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Meat quality analysis of Djallonke lambs co-infected with *Teladorsagia circumcincta* and *Trichostrongylus colubrifromis (*Trichostrongyloidae*)* and treated with two medicinal plants

Ndah Germaine[1], Fonteh A. Florence[2], Tedonkeng Fernand[2], Mpoame Mbida[1], Lumofoet Jules[2], Temgoua I. F. Kengne [2], Kenmogne A.Tayou [2], Nzonang N. Douglas[2], Vemo B. Narcisse[2] and Wabo J. Poné [1]

[1]Research Unit of Biology and Applied Ecology, Faculty of Science, University of Dschang, Cameroon.
[2]Department of Animal Production, Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon.

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Gastrointestinal nematode infection adversely affects small ruminant productivity all over the world, especially in tropical countries. A study was carried out to evaluate the extent to which concurrent infection with these nematodes may influence lamb meat quality, and how phytotherapy might improve these parameters. During the trial, 24 male Djallonke lambs (Age: 3 to 5 months) were experimentally infected with *Teladorsagia circumcincta* (4000 infective larvae) and *Trichostromgylus colubriformis (*10000 infective larvae) and treated from day 26 post infection with methanol extracts of *Harungana madagascariensis* and *Momordica foetida* twice daily. Lambs were divided into 8 groups: An untreated (Group 1), Albendazole 7.5 mg/kg (Group 2), *H. madagascariensis* extract at 125 mg/kg (Group 3), *H. madagascariensis* extract at 250 mg/kg (Group 4), *H. madagascariensis* at 500 mg/kg (Group 5), *M. foetida* extract at 125 mg/kg (Group 6), *M. foetida* 250 mg/kg (Group 7), and *M. foetida* at 500 mg/kg (Group 8). Meat quality attributes of lambs from different treatment groups were evaluated. Treatment with different doses of plant extracts led to differences in the level of parasitic load at necropsy. This effect was accompanied by an elevated pH_{24} in meat from the most severely infected lambs and a concomitant decrease in their chemical composition. This high pH_{24} equally had significant influence on meat flavour, overall acceptability and water retention of lamb meat. The present study suggested that nematode infection may influence pH of resulting carcass, nutritional composition and some sensory parameters of meat while treatment using *M. foetida* at 500 mg/kg maybe important in reducing parasite burden while enhancing quality of subsequent lamb carcass.

Key words: Phytotherapy, meat quality, *Teladorsagia circumcincta, Trichostrongylus colubriformis, Harungana madagascareinsis, Momordica foetida,* Djallonke lambs.

INTRODUCTION

Infection with gastrointestinal nematodes has a worldwide distribution, occurring in both tropical and subtropical areas of the world (Biu et al., 2012b; Mohamed et al., 2016). In Cameroon, gastrointestinal helminth infections are very prevalent, especially in the Western High Lands of the country where the rainfall pattern and ambient temperature favour the growth and multiplication of parasite (Ndamukong et al., 1989). Field trials carried out by Mbafor et al. (2014) in West Region of Cameroon indicated that *Trichostrongylus* and *Teladorsagia* species are among the most common nematodes of sheep in the Western Highlands, with a high prevalence of 93.3 and 53.3%, respectively. During primary infection with *Teladorsagia* spp., dysplasia of the abomasal glands and a reduction in acid-secreting cells occur as the nematodes colonise the stomach mucosa (Fox, 1997; Rinaldi et al., 2011). Severe villus atrophy (decreased villous: crypt ratios), goblet cell hyperplasia as well as sloughing of enterocytes into the intestinal lumen occur with establishment of *Trichostromgylus colubriformis* larvae (Roy et al., 2004). Characteristic dark foul smelling diarrhoea, anorexia, diminished absorptive capacity or poor food conversion efficiency are the consequences of the destruction of the mucosal architecture (Williams and Palme, 2012; Rajib et al., 2014). It has been reported that co-infections with *Teladorsagia* and *Trichostrongylus* spp. has a synergistic effect (Steel et al., 1982; Sykes et al., 1988). The combined effect of anorexia, malabsorption and diarrhoea may result in loss of quantity and quality of resulting carcass (Mushi et al*.,* 2007).

Nowadays, consumers are highly interested in the quality of the products they eat, especially when this refers to meat (Guerrero et al., 2013). Furthermore, meat quality is of significant importance for consumers' health (Ivanov et al., 2017). It has been reported that infections with gastrointestinal nematodes affect some meat characteristics, including the meat color stability, composition and conformation of small ruminants (Arsenos et al*.,* 2009; Zhong et al., 2015).

Although, chemical anthelmintics have long been used in combating helminthiasis, their use is increasingly discredited due to the increasing resistance of these nematode to most classes of anthelmintics available, drug residues in animal products and loss of productivity in host animals (Zhong et al., 2015., Jackson and Coop, 2000; Tsiboukis et al*.,* 2013). The general swing towards the use of natural compounds has stimulated research into their use as anthelminthic alternatives. Thus, many studies have explored the use of plant-derived phenolic compounds, especially tannins, which show direct and indirect anthelmintic activity for gastrointestinal nematode control in ruminants (Vargas-Magaña et al., 2014; Zhong et al., 2015).

Momordica foetida (Cucurbitaceae) and *Harungana madagascariensis* (Hypericaceae) are two medicinal plants widely known for their anthelmintic and appetite stimulating potentials (Pavan et al., 2013; Olukayode et al., 2008). Boronkini et al. (2012) carried out a phytochemical analysis of both plants and reported that they are rich in secondary metabolites such as tannins, flavonoids and alkaloids. In addition, *M. foetida* contains lipids and lipophilic compounds which have been used in fattening domestic herbivores (Oloyede and Aluko, 2012). Furthermore, giving ruminants polyphenolic plants could improve meat quality by increasing antioxidants into the circulatory system, which when assimilated and retained in the meat, they will improve sensory characteristics such as flavor and juiciness scores of meat (Qwele et al*.,* 2013; Moyo, et al., 2014; Zhong et al*.,* 2015).

It is clear that infection with *T. circumcincta* and *T. colubriformis* may depress appetite, reduce nutrient utilization and deplete glycogen reserves, thus influencing meat quality. However, the extent to which these nematodes can influence meat quality remains doubtful (Zhong et al*.,* 2015). Moreover, if this is true, can administration of plant extracts improve nutrient utilization and the resultant meat quality after slaughter? With these questions in mind, the present study was designed to evaluate changes in the nutritional value of meat from lambs co-infected with *T. circumcincta* and *T. colubriformis,* and how treatment use with methanol extracts of *M. foetida* and *H. madagascariensis* may improve these parameters.

METHODOLOGY

Study animals

A total of 24 male Djallonke sheep were used in this study. Ages of the animals ranged between 4 and 5 months. Dentition pattern as described by Samad (2008) was used to determine ages of experimental animals. These animals were acquired from two sheep farmers in Fongo Tongo village, 40 km away from Dschang town. Two weeks before arrival, all the animals in the two farms were vaccinated against Small Ruminant Pests (SRP) using Capri-pestovax and were also treated with anthelmintics (levamisole injection 10 mg/kg and Albendazole tablets 10 mg/kg). Two days after arrival of animals in the experimental animal house of the Faculty of Agronomy and Agricultural Sciences of the University of

*Corresponding author. E-mail: alonjims@yahoo.com.

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Dschang, experimental animals were given antibiotics (Oxytetracycline 1 ml/10 kg body weight), anticoccodia (Toltrazuril, 10 mg/kg), multivitamin and anti-stress (Stress vita 2.5 ml/10 kg body weight). They were allowed to acclimatize for 14 days and their faecal samples examined daily within this period to confirm that animals were helminth free by the use of the concentrated salt flotation technique as described by Thienpont et al. (1986) and Baker (2007). After this adaptation period, all animals were inoculated with the same dose of 14000 L_3 larvae as follows: day 1: 5.000 L3 of *T. colubriformis* per animal using a syringe via the oral route. Day 2: 5.000 L3 of *T. colubriformis* and day 3: 4.000 L3 of *T. circumcincta*. Animals were randomly allocated to eight sub groups of 3 individuals on day 26 post inoculation and treated as follows: Group 1, Untreated group (received the vechicle 3.2% dimethyl sulphoxide); Group 2, Positive control group (Albendazole 7.5 mg/kg); Group 3, *H. madagascariensis* 125 mg/kg; Group 4, *H. madagascariensis* 250 mg/kg; Group 5, *H. madagascariensis* 500 mg/kg; Group 6, *M. foetida* 125 mg/kg; Group 7: *M. foetida* 250 mg/kg; Group 8, *M. foetida* 500 mg/kg body weight. Each group was placed in separate pens of dimension 7.5 m^2 (3 m × 2.5) on slatted floors. A solid partition separated adjacent pens and care was taken to avoid contamination of pens with nematode larvae from outside sources. All animal groups were served 6 kg of the same fresh forage (mainly *Tripsacum laxum* and *Leucaena leucocephala*) harvested 24 h before feeding, washed in clean water, dried in the sun for 2 h and chopped before serving to the animals. Water was provided *ad libitum*. The weight of the animals was taken weekly and weight of food consumed by each group was recorded daily.

Selection of plants

An ethnobotanic study permitted the selection of two medicinal plants with anthelmintic and appetite stimulating potentials. They were harvested in April 2016, identified and authenticated at the National Herbarium of Cameroon in Yaounde by voucher specimen N° 46105/HNC for *H. madagascariensis* and N° 24393/HNC for *M. foetida.* The bark of *H. madagascariensis* and whole aerial parts of *M. foetida* were shade dried at room temperature. The dried plant parts were powdered mechanically using a commercial electrical blender and stored in airtight plastic bags at 4°C until preparation of extracts.

Preparation of methanol extracts

Four hundred and fifty grams of each plant powder were macerated in 3 L of methanol. The mixture was stirred for 10 min and stored for 72 h at room temperature. This solution was sieved through Whatman No. 1 filter paper, divided into portions of 200 ml each then evaporated in a rotavapor at 50°C. The dry extracts were stored at 4°C until used for *in vivo* assays.

Treatment of experimental lambs

Treatment with plant extracts was administered on day 26 post inoculation and subsequently twice daily for 4 days. Albendazole 7.5 mg/kg was administered on the last day of treatment. On day 56 post inoculation (30 days post treatment), all 24 animals were humanely sacrificed, the slaughtering was carried out by severing the jugular vein and the carotid arteries to ensure proper bleeding (Kefyalew et al., 2013). The lambs were bled within 3 min after slaughter and suspended to remove their skin, head (at the occipito-atlantal joint), forefeet (at the carpal-metacarpal joint), and hind feet (at the tarsal-metatarsal joint). The viscera including the gastrointestinal tract were removed.

Meat quality analysis

Meat samples from *longissimus dorsi* muscle were taken between 6 and 11th ribs of each animal and used for physical and technological evaluation while meat from the left hind leg was used for chemical and sensory evaluation.

Physical evaluation

Determination of pH_{24}

To determine pH_{24}, 10 g of *l. dorsi* muscle from each carcass was weighed using an electronic balance (max 6000 g, d = 0.1 g) and refrigerated at 0°C for 24 h. The ultimate pH_{24} was evaluated after thawing by inserting the sharp tip of a portable pH meter (Testo 205, Testo AG, Lenzkirch, Germany) to a depth of about 2 cm into each meat sample. The pH value was then read directly on the pH meter.

Evaluation of technological properties of meat

Drip loss

The drip loss was evaluated following the procedure described by Honikel (1998). One hour after slaughter, 100 g of muscle was weighed and put in nylon net bags. Each bag was hung over a beaker at 4°C for 24 h, after which the samples were removed, dabbed dry on a serviette and reweighed. Percentage drip loss was calculated using the formula:

$$\text{Drip loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\textit{Initial weight}} X\ 100 \quad (2)$$

Cook-out loss

The cook-out-loss was evaluated as described by Paisentier et al. (2003). To this effect, 50 g of *l. dorsi* muscle was weighed and put inside weighed Ziploc bags. These were immersed in a thermostatic water bath at 75°C for 15 min, after which the muscles were removed, allowed to cool to room temperature for about 1 h, dabbed on a paper serviette and re-weighed. The percentage cook-out-loss from each sample was calculated as follows:

$$\text{Cook-out-loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\textit{Initial weight}} X\ 100 \quad (3)$$

Freezing loss

This was determined based on the procedure described by Paisentier et al. (2003). To this effect, 33 g of *l. dorsi* muscle from each lamb carcass was weighed into zip lock plastic bags. These were frozen at -20°C for 14 days. They were then removed and allowed to thaw at room temperature, after which each sample was dabbed dry and re-weighed. Percentage freezing loss was calculated as follows:

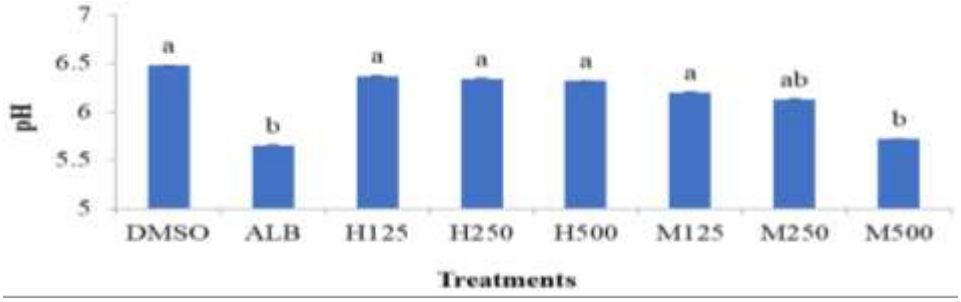

Figure 1. Influence of treatment using methanol extracts of *Harungana madagascariensis* and *Momordica foetida* on pH_{24} of meat from lambs co-infected with *Teladorsagia circumcincta* and *Trichostrongyglus colubriformis*. [ab]Bars with different letters are significantly different. DMSO: Dimethyl sulphoxide (3.2%); Alb: Albendazole 7.5 mg/kg; H125: *Harungana madagascariensis* 125 mg/kg; H250: *Harungana madagascareinsis* 250 mg/kg; H500: *Harungana madagascariensis* 500 mg/kg; M125: *Momordica foetida* 125 mg/kg; M250: *Momordica foetida* 250 mg/kg; M500: *Momordica. foetida* 500 mg/kg.

$$\text{Freezing loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\textit{Initial weight}} X\ 100$$

Evaluation of chemical composition of lamb meat

Meat samples were minced and dried in a ventilated oven at 105°C for 20 to 24 h when a constant weight was attained. Moisture content was calculated as the difference in weight before and after drying. Crude protein, crude lipid and ash contents were estimated on dry matter basis as according to the AOAC (2005). The results were expressed as percentages.

Minerals analysis

Calcium (Ca), magnesium (Mg), and iron (Fe), were determined using Atomic Absorption Spectrophotometer (GBC atomic absorption spectrophotometer, Australia) according to Pauwels et al. (1992) and AOAC (2005). The values of Mg, Ca, and P were determined as mg/g dry weight, while the value of Fe was measured as mg/kg dry weight.

Evaluation of sensory properties

Sensory characteristics of meat were determined after slaughter of animals using 20 test panellists. Test panellist was selected among students of the Department of Animal Production, Faculty of Agronomy and Agricultural Sciences (FASA), University of Dschang. Screening exercises were administered prior to panel selection in order to diagnose the most qualified panel members. These included taste identification and taste intensity exercises, using score charts adapted from Abd El-aal and Suliman (2008) and Dimple and Rohanie (2014). After selection of the most qualified test panellists, samples of meat were sliced into 2.0 cm steaks, put in zip lock bags based on different treatment groups and boiled for 45 min using an electric cooker. The panellists were served with samples of meat in different trays. To evaluate these sensory characteristics, a 5-point scale adapted from Abd El-aal and Suliman (2008) and Dimple and Rohanie (2014) was used. Sensory attributes assessed included tenderness, juiciness, flavour intensity, and overall acceptability as follows: (tenderness: 5 = tender, 1= very tough; juiciness: 5 = juicy, 1= very dry; aroma: 5 = very good flavour, 1 = off flavour; general acceptability: 5 = highly desirable, 1 = extremely poor).

Statistical analysis

Statistical analysis was performed using SPSS version 20.0. To test the effects of treatment on studied parameters, one-way analysis of variance (ANOVA), General Linear Model approach, was used. Pearson correlation coefficient was used to establish the relationship among adult worm burden and pH_{24} of lamb meat. The post hoc test employed for all analysis was Duncan's Multiple Range Test. Results obtained were expressed as mean ± standard deviation. Probability values $P<0.05$, was considered significant.

RESULTS

Results showing the variation in adult worm burden recovered at necropsy from the abomasums and intestines of lambs co-infected with *T. circumcincta* and *T. colubriformis* and treated with albendazole and methanol extracts of *H. madagascariensis* and *M. foetida* in Germaine et al. (2017).

Figure 1 summarizes the influence of treatment using methanol extracts of *H. madagascariensis* and *M. foetida* on meat ultimate pH (pH_{24}).

Ultimate pH_{24} in lamb was observed to be significantly lower ($P<0.05$) in albendazole treated lambs and those treated with *M. foetida* at dose rate 500 mg/kg when compared with untreated group. Treatment with *H. madagascariensis* extracts at all tested doses and *M. foetida* at doses less than 500 mg/kg had no significant influence ($P>0.05$) on meat pH_{24} when compared with untreated lambs. There was a strong positive correlation

Table 1. Influence of treatment using methanol extracts of *Harungana madagascariensis* and *Momordica foetida* on technological properties of lamb meat co-infected with *Teladorsagia circumcincta and Trichostrongylus colubriformis*.

Treatment	Cooking loss (%)	Freezing loss (%)	Drip loss (%)
Vechicle (DMSO 3.2%)	11.14 ± 1.44	9.66 ± 0.04	7.17 ± 0.50[b]
Alb7.5 mg/kg	11.33 ± 2.32	10.31 ± 1.26	9.84 ± 2.82[a]
H125 mg/kg	11.31 ± 1.50	9.31 ± 1.43	7.32 ± 1.71[b]
H250 mg/kg	12.16 ± 2.25	9.16 ± 0.68	7.55 ± 0.39[b]
H500 mg/kg	11.18 ± 1.15	9.46 ± 1.02	7.69 ± 3.39[b]
M125 mg/kg	11.70 ± 1.65	9.85 ± 0.79	7.80 ± 2.21[b]
M250 mg/kg	10.51 ± 1.85	9.44 ± 1.88	7.73 ± 0.75
M500 Mg/kg	11.51 ± 0.43	10.05 ± 1.89	8.70 ± 1.74[ab]
P-value	0.56	0.21	0.01

[abc]Mean values followed by the different latters on the same columns are significantly different (P<0.05). DMSO: Dimethyl sulphoxide (3.2%); Alb: Albendazole 7.5 mg/kg; H125: *Harungana madagascariensis* 125 mg/kg; H250: *Harungana madagascareinsis* 250 mg/kg; H500: *Harungana madagascariensis* 500 mg/kg; M125: *Momordica foetida* 125 mg/kg; M250: *Momordica foetida* 250 mg/kg; M500: *Momordica foetida* 500 mg/kg.

Table 1 shows the effects of treatment on technological properties of lamb carcasses. There was no significant difference between all groups of animals concerning cooking loss and freezing loss. However, significant differences (P ≤ 0.05) in drip loss was found among the different animal groups, with those treated with *M. foetida* 500 mg/kg and albendazole allowing drip significantly more (P<0.05) than all other experimental groups.

Influence of treatment using methanol extracts of *H. madagascariensis* and *M. foetida* on chemical properties of meat is summarized in Table 2. The lipid content showed no significant variation (P>0.05) between the different animal groups. Protein and ash contents showed a reverse trend, being significantly higher in albendazole 7.5 mg/kg, *H. madagascariensis* 500 mg/kg, *M. foetida* 250 mg/kg and *M. foetida* 500 mg/kg treatment groups. This significant difference observed in ash content was more pronounced in the results of individual mineral analysis. Meat from lambs treated with albendazole 7.5 mg/kg, *H. madagascariensis* 500 mg/kg, *M. foetida* 250 mg/kg and *M. foetida* 500 mg/kg recorded significantly higher, calcium, magnesium and phosphorus contents when compared with the untreated lambs. However, no significant difference (P>0.05) in iron content across the different groups was recorded during this study.

Influence of treatment using methanol extracts of *H. madagascariensis* and *M. foetida* on sensory characteristics of lambs co-infected with *T. circumcincta* and *T. colubriformis* is summarized in Table 3. There was a significantly higher flavour liking of meat from lambs treated with albendazole and *M. foetida* 500 mg/kg than all other groups. The overall acceptability result closely matched that of flavour liking, with meat from albendazole and *M. foetida* 500 mg/kg treated lambs being the most acceptable. It was noticed in this experiment that meat from all animal groups was equally tender and juicy.

DISCUSSION

In this study, methanol was used for extraction because of its ability to extract almost all the chemical components of plants due to its high polarity index (Eloff, 1998). Since almost all identified components like tannin, phenol and alkaloids that are active against helminthes are aromatic or saturated organic compounds, they are often obtained through initial extraction with methanol or ethanol (Vilegs et al., 1997; Khadijah, 2015).

The pH of muscle at post mortem is the main indicator of meat quality at a commercial level (Cvrtila Fleck et al., 2015). The present results revealed that pH_{24} differed significantly between treatment groups. It was observed that apart from lambs that received albendazole and *M. foetida* 500 mg/kg, lambs in all other treatment groups (*M. foetida* 125 mg/kg, *M. foetida* 250 mg/kg, *H. madagascariensis* 125 mg/kg, *H. madagascariensis* 250 mg/kg, *H. madagascariensis* 500 mg/kg) and the untreated group had significantly higher pH_{24} (pH ≥ 6). Phillips and Wheeler (2008) reported that ultimate pH_{24} (that is after the post mortem biochemical changes involving the depletion of muscle glycogen are completed) in lamb tends to be higher in animals subjected to chronic stress. Reference has already been made to the fact that the pH_{24} of the best quality lamb meat tends to fall in the pH range of 5.3 to 5.8 (Beriain et al., 2000). The higher pH_{24} could thus be attributed to depleted glycogen reserves, owing to the fact that sheep severely infected with *T. circuncuncta* and *T. colubriformis* have reduced feed intake and significantly lower food utilization ability (Steel et al., 1982; Stear et al., 2003; Rinaldi et al., 2011; Germaine et al., 2017). Abd El-aal and Suliman (2008) had indicated that ultimate pH is affected by factors such as diet and prolonged hunger before slaughter. Stress has a marked negative impact

Table 2. Influence of treatment using methanol extracts of *H. madagascariensis* and *Momordica foetida* on chemical properties of lamb meat, co-infected with *Teladorsagia circumcinta* and *Trichostrongylus colubriformis*.

Chemical composition	Treatment								
	DMSO (Vechicle)	Albendazole	Har 125	Har 250	Har 500	Momo 125	Momo 250	Momo 500	P
Proteins (g)	19.70 ± 0.59^{b}	21.76 ± 0.18^{a}	19.30 ± 0.23^{b}	20.38 ± 0.14^{ab}	21.33 ± 0.10^{a}	20.70 ± 0.35^{ab}	21.27 ± 0.49^{a}	21.43 ± 0.65^{a}	0.04
Ash(g)	2.08 ± 0.06^{b}	2.90 ± 0.14^{a}	2.04 ± 0.02^{b}	2.17 ± 0.19^{b}	2.82 ± 0.11^{a}	2.11 ± 0.11^{b}	2.69 ± 0.42^{a}	2.75 ± 0.15^{a}	0.00
Lipids (g)	3.82 ± 0.33	3.94 ± 0.72	3.36 ± 0.75	3.97 ± 1.11	3.32 ± 0.67	3.72 ± 0.34	3.80 ± 0.44	3.84 ± 0.67	0.08
Moisture (g)	75.38 ± 0.65^{a}	73.52 ± 0.92^{b}	75.66 ± 0.33^{a}	75.57 ±0.27^{a}	74.48 ± 0.34^{ab}	76.28 ±0.44^{a}	75.14 ± 0.28^{a}	73.61 ± 0.33^{b}	0.03
Ca (mg)	6.73 ± 0.05^{b}	7.28 ± 0.1^{a}	6.8 ± 0.1^{b}	6.73 ± 0.05^{b}	7.33 ± 0.05^{a}	6.76 ± 0.05^{b}	7.06 ± 0.15^{a}	7.16 ± 0.05^{a}	0.05
Mg (mg)	20.33 ± 3.21^{b}	27.33 ± 0.30^{a}	23.13 ± 1.15^{b}	23.00 ± 2.64^{b}	26.13 ± 0.81^{a}	23.60 ± 2.62^{b}	25.73 ± 0.25^{a}	27.93 ± 0.47^{a}	0.00
Fe (mg)	1.72 ± 0.05	1.93 ± 0.25	1.72 ± 0.06	1.73 ± 0.15	1.83 ± 0.09	1.70 ± 0.10	1.76 ± 0.05	1.88 ± 0.10	0.09
Ph (mg)	175.67 ± 13.05^{b}	197.67 ± 2.51^{a}	183.67 ± 22.54^{ab}	192.33 ±11.06^{a}	200.00 ± 5.29^{a}	171.00 ± 3.00^{b}	200.00 ± 1.00^{a}	204.00 ± 1.00^{a}	0.04

^{a,bc}Means with the same letters on the same colums are not significantly different (P>0.05). DMSO: Dimethyl sulphoxide (3.2%); Alb: Albendazole 7.5 mg/kg; H125: *Harungana madagascariensis* 125 mg/kg; H250: *Harungana madagascareinsis* 250 mg/kg; H500: *Harungana madagascariensis* 500 mg/kg; M125: *Momordica foetida* 125 mg/kg; M250: *Momordica foetida* 250 mg/kg; M500: *Momordica foetida* 500 mg/kg.

not only on meat pH, but concomitantly on technological properties of resulting carcass. High pH_{24} affects the water binding nature of the proteins and therefore directly affects the water holding capacity of meat (Huff-Lonergan et al., 2010). During this study, it was observed that meat from lambs in the untreated group had an unusually higher water holding capacity, this being evident by their lower drip loss than albendazole and *M. foetida* 500 mg/kg treated lambs. These results are in agreement with the report of Cheng et al. (2008) who indicated that high pH meat does not readily allow drip, thus resulting to dry, firm and dark meat. Again, Phillips and Wheeler (2008) recorded high water holding capacity corresponding to carcass with the highest pH.

This high water holding capacity has a major disadvantage of retaining more water than necessary, leading to more rapid deterioration due to microbial growth; hence, such meat will have a shorter shelf life (Huff-Lonergan et al., 2010). It was observed during our investigations that there was no significant difference between all groups of animals concerning cooking loss and freezing loss. Our results are in conformity with those obtained by Abd El-aal and Suliman (2008) and Fonteh et al. (2015) who equally recorded no significant difference in cooking loss and freeing loss of meat in groups of animals exposed to different stress levels. It was observed in this trial that carcass from different treatment groups with different levels of gastrointestinal adult worm burden had significantly different levels of moisture and crude protein while the lipid content showed no significant variation. Meat from lambs treated with plant extract at doses less than 500 mg/kg had a higher water content (>75 g) and asignificantly lower protein content (<20 g) per 100 g of meat. These values deviated from the standards reported by Sinclair et al. (1990) and Williams et al. (2006). These authors indicated that the protein content of 100 g of lamb meat is between 21.5 and 22.5% and moisture content is approximately 73.5%. The high moisture content could be attributed to increase level of stress due to gastrointestinal parasitaemia. Page et al. (2001) reported that stress promotes accumulation of intracellular water which reflects less light and causes the muscle to appear dark.

On the other hand, the lower protein content could be attributed to their significantly lower ability of feed utilization when compared with healthy animals. Anorexia and and/or reduction in food conversion efficiency has been observed in sheep co-infected with *T. colubriformis* and *T. circumcincta* (Steel et al*.,* 1982; Stear et al., 2003; Rinaldi et al., 2011; Germaine et al., 2017).

Few studies have compared the chemical composition of meat from lambs with different levels of gastrointestinal nematode parasitism. However, the present study report agrees with Valieva et al*.* (2014) who observed significantly higher protein and fat content in healthy

Table 3. Effect of treatment using methanol extracts of *Momordica foetida* and *Harugngana madagascariensis* on sensory characteristics of lamb co-infection with *Teladorsagia circugmcincta* and *Harungana madagascariensis*.

Treatment	Tenderness	Juiciness	Flavour	General acceptability
Vechicle (DMSO)	2.67 ± 1.55	3.88 ± 0.90	2.68 ± 0.58^{b}	3.00 ± 0.78^{c}
Alb 7.5mg/kg	3.3 ± 1.02	3.67 ± 0.58	4.33 ± 0.00^{a}	4.50 ± 0.00^{a}
H125 mg/kg	2.67 ± 0.58	3.0 ± 1.73	2.67 ± 0.58^{b}	3.00 ± 1.00^{c}
H250 mg/kg	2.67 ± 0.57	4.00 ± 1.00	2.67 ± 0.58^{b}	3.33 ± 0.58^{c}
H500 mg/kg	3.33 ± 1.15	4.33 ± 0.58	3.0 ± 1.0^{ab}	3.67 ± 0.58^{ab}
M125 mg/kg	2.68 ± 1.52	3.33 ± 0.57	2.33 ± 0.58^{b}	3.33 ± 0.58^{c}
M250 mg/kg	3.0 ± 0.00	4.33 ± 0.57	3.67 ± 0.58^{a}	3.33 ± 1.15^{c}
M500 mg/kg	4.33 ± 0.58	4.33 ± 0.58	4.00± 0.00^{a}	4.33 ± 0.58^{a}
P-value	0.48	0.53	0.02	0.03

^{a,bc}Means with the same letters on the same colums are not significantly different (P>0.05). DMSO: Dimethyl sulphoxide (3.2%); Alb: Albendazole 7.5 mg/kg; H125: *Harungana madagascariensis* 125 mg/kg; H250: *Harungana madagascareinsis* 250 mg/kg; H500: *Harungana madagascariensis* 500 mg/kg; M125: *Momordica foetida* 125 mg/kg; M250: *Momordica foetida* 250 mg/kg; M500: *Momordica foetida* 500 mg/kg.

sheep as compared to those suffering from echinococcosis. Again, Sykes et al. (1988) observed that infection with nematode parasites have an adverse effect upon nitrogen retention, a feature that has been confirmed by the lower protein content of carcass from sheep co-infected with *T. colubriformis* or *T. circumcincta* than in pair-fed controls. This reduced digestibility contributes to the poorer overall economy of such carcasses with lower protein content. The latter is primarily a reflection of the lower efficiency with which they utilize apparently digested nitrogen. Furthermore, Bermingham et al. (2007) had reported that more skeletal muscle protein may need to be degraded and mobilized to supply increased amino acid demands of the intestine and liver in sheep infected with *T. colubriformis*.

The ash and mineral contents varied between the different treatment groups. Lambs treated with albendazole, *H. madagascariensis* 500 mg/kg, *M. foetida* 500 mg/kg, and *M. foetida* 250 mg/kg (with lower worm burden) had significantly higher calcium, magnesium and phosphorus hence overall ash content. Knox et al. (2006) suggested that the metabolism of mineral ions is modified by the presence of gastrointestinal nematodes. Sykes and Coop (1976) supported this fact by indicating that skeletal calcium and phosphorus in meat from severely infected lambs may be 15 to 45% lower than in uninfected animals.

Many consumers judge meat quality from its sensory characteristics. In this study, co-infection with *T. circumcincta* and *T. colubriformis* had no significant effect on carcass tenderness and juiciness. However, significant differences were recorded for flavor andoverall acceptability. The most preferred carcasses were from albendazole and *M. foetida* 500 mg/kg treated lambs. This could be attributed to pH differences after slaughter. Carcass pH has a significant effect on flavor and overall acceptability, with high pH carcass producing undesirable meat with slightly soapy off flavor (Miller, 2007). The most dominant sulphur (S) compound in cooking meat volatiles is H_2S (Young et al., 1993). These authors further explained that as meat pH increases, more H_2S is evolved during cooking. Their data indicate that a pH increase from 5.6 to 6.6, for example, would increase the evolution of H_2S by about 60%. H_2S has its own odourand is also involved in a reaction that generates the volatile and very odorous compound thiophenol (benzene thiol). Ha and Lindsay (1991) and Lopez and Lindsay (1993a) showed that thiophenol is the source of unpleasant flavour in cooking sheep meat, because thiophenol's precursor, phenylphosphate, is almost unique to sheep. Thus, either directly or indirectly, high pH meat might result in enhanced off flavours, hence less desirable by test panelists.

Conclusion

Parasitism due to co-infection with *T. circumcincta* and *T. colubriformis* had a significant influence on meat pH_{24} with meat from most severely infected lambs (lambs with the highest worm burden) showing the highest pH_{24}. This high pH_{24} had significant influence on meat flavour, overall acceptability and water retention ability of lamb meat. Furthermore, severely infected lambs were inferior in chemical composition, having lower protein and mineral content than healthy lambs, while treatment with methanol extracts of *M. foetida* at 250 and 500 mg/kg and *H. madagascariensis* at 500 mg/kg led to an improvement in meat chemical composition. However, further studies are needed to evaluate the muscle energy status or lactic acid concentration in the muscles of lambs with different levels of gastrointestinal parasitism in order

to confirm these results.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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