

Alterations in Goat Microbiota Following *Panax notoginseng* Supplementation: Metagenomic Insights and Potential for Gastrointestinal Nematode Control

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Abstract

Certain medicinal plants are known to have potent effects on egg hatching and larval motility of gastrointestinal nematodes (GIN) such as *Haemonchus contortus* (barber pole worm). In this study, we investigated the impact of *Panax notoginseng* (*P. notoginseng*) extracts on the gut microbiome of goats, in comparison to *Syzygium aromaticum* and *Piper nigrum* when used as treatments towards *Haemonchus contortus* (*H. contortus*). Using metagenomic analysis of rumen fluid and fecal samples, we observed significant alterations in the microbial community structure, specifically in the *P. notoginseng* treatment group. Notably, several microbial taxa were significantly upregulated in treated animals. These findings provide a foundation for further research to identify and harness microbiome-mediated resistance to gastrointestinal nematode (GIN) parasitism in goats.

Keywords

Medicinal Plants, Goats, Metagenomics, *Panax notoginseng*, Microbiome, Gastrointestinal Nematodes

1. Introduction

Gastrointestinal parasitism poses major challenges to small ruminant production, especially in tropical, sub-tropical, and temperate regions worldwide, often resulting in substantial stock losses and economic hardship [1] [2]. Chemical anthelmintics, the current standard for parasite control, have led to widespread anthelmintic resistance due to overuse, and drug residues in food products pose addi-

tional public health concerns [3]-[5]. As such, research into alternative management options for helminth control is necessary.

Previous *in-vitro* studies from our laboratory (unpublished) have demonstrated potent inhibitory effects of *Panax notoginseng* (*P. notoginseng*) and other medicinal plants on helminth egg hatching and larval motility [6]. However, the *in-vivo* effects—particularly on host microbiome and related parasite resistance—remain unclear. The gut microbiome plays a critical role in host immunity and resistance to parasite infection [7].

2. Objectives

We report the effects of supplementation with *Syzygium aromaticum*, *P. notoginseng* (NOTOGINSENG), and *Piper nigrum* on the goat gut microbiome, aiming to identify microbial signatures associated with anti-parasitic benefits and to assess the potential for these botanicals in GIN parasite management programs.

3. Materials and Methods

3.1. Animals and Housing

Thirty adult Spanish goats (Fecal Egg Count [FEC] 500 - 3000 EPG) were selected from the flock maintained at Langston University. After cessation of Bioworma® and an acclimation period, goats were weighed, randomly assigned to five groups (n = 6 per group), and balanced for initial FEC. Animals were housed individually, with free access to water and provided Johnson grass hay (25 g/kg BW/day) and low protein concentrate pellets (15 g/kg BW/day).

3.2. Treatments

Dried plant materials (*Syzygium aromaticum*, *Piper nigrum*, and *Panax notoginseng*) were obtained commercially, ground into powder, and incorporated into molasses-based pellets and administered orally (50 g/animal/day) for 10 consecutive days (Table 1). Control animals received pellets without plant additives (Table 1). An additional group received a 1:1:1 mixture of the three botanicals (Table 1).

Table 1. The study was designed where group, number of subjects (goats), treatment types, the dose per animal per day of the total days of treatment are described.

Group	No. goats	Treatment	Doses	Days of treatment
1	6	Control		
2	6	<i>Syzygium aromaticum</i>	50 g/animal/day	10 days
3	6	<i>Panax notoginseng</i>	50 g/animal/day	10 days
4	6	<i>Piper nigrum</i>	50 g/animal/day	10 days
5	6	ANN (1:1:1)	50 g/animal/day	10 days

3.3. Sampling and Laboratory Analyses

Feed intake was assessed daily by subtracting orts from feed offered. Body weight was measured on days 0 and 10. Rumen fluid was collected by stomach tube on days 0 and 10 for microbiome analysis. Fecal samples were collected per rectum for FEC, egg hatching, and microbiome analyses. Parasitological methods included: Fecal Egg Counts (FEC) using the modified McMaster technique [8]-[10]. Egg hatching and larval recovery were completed using standard coproculture and baermannization [11]-[13].

Metagenomic DNA extraction was performed using Norgen Biotek Microbiome kits. DNA libraries were prepared (IDT xGen, NEB poly-A selection) and sequenced on an Illumina NovaSeq 6000 ([PE150], 20 M reads/sample). Bioinformatics and Statistical Analysis included sequence analysis with Partek® Flow® and MiniKraken, PCA and differential abundance analyses (Kruskal-Wallis test) were performed. Power analysis (SAS) confirmed the adequacy of $n = 6/\text{group}$ for > 89% statistical power.

4. Results

4.1. Experimental Design and Power Analysis

A sample size of 6 goats per treatment was found adequate (power > 89%) to detect expected FEC difference based on prior studies.

4.2. Microbiome Profiling

When treatment controls were compared to those that were treated with NOTOGINSENG following infection with *Haemonchus contortus*. No significant overall change was observed when pooling treatment groups versus control, except when comparing the NOTOGINSENG treatment group versus the control. Comparison of treatment samples with the NOTOGINSENG group revealed significant microbiome shifts. Differential abundance showed Kruskal-Wallis testing of 1137 points between control and NOTOGINSENG groups revealing 33 significantly upregulated taxa, no downregulated taxa, 409 inconclusive, and 695 insignificant findings (Figure 1, Table 2).

Table 2. Significantly upregulated microbial flora when Control vs NOTOGINSENG are compared.

Feature ID	P-value	Fold change
Helicobacter sp. MIT 01-6242	0.000024	2
Fischerella sp NIES-4106	0.00078	2
Frischella perrara	0.00078	2
Spiroplasma apis	0.00078	2
Stenotrophomonas maltophilia	0.0029	16
Pseudodesulfovibrio piezophilu...	0.03	2
...(see full Table 2 for additional taxa)		

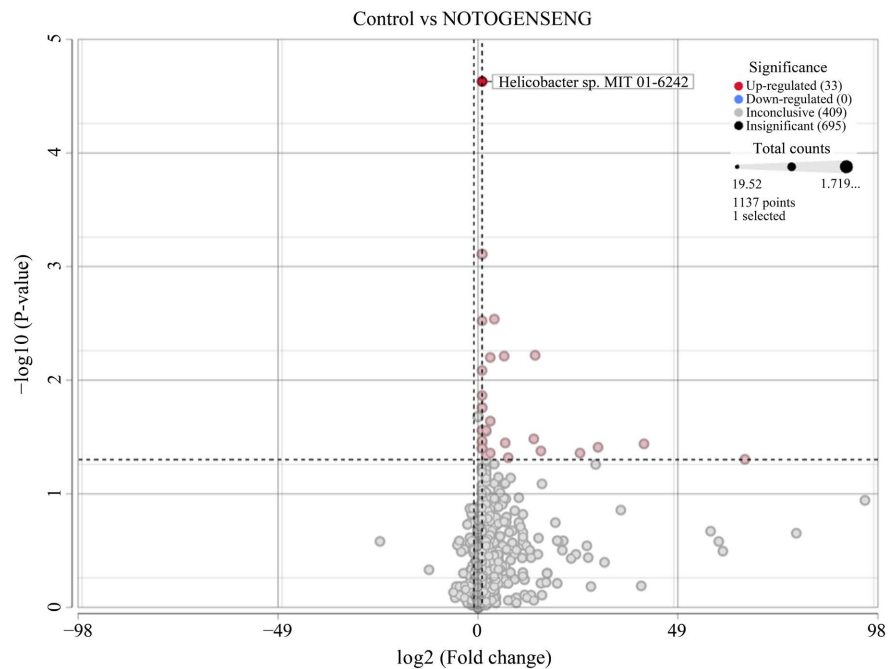


Figure 1. Volcano plot resulting from differential analyses using Kruskal-Wallis points of the presence of microbial organisms.

5. Discussion

P. notoginseng supplementation resulted in significant changes to the microbiota not observed in goats treated with *S. aromaticum* or *P. nigrum*. Increased abundance of *Helicobacter sp. MIT 01-6242* (an organism linked to ulceration in sea otters and known for antibiotic sensitivity) was recorded [14]. *Fischerella sp NIES-4106* is a strain of cyanobacteria that is not responsible for parasitic activity, but may be upregulated as a response to parasitic infection causing a range of symptoms caused by parasites [15]. Like *Fischerella sp NIES-4106*, *Frischella per-rara*, is notably elevated in treated goats, it is known to be a dominant immunomodulator in honeybees, and may be involved in igniting the inflammation caused by GIN [16] [17]. *Spiroplasma apis* is another revealed microorganism that appears to be upregulated when a host is infected by a parasite such as *H. contortus* [17]. The substantial modulation of microbial communities, points to *P. notoginseng* as a promising candidate for further study as a means of microbiome-mediated GIN control. The observed microbial communities are potentially conducive to anti-parasitic effects, possibly enhancing host immunity or antagonizing parasite establishment.

6. Conclusion

P. notoginseng supplementation produced the most notable impact on goat gut microbiota among the botanicals studied. Several upregulated taxa have known or hypothetical roles in immunological and gastrointestinal health. These results suggest a microbiome-mediated mechanism for parasite resistance and support the potential of *P. notoginseng* in sustainable parasite control programs for ruminants.

Author Contributions

Conceptualization, Z.W. and A. S.; methodology, Z.W., A. S., and Y. T.; software, Z.W., A.S., and Y.T.; validation, Z.W., A. S., and Y. T.; formal analysis, Z.W., A. S., and Y. T.; investigation, Z.W., A. S., and Y. T.; resources, Z.W.; data curation, Y.T.; writing—original draft preparation, Z.W., A. S., and Y. T.; writing—review and editing, Z.W., A. S., and Y. T.; visualization, Z.W., A. S., and Y. T.; supervision, Z. W.; project administration, Z. W.; funding acquisition, Z. W. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

- [1] Besier, R.B., Kahn, L.P., Sargison, N.D. and Van Wyk, J.A. (2016) The Pathophysiology, Ecology and Epidemiology of *Haemonchus contortus* Infection in Small Ruminants. *Advances in Parasitology*, **91**, 95-143. <https://doi.org/10.1016/bs.apar.2016.02.022>
- [2] Mamun, M.A.A., Sandeman, M., Rayment, P., Brook-Carter, P., Scholes, E., Kasinadhuni, N., *et al.* (2020) Variation in Gut Bacterial Composition Is Associated with *Haemonchus contortus* Parasite Infection of Sheep. *Animal Microbiome*, **2**, Article No. 3. <https://doi.org/10.1186/s42523-020-0021-3>
- [3] Chiejina, S.N. and Behnke, J.M. (2011) The Unique Resistance and Resilience of the Nigerian West African Dwarf Goat to Gastrointestinal Nematode Infections. *Parasites & Vectors*, **4**, Article No. 12. <https://doi.org/10.1186/1756-3305-4-12>
- [4] Castillo-Mitre, G.F., Olmedo-Juárez, A., Rojo-Rubio, R., González-Cortázar, M., Mendoza-de Gives, P., Hernández-Beteta, E.E., *et al.* (2017) Caffeoyl and Coumaroyl Derivatives from *Acacia cochliacantha* Exhibit Ovicidal Activity against *Haemonchus contortus*. *Journal of Ethnopharmacology*, **204**, 125-131. <https://doi.org/10.1016/j.jep.2017.04.010>
- [5] Leon-Castro, Y., Olivares, J. and Rojas-Hernandez, S. (2015) Chemical Composition of Three Trees Fodders and Effects in Control of *Haemonchus contortus* and Change of Body Weight in Kids. *Agroforestry Natural Ecosystem*, **2**, 193-201.

- [6] Papadopoulos, E. (2008) Anthelmintic Resistance in Sheep Nematodes. *Small Ruminant Research*, **76**, 99-103. <https://doi.org/10.1016/j.smallrumres.2007.12.012>
- [7] Tilahun, Y., Pinango, J.Q., Johnson, F., Lett, C., Smith, K., Gipson, T., *et al.* (2022) Transcript and Blood-Microbiome Analysis towards a Blood Diagnostic Tool for Goats Affected by *Haemonchus contortus*. *Scientific Reports*, **12**, Article No. 5362. <https://doi.org/10.1038/s41598-022-08939-x>
- [8] Stafford, K.J., West, D.M. and Pomroy, W.E. (1994) Nematode Worm Egg Output by Ewes. *New Zealand Veterinary Journal*, **42**, 30-32. <https://doi.org/10.1080/00480169.1994.35778>
- [9] Botura, M.B., Silva, G.D., Lima, H.G., Oliveira, J.V.A., Souza, T.S., Santos, J.D.G., *et al.* (2011) *In Vivo* Anthelmintic Activity of an Aqueous Extract from Sisal Waste (*Agave sisalana* Perr.) against Gastrointestinal Nematodes in Goats. *Veterinary Parasitology*, **177**, 104-110. <https://doi.org/10.1016/j.vetpar.2010.11.039>
- [10] Sunandhadevi, S., Rao, M.L.Y., Dixit, P., Dixit, A.K., Shukla, P.C. and Baghel, R. (2017) *In Vivo* Anthelmintic Activity of a Herbal Formulation against Naturally Acquired Gastrointestinal Nematode in Goats. *Environmental and Ecology Journal*, **35**, 933-935.
- [11] Pena, M.T., Mioller, J.E., Fontenot, M.E., Gillespie, A. and Larsen, M. (2002) Evaluation of *Duddingtonia flagrans* in Reducing Infective Larvae of *Haemonchus contortus* in Feces in Sheep. *Veterinary Parasitology*, **45**, 321-342.
- [12] Van Wyk, J.A. and Mayhew, E. (2013) Morphological Identification of Parasitic Nematode Infective Larvae of Small Ruminants and Cattle: A Practical Lab Guide. *Onderstepoort Journal of Veterinary Research*, **80**, Article 539. <https://doi.org/10.4102/ojvr.v80i1.539>
- [13] Max, R.A. (2010) Effect of Repeated Wattle Tannin Drenches on Worm Burdens, Faecal Egg Counts and Egg Hatchability during Naturally Acquired Nematode Infections in Sheep and Goats. *Veterinary Parasitology*, **169**, 138-143. <https://doi.org/10.1016/j.vetpar.2009.12.022>
- [14] Batac, F.I., Miller, M.A., Moriarty, M.E., Shen, Z., Fox, J.G. and Ottemann, K.M. (2020) Helicobacter Spp. in Necropsied Southern Sea Otters (*Enhydra lutris nereis*) Is Associated with Gastric Ulcers and Sensitive to Multiple Antibiotics. *Frontiers in Marine Science*, **7**, Article 413. <https://doi.org/10.3389/fmars.2020.00413>
- [15] Batsalova, T., Basheva, D., Bardarov, K., Bardarov, V., Dzhabazov, B. and Teneva, I. (2019) Assessment of the Cytotoxicity, Antioxidant Activity and Chemical Composition of Extracts from the Cyanobacterium *Fischerella major* Gomont. *Chemosphere*, **218**, 93-103. <https://doi.org/10.1016/j.chemosphere.2018.11.097>
- [16] Engel, P., Bartlett, K.D. and Moran, N.A. (2015) The Bacterium *Frischella perrara* Causes Scab Formation in the Gut of Its Honeybee Host. *mBio*, **6**, e00193-15. <https://doi.org/10.1128/mbio.00193-15>
- [17] Meeus, I., Vercruyse, V. and Smagghe, G. (2012) Molecular Detection of *Spiroplasma apis* and *Spiroplasma melliferum* in Bees. *Journal of Invertebrate Pathology*, **109**, 172-174. <https://doi.org/10.1016/j.jip.2011.11.006>