 2009. Oral Presentation

TEACHING EXPERIENCE

AGRI 29-206 Introduction to Animal Science: Teaching Assistant.
Assisted in lecture during the absence of the professor. Coordinated and instructed weekly laboratories for this course. All laboratories consisted of hands on learning experiences or calculations.

AGRI 29-406 Beef and Sheep Production: Teaching Assistant.
Assisted in lecture during the absence of the professor. Coordinated and instructed weekly laboratories for this course. All laboratories consisted of hands on learning experiences or calculations.

OUTREACH EXPERIENCE

Delaware State University HBCU-UP program, demonstrated and discussed FEC procedure, 2008-2009.

Farm tours for elementary students, Delaware State University. 2008 – 2011.

Delaware State University Juneteenth Education & Enrichment Celebration, provided information on research and gave farm tour. Hickory Hill Farm, Delaware State University. 2011.

ABSTRACTS

***K.K. Matthews**, D.J. O'Brien*, N.C. Whitley, J.E. Miller, and J.M. Burke. Efficacy of pumpkin seed oil in controlling internal parasites in Katahdin lambs. Southern Sections 2012.

*D.J. O'Brien, **K.K. Matthews***, E.K. Crook, N.C. Whitley, B. Storey, S. Howell, and R. Kaplan. Gastrointestinal nematode (GIN) resistance and GIN management on small ruminant farms in the mid-Atlantic U.S. American Society of Animal Science Joint Annual Meeting. New Orleans, LA.

***K. K. Matthews**, D. J. Jackson-O'Brien*, E. Crook, J. Eierman, and N. C. Whitley, Estrus, Mating and Fertility Response in Meat Goats Following Estrus Synchronization Protocols. Graduate Symposium. Delaware State University. Dover, DE. **1st Place Graduate Poster Presentation**

***K. K. Matthews**, D. J. Jackson-O'Brien*, E. Crook, J. Eierman, and N. C. Whitley. 2011. Estrus, Mating and Fertility Response in Meat Goats Following Estrus Synchronization Protocols. ARD 16th Biennial Research Symposium. Atlanta, GA.

D.J. O'Brien, ***K.K. Mathews***, J.E. Miller, N.C. Whitley, T. Hebb, E.K. Crook, J.L. Eierman. 2009. Natural plant anthelmintic fails to reduce internal parasites in meat goat kids. J. Anim. Sci. 87 (E - Suppl. 2):128.

***K.K. Mathews**, D.J. O'Brien*, J.E. Miller, N.C. Whitley, T. Hebb, E.K. Crook, J.L. Eierman. 2009. Natural plant anthelmintic fails to reduce internal parasites in meat goat kids. DSU Honor's Day.

REFERENCES

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