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Distribution of infection with gastro-intestinal nematodes in different groups of dairy goats in Switzerland and its influence on milk production

Master Thesis

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1. Introduction/Background

Worldwide, goats play an important role in livestock production, particularly in smallholder farms in Asia and Africa. About 90% of the total number of 880 million animals in 2009 are found there (FAO, 2009). In recent years goats also gained importance in Switzerland. After decades of declining goat production the number of goats increased by about 30% within 10 years from 67 000 animals in 2000 to 87 000 in 2010 (Bundesamt für Statistik, 2010). This increase is mainly caused by the rising demand for goat milk products.

In small ruminant livestock production health disorders caused by gastro-intestinal parasites are highly important affecting all animals particularly those with access to pasture. The majority of gastro intestinal nematodes (GIN) belong to the order Strongylida and therefore the term GIN in this work will be used as synonym for this group of nematodes. The most important genera of this group are represented by *Haemonchus sp, Teladorsagia sp, Trichostrongylus sp.,* and *Cooperia sp.* (Schnieder et al., 2006). GIN parasitize the abomasum or the small intestines of their host and can lead to reduced feed intake (Coop et al., 1982), protein losses in the gastrointestinal tract (Poppi et al., 1986) and in the case of *Haemonchus contortus*, a blood sucking nematode of the abomasum, to serious blood loss (Le Jambre, 1995). Particularly in kids, serious production losses and high cost of treatments arise (Nieuwhof and Bishop, 2005). In Great Britain alone the annual cost of GIN infections in sheep are estimated at £84 million due to performance losses, preventive measures and treatment costs (Nieuwhof and Bishop, 2005).

The nematode species which are responsible for parasitic gastroenteritis in goats have a life cycle starting with the excretion of the eggs in the feces of the host. The larvae develop through several weeks or months, depending on weather and temperature, until they are taken up again by the grazing animals (Figure 1). A complex set of factors influence the development and survival of larvae on pasture (Schnieder et al., 2006).

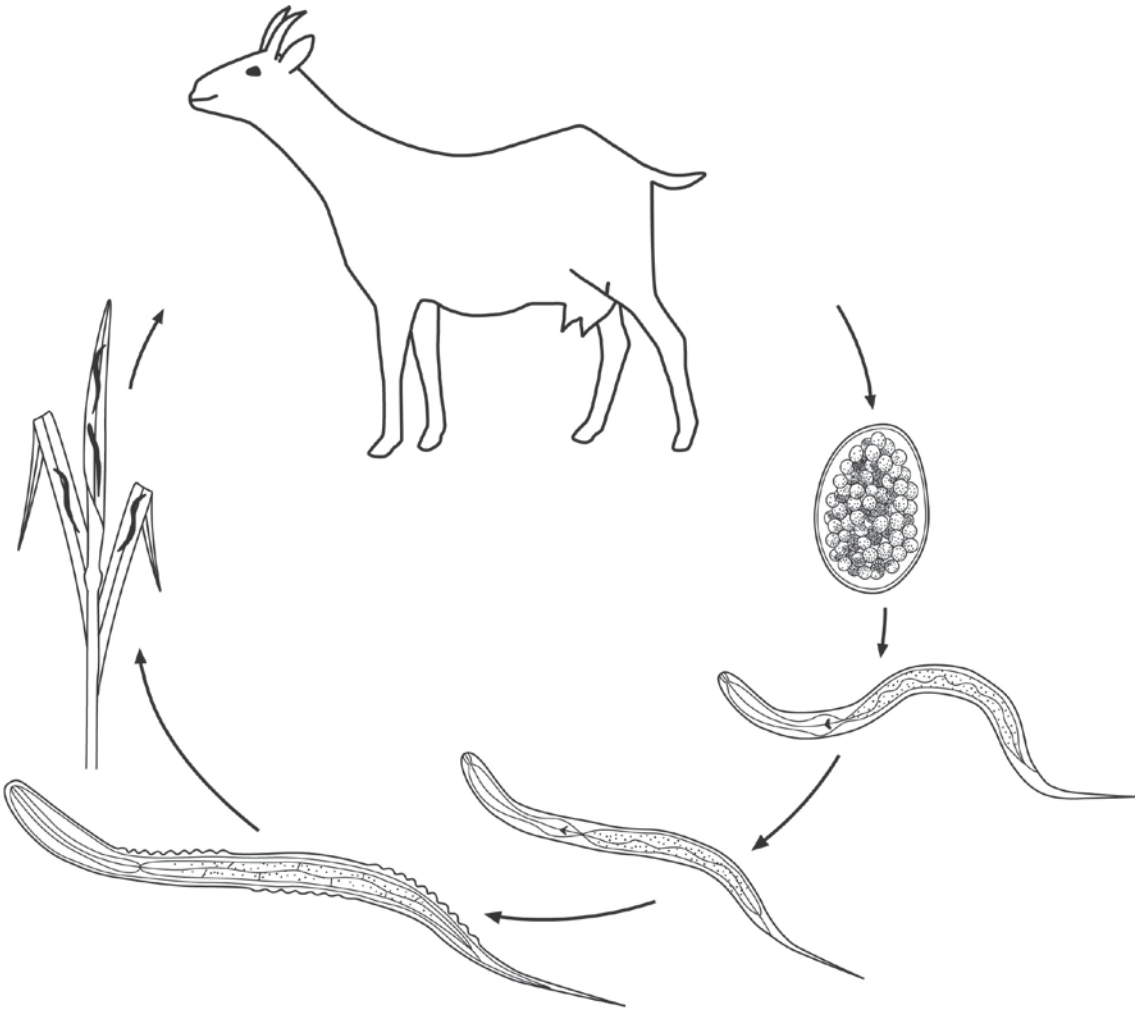

Figure 1: Life cycle of trichostrongyles: After excretion of GIN eggs with feces, non-parasitic L1- and L2-larvae develop. Infectious L3-larvae are spread in the surrounding by precipitation and other mechanical impact and move to the upper layers of the vegetation where they are taken up by the host again. Depending on weather conditions the development to L3 in Central Europe usually lasts 3 to 5 weeks in summer and 2 to 3 months in autumn and spring. In winter L3 can stay inactive on pasture. After uptake parasitic L4-larvae and finally adult worms develop which are able to excrete eggs. The prepatence period within the host lasts 2-4 weeks. In some cases L3 arrest development after uptake by the host and continue their development after 4-6 month. This strategy, which can be initiated by lower temperatures or immunological factors of the host, only applies for a small part of the population and can be interpreted as one way to ensure egg excretion in spring (Schnieder et al., 2006).

The most common practice to control GIN in dairy goats in Switzerland is the treatment of the whole flock with synthetic anthelmintics several times a year (Meyer, 2001). This approach causes some negative effects. First, consumer concerns about drug residues and regulations especially in organic farming put pressure on farmers to switch from synthetic drugs to alternative treatments or preventive control methods (Bio Suisse, 2011; IFOAM, 2011). Secondly the costs for such treatments are quite high with approximately

€15/year/animal (cost for drugs only, personal communication F. Heckendorn). Furthermore most anthelmintics in use have a withdrawal period for meat and milk of several days which, particularly in the case of milk, leads to a loss of income during this time, without any reduction of labor or feed costs. Thirdly through the intensive use of anthelmintics, the evolution of GIN populations resistant against these drugs has become a serious problem. Resistance of nematodes constitutes a major problem particularly in goat production through many years of inappropriate management practices (e.g. “Dose-and-Move”) and underdosing of anthelmintics by suggesting the same effective dose for goats as for sheep although there are differences in metabolism and absorption of anthelmintics between goats and sheep (Hoste et al., 2010; Jackson and Coop, 2000; Meyer, 2001; Schnyder et al., 2005).

To solve the above mentioned problems related with the use of anthelmintics it is necessary to improve alternative control strategies such as pasture management, use of medicinal plants or breeding for GIN resistance. So far the most common control measures of GIN, beside the use of anthelmintics, are based on pasture management strategies in order to keep animals away from contaminated pastures. This can be done by rotational pasturing (moving the animals to clean pasture before the next generation of larvae develops), using the same pasture not every year with the same animal species or cutting the pasture between grazing periods (Schnieder et al., 2006; Thamsborg et al., 1999).

GIN resistant animals would be a cheap and effective method to control parasites. In Australia and New Zealand it was quite successful to breed GIN resistant sheep, which have been selected for low fecal egg counts (FEC) (Karlsson and Greeff, 2006; Liu et al., 2005). For goats no such breeding programs exist at the moment. In contrast to common European breeds, native goat breeds in tropical countries seem to have developed resistances against GIN without human driven selection programs (Behnke et al., 2006; Chiejina et al., 2002; Fakae et al., 2004). This might be explained by the higher selection pressure on goat populations in these countries as anthelmintic treatments are much less conducted when compared to temperate regions such as Europe. Therefore animals most affected by GIN die or are not selected for further breeding (Baker, 1998). This indicates that it is possible to breed for genetic GIN resistance. On the other hand these native breeds usually have low performance in production traits, which raises the question if there is a genetic correlation between GIN resistance and production traits (Pralomkarn et al., 1997). However, also studies with high producing European goat breeds show a high variability of GIN infections between individuals of the same flock suggesting that there are animals with high resistance which could be selected for breeding (Hoste et al., 2002b; Vlassoff et al., 1999). As

mentioned before, attempts to breed for genetic GIN resistance mainly concentrated on sheep (Australia and New Zealand) and left goats out of sight. The few studies looking at the possibility of selecting for genetic GIN resistance in goats, suggest that the heritability of genetic GIN resistance (with FEC as the trait of selection) in goats is lower than in sheep, but still suitable for breeding resistant animals (Baker et al., 2003; Morris and Wheeler, 1997; Vagenas et al., 2002).

In order to breed GIN resistant dairy goats while maintaining reasonable yields it is necessary to investigate if there are relationships between GIN resistance and milk production traits. Infection with GIN represents a permanent physiological stress for goats as the nematodes suck blood in the abomasum or detract nutrients in the intestines. In response to this, animals developed strategies of resilience and resistance. Resilience aims at limiting the effect of GIN on the physiological condition, i.e. maintaining body functions such as lactation during parasitic challenge. This is achieved for example by increased gastrin and pepsinogen concentrations in order to maintain digestion (Hoste, 2001). Also enhanced absorption of nutrients in parasite-free areas of the gut by increasing the mucosal surface or reducing motility of the gut in order to prolong contact time between the luminal contents and the epithelium is a process of resilience (Hoste, 2001). If the impact of parasitism exceeds the specific resilience of a given animal, body functions will be affected. Resistance on the other hand involves immune response which reduces or controls the parasite burden by limiting the establishment, growth rate, fecundity and/or persistence of the parasites. Taken together, milk performance of a highly resilient animal will not be affected even if it has a high worm burden, whereas the worm burden of a highly resistant animal will be limited by immune response. High producing dairy goats allocate a majority of their physiological resources to the production of milk and therefore their resources for immune responses are limited under conditions where animals do not have access to unlimited protein supply (Chartier et al., 2000; Coop and Kyriazakis, 1999). Hence it has been proposed that high producing animals are more susceptible to GIN infection than low producing animals as their immune system lacks resources to limit infection (resistance) under restricted feeding conditions (Chartier et al., 2000). On the other hand it can be hypothesized that a goat with a low milk production can indicate an intense infection with GIN (i.e. an animal with low resilience) or, given that a goat has low milk production without GIN infection, this could also point to high GIN resistance, as more resources can be allocated to the immune response at the first place (Coop and Kyriazakis, 1999; Hoste et al., 2005). If milk performance either of high or low producing animals is not influenced by a high worm burden (compared to milk performance in the same animal without GIN) this would

point to a high resilience of this animal. The relationship between milk production and resistance is not clear cut as it was found that high producing dairy goats have a higher nematode egg excretion (eggs per gramm [EpG]) than low producers (Chartier et al., 2000; Hoste and Chartier, 1993; Hoste et al., 2002b) whereas other studies could not find such a correlation (Etter, 2000; Morris and Wheeler, 1997). With respect to resilience studies showed a stronger impact of GIN infection on lactation in high producing compared to low producing dairy goats (Chartier and Hoste, 1994, 1997; Hoste and Chartier, 1993).

Another way to reduce the use of anthelmintics and slow down the development of resistance of GIN against these drugs is the approach of targeted selective treatment (TST), where only the most seriously infected animals of the flock are treated. TST is based on the observation that in a given flock only a limited number of goats are seriously infected with GIN (Hoste et al., 2001a). At the moment the best option to identify such animals for treatment is to determine the number of GIN eggs in the feces of the animal. This method, based on FEC, requires a laboratory and skilled staff to get meaningful results. Therefore it needs effort, time and money to determine if it is necessary to treat an animal with anthelmintic drugs and so the incentive to do so is quite low (van Wyk et al., 2006). Hence it is useful to find other ways to identify groups of animals which are highly susceptible to nematode infection and to select them for treatment. Previous studies suggest that these groups might be characterized by age and milking performance since some researchers found higher infection rates in young animals (Morris and Wheeler, 1997) and high producers (Chartier et al., 2000; Chartier and Hoste, 1997; Hoste et al., 2002b; Richard et al., 1990) while others did not find higher FECs in young animals (Hoste et al., 2002b; Richard et al., 1990) and high producers (Etter, 2000; Morris and Wheeler, 1997). Nevertheless it was found that such treatment of sub-groups, by using age and milk performance categories, leads to good results with respect to animal health and prevention of resistance of the whole flock (Hoste et al., 2002a; Hoste et al., 2002c).

1.1. Aims/Questions

1. Does GIN infection affect milk production and milk quality traits in dairy goats of the Saanen and Alpine breed?
2. Are goats with higher milk production more susceptible to GIN infection?
3. How does animal age influence the intensity of GIN infection?
4. What is the prevalence of resistance of GIN against the anthelmintics in use?
5. How do farms characteristics affect the intensity of GIN infection in goats?

1.2. Literature survey

1.2.1. Relationship between GIN infection and milk production

1.2.1.1. Influence of GIN infection on milk production

One of the first studies investigating the relationship between infection with internal parasites and milk performance in dairy goats was conducted by Hoste and Chartier (1993) with 48 French Alpine dairy goats. The experimental animals were divided into two groups of 24 goats each. Group A was artificially infected with *H. contortus* and *T. colubriformis* while the other group remained parasite naive. Beside a decrease in body condition score, a decrease in milk yield between -2.5% and -10% was observed in the infected group when compared to the non-infected group. Infected high-producers had higher EPGs and a higher drop in milk production with -13.0% to -25.1%. This was much more pronounced than in infected low-producers. Consistent with the former study, in an experiment by Chartier and Hoste (1997) the negative effects of nematode infection on milk production were stronger in high producing goats (-8% to -35%) compared to low producers (+5% to -23%). Veneziano (2004) found significant positive effects of deworming on milk yield when comparing 4 groups of dairy goats which were treated at different times within a year with a non treated control group. However, in this study differences between high and low producers were not considered.

Another study found no overall differences in change of milk yield after anthelmintic treatment between treatment and control group but found that response to treatment was stronger in high-producers, raising the milk yield by 4-8%, while in low-producers no such effect was detected (Chartier and Hoste, 1994). All these studies indicate a negative effect

of GIN on lactation and a stronger impairment of GIN on milk performance in animals with high milk yields.

1.2.1.2. Influence of milk performance on intensity of GIN infection

Chartier and Hoste (1997) also studied if high or low producers which had previously been infected with GIN established a lower worm burden when compared to animals of the same sub-groups which had not previously been exposed to GIN. It was observed that there was no establishment of resistance against nematode infection (as measured by FEC) in high-producers. In contrast low-producers developed resistance. Hoste et al. (2002b) found significantly higher infection rates in high producing goats compared to low producers after natural infection on 14 different dairy farms in France. Another study found similar results with respect to GIN susceptibility of goats with high milk performance for natural nematode infections in 207 Alpine dairy goats Chartier et al. (2000). The high-producers excreted about two times more eggs than the low producing group. These studies indicate a higher susceptibility for GIN infections in animals with high milk yield.

In contrast to the studies mentioned above Morris and Wheeler (1997) did not find any positive correlations between milk yield and FEC in Saanen goats in New Zealand. They conducted their study over a six years period with 180 to 472 animals (depending on year of study). Overall, records of milk production traits and FEC during this period showed slightly negative phenotypic correlations between these parameters. In this study also genotypic correlations between FEC and milk yield were estimated but they were not significant. Also Etter (2000) did not find significant differences in egg excretion between high and low producers after artificial infection with *T. colubriformis*. Another study investigating the relationship between production traits (live weight and fiber traits) and FEC in cashmere goats did not show any correlation (Vagenas et al., 2002).

1.2.1.3. Allocation of nutrients - development of resistance and/or resilience

It was found that high-producing goats develop a stronger resistance when receiving high protein rations, whereas low-producers do not respond to improved nutrition (Chartier et al., 2000). These findings are consistent with the proposed framework of Coop and Kyriazakis (1999) suggesting that animals allocate their nutrient resources according to their prioritization of body functions, which would be first the maintenance of body protein, second reproduction function (pregnancy and lactation) and only afterwards the expression of immunity. A surplus of nutrients would be used for live weight gain. Therefore, animals which have to (as genetically determined) allocate more resources (protein) for maintaining a high

level of milk production would be more susceptible for infections with nematodes as they have fewer resources available for maintaining their immune response under restricted nutrient supply.

As the amount of fat and protein in the milk is a reflection of resources aswell, it could also be expected that these factors are equally influenced by GIN infections. However when linkages between milk quality parameters such as fat and protein content and FEC were investigated in the past no such correlation was found (Chartier and Hoste, 1994; Hoste and Chartier, 1993; Morris and Wheeler, 1997).

In summary chapters 1.2.1.1, 1.2.1.2 and 1.2.1.3 show that high-producers seem to be less resistant and less resilient to GIN than low-producers, although with regard to resistance results tend to be more equivocal. Beside genetic endowments nutrient supply of the animal seems to play a major role in the degree of resilience and the expression of resistance. Furthermore impacts of parasitism on lactation appear to have a negative influence on milk yield but not on milk constituents.

1.2.2. Relationship between GIN infection and age

In sheep it is widely accepted that older animals have lower intensities of nematode infection. The most likely explanation for this observation is that animals develop immune responses after a prolonged period of GIN exposure at pasture compared to young animals (Hoste et al., 2006; Sechi, 2010). For goats such age dependent effects are less clear-cut. Hoste et al. (2002b) and Richard et al. (1990) investigated factors which determine the susceptibility to parasite infections and detected equal or higher FEC of GIN during different seasons in older goats compared to young animals. The data was not analyzed with respect to milk performance of individual animals which might also have an influence as mentioned above. It was also found that goats have a low ability to develop immune responses against infection with GIN (Hoste and Chartier, 1998). In this study previously infected goats showed similar FEC as goats which were not previously infected. The pathophysiological impacts as measured by packed cell volume, inorganic phosphate and pepsinogen concentrations, were even higher in pre-exposed animals. On the other hand in the above mentioned study of Hoste and Chartier (1998) it was also found that low producing dairy goats had lower FEC after previous infection. On the other hand, Vlassoff et al. (1999) found lower infection rates in older goats when fecal samples of the same animals were taken every 6 month for a 2 year period suggesting that goats to some degree can develop resistance. However, variation between animals was much higher than variation between samplings of the same

animals. Also Hoste et al. (2002b) found that variation between animals within flocks is considerable with an aggregated distribution of eggs and with a high repeatability of FEC results for individual animals. Taken together, the above evidence suggests that *(i)* goats in contrast to sheep do not develop resistance after first infection or *(ii)* develop resistance much slower and therefore do not have significant lower infection rates in older animals. Furthermore, with respect to FEC there seems to be evidence of variation in expression of resistance between animals, which is apparently not acquired during their lifetime but inherent.

It was hypothesized that goats, because of their different history of domestication and their different feeding behavior, did not develop any immunological mechanism to respond to nematode infections (Hoste et al., 2010; Hoste et al., 2008). Instead they avoid infections with GIN due to their different feeding behavior. In contrast to sheep, which are grazers, goats are browsers and preferably eat large amounts of shrubs, vines and wooden plants. As infectious larvae of GIN are found only close to the ground, the risk for infection was much lower for goats in their natural habitat. In this context Saanen and Angora goats were compared with respect to their feeding behavior and FEC. Saanen goats which browsed more and grazed less than Angora goats also had lower FEC (Hoste et al., 2001b). When goats and sheep grazed together on the same pasture, goats were found to have higher GIN infections (Huntley et al., 1995; Jallow et al., 1988) which points to the higher susceptibility in goats than in sheep. But if goats and sheep were kept together at rangeland where browsing was possible goats even had lower FEC than sheep (Jacquiet, 1992).

1.2.3. Development of resistance against anthelmintics in GIN

One of the biggest constraints in the treatment of GIN parasitism is the development of resistance of nematodes against common synthetic anthelmintics. In Europe first reports of anthelmintic resistance against the benzimidazole group were published in the 1980`s for *H. contortus* (Cawthorne and Cheong, 1984) and *T. circumcincta* (Britt and Oakley, 1986) in sheep flocks in the UK. Benzimidazole had been introduced only 20 years before in the UK (Jackson and Coop, 2000), which indicates a quite rapid development of resistance. Whilst in the above mentioned studies no resistance against levamisole was found, in 1992 Hong (1996) also found resistance against this anthelmintic group in the UK. At the same time resistance against ivermectin, belonging to the third group of anthelmintics (macrocyclic lactones), was reported in cashmere goats (Jackson et al., 1992). In Switzerland Meyer (2001) investigated benzimidazole resistance in sheep and goats by conducting fecal egg count reduction tests (FECRT) on 109 farms. She showed that on 81% of sheep farms and

on 91% of goat farms benzimidazole resistance was present. In Meyers study GIN resistance could in almost all cases be attributed to *H. contortus* which was the dominant nematode species in those farms, whereas on farms without resistance other species were dominant. More recently multiple resistance against benzimidazole and ivermectin was found on a Swiss goat farm (Schnyder et al., 2005). Efficacy of benzimidazole and ivermectin was as low as 55% and 61%, respectively, whereas moxidectine had an effectiveness of 96%. In this case the nematode population consisted mainly of *H. contortus* as well. Beside the Swiss study mentioned above also other studies found higher rates of resistance in goats than in sheep (Chartier, 1998; Hong, 1996). It is assumed that the higher resistance of GIN against anthelmintics is partly the result of the more frequent treatment of goats due to their stronger susceptibility to GIN infections, which was explained before. Another reason is the wide spread habit of underdosing anthelmintics when applied to goats (Van Wyk, 2001). Many anthelmintic drugs were developed and registered for the treatment of sheep and it was assumed that the sheep dose is also suitable for goats (Jackson and Coop, 2000). In fact the metabolism of goats differs from the one of sheep and it was shown that absorption, activity and transformation of active compounds is different in goats, leading to lower efficacy of anthelmintics (Hennessy et al., 1993; Sangster et al., 1991).

2. Farms, Material & Methods

2.1. Study design and Study sites

Within the framework of a Swiss project to evaluate the possibilities for breeding GIN resistant goats, 28 farms keeping either the Saanen or the Alpine mountain breed were visited two times between May and October 2011 to collect feces for FEC. The project was conducted by the Research Institute for Organic Agriculture in Switzerland. The farms are located all over Switzerland (Figure 2) and together keep more than 2000 Saanen or Alpine dairy goats.

FEC was always assessed as eggs per gram of feces (EpG, see 2.2 below). On all farms FEC was assessed in different age groups (primiparous and multiparous), which had access to pasture. 50% of the goats of each flock were sampled for fecal material and these samples were subsequently analyzed in bulks of 4 samples. This was done in order to produce comparable data of nematode infection rates in the different goat groups under investigation. Besides, for every farm also the proportion of the different nematode genera was determined by cultivating parts of the collected feces and identifying the different genera by microscope thereafter. According to FEC results of the first sampling (i.e. early summer), three farms with a mean high overall FEC of goats and willingness of the farmers to participate more intensively in the study were selected for further investigation (Figure 3). These farms were:

- Farm A (Ramseier) located in the canton Bern close to the village of Eggiwil in the West of Switzerland keeping 41 Alpine dairy goats. The farm has 0,7 ha of pasture to which the goats have access between May and October for about 10h/day in spring and autumn and for about 3h/day in summer. In autumn the goats are moved to other pastures which had been cut before. 300g-400g of concentrate, 500g maize pellets, 500g sugar-beet chips and aftermath ad libitum is offeres to each animal per day. During spring and summer the animals use the same pasture every day and they are not moved. In autumn the pasture is enlarged, allowing the goats to take up a bigger proportion of their daily ration from pasture. The whole flock was last dewormed in July 2010 with Eprinex® and afterwards goats had been dewormed individually according to visual appraisement by the farmer with Endex®. For the study in 2011 first Eprinex® and, as Eprinex® showed low efficiency, later Endex® was used.

- Farm B (Wohlgesinger) located in the canton Sankt Gallen close to the town of Wiesen in the North East of Switzerland keeping 49 Alpine dairy goats. The farm has 7ha of pasture to which the goats have access 5 to 7 hours a day between March and November. Additionally to pasture 1000g of concentrates per animal and day are provided. A rotational pasture system is used where the animals are put on a plot which is extended every day by some meters before the animals are moved to another plot after 2-3 weeks. After pasturing the plot is mowen. This cycle is repeated 3 times per year for each plot. Animals usually are dewormed 2 times a year with Cydectin®, but in during the study Hapadex® was used. After deworming animals usually stay on the same plot.
- Farm C (Kursner) located in the canton Vaud close to the town of Aubonne in the South West of Switzerland keeping 117 Alpine dairy goats. The farm has 20ha of pasture to which the animals have access all day between March and October. Additionally to pasture each animal receives 800g of concentrates per day and has ad libitum access to hay. A rotational pasture system is used where animals pasture between 1 and 3 weeks on the same plot before moving to another. Most plots are pastured up to 8 times a year, some of them are mown in late summer. Deworming of goats is conducted 2 to 3 times a year with Eprinex®, but because of serious problems of avermectin resistance, since November 2010 with Hapadex®. There is no strategy of keeping pastures clean (from parasites) or preventing resistance by moving the animals to a new plot before or after deworming.

For these three farms FEC and milk yield data of lactating goats were collected individually for each animal in June. For Farm A also milk composition was assessed. After this first individual FEC assessment the goats were dewormed with anthelmintics and a further assessment of FEC and milk production was done 10 days afterwards in order to assess milk production without GIN. Beside the development of milk production between these two investigations the resistance of the GIN population under study towards the drug used for deworming was determined by means of a fecal egg count reduction test (FECRT, see chapter 2.2). Not successfully dewormed animals were used as control (see chapter 2.7 for details). Furthermore on farm A only 50% of the flock was dewormed, while the other 50% was not treated and represented the control group.

Individual situations of each farm, regarding topographical conditions, pasture management and former anthelmintic treatments, were assessed by a questionnaire which was completed in a short interview with the farmer.

Originally there was a fourth farm (farm D, Sommer) for which milk yield should have been measured. Because deworming at this farm failed, only FEC for the different age groups and FECR but no influence of reduced FEC on milk production could be assessed for this farm.

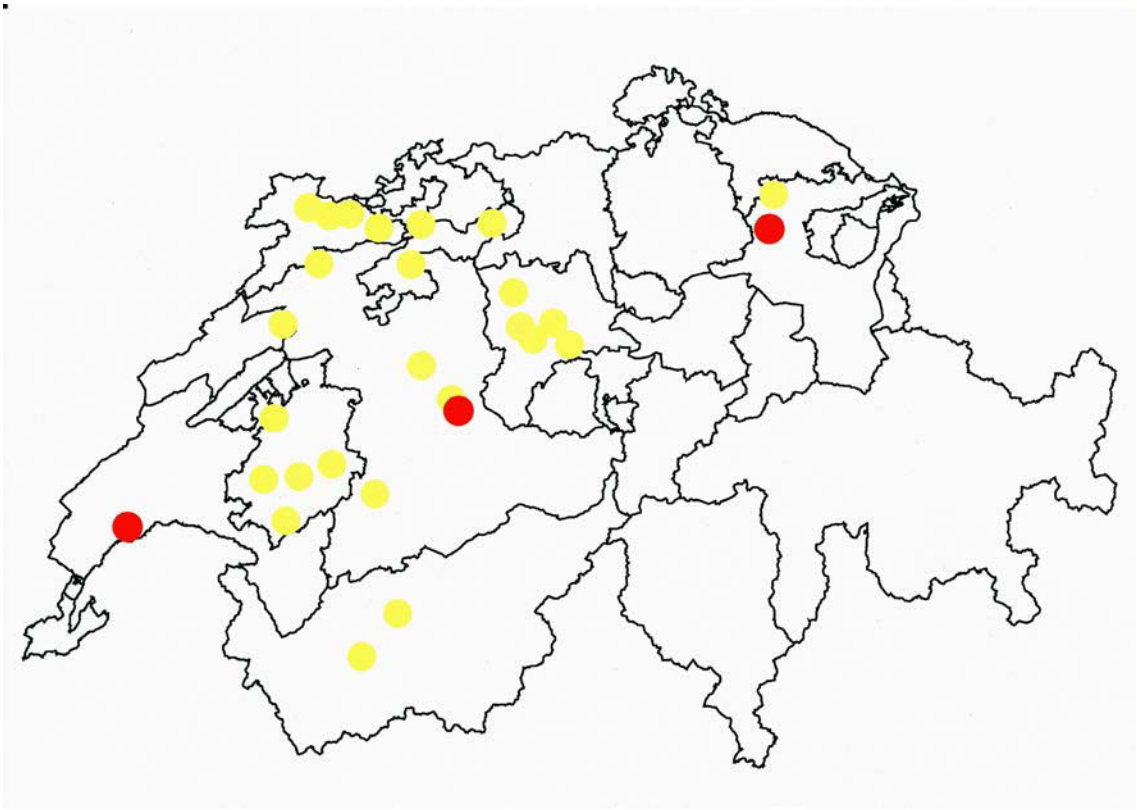

Figure 2: Locations of the 25 farms where bulk FEC for 50% of the flock was assessed (yellow) and of the 3 farms with additionally individual assessments of FEC and milk production (red)

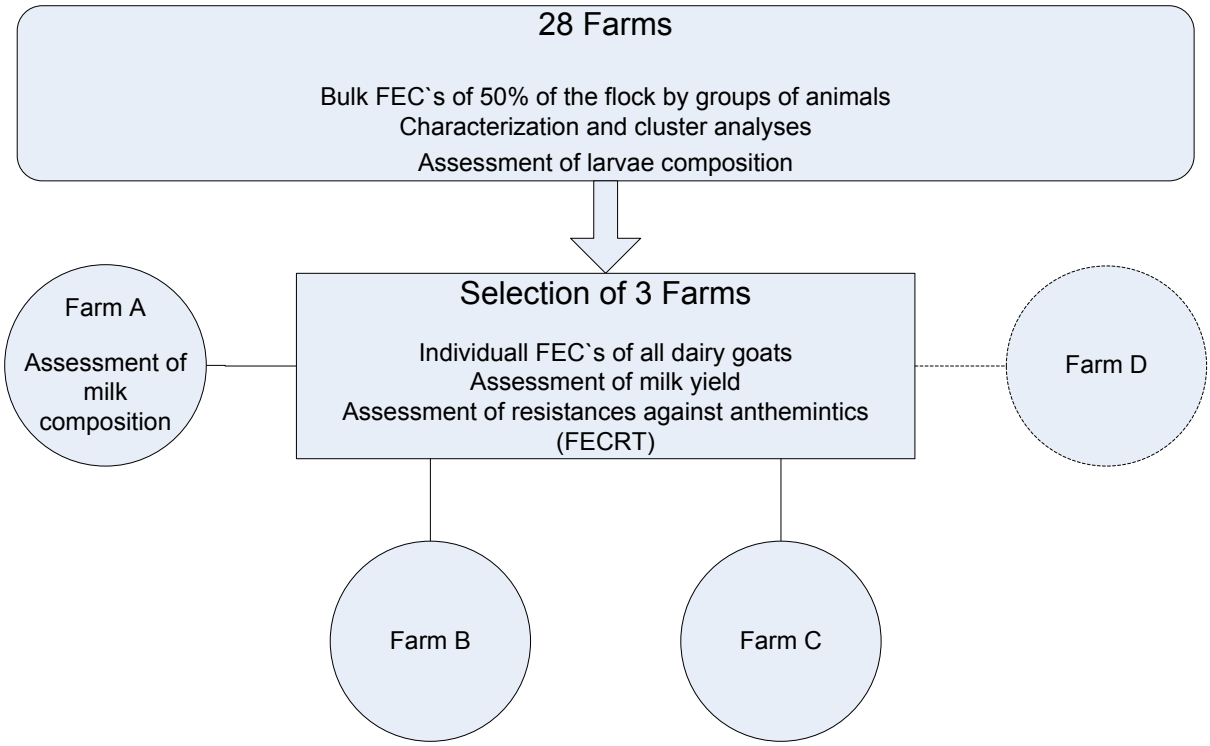

Figure 3: Study design

2.2. Fecal egg count (FEC) and fecal egg count reduction test (FECRT)

In order to assess EpG of the goats, FEC according to a modified McMaster method was conducted (Schmidt, 1971). 4g of each sample were weighed into a mortar and homogenously mixed with a flotation solution ($ZnCl_2$, specific gravity 1.6 g/ml). After filling through a sieve into a measuring cylinder the solution was diluted up to 60ml. The dilution was filled into McMaster chambers with automatic pipettes and afterwards examined under a microscope at a magnification of 40x. All nematode eggs were counted and multiplied with a factor of 50 to get the EpG.

Fecal egg count reduction tests based on flock means (FECRT) and individual fecal egg count reduction tests (iFECRT) as described by Cabaret and Berrag (2004) and Coles et al. (1992) were conducted on farms (A,B,C and D) assessing EpG in the feces of the animals before and 10 days after treatment with anthelmintics. For this purpose the animals were dewormed after first sampling of feces for FEC and a second sampling was made 10 days later. The presence of anthelmintic resistance was calculated by the mean EPG reduction (%):

$$FECR\% = 100 \times (1 - [\, EPG_{post} / EPG_{prä}])$$

$iFECR\% = (1/n) \times \sum(100 \times [1 - EPG_{i,post}/EPG_{i,prä}])$

FECRT based on flock means has been recommended as a suitable method to detect GIN resistance against anthelmintics by the World Association for the Advancement of Veterinary Parasitology (Coles et al., 1992). In this study iFECRT was additionally calculated because it has been proposed to be a more sensitive method to assess anthelmintic resistance as it does not overvalue single animals which excrete eggs far above average (Cabaret and Berrag, 2004).

2.3. Larvae composition

Random fecal samples of 50% of the animals of each farm were bulked and cultured. For five farms fecal samples for larvae differentiation were taken two times (i.e. spring and autumn). Feces were mixed with saw dust and water and kept in two covered jars permeable to air for 10 days at 24°C. Both jars represented one sample of the same farm. Every two days the culture was mixed and humidity was checked. For extraction of L3-larvae the jar was turned upside down with the opening downwards into a water filled petri dish. During the next 24h the larvae migrated from the culture into the water in the petri dish outside the jar. This solution was transferred into an airated culture flask with a pipette and kept at 4°C until differentiation.

For differentiation the solution was transferred into a 50ml falcon tube and was allowed to sediment for at least 15min. After sedimentation the supernatant was dicarded using a pipette. 60µl of the remaining solution was put on a microscope slide and mixed with some drops of Lugol`s iodine to inactivate larvae. 100 larvae were morphologically differentiated under the microscope according to the identification key of Eckert et al. (2005) (Figure 4).

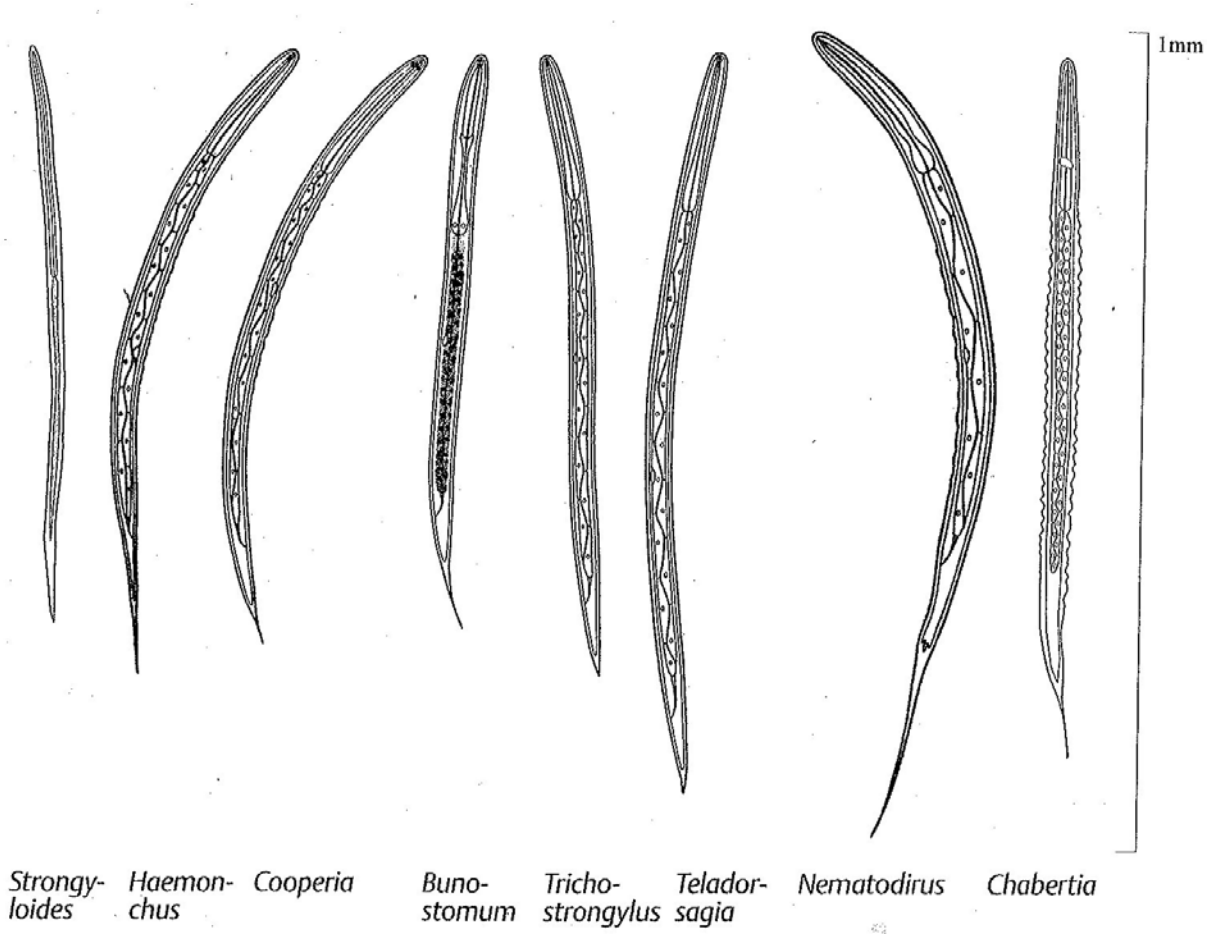

Figure 4: Third stage larvae (L3) of gastro-intestinal nematodes (Eckert et al., 2005)

2.4. Milk yield and components

Milk yield was assessed by an automatic device measuring milk yield (kg) at the milking machine of the farms at the day of first fecal sampling and again at the day of the second fecal sampling 10 days later. Milk yield recordings were done at evening milking for farm B and C and at morning and evening milking for farm A. On farm A also milk components were assessed in milk samples which consisted of 50% morning and 50% evening milk. The samples were analyzed by the Laboratory of Caprovis Data Ag in Bern.

2.5. Anthelmintic treatments

On farm A deworming was done first by the farmer himself using Eprinex® Pour-On (5mg/l eprimectin, family of macrocyclic lactones) but reduction of FEC after 10 days was very low. Therefore the sampling and deworming was repeated two month later by the author. This time each goat was weighed and dewormed with Endex® dosing 3.2ml / 10kg body weight. Endex® contains 50mg/ml triclabendazole and 37,5mg/ml levamisole.

Anthelmintic treatments on Farm B and C were conducted by the farmers themselves.

On farm B all animals in the flock for which FEC after first sampling had shown EpG >500 were dewormed using 13,5ml Hapadex® (oral suspension 15%) per animal.

On Farm C the farmer treated the whole flock with Hapadex® (oral suspension 15%) dosing two times 3 ml per animal within 24h. This was done according to recommendation of the farm veterinarian. Hapadex® contains 150mg/ml netobimine which belongs to the anthelmintic family of benzimidazoles.

2.6. Questionnaire

On all 28 farms enrolled in the project short interviews using a questionnaire were carried out with the farmers in order to collect information on farm and management practice. The questionnaire included questions on farm and flock size, geographical location, management strategies, such as pasture system, feeding and previous measures taken in order to prevent and cure GIN infection. Furthermore it was checked if the farm participates in the parasite control program of the Swiss Health Consulting Service for Small Ruminants (Beratungs- und Gesundheitsdienst für Kleinwiederkäuer, BGK). With this data it was intended to determine if there are differences in the mentioned factors between farms with very low or very high infection rates as well as to create categories of farms with similar conditions to compare their EPG more easily. Furthermore it was necessary to collect information about the farms to improve service for them during the project period and provide support for further farm visits.

2.7. Data management and statistics

Animals were grouped into dewormed and not dewormed animals. All animals where anthelmintic treatment took place and EpG reduction was at least 80% were considered as dewormed. All animals where no anthelmintic treatment was conducted and EpG where not reduced by more than 20% at second sampling were considered as not dewormed. All other animals (EPG reduction >20% - <80%) were not included in data analysis.

Furthermore animals were grouped according to their milk yield into high producers (HP) and low producers (LP). LP are defined as animals within the lower 50% of milk yield of each flock whereas HP refers to the higher 50% in milk yield of each flock. Animals were further categorized into high high producers (HHP), medium producers (MP) and low low producers

(LLP). Here the groups constitute the lowest, the middle and the highest third in milk production in each flock respectively (Figure 5).

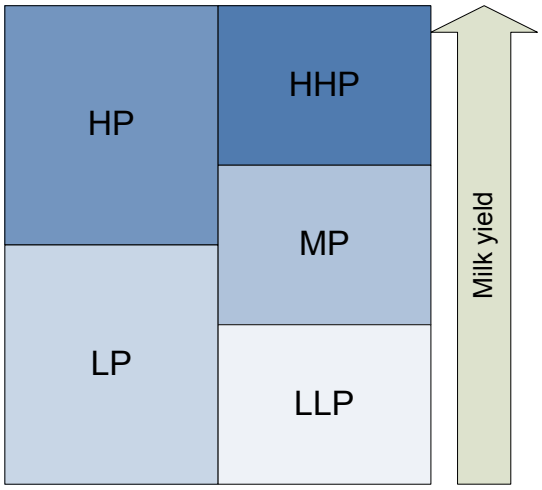

Figure 5: Grouping of animals in a given flock according to milk yield

For milk components animals were classified in a similar way, by dividing into high fat/low fat, high protein/low protein and high urea/low urea animals representing again the upper and lower half of the flock according to the content of the respective component.

On farm A, where deworming and milk yield assessment was conducted two times (see 2.2), data of first sampling was used to compare the FEC in different groups of goats (primiparous/multiparous, high producer/low producer). This was done; because the first sampling was conducted at the same time as at the other farms and therefore data are comparable between the farms, as conditions (forage quality, age of animals, point of lactation period) change during the season.

FEC data of animals from farms with bulk assessment was only used for comparison between primiparous and multiparous goats if at least three bulks of each group were available. Farms with a number of bulks below three were discarded.

Data was summarized; square means, standard deviations and ranges were calculated using Microsoft Excel 2010. Linear regression and coefficient of determination (R^2) was calculated with Sigma Plot 10.0 to assess correlations between FECR and change in milk yield. Square means for differences in milk yield, milk components and egg excretion were always calculated from individual differences of each animal. For further statistical analyses the statistic program SAS 9.2 was used. After testing for normal distribution of residues, differences between age, production and dewormed/not dewormed groups were statistical analyzed using mixed effect models analyses of variance considering farms always as

random effects. When differences in milk yield change after deworming were analyzed, deworming and age were considered as fixed effects and milk yield change was used as covariate. When differences in egg excretion between groups were analyzed age and milk performance were considered as fixed effects and egg excretion was used as covariate. Statistical significance was assumed at $p<0.05$. A cluster analysis of farm characteristics was conducted using PASW Statistics 18 (SPSS). All 28 study farms were clustered using the categories management zone, number of animals, pasture system, participation in the parasite control program and stocking rate. Analyses were conducted with two and three cluster as outcome.

3. Results

3.1. L3-larvae differentiation

Differentiation of L3-larvea showed that *Haemonchus contortus, Trichostrongylus sp., Teladorsagia sp., Chabertia/Oesophagostum* and *Strongyloides* were present on t he examined farms. Figure 11 shows that in spring and s ummer samples the average composition of GIN larvae was dominated by *H. contortus* (73%), whereas in autumn the difference between proportions of *H. contortus* and *Trichostrongylus sp.* was much less with 51% and 39% respectively (Figure 6: L3-larvea composition in autumn (n= 9 farms)).

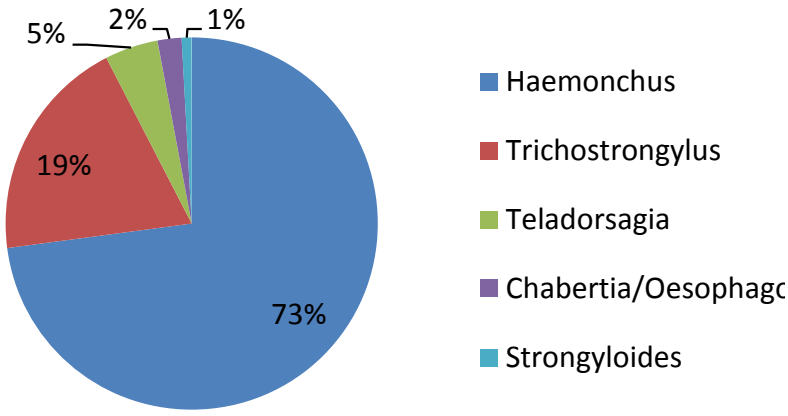

Figure 6: L3-larvae composition in spring/summer (n = 23 farms)

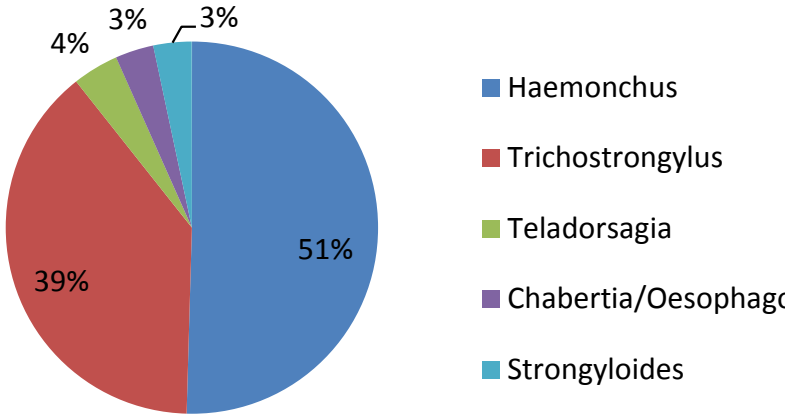

Figure 7: L3-larvea composition in autumn (n = 9 farms)

For the five farms for which L3-larvea differentiation was conducted two times the results point out the shift in larvae composition during the season. At both times *H. contortus* was

dominant, but as in spring/summer period it accounted for 92% (Figure 13) in autumn the percentage dropped to 69% (Figure 14).

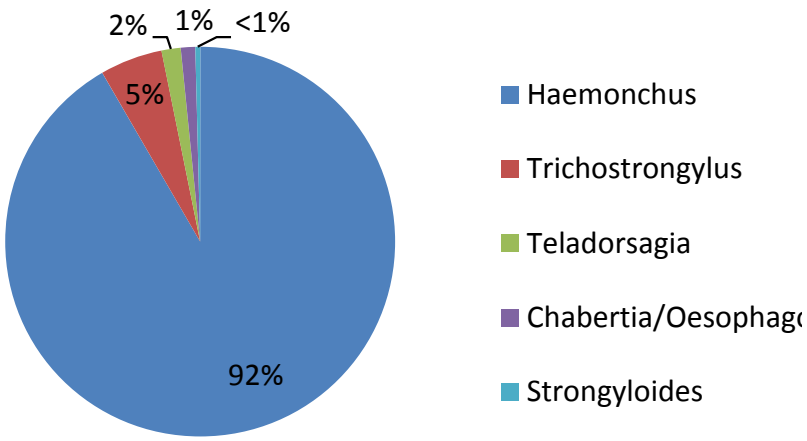

Figure 8: L3-larvea composition in spring/summer (n = 5 farms)

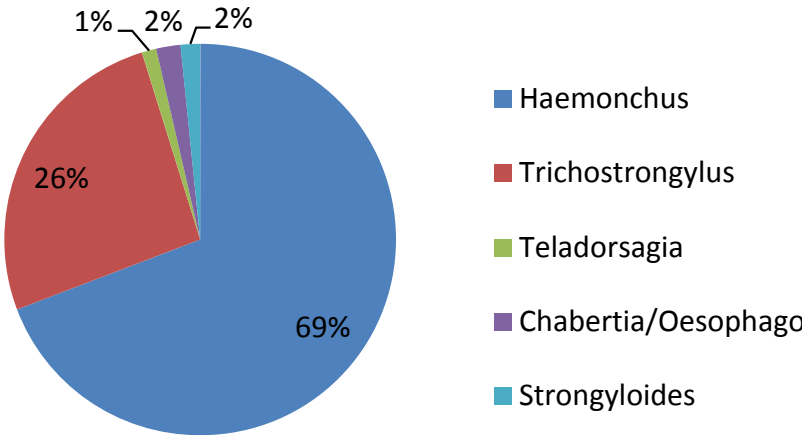

Figure 9: L3-larvae composition in autumn (n = 5 farms)

On the three farms for which milk production parameters were assessed *H. contortus* accounted for 84% (farm A, spring), 86% (farm B, spring) and 72% (farm C, spring). On farm D where only FECR was conducted, *H. contortus* accounted for 87% (spring) of egg excretion (Table 12).

Table 1: Proportions of L3-larvaes on farms with milk production assessment and/or FECRT

Farm	Haemonchus	Trichostrongylus	Teladorsagia	Chabertia/ Oesophagostonum	Strongyloides
A	84%	10%	6%	-	-
B	86%	10%	-	2%	2%
C	72%	9%	19%	-	-
D	87%	8%	5%	-	-

3.2. Fecal egg count reduction

Anthelmintic treatment of animals on four farms A-D showed reduction rates between 5.5% and 87.3% (iFECR) and 1% and 87% (FECR), respectively (Table 13). After the second deworming with Endex®, on farm A the treatment was successful with an efficiency of 99.5% (iFECR) and 100% (FECR), respectively.

Table 2: Individual fecal egg count reduction (iFECR) and fecal egg count reduction (FECR) for each farm and anthelmintic product. At farm A deworming was conducted two times.

Farm	iFECR [%]	(range)	FECR [%]	n
A 1 [Eprinex®]	43.0	(-36-100)	40	29
A 2 [Endex®]	99.5	(95-100)	100	21
B [Hapadex®]	87.3	(64-100)	87	33
C [Hapadex®]	37.0	(-1548-100)	59	117
D [Eprinex®]	5.5	(-182-100)	1	34

3.3. Effect of EPG-reduction on milk yield

For none of the farms a significant correlation between the change in milk yield and FEC of individual animals between day 0 and day 10 was found (R^2 always <0.015). On average the treatment group on farm A showed a (not significant) rise in milk yield (+9%) compared to the untreated group (-5%, Table 1). On farm B there was no difference in change of milk yield between the treated and the untreated group (+3.8% vs. +4.2%, Table 2). On farm C milk yield in dewormed animals increased less (+4.3%) than in not dewormed animals (+14%, Table 3). Dewormed LP/LLP goats on all farms had a higher increase (or lower decrease in the case of farm C) in milk yield between day 0 and day 10 compared to not dewormed LP/LLP goats (farm A: +15%/+14.8%, farm B: +3.9%/+17.9%, farm C: -8.8%/-4%, all: +1.9%/+8.8%) than dewormed HP/HHP goats compared to not dewormed HP/HHP goats (farm A: +10/+8%, farm B: -4%/+4%, farm C: -12.7%/-9.7%, all: -1.1%/+1.7%, Figure 6), but these differences were not significant. For the model with milk performance as fixed effect (HP/LP or HHP/LLP) there was no significant influence of deworming on milk yield, neither when grouped in HP/LP (p = 0.919) nor when grouped in HHP/LLP (p = 0.298). Also when milk performance was replaced by age as fixed effect differences between dewormed and not dewormed animals were not significant either (p = 0.637). Differences in change of milk yield between day 0 and day 10 between HP and LP (p = 0.025) respectively HHP and LLP (p = 0.005) groups, without consideration of dewormed and not dewormed groups were significant but therefore not linked to treatment.

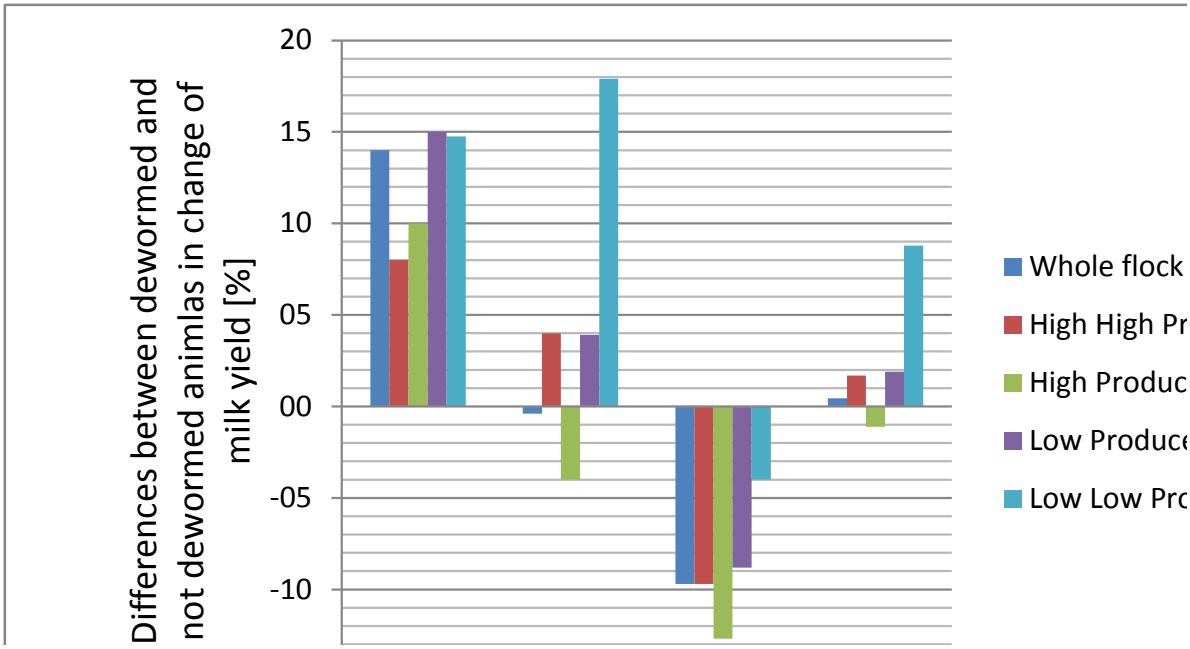

Figure 10: Change in milk yield (%) between day 0 and day 10. Differences between dewormed animals and not dewormed animals on farm A (n = 39), B (n = 42), C (n = 41) and for all farms (n = 122). Comparison of production groups and all animals of each farm (whole flock).

Table 3: Mean fecal egg count and milk yield of different groups on day 0 and 10 and mean of individual differences in fecal egg count and milk yield on farm A

Group	Fecal egg count [eggs/g]		Mean MY [kg]		Mean difference in fecal egg count [%] (mean±sd)	Mean difference in milk yield [%] (mean±sd)	n
	day 0 (mean, range)	day 10 (mean, range)	day 0 (mean±sd)	day 10 (mean±sd)			
Dewormed	1602 (50-54)	5 (0-50)	1.33 ± 0.39	1.40 ± 0.39	-100 ± 1	9.0 ± 29.7	22
Not dewormed	697 (50-2600)	965 (450-3450)	1.48 ± 0.35	1.41 ± 0.44	107 ± 262	-5.0 ± 19.5	17
Dewormed HP	1275 (100-3500)	5 (0-50)	1.66 ± 0.28	1.71 ± 0.28	-99 ± 2	4.0 ± 17.6	10
Not dewormed HP	723 (50-2600)	1036 (450-3450)	1.67 ± 0.26	1.58 ± 0.43	142 ± 323	-6.0 ± 17.4	11
Dewormed LP	1875 (50-5450)	4 (0-50)	1.06 ± 0.22	1.15 ± 0.26	-100 ± 1	13.0 ± 37.3	12
Not dewormed LP	650 (350-1200)	833 (550-1400)	1.12 ± 0.15	1.08 ± 0.27	43 ± 63	-2.0 ± 24.6	6
Dewormed HHP	1825 (450-3500)	0 -	1.82 ± 0.25	1.77 ± 0.34	-100 ± 0	-2.0 ± 18.7	6
Not dewormed HHP	813 (50-2600)	1156 (450-3450)	1.76 ± 0.24	1.61 ± 0.50	168 ± 379	-10.0 ± 17.3	8
Dewormed LLP	1661 (50-5450)	6 (0-50)	0.98 ± 0.20	1.13 ± 0.30	-99 ± 2	19.8 ± 41.1	9
Not dewormed LLP	700 (550-1400)	860 (550-1400)	1.08 ± 0.13	1.14 ± 0.26	36 ± 68	5.0 ± 18.9	5

Table 4: Mean fecal egg count and milk yield of different groups on day 0 and 10 and mean of individual differences in fecal egg count and milk yield on farm B

Group	Fecal egg count [eggs/g]		Mean milk yield [kg]		Mean difference in fecal egg count [%] (mean±sd)	Mean difference in milk yield [%] (mean±sd)	n
	day 0 (mean, range)	day 10 (mean, range)	day 0 (mean±sd)	day 10 (mean±sd)			
Dewormed	996 (550-2250)	384 (0-1850)	1.44 ± 0.40	1.48 ± 0.42	-90 ± 7	3.8 ± 15.2	28
Not dewormed	296 (100-450)	102 (0-400)	1.21 ± 0.42	1.26 ± 0.49	303 ± 247	4.2 ± 11.9	14
Dewormed HP	859 (550-1950)	1014 (600-1850)	1.69 ± 0.30	1.71 ± 0.40	-90 ± 6	0.6 ± 10.8	16
Not dewormed HP	275 (100-450)	81 (0-200)	1.78 ± 0.29	1.85 ± 0.44	393 ± 228	4.6 ± 18.1	4
Dewormed LP	1179 (550-2250)	1163 (750-1850)	1.10 ± 0.21	1.16 ± 0.16	-91 ± 7	8.0 ± 19.3	12
Not dewormed LP	305 (150-400)	129 (0-400)	0.98 ± 0.18	1.03 ± 0.25	267 ± 256	4.1 ± 9.7	10
Dewormed HHP	870 (550-1950)	955 (600-1450)	1.83 ± 0.30	1.89 ± 0.41	-89 ± 7	2.9 ± 11.5	10
Not dewormed HHP	333 (250-450)	85 (0-200)	1.90 ± 0.17	1.90 ± 0.52	308 ± 185	-1.1 ± 17.4	3
Dewormed LLP	1170 (600-2100)	1300 (850-1850)	0.90 ± 0.19	1.04 ± 0.09	-92 ± 6	19.0 ± 22.1	5
Not dewormed LLP	300 (150-400)	120 (50-400)	0.89 ± 0.11	0.90 ± 0.17	288 ± 310	1.1 ± 10.0	7

Table 5: Mean fecal egg count and milk yield of different groups on day 0 and 10 and mean of individual differences in fecal egg count and milk yield on farm C

Group	Fecal egg count [eggs/g]		Mean milk yield [kg]		Mean difference in fecal egg count [%] (mean±sd)	Mean difference in milk yield [%] (mean±sd)	n
	day 0 (mean, range)	day 10 (mean, range)	day 0 (mean±sd)	day 10 (mean±sd)			
Dewormed	1548 (250-4150)	212 (0-800)	1.12 ± 0.28	1.15 ± 0.36	-87 ± 7	4.3 ± 23.6	21
Not dewormed	688 (0-1950)	816 (200-1850)	1.18 ± 0.32	1.32 ± 0.33	103 ± 354	14.0 ± 17.8	20
Dewormed HP	1922 (400-3900)	289 (50-600)	1.39 ± 0.14	1.34 ± 0.42	-86 ± 4	-4.3 ± 27.5	9
Not dewormed HP	660 (50-1500)	837 (250-1450)	1.45 ± 0.19	1.56 ± 0.23	188 ± 483	8.4 ± 15.4	10
Dewormed LP	1267 (250-4150)	154 (0-800)	0.92 ± 0.15	1.01 ± 0.23	-88 ± 8	10.8 ± 18.8	12
Not dewormed LP	715 (0-1950)	795 (200-1850)	0.90 ± 0.11	1.09 ± 0.25	8 ± 19	19.6 ± 19.0	10
Dewormed HHP	1600 (400-2750)	233 (50-500)	1.47 ± 0.08	1.45 ± 0.47	-86 ± 4	-1.2 ± 32.5	6
Not dewormed HHP	607 (50-1300)	796 (250-1400)	1.54 ± 0.15	1.65 ± 0.21	251 ± 576	8.5 ± 18.9	7
Dewormed LLP	800 (300-2600)	42 (0-100)	0.80 ± 0.12	0.92 ± 0.16	-92 ± 9	15.5 ± 15.5	6
Not dewormed LLP	556 (0-1050)	650 (200-1150)	0.87 ± 0.08	1.05 ± 0.26	9 ± 20	19.5 ± 21.5	8

Table 6: Mean fecal egg count (FEC) at day 0 and 10 and m ean of individual differences in FEC and milk yield (MY) of animals at all farms. Absolute numbers for milk yield are not given due to different methods of milk yield measurement on the farms

Group	Fecal egg count [eggs/g] day 0 (range)	Fecal egg count [eggs/g] day 10 (range)	Individual mean difference FEC [%] (±sd)	Individual mean difference MY [%] (±sd)	n
All goats	1240 (0-8900)	513 (0-3450)	-17 ± 181	8.6 ± 35.7	206
Dewormed	1347 (50-5450)	104 (0-800)	-92 ± 7	5.6 ± 22.7	71
Not dewormed	583 (0-2600)	920 (200-3450)	160 ± 304	5.2 ± 18.5	51
Dewormed HP	1251 (100-3900)	113 (0-600)	-92 ± 7	0.4 ± 17.9	35
Not dewormed HP	626 (50-3600)	977 (250-3450)	201 ± 381	1.5 ± 17.4	25
Dewormed LP	1440 (50-5450)	96 (0-800)	-93 ± 8	10.6 ± 25.9	36
Not dewormed LP	542 (0-1950)	865 (200-1850)	120 ± 202	8.7 ± 19.2	26
Dewormed HHP	1330 (400-3500)	102 (0-500)	-91 ± 7	0.4 ± 19.9	22
Not dewormed HHP	653 (50-2600)	1040 (350-2450)	223 ± 428	-1.3 ± 19.0	18
Dewormed LLP	1280 (50-5450)	45 (0-400)	-95 ± 7	18.3 ± 29.7	20
Not dewormed LLP	503 (0-1200)	800 (200-1450)	119 ± 226	9.5 ± 18.7	20

3.4. Effect of EPG-reduction on milk components

Milk components fat and pr otein measured on farm A differed slightly at day 10 after deworming between treated and not treated animals (Table 5, Table 6, Figure 7). Fat and Protein content increased more in the not dewormed group but differences were not significant as $p = 0.5254$ for fat and $p = 0.9147$ for protein. Urea content was much higher at day 10 in the not dewormed group whereas urea content in the milk of dewormed animals decreased (Table 7, Figure 7). However also this difference was not significant ($p = 0.225$).

Table 7: Mean fat content of different groups on day 0 and 10 and mean of individual differences in fat content on farm A

Group	Mean fat content [%] day 0	Mean fat content [%] day 10	Individual mean difference fat content [%]	n
All goats	2.99 ± 0.5	3.18 ± 0.56	7.66 ± 16.02	40
Dewormed	3.01 ± 0.5	3.16 ± 0.47	6.40 ± 13.79	22
Not dewormed	2.96 ± 0.4	3.21 ± 0.68	8.79 ± 19.41	17

Table 8: Mean protein content of different groups on day 0 and 10 and mean of individual differences in protein content on farm A

Group	Mean protein content [%] day 0	Mean protein content [%] day 10	Individual mean difference protein content [%]	n
All goats	3.33 ± 0.52	3.39 ± 0.39	2.89 ± 9.86	40
Dewormed	3.42 ± 0.53	3.48 ± 0.34	2.58 ± 8.05	22
Not dewormed	3.22 ± 0.52	3.28 ± 0.44	2.93 ± 12.22	17

Table 9: Mean urea content of different groups on day 0 and 10 and mean of individual differences in urea content on farm A

Group	Urea content [mg/dl] day 0	Urea content [mg/dl] day 10	Mean difference urea content [%]	n
All goats	53.8 ± 9.6	53.4 ± 6.3	1.7 ± 18.8	40
Dewormed	56.4 ± 8.5	54.8 ± 5.5	-1.5 ± 12.0	22
Not dewormed	50.3 ± 10.3	51.4 ± 7.2	6.1 ± 25.3	17

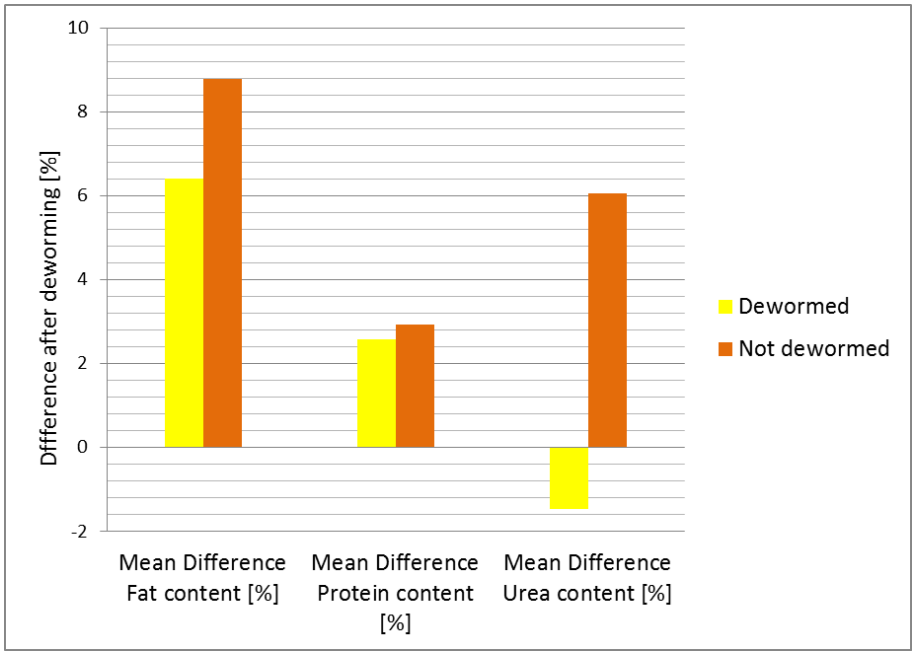

Figure 11: Differences in milk fat, protein and urea content in dewormed and not dewormed groups at day 10 after treatment

3.5. FEC and milk performance

On all farms egg excretion before treatment was higher in HP and HHP groups than in LP and LLP groups respectively (Table 8). On all studied farms on average HP goats excreted 42% more eggs than LP goats and H HP goats excreted 78% more eggs than LLP. Differences between the HP and the LP group and between the HHP and the LLP group were significant (p=0.038 and p = 0.0004 respectively). When age was included in the model as fixed effect no significant effect of performance was observed anymore (p=0.9312 and p = 0.1192 respectively).

Table 10: Mean fecal egg count (eggs/g) of different groups on each farm and for all three farms together before anthelmintic treatment

Group	Farm A	n	Farm B	n	Farm C	n	ABC	n
HHP	2068 (200-4700)	12	785 (250-1950)	17	1737 (50-8900)	39	1560 (50-8900)	68
HP	1322 (150-4700)	21	788 (100-1950)	25	1659 (50-8900)	59	1482 (50-8900)	95
LP	844 (0-1950)	17	748 (150-2250)	24	1217 (0-4150)	59	1043 (0-4150)	100
LLP	724 (0-1950)	14	623 (150-2100)	13	1000 (0-3250)	37	876 (0-3250)	54

When sampling on farm A took place the second time (after unsuccessful deworming) FEC was higher in low producing groups (HP/LP = 1020/1467 [eggs/g], HHP/LLP = 1280/1318 [eggs/g]). This was not included in the statistical analysis as it was the only sampling which was conducted in autumn.

3.6. FEC and age

FEC in different age groups was conducted on the 4 farms with individual sampling and on 15 farms where there were more than three bulks of each group. At all farms egg excretion was higher in multiparous goats (Table 9), on average 110%. Overall these differences were significant ($p < 0.0001$), but could not be analyzed under consideration of milk performance as there was no data of milk yield for farm D and the 15 farms with bulk assessment. When data was analyzed for farms A, B, C only, differences between primiparous and multiparous goats were significant ($p < 0.0001$) also under consideration of milk performance as fixed effect ($p = 0.0021$ when milk performance categories HHP/LLP and $p = 0.0155$ when categories HP/LP were used in the model).

Table 11: Fecal egg count (eggs/g) of first lactating and multiparous goats on each farm and for all farms.

Group	Farm A	n	Farm B	n	Farm C	n
Primiparous	500 (150-1150)	7	363 (100-750)	16	458 (150-750)	13
Multiparous	1426 (0-4700)	34	965 (250-2250)	33	1576 (0-8900)	104

Group	Farm D	n	All	n
Primiparous	1046 (250-4200)	36	735 (100-4200)	72
Multiparous	1795 (200-6750)	81	1542 (0-8900)	251

Also when comparing primiparous and multiparous goats on farms where bulk samples were taken, the multiparous goats had significantly higher FEC (p = 0.0022) (Table 10). Again, as milk yield was not measured on these farms it could not be considered for analysis.

Table 12: Fecal egg count (eggs/g) of first lactating and multiparous goats on 15 farms with bulk samples

Group	Fecal egg count	n
Primiparous	739 (0-3200)	67
Multiparous	1080 (0-4000)	130

When sampling was carried out the second time at farm A FEC showed reverse results with higher egg excretion in the primiparous group (2749 [eggs/g]) than in the multiparous group (891 [eggs/g]). Also this was not statistically tested.

3.7. FEC and level of milk components

Mean FEC was higher in high fat, high protein and low urea groups (Table 11). Significance for difference in egg excretion was not present for fat and protein. For urea p-value was close to significance (p = 0.052), but when age was considered as a fixed effect no significant effect was detected anymore (p = 0.8899).

Table 13: Fecal egg count and mean proportion of milk components of different groups on farm A

Group	Fecal egg count [eggs/g]	Fat content [%]	Protein content [%]	Urea content [%]	n
High fat goats	1069 (100-3500)	3.33 ± 0.41	3.46 ± 0.59	55.00 ± 8.64	19
Low fat goats	1389 (50-5450)	2.61 ± 0.25	3.19 ± 0.40	52.47 ± 10.70	21
High protein goats	930 (100-3500)	3.22 ± 0.50	3.68 ± 0.51	54.90 ± 7.94	20
Low protein goats	1513 (50-5450)	2.75 ± 0.38	2.98 ± 0.21	52.70 ± 11.10	20
High urea goats	1446 (50-5450)	2.99 ± 0.55	3.41 ± 0.61	60.22 ± 5.53	23
Low urea goats	918 (50-3500)	2.98 ± 0.44	3.22 ± 0.34	45.12 ± 6.59	17

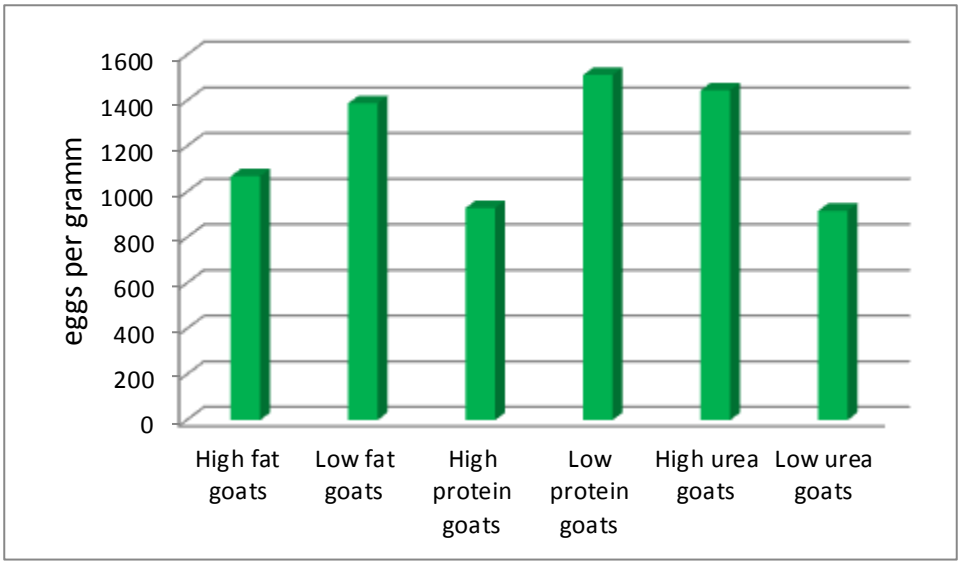

Figure 12: Differences in fecal egg count of groups classified by their proportion of milk components

3.8. Characterization of the farms using cluster analysis

The results for the analysis with 2 clusters were as follows: Cluster 1 consisted of 9 and cluster 2 of 19 farms differing manly in flock size and stocking rate with cluster 1 having smaller flock sizes and higher stocking rates. For the other categories there was an even distribution among the two clusters. Average FEC of dairy goats for both cluster were almost similar (975 [EpG] and 931 [EpG] respectively).

The results for the analysis with 3 clusters were as follows: Cluster 1 consisted of 21, cluster 2 of 2 and cluster 3 of 5 farms with cluster 1 having low stocking rates and being predominantly located in higher management zones, cluster 2 having low stocking rates and location in low land and cluster 3 with bigger flock size, low stocking rates and predominant location in the hilly zone. Regarding the pasture type farms of cluster 1 and 3 had predominantly permanent grazing systems, whereas farms of cluster 2 had predominantly open yards with small amounts of herbage. Rotational pasture systems were evenly distributed. Also the proportion of farms which participate in the parasite control program was not different between clusters. FEC of dairy goats differed slightly between the clusters with cluster 1 having 915 [EpG], cluster 2 807 [EpG] and cluster 3 1126 [EpG] in average.

4. Discussion

4.1. Nematode genera

FEC is an indirect parameter to estimate the virtual worm burden of an animal. Cabaret et al. (1998) found that there is a good correlation between egg excretion and worm burden with a relationship between the number of worms and EpG in the feces of dairy goats of Log Worms = 0.11 + 1.20 Log EpG (r = 0.80; P < 0-001). As *H. contortus* was found to be more prolific than other species and therefore contributes predominantly to egg excretion the relationship between the number of worms and EpG is improved if the percentage of *H. contortus* in the nematode population is considered as Log Worms = 2.55 + 0.85 Log EpG – 0.47 Log Hae (Hae = percentage of *H. contortus* + 0.1; r = 0.83; P < 0.001) (Cabaret et al., 1998). Hence FEC can only be representative and comparable between flocks if it is conducted together with larvae differentiation simultaneously. This was one of the reasons why nematode genera were assessed in the present study. At the time of first sampling (farms A, B, C, D) all flocks had similar larvae composition. At second sampling on farm A no fecal samples for larvae differentiation were taken. Taking into account the shift of larvae composition on the other farms (between spring and autumn) it can be assumed that at second sampling on farm A would have revealed at lower proportion of *H. contortus* as well.

The GIN population of the four flocks enrolled in our study consisted predominantly of *H. contortus*. While actually *H. contortus* is reported to occur mainly in tropical and subtropical regions with prevalent resistance against anthelmintics (Chandrawathani et al., 2003; Mwamachi et al., 1995; Zajac and Gipson, 2000), *H. contortus* as the predominant species in nematode populations of goats was recently also found several times in Switzerland (Artho, 2007; Meyer, 2001; Scheuerle et al., 2010). Increasing occurrence of this “tropical” nematode species which has its temperature optimum for development above of the one of other nematode species could be caused by increases in international animal traffic (Schnyder et al., 2005; van Dijk, 2010) and rising temperatures in alpine regions due to climate change (van Dijk, 2010). As *H. contortus* is particularly vulnerable to late frost in spring (van Dijk, 2010) and as spring temperatures in Switzerland in the year of our study were above average (MeteoSchweiz, 2011) this could also have contributed to the high proportion of *H. contortus* resulting from the larval differentiation of spring/summer samples.

Given the aforementioned and the fact that *H. contortus* is a blood sucking nematode which causes anemia, it can be assumed that the FAMACHA©-Scoring-System as a method for

targeted selective treatment could also be suitable for goats in Switzerland as already suggested by Scheuerle et al. (2010). This approach aims at selecting animals according to the color of their inner eye lid by comparing it with a color chart. A pale eye lid indicates anemia which can be caused by *H. contortus*. However this color chart was developed for Boer sheep in South Africa (van Wyk and Bath, 2002) and thus would need to be adapted for goats in Switzerland. It was already suggested by Moors and Gauly (2009) that adaptation might even be required for different sheep breeds.

A shift of the population composition was observed during pasture season towards less *H. contortus* and more *T. colubriformis* in autumn than in spring. This may be explained by a different chronology of the development cycle of the two nematode species. *H.* contortus reaches its peak in egg excretion in spring, leading to hatching and development to infectious larvae mainly in summer. Also, *H. contortus* has a high potential for hypobiosis which allows the parasite to overwinter within the host. In contrast *T. colubriformis* has its peak in egg excretion in summer and infectious larvae overwinter mainly on pasture (Figure 14) (Uriarte, 2003; van Dijk, 2010; Waller, 2004). For anthelmintic resistance the composition of GIN population might play a role as well as it was found that resistance against anthelmintics occurs more often at sheep and goat farms with a high proportion of *H. contortus* and that eggs which were excreted after anthelmintic treatment derived almost solely from *H. contortus* (Meyer, 2001). Also Schnyder et al. (2005) found multiple anthelmintic resistances related to *H. contortus* in Swiss goats. Higher proportions of *H. contortus* in autumn samples were also found by Richard et al. (1990). This can lead to the assumption that efficiency of anthelmintic treatments is influenced by nematode composition and therefore time of treatment might play an important role.

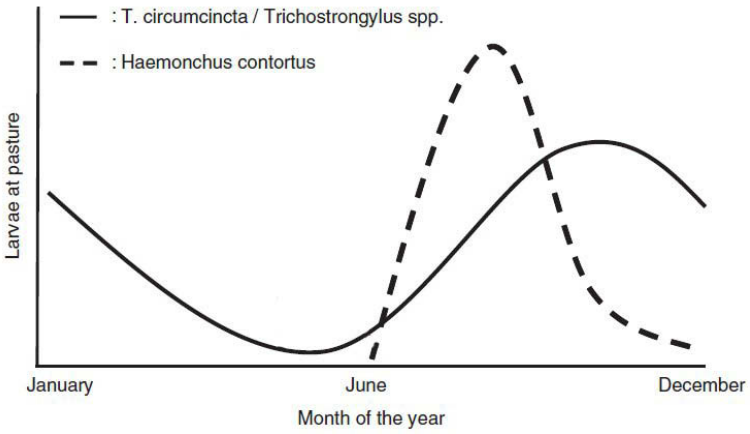

Figure 13: Schematic illustration of infectious nematode larvae at pasture in the UK (adopted from(van Dijk, 2010). Larvae hatch after 3-5 weeks in summer and after 2-3 month in spring and autumn (Schnieder et al., 2006). Correspondingly peak of egg excretion is earlier than peak of larvae. As climate conditions in Switzerland are different seasonality also differs.

4.2. Resistance against anthelmintics

For the groups of benzimidazoles and avermectins resistance of GIN in Switzerland had recently been documented (Artho, 2007; Meyer, 2001; Schnyder et al., 2005) and it can therefore be assumed that resistance against Hapadex® and Eprinex® might have played a role in the flocks of the present study. In fact, the results of the FECRT on farms A1, A2, B, C and D point at the presence of resistance of GIN against these two anthelmintics (Hapadex® and Eprinex®). However these results should be regarded with caution as the deworming procedure was not controlled by the author. Proper deworming should be carried out according to live weight assessment of the animals in order to dose anthelmintics accurately in relation to the body weight. Furthermore proper application must be assured. This was only assured for the second deworming on farm A where treatment was carried out through the author with Endex®. It was the only treatment which showed efficiency close to 100%. In all other cases treatment was carried out by the farmers themselves without weighting the animals.

For levamisole (one of the active components of Endex®) resistance of GIN in goats so far has not been reported in Switzerland and anthelmintics of this group are rarely used by goat farmers (Artho, 2007; Meyer, 2001).

Overall it can be stated that the conducted FECRT does not provide definite evidence about resistance against anthelmintics, but to conlusions about efficiency of common deworming practice. For Eprinex® proper dosing is further hindered by the fact that it is usually applied

(also in the case of our study) by pouring it over the back of the animals (Eprinex®-pour-on). Depending on the thickness of the fur, licking (by other animals), grinding of the solution at equipment or trees and out door conditions (if left outdoor), absorption of the active substance can differ. If the detected inefficiency is not the result of existing resistances against the used anthlemintics, but of treatment practices, it can be expected that these resistances will occur in the near future on the investigated farms, as constant under dosing of anthelmintics inevitably leads to development of resistances against them (Van Wyk, 2001).

4.3. Relation between FEC and milk traits

4.3.1. Influence of GIN infection on milk performance

In the present study milk yield change in response to successful anthelmintic treatment varied between the farms. This finding might be related to the fact that conditions, such as the nutrient supply were different on each farm. As observed by Chartier et al. (2000) and proposed by Hoste et al. (2005) and Hoste et al. (2008) improved nutrition of the host can reduce the negative effects of GIN on metabolism and thereby prevent the influence of the parasites on lactation. Therefore, if a farm in general has a good nutrient supply, the anthelmintic treatment would have less effect on change in milk yield when compared to a farm with less favorable feeding conditions. Our data tend to support this hypothesis, as on farms B and C where milk yield decreased in the treated group compared to the control group, feeding was based on medium quality pasture whereas on farm A where milk yield increased after deworming, the main intake of animals was hay and concentrate of high quality. In autumn, when the second sampling took place on farm A the farmer had changed the feeding practice to a more pasture based system as pastures usually used for mowing then also were available for the goats. In this situation, milk yield decreased after treatment, as observed for farms B and C before. Assuming that a pasture based feeding system in most cases limits nutrient supply compared to systems in which concentrates account for a substantial part of the feeding ratio, this leads to the conclusion that in pasture based systems influence of GIN on milk production may be stronger (i.e. deworming has a stronger effect). A detailed assessment of nutrient composition in the feed ration and feed intake in each farm would have been very useful for the interpretation of the present results. Results of previous studies found an increase in milk production of dairy goats after deworming (Chartier and Hoste, 1994; Veneziano, 2004) or a decrease in milk production after artificial infection (Hoste and Chartier, 1993). In these studies nutrient intake was controlled and uniform for all animals. Our results were not coherent with these studies as it could not

clearly be observed that milk yield after deworming increased. This was only the case at farm A. It should be considered that in contrast to the mentioned studies our study was conducted under field conditions where feed intake could not be controlled. Results of the study by Chartier and Hoste (1994), also conducted under pasture conditions seem to be more similar to our findings as they could not find an overall increase of milk yield after anthelmintic treatment. However, they observed a stronger response to anthelmintic treatment in high producers which conflicts with the results of the present study where, if at all, dewormed low producers had a stronger increase (or lower decrease) in milk production than dewormed high producers. Consistent with the studies mentioned before also Chartier and Hoste (1997) found a stronger decrease in milk yield after infection with GIN in high producers, but as there was no non-infected control group in their study it cannot be proven that the drop in milk yield was in fact linked to GIN infection.

In the case of farm A the time of sampling could also have influenced the effect of GIN on milk yield as the result of larvae differentiation showed different compositions of nematode genera in autumn and in spring. As the different nematodes also differ in their pathology and probably also in costs for immune response, the influence on milk production could be different as well. Other studies investigating the influence of GIN on milk yield (Chartier and Hoste, 1994; Hoste and Chartier, 1993; Sechi, 2010; Veneziano, 2004) were conducted with mixed infections and did not compare differences in impact of nematode genera.

In this study milk components were not influenced by nematode infections as there was clearly no increase in fat and protein content in the dewormed group compared to the control group. This is in accordance with the results of other studies with goats (Chartier and Hoste, 1994; Hoste and Chartier, 1993; Morris and Wheeler, 1997) and more recently has also been shown for dairy ewes (Sechi, 2010).

The 10 days period between anthelmintic treatment, fecal sampling and milk production assessment was chosen due to the recommendation of Coles et al. (1992) for detection of anthelmintic resistance (FECRT) and similar periods (14 days) between treatment and milk production assessment of Veneziano (2004). Other studies assessing the effect of anthelmintic treatment on milk production unfortunately do not mention exact time periods between treatment and recording of milk production in their publications (Chartier and Hoste, 1994; Sechi, 2010). Hoste and Chartier (1998) found that the peak physiological impact (packed cell volume, concentration of serum pepsinogen) of a mixed infection with *H. contortus* and *T. colubriformis* was reached about 4 weeks after infection which coincided with the peak of egg excretion. This shows that after infection with GIN, the larvae need

some time to develop to adult worms in order to cause serious harm to the host. After deworming the reverse effect could be expected to occur faster even if nutrients might be needed for regeneration from GIN infection. However, it would be useful to study if a longer period between treatment and second assessment of milk production would show a stronger effect.

4.3.2. Susceptibility to GIN infections according to milk performance

The work by Etter (2000) and Chartier et al. (2000) suggests that regarding the susceptibility to GIN infection of high producing dairy goats contrasting results have been found in controlled experiments and field studies, respectively. They assumed that for high producing goats not genetic factors but nutrient supply is determining susceptibility to GIN infection as under controlled conditions with an elevated supply of protein high producing goats did not have higher infection rates than low producers (Etter, 2000), whereas under pasture conditions GIN infections of high producing goats were higher but could be decreased by protein supplementation (Chartier et al., 2000). The framework for the allocation of nutrients of Coop and Kyriazakis (1999) (see chapter 1.2.1.3) hypothesizes that lactation as a reproductive function is influenced comparatively late by nutrient deficiency (Figure 15). This leads to the conclusion that high producing goats under limited nutrient supply have fewer resources available for immune response. Hence they will be more susceptible for infection with GIN. On the other hand low producing goats under the same conditions have more resources available for their immune response as they have to allocate fewer nutrients to the maintenance of lactation. Hence low producers will be less susceptible for GIN infection. In both cases milk performance will not be influenced by nutrient deficiency (e.g. caused by parasitism) until a critical point of undersupply as lactation is higher in priority (still with respect to the framework). This would also explain the low (or not existing) respond to deworming discussed in chapter 4.1.1, as milk traits will be affected relatively late by GIN as long as a critical point of undersupply is not reached. Results of studies which showed higher FEC in ewes and goats around parturition, when nutritional demands are higher (Etter, 1999; Ortega-Mora et al., 1999), seem to support this relationship between nutrient supply and susceptibility. Also in this case the higher susceptibility could be avoided through a surplus of protein (Etter, 1999). Results of the present study for susceptibility of high and low producers seem to agree with that as high producers on average showed higher egg excretion rates.

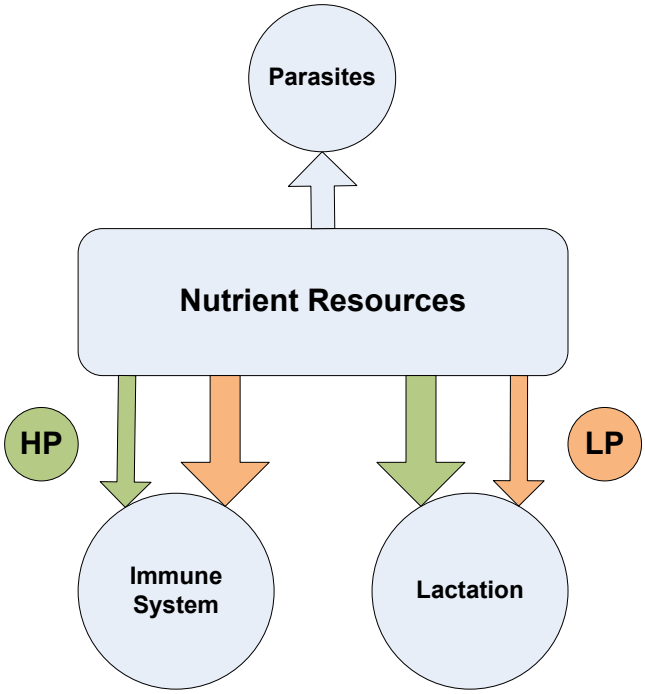

Figure 14: Model of allocation of nutrients according to physiological functions: HP goats allocate more of their resources to lactation, whereas LP goats can allocate more to their immune system. If resources get scarce because of parasitism, LP goats consequently lack nutrients for maintaining their immune response later than HP goats (modified after Coop and Kyriazakis, 1999).

Another explanation for a higher worm burden in high producers is that, because of a higher demand for nutrients (Avondo, 2002), high producers take up more herbage in pasture based feeding systems. Hence they ingest more nematode larvae on contaminated pastures which leads to the establishment of a higher worm burden. In the present study this could not be examined as feed intake on pasture was not recorded. It can be hypothesized that this might play a role if pasture constitutes a major part of the feed intake. If however, pasture is limited this might not be influential as animals do not have the chance to graze according to their nutrient demand.

It has to be mentioned that for the second sampling at farm A in autumn, which was necessary because of logistic problems linked to the farm, reverse results for infection rates in high and low producers as well as for first lactating and multiparous goats, were found. This will be further discussed in the next chapter (3.4).

Interestingly in the present study goats with high GIN infection tend to have higher fat and protein content in their milk than animals with low infection. This would again support the theory of allocating scarce resources first to lactation and to immune responses as a second

priority. However, this effect was not significant as age seemed to be a more important factor in this case.

4.4. Relation between FEC and age

In our study older animals excreted more nematode eggs than young animals. This raises the question if the reason for that might be the common practice of keeping young animals away from pasture during their first year, which was also the case at the studied farms. First samplings took place 6-9 weeks after the beginning of the pasture period and prepatency of GIN is 2-4 weeks (Schnieder et al., 2006). Therefore the excreted eggs should originate mainly from the nematode generation of the current year and the host animal's worm burden of the previous grazing period should not significantly influence the results. Nevertheless, in contrast to the other samplings (at farms B, C, D and first sampling at farm A) conducted in spring, results of the second sampling on farm A in autumn showed higher egg excretion in primiparous goats. So on farm A primiparous goats excreted less nematodes eggs in spring but more nematode eggs in autumn than multiparous goats. This might indicate that the worm burden of parasite naive young animals might establish slower but more intense and/or egg production of hypobiotic last year's nematodes in the multiparous goats is higher than of nematodes derived from infections in spring. It was reported that *H. contortus* is mainly responsible for hypobiotic stages of nematodes in the host during the winter whereas overwintering strategy of *T. colubriformis* mainly relies on overwintering larvae on pasture (Langrová, 2008; Waller, 2004). Taken this difference into account also the results of larvae differentiation suggest that excreted eggs in spring might origin from last year's nematodes as *H. contortus* was the dominant species in spring and egg excretion of *T. colubriformis* increased in summer and autumn. However, as population dynamics of GIN are not completely investigated so far it cannot be affirmed certainly from which nematode generation the excreted eggs descend. At farms B, C and D animals which had been on pasture in the previous year were dewormed during winter, which would lead to the assumption that no nematodes should have been present in the multiparous goats at the beginning of the pasture period. However, as results of FECRT (see chapter 3.7) suggest, this might have not been completely successful and therefore animals might have still carried hypobiotic worms of the last year into the new pasture season. On the other hand multiparous goats of the 15 farms where analyses of bulk samples were conducted also showed higher FEC than primiparous animals. At 6 of these farms samples were taken later in summer (after 1st of July) or autumn and if only these farms were considered multiparous goats still had higher mean FEC (1253 vs. 1063 eggs/g). Hoste et al. (2002b) also

investigated susceptibility of goats to GIN with respect to age but could not draw any sound conclusions. The results of the present study are more coherent with the results of Richard et al. (1990) who also found higher egg excretion in multiparous goats. In their study samples were also taken in spring and autumn (but not on the same farms). In autumn egg excretion of first lactating goats was higher compared to spring, but still was slightly lower than FEC of multiparous animals. Nevertheless it is not exactly clear why older animals showed higher FEC. Older animals also had higher milk yield and so GIN susceptibility with respect to milk performance as explained in chapter 4.1 might play a role. But in contrast to other studies investigating the influence of age on susceptibility to GIN infection (Hoste et al., 2002b; Richard et al., 1990; Vlassoff et al., 1999), in the present study age and milk performance were analyzed together and therefore an influence of milk performance on GIN susceptibility with respect to age could be excluded.

It was assumed that goats develop an immune response against GIN much slower than sheep (Hoste and Chartier, 1998; Hoste et al., 2008) for which it was shown that multiparous ewes are less susceptible to GIN infections than primiparous animals (Hoste et al., 2006; Sechi, 2010). Although in our study the sample sizes of first lactating goats for some farms were quite small the present results seem to support these presumptions as older animals definitely did not show higher resistance against GIN (as measured by FEC). In order to investigate if immune response in goats is developing later in age as suggested by Vlassoff et al. (1999) it would have been necessary to analyze more age categories.

4.5. Targeted selective treatment

The level of infection in different production and age groups was also investigated in the present study in order to identify suitable groups in dairy goat flocks for targeted selective treatment (TST). This allows reducing costs and preventing the development of anthelmintic resistance in GIN by establishing so called refugia. The approach of TST aims at not treating the whole flock but only the most susceptible animals of a flock (Van Wyk, 2001). The concept of refugia explains the development of resistant nematode populations through wrong treatment practices (Van Wyk, 2001). It is based on the fact that if anthelmintics are applied, necessarily the most resistant strains of the nematodes survive and will constitute the next population on the pasture. This is much more the case if common treatment practices as “dose and move” are used. The animals are moved to a new, clean pasture after treatment and as there is only a resistant population present the next generation of worms will solely establish from the resistant strains. After a short time the nematodes on pasture will consist only of resistant parasites. To avoid such a development refugia should

be established. Refugia consist of a population of non-resistant nematodes on pasture, hence originating from not previously treated animals. This can be achieved by TST or through moving the animals to a new pasture first and treating them a few days later (Van Wyk, 2001) Studies examining TST (Hoste et al., 2002a; Hoste et al., 2002c) divided goats into two groups. In one group only goats in first lactation and with the highest level of milk production were treated with anthelmintics while in the other group all the animals were treated. No significant differences in average egg excretion or milk yield between the groups were detected. Hence the effect of treatment on FEC and milk yield was quite similar in selectively treated and systematically treated groups. Besides avoiding resistance against anthelmintics also the economic benefits for farmers can be considered as an important reason to introduce TST in animal production (van Wyk et al., 2006). The results of our study suggest that, as variation of egg excretion within groups of age and milk performance was bigger than between groups, it might be difficult to identify animals which require treatment on the basis of milk yield and or age. However as the above mentioned studies gained satisfactory results by treating only a part of the flock, this approach should be further investigated.

4.6. Influence of farm characteristics on GIN infection

Group sizes of farms for cluster analyses were quite inhomogeneous (particularly when using three clusters) and characteristics of the different clusters were not completely distinct. Differences in FEC between clusters were marginal and cannot be used as a basis for any conclusion about the influence of farm characteristics on infection with GIN. Observations by the author were made that animals at studied farms which had low stocking rates and/or conduct transhumance using seasonal mountain pasture had lower egg excretion than animals on other farms. Thus it could be hypothesized that such farming systems, usually characterized by low stocking rates and non-permanent pasture as well as less favorable conditions for nematode larvae in high altitudes, might prevent heavy infection or that there might be a critical minimal size of pasture which hinders the establishment of big GIN populations. A negative correlation between stocking rate (surface/goat) and FEC in goats was found by Vallade (2000) and also for sheep higher worm burdens and density of infectious larvae on pastures with higher stocking rates were reported by Thamsborg (1996). In the present study the four farms with stocking rates below 0.5 livestock units/ha (average 0.3), showed average FEC of 680 eggs/g per animal, whereas the rest of the farms with an average stocking rate of 17.88 LUs/ha showed average FEC of 1100 eggs/g per animal. However there is no statistical evidence of this observation as just 3 farms with

transhumance took part in the study and FEC on these farms was conducted by bulk samples.

5. Conclusions

There was no clear effect of deworming on milk yield. Alternatively it can be stated that GIN infection had no or low effect on milk yield and milk components. Hence goats seem to be highly resilient to GIN infection. Resilience in low producers attended to be (not significantly) lower than in high producers which contradicts previous studies concerning this issue.

A tendency of higher egg excretion (but not significant) was found in goats with high milk yield suggesting higher susceptibility of high producers to GIN. According to the studied literature this above-average susceptibility in high producers is most likely based on higher and not fulfilled nutrient demands and not on genetic endowments. Also higher herbage intake on pasture (and therefore intake of infective larvae) might play a role. This leads to the conclusion that high producers are more susceptible to GIN infections in pasture based feeding systems with no or only low amount of concentrates in the feeding ratio. Hence increasing milk yield in Saanen and Alpine goats at some point exceeds the physiological capability of the animals to maintain their immune defense in pasture systems, because they lack nutrients. If pasture based husbandry should be retained in goat farming without increasing the parasite problem, breeding should not be focused on milk performance as the most important trait. It could be an option for future considerations to include fitness and health traits as breeding aims. More detailed studies will be necessary to affirm these assumptions.

FEC was not higher in younger goats as has been previously reported for sheep. In contrast multiparous goats showed higher egg excretion than primiparous in most cases. This leads to the conclusion that there is now or low establishment of resistance during the lifetime of goats. As variability between individuals was higher than between groups of age (and also milk performance and between farms), it can be assumed that GIN resistance in goats might rather be inherent than acquired. This may be important when it comes to the selection of resistant animals for breeding as it suggests that there might be a genetic disposition for GIN resistance and that it is not important at which age breeding traits such as FEC are recorded. On the other hand the different results of FEC and of nematode composition in spring and autumn suggest that it might be important at which point of time during pasture season these traits are recorded. To evaluate if such breeding can be successful further investigations are necessary.

Regarding age groups multiparous goats had higher FEC indeed, but it can be doubted if this is caused by higher susceptibility of older animals. The results of our study suggest that milk performance as criteria for grouping goats might be more suitable for TST than grouping according to age. High producers, particularly the highest third of the flock, could be a possible target for treatment. But as mentioned before the variability between individuals was much higher and so there might still be a risk to leave animals which suffer from high GIN infection, but do not belong to the treated group. In summary it can be said that TST might be not as useful for parasite control in goats as it probably is in sheep.

The results of FECRT suggest that common treatment practice with most of the anthelmintics used in the study is not efficient. Resistances against benzimidazols and avermectins on the studied farms are likely but the study design did not allow to finally prove this. Resistance against levamisol was not present at the farm where deworming was conducted with Endex®. If the low efficiency of deworming does not originate from resistance against anthelmintics but from wrong application, resistance is likely to occur soon on these farms. Further agricultural extension with focus on goats will be necessary to improve the efficiency of parasite control measurements and to prevent the establishment of resistant GIN populations in the future.

Nematode populations on the studied farms were found to consist predominantly of *H. contortus*, which is in line with recent studies reporting high proportions of *H. contortus* in nematode populations in goats in Switzerland. This suggests that dominance of *H. contortus* in Switzerland is increasing, particularly in goats. It implies a possible application of the FAMACHA-score for goats in Switzerland in the future, which has to be further evaluated. The predominance of *H. contortus* can also lead to more frequent occurrence of anthelmintic resistance in GIN as *H. contortus* was reported to be mainly responsible for anthelmintic resistance in many cases. The shift in nematode composition between spring and autumn leads to the conclusion that treatment in autumn might be more effective and can help to prevent the development of resistances as proportions of *H. contortus* are lower then.

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9. Abstract

The aim of this field study was to investigate interactions between GIN infection and milk yield in order to prepare ground for breeding GIN resistant dairy goats as well as to identify groups with higher susceptibility to GIN infections in order to reduce the number of anthelmintic treatments. Influence of GIN infections on milk performance (milk yield and milk components) and susceptibility for GIN infection according to the level of milk yield was assessed. Dairy goats with higher risk of GIN infection according to their age were also identified. Resistance of GIN against anthelmintics used in the study and influence of farm factors on GIN infection were also investigated.

The study was conducted in Switzerland with Saanen and Alpine dairy goats. On three farms fecal egg count (FEC) was conducted and milk yield was assessed. After parts of the flock were dewormed FEC and milk yield were measured again 10 days later. On four farms fecal egg count reduction test (FECRT) was conducted. On 15 farms FEC was conducted in bulk samples and animals were grouped according to their age. On 28 farms bulk samples and farm characteristics were recorded. Furthermore genera composition of GIN was assessed on each farm.

Genera composition was dominated by *Haemonchus contortus* with a shift towards less *H. contortus* and more *Trichostrongylus sp.* in autumn. FECRT showed low success of deworming on all farms. Only in one case FECR was close to 100%. A clear negative influence of GIN infection on milk yield could not be found as results for change in milk yield after deworming were equivocal. There was a tendency of higher GIN infections in high producing goats but differences were not significant. Multiparous goats showed significant higher FEC than primiparous. However, time of sampling and nutrient supply seem to have a considerable influence on intensity of GIN infection and its physiological impact under field conditions.