Implications of Tannin Containing Plants for Productivity and Health in Small Ruminant Animals: A Review

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ABSTRACT

Infection with parasitic nematodes is a serious threat to health and production of small ruminant worldwide. It causes reduction in feed intake, weight gain and eventually death of the host. The primary control method of the nematode infection relied on frequent use of anthelmintic drugs. Unfortunately, this control strategy is no longer effective due to widespread anthelmintic resistance, which necessitates search for novel approaches to control nematodes. Condensed tannin (CT) containing forages have been used as anthelmintic to control parasitic nematodes for years. This paper reviews available information about effects of CT on productivity and health of small ruminants infected with parasitic nematodes. Many of temperate and tropical forages are nutraceutical plants (possess both nutritional and health benefits). Consumption of CT containing forages reduced negative impacts of gastrointestinal parasitism in sheep and goat by regulating establishment of worm as shown in reduced worm burdens, fecal egg count (FEC) and worm fecundity. Parasitized sheep and goats fed forages containing CT had high feed intake and body weight gain, probably due to increase in protein and amino acids supply. Condensed tannins containing feeds result in lighter meat color and tend to improve antioxidant activity. Therefore, the use of CT containing forages to control parasitic nematodes and improve production of small ruminants is one of the alternatives to anthelmintic drugs.

Key words: Condensed tannin, Goats, Meat, Milk, Parasitic nematodes, Sheep.

Endo-parasitic nematodes represent a major threat to the health and production of small ruminant worldwide. Infection with these parasites could result in a huge economic loss for producers (Pathak et al., 2016; Atiba et al., 2016). The main clinical signs of the parasitic infection include reduction in feed intake, poor reproduction, growth performance and eventually death (Nnadi et al., 2009). Until now, anthelmintic drugs are the basis of nematode control method in sheep and goats. However, the drugs have been rendered ineffective by widespread development of anthelmintic resistance among nematode species (Coles et al., 2006; Kaplan and Vidyashankar, 2012). Moreover, this method is not economically viable for some small scale producers due to financial challenges or availability of drugs and consumers demand for chemical free animal products (Hoste et al., 2012; Raju et al., 2015; Atiba et al., 2016). Therefore, affordable and sustainable alternative parasite control methods have been evaluated to reduce dependence on anthelmintic drugs (Arroyo-Lopez et al., 2014). Many studies have shown that feeding tannins containing plants can reduce detrimental effects of parasitic nematode infection in sheep and goats (Kahiya et al., 2003; Iqbal et al., 2007; Marume et al., 2012).

Tannins are complex group of polyphenolic compounds that dissolve in water and have similar physical and chemical properties (Acamovic and Brooker, 2005). Generally, tannins are classified into two distinct groups, hydrolysable and condensed. Hydrolysable tannins (HT) are esters of phenolics acids such as gallic acids in gallotannins or other phenolic acids derived from the oxidation of galloyl residues as in ellagittannins and a polyl, usually D-glucose.
threshold level, nevertheless can improve nutritional status of parasitized ruminants (Min and Hart, 2003; Huang et al., 2017). Moreover, tanniniferous forages are rich in nutrient particularly protein content making them potential source of animal feed. In the past two decades, the concept of using tannins containing forages as nematicidal plants (plants combining both nutrition and health benefits) has emerged as a promising alternative to anthelmintic drugs (Kahiya et al., 2003; Marume et al., 2012; Arroyo-Lopez et al., 2014; Hoste et al., 2015). Therefore, this paper reviews available information about effects of condensed tannins on productive performances and hematobiochemical as well as parasitological parameters.

Tannins are heterogeneous polyphenolic compounds found in wide range of plants species and their concentration levels vary greatly not only between plants species but also between the parts (Table 1) (I did not find Tables in the MS). They occur in every part of plant including seeds, leaves, fruits, barks, roots and wood and are present in higher concentration particularly in tropical plants (Pathak, 2013b). However, tannin content in many plant species seems to be greatly influenced by environmental factors such as season, water availability and stage of plant growth (Sampaio et al., 2011; Mcmahon et al., 2011). The HT are common in dicotyledonous plants whereas, CTs are the most abundant type of tannins found in both angiosperms and gymnosperms (Huang et al., 2017). The CT are very common in forages legumes of Fabaceae family (e.g. lespedeza spp and Onobrychis spp) , shrubs (Acacia spp) and the leaves as well as barks of other plants (Min et al., 2003). These plants are widely distributed and are suitable for feeding ruminants (Vasta et al., 2008). They have been exploited as alternative sources of feed to replace cereal concentrate in small ruminant diet and their utilization has increased in recent years. Tanniniferous plants are also believed to have positive effect on animal health as they have been shown to minimize the risk associated with parasitic nematodes infection.

This study focuses on the use of tanniniferous plants to combat parasitic nematode infection in small ruminants. The study applied internet search to specifically identify relevant scientific articles. The literature on the use of tanniniferous plants in sheep and goats production was systematically reviewed between December 2018 and November 2019, at Jilin Agricultural University, China. Relevant scientific papers published in English peer-reviewed journals were searched using the key words combination (tanniniferous plants or forages or legumes, parasitic nematode and small ruminants or sheep or goats). The online electronic database through Google scholar, Scopus, Web of Science and Science direct were searched to capture the latest information. The available relevant papers in the field were reviewed and summarized in the article.

Effect of CT on nutrition and performance of the host
Gastrointestinal parasites are known to be the main cause of poor performances of sheep and goats. Infestation with parasitic nematodes may reduce voluntary feed intake, weight gain, cause anemia and eventually host death. However, it has been known that consumption of tanniniferous forages could reduce negative effects of parasitic nematodes infection in small ruminants (Paolini et al., 2003; Hoste et al., 2012; Arroyo-Lopez et al., 2014). Many plant species of families Fabaceae, FAGACEAE, Anacardiaceae among others have been used to improve performance of parasitized sheep and goats (Athanasiadou et al., 2001; Iqbal et al., 2007; Marume et al., 2012; Villaalba et al., 2014).

Voluntary feed intake
The most significant effect of parasitism with nematodes is reduction in voluntary feed intake, which influences growth performance of small ruminants. Gastrointestinal infection in sheep and goats may result in 6-50% reduction in feed intake. It has been speculated that such effect could raise from abdominal pain or discomfort associated with gastrointestinal nematodes activities, with extend depending on the host age, breed and parasite species (Poppi et al., 1990; Knox et al., 2006).

The CT in forage legumes seem to be effective in suppressing gastrointestinal nematodes in sheep and goats. Sainfoin is a perennial forage legume of family Fabaceae commonly found in temperate regions. This legume has been used as pasture, conserved as hay or silage for sheep and goats. Confinement feeding trial has shown that Trichostrongylus colubriformis infected sheep consuming Sainfoin hay (S) containing 2% CT had higher feed intake compared to those on grass hay (G) containing 1% CT (Rios-De-Álvarez et al., 2008). This could be due to nutritional modulation of host immune responses or ingestion of CT, which would regulate establishment of worm and reduce the degree of anorexia (Hoste et al., 2006; Houdijk, 2012). Moreover, tanniniferous forages are more palatable. Similarly, Romero et al. (2016) found that supplementation with perennial peanut (PEA) and Sericea lespedeza (LES) hays tended to increase feed intake (757 and 745 g/d, respectively) of nematode infected goats in confinement (Table 2). This could be attributed to the CT content in PEA and LES which suppressed parasitic nematodes. Indeed, a large number of studies have shown that CT containing forages improved feed intake of parasitized lambs (Lisonbee et al., 2009; Merera et al., 2013) and goats (Seng et al., 2007; Moore et al., 2008; Sokerya et al., 2009; Amit et al., 2013). However, some results showed that feed intake of nematode infected sheep (van Zyl et al., 2017) and goats (Lopes et al., 2016) were not affected by feeding tanniniferous forages (Table 2). Nevertheless, high CT concentration level has been associated with decreased diet palatability, reduced voluntary feed intake, disturbed digestibility and decreased nutrient intake (Pathak, 2013b; Addisu, 2016). Heckendorf et al. (2007) observed lower feed intake in Swiss lambs artificially infected with Haemonchus contortus consuming Chicory, Birdsfoot and
Sainfoin containing, respectively, 3.1, 15.2 and 26.1 CT g/kg DM (Table 2). This might be due to CT concentration level or parasite species. Haemonchus contortus is the most pathogenic and prolific endoparasitic nematode. Adult female H. contortus can lay up to 5000-10000 eggs per day (Sinnathamby et al., 2018), increasing worm load and severity of the infection.

Weight again

Endoparasitic nematodes found in the abomasum or small intestine cause reduction in weight gain of sheep and goats. However, consumption of CT containing forages seems to improve weight gain of the host in spite of the infection. In a feeding trial in Pakistan using H. contortus infected sheep (Iqbal et al., 2007), diet supplement was offered daily and contained low and high tannin, respectively, 2 and 3% CT. The results showed that weight gain was significantly higher (8.2 kg) in 3% CT supplemented sheep compared to 2% CT supplemented sheep (6.8 kg) and tannin-free sheep (4.8 kg). An increased in weight gain has been used as a marker of resilience in nematode infected ruminants. Additionally, a number of studies are also in agreement with these results in parasitized sheep supplemented with L. pallida (Merera et al., 2013), Sainfoin (Arroyo-Lopez et al., 2014) and Leucaene cuneata (Zyl et al., 2017). Most of CT containing forages are rich in protein content and are more digestible (Torres-Acosta et al., 2012).

Albizia, a genus of Fabaceae family comprises of more than 150 species, widely distributed in tropical regions in Africa and in South Central America. Albizia anthelmintica is believed to be rich in CT and other bioactive compounds rendering it potential drug for many diseases of animals. Administering trials with Albizia anthelmintica capsules (Gradé et al., 2008) were carried out using parasitized sheep to address some of the shortcomings from feeding experiments. The results showed that CT drenched increased weight gain of the sheep (Table 2). This could be due to increase in amount of protein by-pass ruminal degradation. Moreover, converting the CT containing forages into hay seems to increase protein bound and possibly covalently linked between CT and protein (Mueller-Harvey et al., 2019). Some results from study under temperate condition showed that supplementation with sun-dried Sericea lespedeza increased weight gain of goats naturally infected with nematodes (Moore et al., 2008). Similar observations were made by Sokerya et al. (2009) in Cambodian goats infected with nematodes fed cassava foliage and Marume et al. (2012) in Xhosa lop-eared goats of South Africa fed Acacia karroo. Contrary, Seng et al. (2007) and Osoro et al. (2007) reported that feeding nematode infected goats tanniferous plants did not increase weight gain (Table 2). This could be due to low total feed intake and availability of nutrient in the feed.

Effect of CT on hematobiochemical parameters of the host

Gastrointestinal parasitism in sheep and goats is directly associated with anemia and hypoproteinemia resulting from endogenous protein and blood losses. Studies show that supplementation with CT containing forages alleviate impacts of parasitism in sheep and goats (Arroyo-Lopez et al., 2014; Singh et al., 2016). A pasture trial conducted by Merera et al. (2013) showed that supplementation with Leucaene pallida significantly increased packed cell volume (PCV) of nematode infected Horro lambs compared to those assigned grazing alone. In the United States, Moore et al. (2008) evaluated the anthelmintic effects of S. lespedeza (SL) on H. contortus infected goat kids randomly assigned to two dietary treatments consisting of 75% SL hay (CT) or Bermuda grass (no CT) and 25 % concentrate. At the end of experimental period, a significant increase in PCV was recorded in goats in the SL group relative to those in no CT group. Similar results have been obtained by Merera et al. (2013) and Arroyo-Lopez et al. (2014) from infected lambs fed sainfoin. The increased in PCV could be due to reduce number of blood sucking parasites in abomasum and small intestine by CT or improved protein nutrition allowing the host to replace lost protein more rapidly. Further, Villalba et al. (2013) reported increased in MCHb of H. contortus infected sheep fed sainfoin (Onobrychis vicifolia) but no effect was observed on MCV. In contrast, Sokerya et al. (2009) reported that feeding Manihot esculenta to nematode infected goats for long-term reduced PCV from 30% to 25% (Table 3). Contrary, Seng et al. (2007) have shown that CT had no effect on PCV of nematode infected goats of Cambodia fed fresh Manihot esculenta foliage for short-term.

A number of studies have examined the effects of CT on different biochemical variables (hemoglobin, Protein,
Table 2: Feed intake and weight gain of nematode infected sheep and goats fed plants containing CT.

| Host          | Nematode                  | Plant                | CT % | FI          | DWG          | Reference                          |
|---------------|---------------------------|----------------------|------|-------------|--------------|------------------------------------|
| Sheep         | H. contortus and          | Chicory              | 3.1  | Increased   | Significant  | Hechendorn et al., 2007            |
|               | C. curticei               | Birdfoot             | 1.5  | Increased   | Increased    |                                    |
|               |                           | Sainfoin             | 2.6  |             |              |                                    |
| Goats         | Mixed species            | PEA and SL           | 11.4 | Increased   | Increased    | Romero et al., 2018                |
| Sheep         | Mixed species            | Alhizia anthelmintica| 0.04, 0.08, 0.18 | - | NS | Gradé et al., 2008 |
| Sheep         | H. contortus              | Commercial product   | 3.0  | -           | Significant higher (8.2 kg)       | Iqbal et al., 2007 |
| Sheep         | T. colubriformis          | Sainfoin             | 2.0  | No increased | High (75.2 ±8.8 g) | Rios-De-Álvarez et al., 2008 |
| Sheep         | H. contortus              | Sainfoin (Visnovsky) | 8.1  | Slightly increased | No effect | Azuhwni et al., 2013 |
| Goats         | Mixed species            | Cassava (Manihot esculenta) | ND | Increased | Significant increased | Seng et al., 2007 |
| Goats         | H. contortus and          | Cassava (Manihot esculenta) | ND | No effect | increased (42.5 g and 59.0 g) | Sokerya et al., 2009 |
|               | T. colubriformis          |                      |      |             |              |                                    |
| Sheep         | Mixed species            | Leucaena palida      | ND   | Increased   | Significant higher | Chala et al., 2013 |
| Sheep         | Mixed species            | Quebracho            | ND   | Increased   | No effect    | Lisonbee et al., 2009 |
| Sheep         | H. contortus and          | Sainfoin             | ND   | -           | No effect    | Arroy-Lopez et al., 2014 |
|               | T. colubriformis          |                      |      |             |              |                                    |
| Goats         | Mixed species            | Pistacia lentiscus   | 20.8 | Increased   | Increased    | Amit et al., 2013 |
|               |                          |                      |      |             |              |                                    |
| Goats         | Mixed species            | Bauhinia pulchella   | 13   | No effect   | Increased    | Lopes et al., 2016 |
| Sheep         | Mixed species            | L. cuneata           | 8.0  | No effect   | Significant increased | Zy et al., 2017 |
| Goats         | Mixed species            | S. lespedeza         | 6.5  | Increased   | Significant increased | Moore et al., 2008 |

CT: Condensed tannins; NS: Not significant; PEA: peanut; SL: Sericea lespedeza; FI: Feed intake; DWG: Daily weight gain; ND: Not determined; DM: Dry matter; BW: Body weight; d: day; g: gram; kg: kilo gram.
Increased plasma amino acids in parasitized sheep (Azuhnwi et al., 2013; Rios-De-Álvarez et al., 2014) and goats (Singh et al., 2016) receiving different tanniniferous forages. Azuhnwi et al. (2013) reported increased in plasma essential and semi-essential amino acids (AA) concentration in lambs artificially infected with H. contortus fed sainfoin. This increased in essential and semi-essential amino acids concentration could be due to increase in amino acids supply and absorption in small intestine. In addition to improve protein nutrition, CT can also modulate activity of host immune cells. Eosinophil cells are the most important elements in the response to nematode infection and are often associated with the expression of host resistance against the parasites (Terefe et al., 2005; Alba-Hurtado and Muñoz-Guzmán, 2013). Contrary, study carried out by Marume et al. (2012) showed that supplementation of Xhosa lop-eared goats with Acacia karroo did not affect eosinophil cell count. Similar results have been observed by Joshi et al. (2011) in H. contortus infected goats consuming Sericea lespedeza (Table 3). The lack of effect here is difficult to explain; probably, the goat breeds are naturally resistant to nematode infection.

**Effect of CT on parasite**

The CT have demonstrated good anthelmintic effects in both *in vitro* and *in vivo* studies on endoparasitic nematodes. These effects include reduction in egg excretion, worm number, lower fertility, lower worm establishment as well as impairing hatching and development of egg into third-stage larvae (Hoste et al., 2015).

Early evidence of CT effect on nematodes causing reduction in egg excretion and worm number has been reported under both temperate (Heckendorn et al., 2007; Moore et al., 2008; Joshi et al., 2011; Marume et al., 2012) and tropical conditions (Kahiya et al., 2003; Seng et al., 2007; Ibqbal et al., 2007; Max et al., 2007; Gradé et al., 2008; Sokerya et al., 2009; Minho et al., 2010; Merera et al., 2013). Recent results obtained from *H. contortus* and *T. colubriformis* infected sheep (Rios-De-Álvarez et al., 2008; Azuhnwi et al., 2013; Villalba et al., 2013; Arroyo-lopez et al., 2014; Zyl et al., 2017) showed significant reductions in egg excretion and adult worm number in the presence of tanniniferous forages (Table 4). Counting of worm egg excreted with feces is a practical and cost effective diagnostic tool for determining parasitism in small ruminants (Rinaldi et al., 2019). This method is used to estimate worm burden in sheep and goats. Few tanniniferous forages have been extensively investigated through *in vitro* assays and controlled *in vivo* studies. For instance, the results from *in vitro* assays that evaluated inhibitory capacity of *Ziziphus nummularia* and *Acacia nilotica* extracts against egg hatching and development of larvae were somehow discouraging (Bachaya et al., 2009), however, the results of *in vivo* studies on sheep naturally infected nematodes were much more encouraging. Moreover, goats fed heather...
Table 4: Parasitological parameters of nematode infected sheep and goats fed plants containing CT.

| Host         | Nematode            | Plant                        | CT%  | FEC          | Worm burden | Worm fecundity | Reference                  |
|--------------|---------------------|------------------------------|------|--------------|-------------|----------------|----------------------------|
| Sheep        | T. colubriformis    | Sainfoin (Onobrychis vicifolia) | 2.0  | No effect    | No effect   | No effect      | Ríos-De-Álvarez et al., 2008 |
| Goats        | H. contortus        | Acacia karroo                | 2.1  | -            | Significant reduced | - | Marume et al., 2012 |
| Goats        | Mixed species       | Cassava (Manihot esculenta)  | 2.3  | Reduced      | No effect   | Reduced        | Iqbal et al., 2007 |
| Sheep        | H. contortus        | A. niiatica and Z. nummularia| ND   | Reduced 79-85%| Reduced    | Reduced        | Bachaya et al., 2009 |
| Goats        | Mixed species       | Cassava (Manihot esculenta)  | ND   | Reduced      | Significant reduced | Reduced        | Sokerya et al., 2009 |
| Sheep        | Mixed species       | Leucaena paliida             | ND   | Significant reduced | Reduced | - | Mereta et al., 2013 |
| Goats        | Mixed species       | Peanut and S. lespedeza       | 11.4 | Reduced      | Significant reduced | Reduced | Romero et al., 2018 |
| Sheep        | H. contortus        | Sainfoin                     | ND   | Reduced      | Reduced     | Reduced        | Arroy-Lopez et al., 2014 |
| Goats        | Mixed species       | B. pulchella                 | 13.1 | No effect    | Reduced     | Reduced        | Lopes et al., 2016 |
| Goats        | Mixed species       | S. lespedeza                 | 6.5  | Reduced      | -           | -              | Moore et al., 2008 |
| Goats        | H. contortus        | S. lespedeza                 | ND   | Reduced significantly | - | No effect | Joshi et al., 2011 |
| Goats        | H. contortus        | A. nilotica and karroo       | 0.6-2.2 | Reduced significantly 10-34% reduced | - | - | Kahiya et al., 2003 |
| Goats        | T. colubriformis    | Heather                      | ND   | Significantly decreased | Reduced | Reduced | Moreno-Gonzalo et al., 2012 |
|              |                     |                              |      | by 47 and 66% |            |                |                            |
| Sheep        | Mixed species       | Sainfoin (Visnovsky)         | 8.1  | Decreased by 53% | Reduced     | Reduced        | Azuñwi et al., 2013 |
| Sheep        | H. contortus        | Onobrychis vicifolia         | 10.1 | Reduced      | -           | -              | Villaiba et al., 2013 |
| Sheep        | Mixed species       | L. cuneata                   | 8.0  | Reduced      | -           | -              | Zyl et al., 2017 |
| Sheep        | H. contortus        | Mimosa caesalpinifolia       | 6.4-12.8 | Reduced 66.9% | 57.7%       | -              | Brito et al., 2018 |
|              | O. columbánum       |                              |      |              |             |                |                            |
| Sheep        | Mixed species       | Albizia anthelmintica        | ND   | Reduced by 78% | -           | -              | Gradé et al., 2008 |
| Sheep        | H. contortus and    | Chicory                      | 3.1  | Reduced by 44% | Reduced     | -              | Hechendorn et al., 2007 |
|              | Cooperia curticei   | Birdsfoot                    | 1.5  | Reduced by 47% | -           |                |                            |
|              |                     | Sainfoin                    | 2.6  | Reduced by 57% | -           |                |                            |
| Sheep        | T. colubriformis    | Acacia mearnsii              | 15.0 | Significant reduced | Significant reduced | - | Minho et al., 2010 |
| Goats        | Mixed species       | Acacia polyacantha           | 32.4 | Reduced by 27% | Reduced by 13% | - | Max et al., 2007 |

CT: Condensed tannins; FEC: Fecal egg count; ND: Not determined.
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(Calluna vulgaris) (Moreno-Gonzalo et al., 2012) and perennial peanut or Sericea lespedeza (Romero et al., 2018) had lower egg excretion, adult worm number and worm fecundity. Similar results were reported by Brito et al. (2018) who observed 57.7 % and 66.9% reduction, respectively, in adult H. contortus and egg excretion in sheep consuming Mimosa caesalpinifolia (Table 4). It is generally assumed that CT could reduce adult worm number, egg excretion, egg hatching and larvae development through direct or indirect effects. Direct effects of CT could be mediated through CT-parasite interactions, thereby affecting physiological functions of the worms and causing their death (Hoste et al., 2006; Arroyo-Lopez et al., 2014). The CT can also bind to the free proteins, resulting in reduced nutrient availability and hence larval starvation and death (Athanasiadou et al., 2001; Iqbal et al., 2007). Indirectly, CT can improve host protein nutrition by increasing amount of by-pass protein, thereby improving host resistance to parasites. However, in goats grazed B. pulchella in tropical area of Brazil, Lopes et al. (2016) found no effect of CT on egg excretion but CT significantly reduced egg hatching percentage (Table 4). The lack of effect could be due to repeated and heavy mixed infection which overwhelmed the effect of CT.

Effect of CT on meat

Little work has been done to investigate effects of CT on carcass characteristics and meat quality of nematodes infected lambs (Pathak et al., 2013a; Zhong et al., 2015) and goats (Min et al., 2015) consuming different tanniniferous forages. Parasites infestation causes extensive protein losses leading to poor growth, meat production and meat quality of ruminants. The most convincing evidence to support the effect is that some results indicating an improved meat color (significant increased in redness and antioxidant activity) (Zhong et al., 2015) has been exhibited when lambs consumed green tea polyphenol (4g GTP). The mechanism by which CT effects meat color is unclear but can partly be explained by reducing biohydrogenation and thus exerting positive effects on the oxidative stability of the meat (Garcia et al., 2019). Skatole and indole are the main meat volatiles that strongly affect flavor. According to Priolo et al. (2009), skatole and indole were lower in fat of lambs supplemented with tannin compared to non-supplemented animals. In tropical regions of Asia, several trees of Myrtaecae and Moraceae families have been identified and explored for their tannins contain (Pathak et al., 2013a). Parasitized sheep consuming Ficus infectoria and Psidium guajava had significantly high carcass dressing percentage (Pathak et al., 2013a). However, fresh carcass weight and gastrointestinal weight were not affected in this experiment. Further researches in this area are needed to fully understand the mechanism through which CT affects meat color.

Effect of CT on milk

Up to now, effect of CT on milk yield and composition of nematodes infected sheep and goats has not been intensively investigated. However, milk production and composition of ruminants fed tanniniferous forages have been documented (Vasta et al., 2008; Kushwaha et al., 2011; Priolo, 2014; Morales and Ungerfeld, 2015). Recently, Abo-donia et al. (2017) reported that increased in dietary tannin increased concentration of cis-14 C18:1, cis-9, cis-12 C18:2 n-6 LA, total cis monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 and n-6 polyunsaturated fatty acids but reduced fat content in goat milk. Similar observations were made by Keles et al. (2017) who noted that increased in tannin level increased in C18:0 and total protein of goat milk. Further ewe receiving Hazelnut skin had greater milk MUFA and 18:1 trans than ewe fed no hazelnut (Campione et al., 2020). Tanniferous forages/tannin-containing diet could be used as effective means to increase unsaturated fatty acids content in ruminant milk.

CONCLUSION

Consumption of CT containing forages enhanced host resistance to endoparasitic infection as depicted in reduced adult worm number, egg excretion and increased PCV, albumin and total protein. Tanniferous forages can also improve host resilience to nematode infections by reducing detrimental impacts and increasing feed intake and weight gain. The effect of CT containing forages on meat quality of nematode infected ruminants has been less studied so far. However, tanniferous forages can improve meat color and antioxidant activity as well as increase unsaturated fatty acids in the milk. Therefore, CT containing forages have great potential to improve production of sheep and goats and potential anthelmintic properties to reduce reliance on anthelmintic drugs to combat endoparasites. Further researches to determine applicable CT doses and develop effective tools as well as methods of extraction are crucial.

Conflicts of interest

No potential conflicts of interest.

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