

**UNIVERSIDADE ESTADUAL PAULISTA - UNESP  
CÂMPUS DE JABOTICABAL**

**PARASITAS E SEU IMPACTO NO CHACCU DE VICUNHAS  
EM COMUNIDADES ANDINAS NO PERU:  
UMA ABORDAGEM ONE HEALTH**

**Carmen Andrea Arias Pacheco  
Médica Veterinária**

**2020**

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**Discente: Carmen Andrea Arias Pacheco**

**Orientador: Prof. Dr. Estevam G. Lux Hoppe**

Dissertação apresentada à Faculdade de Ciências Agrárias e Veterinárias – UNESP, Campus de Jaboticabal, como parte das exigências para a obtenção do título de Mestra em Medicina Veterinária, área: Medicina Veterinária Preventiva.

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**TÍTULO DA DISSERTAÇÃO: PARASITAS E SEU IMPACTO NO CHACCU DE VICUNHAS EM  
COMUNIDADES ANDINAS NO PERU: UMA ABORDAGEM ONE HEALTH**

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**ORIENTADOR: ESTEVAM GUILHERME LUX HOPPE**

Aprovada como parte das exigências para obtenção do Título de Mestra em **MEDICINA  
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Jaboticabal, 27 de fevereiro de 2020

## **DADOS CURRICULARES DO AUTOR**

CARMEN ANDREA ARIAS PACHECO – nascida em 07 de março de 1991, é natural da cidade de Lima, Peru. Iniciou sua graduação no curso de Medicina Veterinária no ano de 2009, na Facultad de Medicina Veterinaria da Universidad Nacional Mayor de San Marcos (FMV – UNMSM), tendo finalizado a mesma em dezembro de 2014. Trabalhou no setor privado na área da Clínica Médica de pequenos animais desde janeiro de 2015 até janeiro de 2018 na cidade de Lima. Em 2018, ingressou no Programa de Pós-graduação (Mestrado) em Medicina Veterinária da Faculdade de Ciências Agrárias e Veterinárias (FCAV/UNESP), Campus de Jaboticabal, sob orientação do Prof. Dr. Estevam G. Lux Hoppe, professor responsável pelo Laboratório das Enfermidades Parasitárias dos Animais (LabEPar), do Departamento de Patobiologia e Teriogenologia da FCAV/UNESP.

*“Nada é absoluto. Tudo muda, tudo se move,  
tudo gira, tudo voa e desaparece.”*

Frida Kahlo

*Dedico este trabalho primeiramente a Deus,  
por guiar meu caminho e me dar forças para  
me erguer e aprender dos meus fracassos.*

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## SUMÁRIO

	Página
Certificado da Comissão de Ética no Uso de Animais – CEUA.....	ii
RESUMO.....	iii
ABSTRACT .....	iv
LISTA DE ABREVIATURAS.....	v
LISTA DE TABELAS .....	vi
LISTA DE FIGURAS .....	vii
CAPÍTULO I – Considerações Gerais das vicunhas no Peru.....	1
1. INTRODUÇÃO.....	1
2. REVISÃO DA LITERATURA.....	3
2.1 Aspectos gerais dos Camelídeos Sul-americanos (CSA).....	3
2.2 A vicunha ( <i>Vicugna vicugna</i> ) .....	4
2.3 Estudo parasitológico nos animais silvestres.....	6
3. REFERÊNCIAS.....	7
CAPITULO II - Parasitological status of vicuñas from southeastern Peru and its relationship with fibre quality. ....	11
1. INTRODUCTION.....	12
2. METHODS .....	14
2.1 Ethics statement and research authorization .....	14
2.2 Sampling and sample processing .....	14
2.3 Statistical analysis.....	15
3. RESULTS AND DISCUSSION.....	16
4. REFERENCES.....	29

## Certificado da Comissão de Ética no Uso de Animais – CEUA



**UNIVERSIDADE ESTADUAL PAULISTA**  
**"JÚLIO DE MESQUITA FILHO"**  
 Câmpus de Jaboticabal




### CEUA – COMISSÃO DE ÉTICA NO USO DE ANIMAIS

#### CERTIFICADO

Certificamos que o projeto de pesquisa intitulado **“Parasitas e seu impacto no chaccu de vicunhas em comunidades andinas no Peru: Uma abordagem One Health”**, protocolo nº 016205/18, sob a responsabilidade do Prof. Dr. Estevam Guilherme Lux Hoppe, que envolve a produção, manutenção e/ou utilização de animais pertencentes ao Filo Chordata, subfilo Vertebrata (exceto o homem), para fins de pesquisa científica (ou ensino) - encontra-se de acordo com os preceitos da lei nº 11.794, de 08 de outubro de 2008, no decreto 6.899, de 15 de julho de 2009, e com as normas editadas pelo Conselho Nacional de Controle de Experimentação Animal (CONCEA), e foi aprovado **“Ad referendum”** pela COMISSÃO DE ÉTICA NO USO DE ANIMAIS (CEUA), da FACULDADE DE CIÊNCIAS AGRÁRIAS E VETERINÁRIAS, UNESP - CÂMPUS DE JABOTICABAL-SP.

Vigência do Projeto	01/12/2018 a 31/12/2019
Espécie / Linhagem	<i>Vicugna vicugna</i>
Nº de animais	150
Peso / Idade	Variado
Sexo	Ambos os sexos
Origem	Peru

Jaboticabal, 14 de novembro de 2018.

  
**Profª Drª Fabiana Pilarski**  
 Coordenadora – CEUA

## PARASITISMO EM VICUNHAS DO SUDESTE DOS ANDES PERUANOS E SUA RELAÇÃO COM A QUALIDADE DA FIBRA.

**RESUMO** – As vicunhas (*Vicugna vicugna*) são camelídeos sul-americanos silvestres adaptados às rigorosas condições climáticas da Cordilheira dos Andes. Esses animais possuem uma das fibras animais mais finas do mundo e de grande valor econômico. O estudo das doenças parasitárias que afetam a saúde e produtividade da espécie é o primeiro passo na implementação de medidas preventivas, programas de controle e educação em saúde. Nosso objetivo é descrever a população parasitária de vicunhas de três comunidades andinas e sua relação com a qualidade das fibras usando 115 amostras de fezes e 22 de fibra, além de registros de sexo, idade, escore de condição corporal e sistema de manejo. O diagnóstico coparasitológico revelou que 84,4% dos animais apresentaram pelo menos um tipo de ovo/oocisto de parasitas, sendo os ovos de estrombilídeos (54,8%) e os oocistos de *Eimeria punoensis* (38,3%) os mais frequentes. As vicunhas silvestres apresentaram maior prevalência de ovos estrombilídeos (91,4%) do que os animais semicativos (38,8%), e a idade foi significativa para a infecção por *Eimeria* spp., já que as crias (100%) tiveram a maior frequência quando comparadas aos animais juvenis (84,2%) e adultos (49,4%). A identificação de larvas revelou uma forte influência de animais domésticos na comunidade de parasitas da vicunha, apresentando o primeiro relato de *Bunostomum phlebotomum* e *Gaigeria pachyscelis* em vicunhas do sudeste Peru. O diâmetro de fibra das fêmeas ( $13,05 \pm 0,73 \mu\text{m}$ ) foi significativamente mais fino do que os machos ( $14,22 \pm 1,22 \mu\text{m}$ ), e a infecção por *Eimeria* spp. afetou negativamente seu diâmetro e resistência. Nossos resultados fornecem dados para a vigilância de doenças e incentivam novos estudos parasitológicos em vicunhas.

**Palavras-chave:** comunidades andinas, *chaccu*, camelídeos sul-americanos, interação parasita-hospedeiros, qualidade de fibra

## PARASITOLOGICAL STATUS OF VICUÑAS FROM SOUTHEASTERN PERUVIAN HIGHLANDS AND ITS RELATIONSHIP WITH FIBRE QUALITY.

**ABSTRACT** – The vicuñas (*Vicugna vicugna*) are wild Neotropical camelids adapted to the harsh climatic conditions of the Andes. These animals have one of the finest animal fibers in the world and an important position in the international market. Studies of parasitic diseases affecting animal health and productivity are the first step in the implementation of preventive measures, control programs and health education. We aim to describe the parasite population of vicuñas from three Andean communities and its relationship with fibre quality using 115 fecal and 22 fibre samples, records of sex, age, body condition score, and management system. Coproparasitologic diagnostic revealed that 84.4% of animals presented at least one type of parasite egg/oocyst. Most frequent parasite egg/oocyst were Strongyle-type eggs (54.8%) and *Eimeria punoensis* (38.3%). Wild vicuñas had a higher prevalence of Strongyle-type eggs (91.4%) than semi-captive (38.8%) animals, and age was significant to *Eimeria* infection, crias (100%) had the highest frequency when compared to yearlings (84.2%) and adults (49.4%). Larvae identification revealed a strong influence of domestic animals on vicuña parasite community, presenting the first report of *Bunostomum phlebotomum* and *Gaigeria pachyscelis* in vicuñas from Southeastern Peru. Females had a significantly finer diameter of fibre ( $13.05 \pm 0.73 \mu\text{m}$ ) than males ( $14.22 \pm 1.22 \mu\text{m}$ ), and infection with *Eimeria* spp. affected negatively fibre diameter and resistance. Our results provide data for disease surveillance and encourage further parasitological studies in vicuñas.

**Key words:** high Andean communities, *chaccu*, Neotropical camelids, parasite-host relationship, fibre quality.

## LISTA DE ABREVIATURAS

CSA	Camelídeos Sul-americanos
CV%	Diameter variation coefficient of fibre – Coeficiente de variação da fibra
EPG	Eggs per gram of faeces – Ovos por grama de fezes
FOB	Free on board
GIN	Gastrointestinal nematodes – Nematódeos gastrointestinais
MASL	Meters above sea level – Metros acima do nível do mar
MUS	Sustainable use modules - Módulos de Uso Sustentável
OFDA	Optical-based Fibre Diameter Analyser

## LISTA DE TABELAS

<b>Table 1.</b> Prevalence (%) and mean intensity (EPG, range) of gastrointestinal nematodes eggs in vicuñas from the Cusco Region, Peru.....	18
<b>Table 2.</b> Morphometry ( $\mu\text{m} \pm \text{SD}$ ) of gastrointestinal nematodes larvae from vicuñas of the Cusco Region, Peru .....	21
<b>Table 3.</b> Prevalence (%) of <i>Eimeria</i> spp. oocysts found in feces of vicuñas from the Cusco Region, Peru .....	24
<b>Table 4.</b> Fibre diameter ( $\mu\text{m} \pm \text{SD}$ ) and diameter variation coefficient ( $\text{CV}\% \pm \text{SD}$ ) comparison of means between sexes. ....	25
<b>Table 5.</b> Fibre diameter ( $\mu\text{m} \pm \text{SD}$ ) and diameter variation coefficient ( $\text{CV}\% \pm \text{SD}$ ) of vicuñas negative to <i>Eimeria</i> infection, mono-infected and co-infected. ....	26
<b>Table 6.</b> Fibre diameter ( $\mu\text{m} \pm \text{SD}$ ) and diameter variation coefficient ( $\text{CV}\% \pm \text{SD}$ ) comparison of means for each parasite found in vicuñas of the Cusco Region, Peru (n=22).....	27

**LISTA DE FIGURAS**

**Figure 1.** Typical appearance of gastrointestinal parasite eggs found in vicuñas from Cusco Region, Peru. (A) *Nematodirus spathiger*, (B) *Nematodirus lamae*, (C) *Lamanema chavezii*, (D) Strongyle-type egg, (E) *Trichuris* spp., (F) capillarid egg.... 17

**Figure 2.** Morphology of two nematode larvae (40x) from the Ancylostomatidae family compatible with (A) *Bunostomum phlebotomum* and (B) *Gaigeria pachyselis*. .....20

**Figure 3.** *Eimeria* spp. sporulated oocysts found in vicuñas from Cusco Region, Peru. (A) *E. macusaniensis*, (B) *E. lamae*, (C) *E. alpaca*, (D) *E. punoensis*. .....22

## CAPÍTULO I – Considerações Gerais das vicunhas no Peru

### 1. INTRODUÇÃO

A exploração dos camelídeos Sul-americanos (CSA) é desenvolvida pelas comunidades andinas desde a época pré-colombiana, representando um elemento primordial na sustentabilidade econômica e produtiva dessas sociedades (Pinto et al., 2010). Estes animais são considerados um recurso genético de grande importância social, cultural e científica. Sob o termo CSA incluem-se duas espécies domesticadas, a alpaca (*Vicugna pacos*) e a lhama (*Lama glama*); e duas espécies selvagens, a vicunha (*Vicugna vicugna*) e o guanaco (*Lama guanicoe*) (Bravo, 2015). Entre os produtos obtidos destes animais, destacam-se a carne, o couro, a fibra e o esterco. Em adição, as lhamas são muito úteis também como animais de carga (Mengoni e Yacobaccio, 2006). Estes animais têm a vantagem de resistir ao ambiente adverso da Cordilheira dos Andes, caracterizado principalmente por condições desérticas, de clima frio e baixa disponibilidade de pastagens (Pinto et al., 2010, MINAGRI-DGFFS, 2014).

A vicunha é a menor das quatro espécies de CSA, habitando os Andes do Peru, Bolívia, Chile, Argentina e Equador, neste último como resultado de doações de matrizes pelos outros países nos anos 90 (Laker et al., 2006). O corpo desta espécie está coberto por uma das fibras animais mais finas, macias, resistentes e leves do mundo (MINAGRI-DGPA, 2019). Dado o elevado preço desse produto no comércio internacional, a comercialização da fibra de vicunhas tem papel importante na renda de muitas comunidades andinas. No Peru, onde a maior população de vicunhas é encontrada (208.899 indivíduos) (MINAGRI-DGFFS, 2014), a obtenção da fibra é feita usando o método do “chaccu” ou “chaku”, uma palavra quíchua referida ao método comunitário de captura desenvolvido nos tempos do antigo Peru. O “chaccu” é baseado em formar uma barreira humana que, ao caminhar, vai se fechando e direcionando as vicunhas para um cercado com espaço suficiente para abrigá-las sem lhes causar danos. Essas vicunhas contidas são submetidas a tosquia da sua fibra e imediatamente devolvidas à natureza (Lichtenstein et al., 2002).

Durante vários anos de programas de conservação que iniciaram com a criação da Reserva Natural Pampa Galeras Bárbara D'Achille no ano 1967, e superando as crises econômicas e sociais da época do terrorismo no Peru, o manejo das vicunhas mudou de uma política de conservação baseada na proibição total do comércio para uma focada no uso sustentável (Cepeda-Caceres, 2019), com o fim de protegê-las da caça excessiva que sofreram durante vários anos e as aproximou do perigo de extinção. Nesse sentido, a base do incentivo para sua conservação radica na sustentabilidade da atividade de extração da fibra mediante a tosquia de animais vivos, sem danos à saúde ou integridade física destes e gerando um retorno econômico que beneficia as comunidades andinas que protegem a espécie (Sahley et al., 2007, McAllister et al., 2009). Essas comunidades, na sua maioria, vivem em situação de pobreza ou pobreza extrema (INEI, 2019), o que eleva a importância da vicunha como uma fonte significativa de renda.

O impacto do parasitismo na produção e saúde animal tem sido amplamente estudado em várias espécies, no entanto, a pesquisa em vicunhas é limitada. Estes animais podem ser afetados por parasitas dos ruminantes domésticos e por parasitas hospedeiro-específicos, existindo relatos de prevalência variada de nematódeos gastrointestinais, ácaros, *Eimeria* spp. (Welchman et al., 2008, Ballweber, 2009, Cebra et al., 2014), e também sendo descritos como hospedeiros de parasitas zoonóticos, tais como *Fasciola hepatica* e *Toxoplasma gondii* (Zuzunaga et al., 2006, Samamé et al., 2016). Em CSA domésticos, as perdas econômicas causadas por parasitismo alcançam os US\$ 700.000 anuais, principalmente por perdas em produção de carne e fibra (Pérez et al., 2014). Diversos estudos em ovinos indicam que a competição por nutrientes, especialmente proteínas, entre o hospedeiro e os parasitas influencia o crescimento e o diâmetro da lã (Khan et al., 2012). Do mesmo modo, o parasitismo em vicunhas poderia ter impacto sobre a produção e qualidade da fibra, ameaçando imediatamente a saúde, a importância econômica e a sobrevivência destes camelídeos selvagens em toda a sua extensão. Portanto, considerando a interdependência da conservação das vicunhas com o manejo comunitário da sua fibra pelas comunidades andinas e com o propósito de melhorar a compreensão dessa inter-relação humano-animal e patógenos relacionados, objetivou-se avaliar o parasitismo e seu impacto na saúde do animal com relação à qualidade da fibra.

## 2. REVISÃO DA LITERATURA

### 2.1 Aspectos gerais dos Camelídeos Sul-americanos (CSA)

Os camelídeos são mamíferos classificados na Ordem Cetartiodactyla, subordem Tylopoda e Família Camelidae (Wheeler, 2012, Acebes et al., 2019). A evolução destes animais começou no oeste da América do Norte, 40 a 50 milhões de anos atrás, porém foi durante a época do Pleistoceno, há três milhões de anos, quando um grupo de camelídeos atravessou o Estreito de Bering em direção à Ásia e África, e outro grupo se deslocou em direção às Américas Central e do Sul, dando origem às Tribus Camelini e Lamini, respetivamente (Marín et al., 2007, Bravo, 2015). As espécies da Tribo Lamini distribuem-se na Cordilheira dos Andes e são conhecidas como Camelídeos do Novo Mundo ou Camelídeos Sul-americanos (Pinto et al., 2010). Atualmente, quatro espécies pertencentes a dois gêneros de camelídeos habitam na América do Sul, com duas espécies selvagens, o guanaco (*Lama guanicoe* Müller 1776) e a vicunha (*Vicugna vicugna* Molina 1782); e duas espécies domésticas, a lhama (*Lama glama* Linnaeus 1758) e a alpaca (*Vicugna pacos* Linnaeus 1758).

Os CSA desenvolveram importantes adaptações anatômicas e fisiológicas relacionadas às condições de escassez de oxigênio das regiões alto-andinas. Estes animais possuem excelentes mecanismos de captação de oxigênio em nível pulmonar, e maior eficiência no transporte e utilização de oxigênio, evitando assim os efeitos graves da hipóxia atmosférica (Quispe, 2011). Nos CSA, a fisiologia digestiva e o ciclo de ruminação evoluíram paralelamente aos sistemas digestivos dos ruminantes, sendo semelhantes, mas não análogos (Bravo, 2015). Devido à baixa qualidade das pastagens naturais dos Andes, os camelídeos retêm os alimentos por mais tempo, aumentando a eficiência digestiva e melhorando a extração de proteínas e a energia dessas forragens (Sponheimer et al., 2003, Pinto et al., 2010, Bravo, 2015). Além disso, possuem lábio leporino, o que permite a melhor seleção e apreensão das pastagens andinas (Pinto et al., 2010).

## 2.2 A vicunha (*Vicugna vicugna*)

A vicunha se distribui em uma área de aproximadamente 300.000 km<sup>2</sup> na Cordilheira dos Andes. Atualmente, estes animais estão limitados à ecorregião da Puna, em um ambiente de altitude extrema (>3.800 metros acima do nível do mar) caracterizado pela intensa radiação solar e a baixa pressão atmosférica (Acebes et al., 2019, González et al., 2019). Devido à ausência de cascos nas patas, dotadas apenas de almofadas macias nos dois dígitos, a compactação do solo e o impacto do pastejo causados por esses animais sobre a vegetação é baixo (Bonavia, 2008). Na Puna úmida, o pastejo das vicunhas é seletivo, com marcada preferência pelas gramíneas curtas e herbáceas, com alto teor de água, já na Puna seca, as vicunhas mostram-se mais generalistas (Borgnia et al., 2010). A organização social da vicunha é caracterizada pela existência de famílias poligâmicas dominadas pelo macho, grupos de machos e machos solitários. O líder do grupo familiar defende seu território contra qualquer ameaça e expulsa suas próprias crias quando as fêmeas atingem os 10-11 meses de idade e os machos, 6-9 meses de idade (Wheeler, 2006).

Duas subespécies de vicunhas foram descritas com base em diferenças morfológicas, moleculares e geográficas (Marín et al., 2007, Wheeler, 2012, Casey et al., 2018). A vicunha do norte (*Vicugna vicugna mensalis*) é relatada entre 9°30'S e 18°S de latitude e é a menor das duas subespécies. Esta possui uma pelagem de cor canela-escura na cabeça, no pescoço, nas costas e na cauda, e de cor branca na parte inferior do rosto, na região ventral do corpo e da cauda; distingue-se principalmente por apresentar longos pelos brancos no peito (Wheeler, 2012, González et al., 2019). Por outro lado, a vicunha do sul (*Vicugna vicugna vicugna*) distribui-se entre os paralelos 18°S e 29°S, possuindo pelagem bege mais clara, pelos mais curtos no peito, e a cobertura branca abrange uma maior porção do corpo (Wheeler, 2012, González et al., 2019).

A fina pelagem ou fibra da vicunha é uma característica da adaptação da espécie ao ambiente hostil da puna alto-andina. Está composta de duas camadas: a camada externa formada por fibras grossas e longas; e a camada interna, de fibras finas e curtas (MINAGRI-DGFFS, 2014). O fino diâmetro destas fibras (11,9 – 14,7 µm) as torna uma das melhores fibras naturais do mundo (Quispe et al., 2009).

A exploração deste recurso foi desenvolvida desde tempos do Antigo Peru pelos povos andinos, quando a vicunha era considerada o gado dos deuses; sua utilização estava restrita aos rituais cerimoniais e sua fibra só podia ser empregada em algumas roupas da nobreza local. A partir da invasão europeia e até os anos 70 do Século XX, a caça furtiva para obtenção indiscriminada da fibra acabou com aproximadamente 99% da população total, deixando a espécie próxima da extinção (Hurtado de Mendoza, 1987, Wheeler e Hoces, 1997). A partir de então, somando esforços locais, nacionais e internacionais, os programas de conservação da espécie expandiram a população de 66.559 vicunhas no ano 1994 para 208.899 no ano de 2012 (MINAGRI-DGFFS, 2014, Acebes et al., 2019). Atualmente, a IUCN Red List classifica a vicunha como de Preocupação Menor (LC – Least Concern ver 3.1), que não é uma categoria de ameaça, em vista da ampla distribuição da espécie, inclusive com número considerável de áreas protegidas (Acebes et al., 2019). No entanto, o Governo Peruano considera a espécie como Quase Ameaçada (NT – Near Threatened) (SERFOR, 2018). Apesar disso, a classificação dentro do Anexo II da Convenção sobre o Comércio Internacional de Espécies da Flora e da Fauna Selvagens Ameaçadas de Extinção (CITES) permite seu uso econômico em benefício das comunidades andinas, sob estrito cumprimento da regulamentação nacional, a fim de se evitar atividades prejudiciais à sobrevivência dos animais (MINAGRI-DGFFS, 2014).

No Peru, do total de vicunhas descritas no censo de 2012, 69,9% encontram-se em estado selvagem, sob a jurisdição das comunidades andinas com permissão de aproveitar os benefícios da fibra dos animais, e o 30,1% estão em sistemas de semicativeiro, em grandes áreas de mais de 500 ha limitadas por cercos, onde as vicunhas são mantidas e protegidas de predadores e caçadores furtivos (Quispe et al., 2009). Em ambos os casos, o manejo comunitário das vicunhas é feito mediante o “chaccu”, o que permite a sustentabilidade da atividade de extração da fibra visando a melhora da qualidade de vida das comunidades alto-andinas e servindo como um incentivo para a conservação da espécie.

Segundo os dados do MINAGRI-DGPA (2019), no ano 2018 foram tosquiadas 48.323 vicunhas em 553 “chaccus”, obtendo um total de 8.258 kg de fibra, e um

rendimento aproximado de 171 gramas de fibra por indivíduo. Além disso, as exportações de fibras de vicunha e seus derivados no período de 2014 a 2018 somaram US\$ 16,4 milhões em valor FOB. O que representa uma renda importante para o Governo e para os povoadores andinos.

### **2.3 Estudo parasitológico nos animais silvestres**

A análise da diversidade de parasitos em animais silvestres destaca o papel de cada espécie na manutenção e propagação das doenças, o que está relacionado à forma como ocorre a transmissão, a abundância de cada hospedeiro e as interações entre os hospedeiros (Rhyan e Spraker, 2010; Power and Mithchell, 2004). Frequentemente, a invasão humana em áreas de vida silvestre e o aumento de populações animais que prosperam perto dos seres humanos são fatores que permitem o surgimento ou ressurgimento dessas doenças (Chomel, 2008). Essa interface próxima facilita o intercâmbio de patógenos entre animais domésticos, animais selvagens e humanos, resultando em alterações no padrão epidemiológico de enfermidades novas ou já bem conhecidas, com impacto econômico, à saúde pública e/ou à conservação da vida selvagem (Rhyan e Spraker, 2010).

No particular caso das vicunhas, sua conservação está diretamente aos benefícios econômicos a diversas comunidades que se beneficiam da utilização da fibra. O estudo do parasitismo, bem como de outras enfermidades que ameacem o bem-estar e a capacidade de produção da espécie, é relevante, e também é o primeiro passo na implementação de medidas preventivas, programas de controle e educação sanitária.

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## **CAPITULO II - Parasitological status of vicuñas from southeastern Peru and its relationship with fibre quality.**

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**ABSTRACT** - We aim to describe the parasitic population in vicuñas from three Andean communities and its relationship with fibre quality using 115 fecal and 22 fibre samples, classified according to sex, age, body condition score, and management system. Coproparasitologic diagnostic revealed that 84.4% of animals presented at least one type of parasite egg/oocyst. Most frequent parasite egg/oocyst were Strongyle-type eggs (54.8%) and *Eimeria punoensis* (38.3%). Wild vicuñas had a higher prevalence of Strongyle-type eggs (91.4%) than semi-captive (38.8%) animals, and age was significant to *Eimeria* infection, crias (100%) had the highest frequency when compared to yearlings (84.2%) and adults (49.4%). Larvae identification revealed a strong influence of domestic animals on vicuña parasite community, presenting the first report of *Bunostomum phlebotomum* and *Gaigeria pachyscelis* in vicuñas from Southeastern Peru. Females had a significantly finer diameter of fibre ( $13.05 \pm 0.73 \mu\text{m}$ ) than males ( $14.22 \pm 1.22 \mu\text{m}$ ), and infection with *Eimeria* spp. affected negatively fibre diameter and resistance. Our results provide data for disease surveillance and encourage further parasitological studies in vicuñas.

**Key words:** chaccu, neotropical camelids, fibre quality, parasite

## 1. INTRODUCTION

The vicuñas (*Vicugna vicugna*) are the smallest of the four Neotropical camelid species. These mammals are greatly adapted to the extreme altitude environments (>3,800 m.a.s.l.) of the Andean Mountains (Quispe et al., 2019), with arid landscapes and hypoxic atmosphere. They consume food with high water content and carry out a low-impact grazing, behaving as strictly grazers in wet puna and generalist ungulates in dry puna (Borgnia et al., 2010). Two vicuña subspecies are recognized: the smaller northern vicuña (*Vicugna vicugna mensalis*), with darker cinnamon pelage and long white hairs on the chest, is reported between 9° 30' and 18° S latitude; and the southern vicuña (*Vicugna vicugna vicugna*), with lighter beige pelage and shorter hairs on the chest, is found between 18° and 29° S latitude (Wheeler, 2012, González et al., 2019).

The vicuña population recovered considerably in all Andean countries after a period of near extinction in the mid-1970's. Strong conservation efforts to end illegal hunting, and stimulus to sustainable fibre use were responsible for this recuperation (Casey et al., 2018). In Peru, where half of this camelid world population is concentrated, 208,899 individuals live in wilderness and in semi-captivity and captivity systems (MINAGRI-DGFFS, 2014). The ex-situ maintenance of vicuñas is only for academic research, animal display, and rescue purposes. In the semi-captivity systems, called MUS (sustainable use modules), vicuñas are maintained in areas ranging from 500 to more than 1000 ha (Quispe et al., 2009). The Peruvian environmental authority classifies the vicuñas as Near Threatened (SERFOR, 2018), while the IUCN Red List of Threatened Species categorizes it as a Least Concern species (Acebes et al., 2018).

Vicuña fibre is one of the finest and most valuable natural fibre, especially due to its diameter fineness (11.9 – 14.7 µm), great resistance, smoothness, and its capacity to maintain heat (Quispe et al., 2009, MINAGRI-DGPA, 2019). In recent years, this species management have changed from a policy of conservation based on total ban on trade to one focused on sustainable use, therefore its international commercialization is regulated by The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Thus, once a year in Peru,

during large-scale community-based events called chaccu, vicuñas are captured, shorn, and released. The chaccus are controlled, supervised and documented by authorized local Andean communities and the Peruvian government, so that only officially obtained fibre can be sold to the market, and consequently safeguarding the species from poachers (Sahley et al., 2007, Cardellino and Mueller, 2008, McAllister et al., 2009). In Peru, during the 2014 – 2018 period, exportation of vicuña fibre and its derivatives reached an FOB value of US\$ 16,4 million, income that benefits at least 275 authorized Andean communities (MINAGRI-DGPA, 2019).

Inside and outside of protected areas, vicuñas coexist with people and domestic animals that include sheep, goat, cattle, alpacas, and llamas. This proximity facilitates the exchange of pathogens between humans, domestic, and wild animals, modifying the epidemiological pattern of new or well-known diseases, with impact on the economy, public health and/or wildlife conservation (Rhyan and Spraker, 2010). Considering the Neotropical camelids, parasitism is a major health concern, with infections of a variety of parasites, some appear to be exclusive to camelids (i.e. *Graphinema aucheniae*, *Camelostrongylus mentulatus*, *Nematodirus lamae*, and *Lamanema chavezii*), yet others are shared with domestic animals and wildlife species (i.e. *Ostertagia* spp., *Haemonchus contortus*, *Trichostrongylus* spp., *Cooperia* spp. and *Oesophagostomum*) (Welchman et al., 2008, Ballweber, 2009, Cebra, 2014), moreover vicuñas can be hosts of parasites of zoonotic importance such as *Fasciola hepatica*, and *Toxoplasma gondii* (Zuzunaga et al., 2006; Samamé et al., 2016)

Signs of parasitism in Neotropical camelids are varied, depending on parasite community, host conditions, and climate factors. In camelids, parasite-monitoring strategies are mainly limited to fecal examinations based on flotation and sedimentation techniques, although intermittent or low egg excretion rates hinder the diagnosis. Additionally, there is poor correlation between the eggs/oocysts counting, the parasite burden, and the severity of infection (Cebra and Stang, 2008, Franz et al., 2015, Kultscher et al., 2019). Nevertheless, no fecal analysis method has been proved to be superior and, despite its limitations, they provide significant information for diseases surveillance in wild animals. We present here the results of the parasitological

status of vicuñas, a genetic resource of high socioeconomic and cultural value, from three rural communities of Cusco, in Southern Peru, and its influence on fibre quality.

## 2. METHODS

### 2.1 Ethics statement and research authorization

The present study was approved by the Animal Ethics Committee (CEUA) of the FCAV/UNESP, Jaboticabal, SP, Brazil (protocol No. 016205/18), and by the National Forest and Wildlife Service, SERFOR, Peru (Authorization Code No. AUTIFS-2018-034). The temporal capture and sampling of vicuñas (*V. v. mensalis*) during scheduled *chaccus* on the Cusco Region, in Peru, was approved to evaluate individuals' health status through physical, parasitological, and fibre quality assessments.

### 2.2 Sampling and sample processing

Eighty fecal samples and 22 fibre samples of semi-captive vicuñas from a rural community in Quehue District (Canas, Cusco) at 3,792 masl were collected, as well as 35 wild vicuña fecal samples from two rural communities (Phaco and Canllini) in Pitumarca District (Canchis, Cusco) at 3570 masl. The sex of each animal was registered, and the age determined by body size and teeth, consisting of 85 adults (> 2 years), 19 yearlings (<2 years) and 11 *crias* (<1 year). Registers of Body Condition Score was based on a scale of 1 to 5, the lowest being a very poor condition and the highest obesity (Van Saun and Herdt, 2014)

Individual samples of fibre (3-4g) were collected from the middle rib zone and the fecal samples were taken directly from the rectum of each animal with aid of plastic bags, refrigerated at 4 °C until further examination. Coproparasitological diagnostic was based on Gordon & Whitlock (modified by Ueno and Gonçalves, 1998), Willis-Mollay, and sedimentation techniques. The modified Baermann technique was used to evaluate pulmonary nematodes. *Eimeria* spp. identification was made using the information of Dubey (2018). Finally, fecal samples were cultured to obtain nematodes

L3 larvae. These larvae were identified at generic level following the keys proposed by van Wyk and Mayhew (2013), Hansen and Shivnani (1956), Keith (1953) and Ortlepp (1937), based on aspects such as: shape of anterior and posterior regions, total sheath and total body length, intestinal cells number and shape, and sheath tail extension length.

The fibre analyses were carried out using the OFDA 2000® equipment from the Fibre and Genetic Improvement Laboratory of the Veterinary Institute IVITA Marangani, Marangani district, Cusco Region, Peru. Identification and measurement of gastrointestinal nematodes larvae were conducted at the Laboratory of Parasitic Diseases (LabEPar), FCAV/Unesp, Jaboticabal, São Paulo state, Brazil.

### **2.3 Statistical analysis**

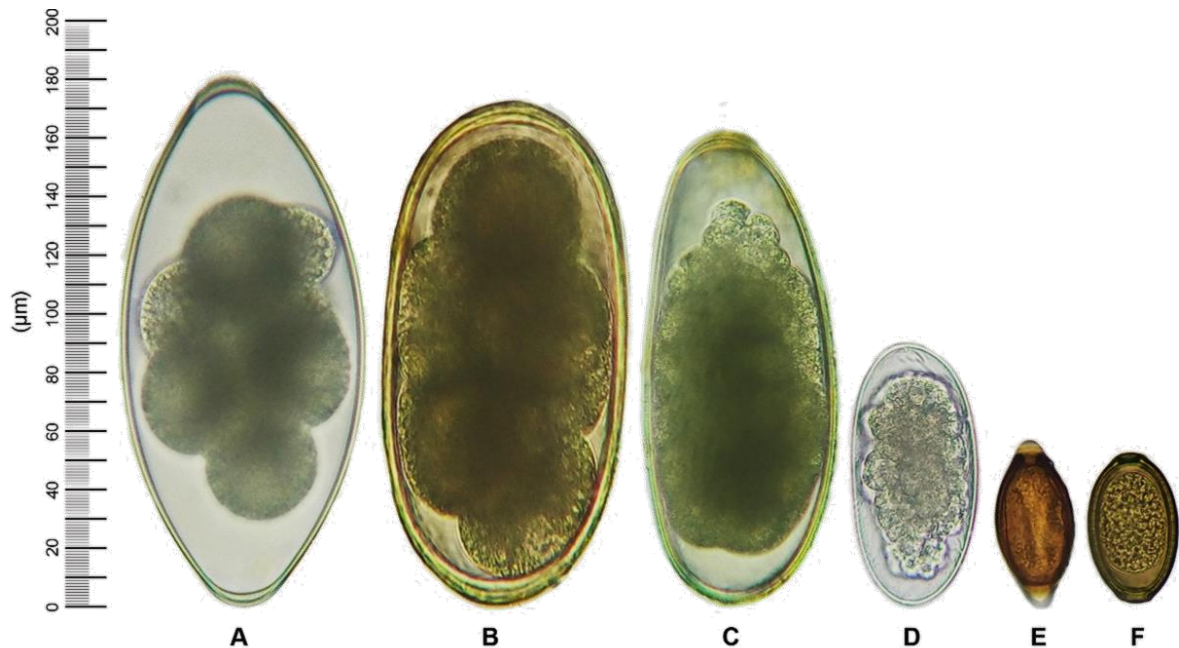
The descriptors of infection (prevalence, mean intensity and mean abundance) described by Bush et al. (1997) were calculated. All the continuous data were submitted to Shapiro-Wilk or Anderson-Darling normality tests, and to Bartlett test for evaluation of the homogeneity of variances. To compare the prevalence and parasite load, Fisher's exact test and the non-parametric Kruskal–Wallis test were applied. Pearson's Chi-squared test was performed to evaluate parasite infection, management, age, and sex of the hosts. To assess the impact of parasite infection on the diameter and resistance of fibre, mean of continuous data were compared with Student's t-test, Welch test, and Wilcoxon test. After that, Fisher's Exact Test and Simple Logistic Regression was performed with dichotomized data. Two-way analysis of variances ANOVA and post-hoc Tukey test were used to evaluate the impact of *Eimeria* infection on diameter and resistance of fibre. All data were evaluate using the statistical software R version 3.5.3.

### 3. RESULTS AND DISCUSSION

*Eimeria* and/or nematodes were diagnosed in 84.4% (IC 95%: 76.6 – 89.9%) of the 115 vicuñas examined. The general prevalence of nematode eggs and *Eimeria* spp. was 68.7% (IC 95%: 59.7 – 76.5%) and 60.0% (IC 95%: 50.9 – 68.5%), respectively. These results are higher than the 40.7% (61/150) of GIN eggs and 7.3% (11/150) of coccidia oocysts found in Argentinean vicuñas (Marcoppido et al., 2016), but lower than the 87.5% of GIN eggs (28/32) and 100% (32/32) of coccidia oocysts in Bolivian vicuñas (Beltrán-Saavedra et al., 2011). However, in alpacas from the same studied region, prevalence rates of helminths (68.4%) and coccidia (61.5%) are comparable to our findings (Pérez et al., 2014). These rates could mean a constant exposure at all stages of life and a constant environment contamination, related to the specific geographic and ecological characteristics of the region, as there is a relatively higher population density of vicunas in the studied area than in Bolivia and Argentina (MINAGRI-DGFFS, 2014).

Among the gastrointestinal parasites, Strongyle-type eggs (54.8%, IC 95%: 45.7 – 63.6%) were the most frequent, followed by eggs of *Nematodirus spathiger* (13.9%, IC 95%: 8.8 – 21.4%), *Lamanema chavezii* (13.0%, IC 95%: 8.1 – 20.4%), *Nematodirus lamae* (11.3%, IC 95%: 6.7 – 18.4%), *Trichuris* spp (9.6%, IC 95%: 5.4 – 16.3%), and capillarid eggs (2.6%, IC 95%: 0.9 – 7.4%) (Figure 1). We did not find *Fasciola* eggs, even though human and animal fasciolosis are particularly important issues in Peru (Espinoza et al., 2010), and the Andean altiplano (northern Bolivian and the Peruvian high Andean regions) is recognized as an hyperendemic area (Fuentes et al., 2005). In fact, these areas between 3800 – 4100 m.a.s.l. are characterized by the absence of temperature seasonality and *Fasciola* presents an irregular distribution, depending on the presence of suitable water bodies to support the snail intermediate host population (Fuentes et al., 2005, Mas-Coma et al., 2005). The irregular pattern is also reflected in the low rates of fasciolosis in livestock abattoir data from southeastern Peru (Espinoza et al., 2010), contrasting to what was reported in central Peruvian Andes, where the inter-Andean valley provide favorable conditions to *Fasciola* development, and vicuñas become a significant host for this digenean (Samamé et al., 2016). Likewise, the absence of this parasite coincides with that described in wild camelids in southern

countries, such as in Bolivian vicuñas (Beltrán-Saavedra et al., 2011) where this ecological pattern is present, and in Chilean guanacos (Correa et al., 2012), where colder temperatures (5°C to 6°C) inhibit the development of the parasite and its intermediate host.



**Figure 1.** Typical appearance of gastrointestinal parasite eggs found in vicuñas from Cusco Region, Peru. (A) *Nematodirus spathiger*, (B) *Nematodirus lamae*, (C) *Lamanema chavezii*, (D) Strongyle-type egg, (E) *Trichuris* spp., (F) capillarid egg.

No statistical differences were found between management system, age, or sex of the host, this could be related to the common application of anthelmintics (albendazole/ivermectin) as preventive and therapeutic control in every *chaccu*. Nevertheless, the difference on the prevalence of Strongyle-type eggs between wild (91.4%, IC 95%: 77.6 – 97.0%) and semi-captive (38.8%, IC 95%: 28.8 – 49.7%) animals was significant ( $p < 0.05$ ) (Table 1). It is important to note that semi-captivity systems are easier to manage, ensuring that all animals are captured, evaluated, and dosed with anthelmintics, in contrast to wild vicuñas. Additionally, the communities that manage free-living vicuñas have permanent water sources (Pacheco et al., 2019), which would provide better conditions for parasite survival throughout the year.

**Table 1.** Prevalence (%) and mean intensity (EPG, range) of gastrointestinal nematodes eggs in vicuñas from the Cusco Region Peru.

	Management type				Age			Sex		% Total (n)
	Wild	Semi-captive	Crias	Yearlings	Adult	Male	Female			
Strongyle-type eggs	91.4% <sup>a</sup>	38.8% <sup>b</sup>	36.4%	78.9%	49.4%	62.1%	44.9%	54.8% (63)		
	87.5 (50-400)	65 (50-200)	62.5 (50-100)	86.7 (50-200)	76.3 (50-400)	86.3 (50-400)	60.5 (50-150)			
<i>Nematodirus spathiger</i>	17.1%	12.5%	27.3%	15.8%	11.8%	15.2%	12.2%	13.9% (16)		
	58.3 (50-100)	50 (50)	50 (50)	66.7 (50-100)	50 (50)	50 (50-100)	50 (50)			
<i>Nematodirus lamae</i>	20.0%	7.5%	0.0%	5.3%	14.1%	10.6%	12.2%	11.3% (13)		
	78.6 (50-200)	50 (50)	-	<50	45.8 (50-200)	57.1 (50-200)	50 (50)			
<i>Trichuris</i> spp.	11.4%	8.8%	18.2%	15.8%	7.1%	12.1%	6.1%	9.6% (11)		
	50 (50)	50 (50)	50 (50)	50 (50)	50 (50)	50 (50)	50 (50)			
Capillarid eggs	2.9%	2.5%	0.0%	5.3%	2.4%	62.1%	0.0%	2.6% (3)		
	50 (50)	50 (50)	-	50 (50)	50 (50)	50 (50)	-			
<i>Lamanema chavezii</i>	14.3%	12.5%	9.1%	21.1%	10.6%	10.6%	16.3%	13.0% (15)		
	<50	<50	<50	<50	<50	<50	<50			
% Total (n)	94.3% (32)	57.5% (46)	72.7% (8)	84.2% (16)	64.7% (55)	75.8% (50)	59.2% (29)	68.7% (79)		

<sup>a,b</sup> Rows with distinct superscripts inside each category indicate statistical difference.

Studies in Neotropical camelids show that, even though these animals are susceptible to infection with domestic ruminant parasites, they excrete fewer eggs in their feces (Green et al., 1996). This, associated with their latrine use behavior, may avoid parasites spreading and could diminish the infection pressure (Cebra, 2014, Kulstcher et al., 2019). Noticeably, a very low egg count was observed in all studied animals with parasite infection. One of the few studies on coproparasitology of wild vicuñas reported a Strongyle-type EPG counts between 20 and 160 (Marcoppido et al., 2016). Although this count was exceptionally low, we found that wild vicuñas had a higher prevalence and EPG count than semi-captive vicuñas in general.

Identification of the L3 larvae is summarized in Table 2. Two Ancylostomatidae species were recognized: *Bunostomum phlebotomum* and *Gaigeria pachyscelis* (Figure 2). The first one is commonly found in the intestine of cattle, but rarely in goats and stags (Mehlhorn, 2015). The infection can occur both by ingestion and skin penetration of the infective third-stage larvae, and the disease is associated to anemia and black tarry feces in young animals (Craig, 2009). The latter affects the small intestine of sheep, goats, and wild ruminants (Taylor et al., 2016). Its greater capacity to suck blood is related to moderate to severe anemia, hypoproteinemia, emaciation, and death of the hosts (Craig, 2009). To our knowledge, this is the first report of these species in vicuñas. This clear example of pathogen spillover from domestic to wild animals could be related to the increasing host densities of the former in areas where wildlife occur, what could increase the transmission rates both within domestic populations and between domestic and wild species (Power and Mitchell, 2004). Unfortunately, the impact of these parasites on vicuñas has not yet been elucidated.

In Neotropical camelids, host-specific parasites (e.g., *Graphinema aucheniae*, *Camelostrongylus mentulatus*, *Nematodirus lamae*, *Lamanema chavezi*, *Trichuris tenuis*, and *Eimeria* spp.) may prevail in areas where vicuñas live relatively isolated (Cebra, 2014). However, in many sectors of the Andean highlands, mainly in those with access to water sources, vicuñas often share the same pastures and territory with domestic animals, and common parasites of ruminants might predominate (e.g., *Ostertagia* spp., *Haemonchus contortus*, *Trichostrongylus* spp., *Cooperia* spp. and *Oesophagostomum* spp.) (Cebra, 2014, Marcoppido et al., 2016). Our results indicate

a strong influence of domestic animals on vicuña parasite community, as *Trichostrongylus* spp., *Haemonchus* spp., *Cooperia* spp., *Teladorsagia* spp., and *Oesophagostomum* spp. were more frequent than vicuña-specific parasites like *Lamanema chavezii* or *Nematodirus lamae*. Cattle, sheep, alpacas, and llamas are common domestic animals for Andean communities, moreover areas of many MUS and some wild vicuñas territories were previously used for livestock production and could be associated with our findings.

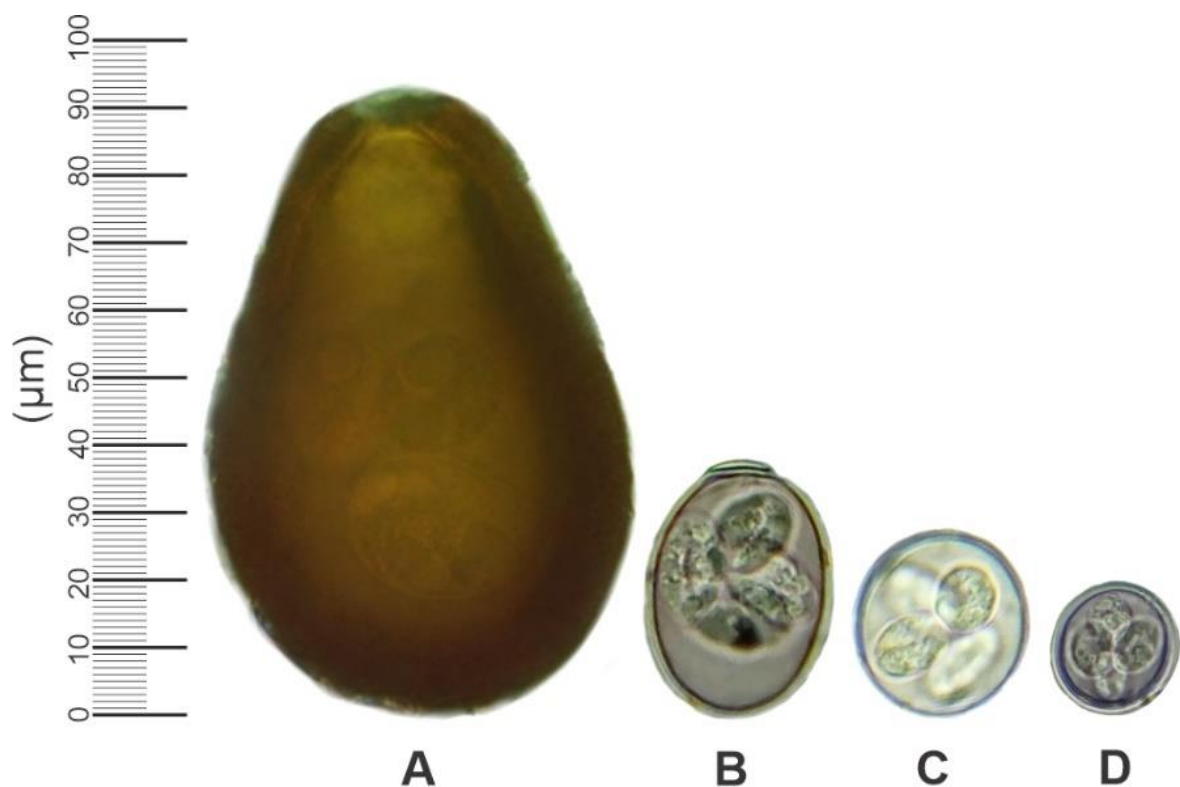


**Figure 2.** Morphology of two nematode larvae (40x) from the Ancylostomatidae family compatible with (A) *Bunostomum phlebotomum* and (B) *Gaigeria pachyselis*.

**Table 2.** Morphometry ( $\mu\text{m} \pm \text{SD}$ ) of gastrointestinal nematodes larvae from vicuñas of the Cusco Region, Peru.

	<i>Trichostrongylus</i> spp.	<i>Haemonchus</i> spp.	<i>Cooperia</i> spp.	<i>Teladorsagia</i> spp.	<i>Esophagostomas</i> spp.	<i>Nematodirus</i> <i>spathiger</i>	<i>Bunostomum</i> <i>phlebotomum</i>	<i>Gaigeria</i> <i>pachyscelis</i>
Total sheath length	631.39 $\pm$ 36.46	736.84 $\pm$ 26.37	719.6 $\pm$ 1.34	798.73 $\pm$ 55.66	797.72 $\pm$ 55.51	1162.44 $\pm$ 66.11	484.48 $\pm$ 73.03	670.82 $\pm$ 65.62
Total larva length	586.54 $\pm$ 37.35	666.35 $\pm$ 22.87	605.17 $\pm$ 6.92	742.01 $\pm$ 37.57	641.33 $\pm$ 52.13	809.59 $\pm$ 55.99	443.75 $\pm$ 70.28	541.84 $\pm$ 64.18
Sheath tail extension	42.91 $\pm$ 5.43	65.34 $\pm$ 3.84	111.02 $\pm$ 1.52	54.15 $\pm$ 18.76	149.56 $\pm$ 16.88	352.85 $\pm$ 10.12	50.73 $\pm$ 11.89	128.98 $\pm$ 28.63
Buccal capsule length	-	-	-	-	-	-	12.29 $\pm$ 2.55	16.83 $\pm$ 2.77
Esophagus length	148.05 $\pm$ 10.71	158.01 $\pm$ 10.22	162.95 $\pm$ 5.90	149.26 $\pm$ 13.36	161.90 $\pm$ 13.05	198.25 $\pm$ 11.66	109.96 $\pm$ 10.16	132.79 $\pm$ 4.43
Esophagus posterior bulb								
Length	-	-	-	-	-	-	19.17 $\pm$ 3.00	20.82 $\pm$ 3.13
Width	-	-	-	-	-	-	13.44 $\pm$ 1.64	15.43 $\pm$ 1.68
Intestine length	387.52 $\pm$ 29.78	450.63 $\pm$ 21.56	377.86 $\pm$ 6.29	521.12 $\pm$ 26.14	407.81 $\pm$ 36.12	525.10 $\pm$ 49.63	278.99 $\pm$ 57.00	338.97 $\pm$ 51.60
Length from the anal pore to the tip of the tail	50.97 $\pm$ 6.92	57.71 $\pm$ 7.87	64.37 $\pm$ 5.28	71.63 $\pm$ 5.01	71.62 $\pm$ 8.44	86.25 $\pm$ 5.30	42.51 $\pm$ 12.87	53.25 $\pm$ 14.78

*Eimeria* spp. are important parasites of Neotropical camelids, especially during the first months of life, although it also can also be pathogenic to adults, depending on the animal physiological status (i.e. concurrent infections, stress, nutrition), and environmental conditions (i.e. temperature, relative humidity). To date, clinical coccidiosis has not been described in vicuñas, yet the importance of these protozoans is well documented in llamas and alpacas (Perez et al., 2014, Camareno et al., 2016, Díaz et al., 2016). Based on Dubey (2018), the five species of *Eimeria* (*E. lamae*, *E. alpaca*, *E. punoensis*, *E. ivitaensis*, *E. macusaniensis*) were morphologically distinguished in size and shape from each other without the need of sporulation (Figure 3). The sixth species of this genus, *E. peruviana*, has not been diagnosed after the original description by Yakimoff, in 1934, and its validity is questioned by some parasitologists (Cafrune et al., 2014, Diaz et al., 2016, Dubey, 2018).



**Figure 3.** *Eimeria* spp. sporulated oocysts found in vicuñas from Cusco Region, Peru. (A) *E. macusaniensis*, (B) *E. lamae*, (C) *E. alpaca*, (D) *E. punoensis*.

Only *E. ivitaensis* was not observed in the present study, 60% and 35.7% of the animals were positive to at least one of the four *Eimeria* species identified or presented co-infection between them, respectively. Interestingly, *E. lamae*, one of the most pathogenic *Eimeria*, had very low frequency (6.1%). All parasitized vicuñas had low infection intensities, indicating that the presence of this parasite in animals is not necessarily related to clinical disease outbreaks but could represent a potential risk of acquiring clinical coccidiosis (Díaz et al., 2016). The most frequent coccidian was *E. punoensis* (38.3%), and this observation may be related to the shorter sporulation time and prepatent period of the species (Perez et al., 2014, Cebra et al., 2014).

Prevalence by type of management, age, and sex is summarized on Table 3. Only age was related to *Eimeria* spp. infection, *crias* were more susceptible to this parasite than yearlings or adults as it was described in llamas and alpacas (Pérez et al., 2014, Camareno et al., 2016). The main signs of infection by gastrointestinal parasites in Neotropical camelids are poor weight gain or ill thrift, which may progress to weakness, lethargy, anorexia, sepsis and death. Diarrhea is uncommon, except in cases of infection by *Eimeria* or *Trichuris*. The latter, along with *Haemonchus*, can cause moderate to severe anemia in infected animals (Cebra, 2014). Nonetheless, most of vicuñas examined were in moderate health condition, with body score between 2.5 - 3 in a 5 scale. No clinical signs associated with parasitic infection were observed, and no animal death was registered during the *chaccus* or immediately after them. Particularly, we believe that lack of clinical signs during *Eimeria* infection could be related to individuals experimenting a gradual recovery of health in convalescent period of the disease, as no *crias* under 6-month-old were evaluated and the first three months of life are the most critical for infection (Rodríguez et al., 2012).

**Table 3.** Prevalence (%) of *Eimeria* spp. oocysts found in feces of vicuñas from the Cusco Region, Peru.

	Management			Age			Sex		%Total
	Wilderness	Semi-captive	Crias	Yearlings	Adult	Male	Female		
<i>E. macusaniensis</i>	48.6%	28.8%	54.5%	47.4%	29.4%	39.4%	28.6%	34.8%	(40/115)
<i>E. lamae</i>	8.6%	5.0%	0.0%	0.0%	8.2%	6.1%	6.1%	6.1%	(7/115)
<i>E. alpaca</i>	60.0%	7.5%	36.4%	42.1%	17.6%	19.7%	28.6%	23.5%	(27/115)
<i>E. punoensis</i>	45.7%	35.0%	81.8%	52.6%	29.4%	39.4%	36.7%	38.3%	(44/115)
% Total	88.6% (31/35)	47.5% (38/80)	100.0% <sup>a</sup> (11/11)	84.2% <sup>b</sup> (16/19)	49.4% <sup>b</sup> (42/85)	65.2% (43/66)	53.1% (26/49)	60.0%	(69/115)

<sup>ab</sup> Rows with distinct superscripts inside each category indicate statistical difference.

Vicuñas fibre grows very slowly, animals are shorn every two years or when their fibre is at least 2.5 cm long, so they can produce about to 250g/animal in every shorn, approximately 1kg of fleece in their average 8-year life (Quispe et al., 2009). The negative effects of clinical and subclinical parasitism have been largely associated to reduction of animal production (MacRae, 1993, Rushton, 2009), and can be related to negative effects on vicuña fleece resistance and diameter. Fibre diameter or fineness is one of the most important technological characteristics since the value of vicuña fleece increases as the diameter decreases. Likewise, the diameter variation coefficient (CV%) is a characteristic associated to fibre uniformity and resistance, low CV% indicate more regularity and greater resistance, its value should be about 24% to obtain a better spinning performance (Quispe et al., 2013).

In this study, all fibre samples were obtained from semi-captive adults (10 female and 12 male vicuñas). The logistic regression analysis revealed that sex is related to fibre diameter (OR=15.4,  $p = 0,0224$ ), as females had a significantly finer diameter than males, however CV% values did not differ between them (Table 4). Most of studies about vicuñas fleece did not shown differences between sexes (Takashima et al., 2017, Quispe et al., 2018), though Pacheco et al. (2019) described a thinner fibre in yearlings and adult females.

**Table 4.** Fibre diameter ( $\mu\text{m} \pm \text{SD}$ ) and diameter variation coefficient (CV%  $\pm \text{SD}$ ) comparison of means between sexes.

	Sex	
	Female (11)	Male (12)
Diameter ( $\mu\text{m}$ )	13.05 $\pm$ 0.73 <sup>a</sup>	14.22 $\pm$ 1.22 <sup>b</sup>
CV%	26.65 $\pm$ 5.17	25.10 $\pm$ 3.43

<sup>ab</sup>Rows with distinct superscripts indicate statistical difference.

Of all the parasites observed, only *E. macusaniensis* and *E. lamae* had influence over the fleece CV% and diameter ( $\mu\text{m}$ ), respectively (Table 5). Nevertheless, these fleece characteristics were still between the accepted average fineness and resistance values. Curiously, vicuñas co-infected with two *Eimeria* spp. showed a thinner fibre and higher CV% when compared to animals with monospecific *Eimeria* infection and negative individuals (Table 6). Fibre characteristics of individuals presenting monospecific infection with *E. punoensis*, *E. alpaca*, and *E. macusaniensis* did not contrast with those of uninfected animals. In their life cycle, small *Eimeria* spp. multiply in intestinal villi, inducing a mucosal loss and villus shortening, while the large species replicate in the epithelium of the lamina propria (Rodríguez et al., 2012). Although the association of parasites is related to more serious cases of infection, the lack of clinical signs of the observed associations of *E. punoensis* x *E. macusaniensis*, and *E. punoensis* x *E. lamae* could have been limited by the low parasitic intensity they presented and to the animals age, as a study in alpacas indicates that subclinical disease is the most common in adults (Camareno et al., 2016). Our results indicate that subclinical *Eimeria* spp. co-infection weakens the fibre as diminish its diameter, so fibre could be easier to break, interfering with the spinning, and consequently decreasing its commercial value. Nonetheless, we should emphasize that our sample size was too small to make definitive conclusions and this limitation should be improve in other studies to complete the information.

**Table 6.** Fibre diameter ( $\mu\text{m} \pm \text{SD}$ ) and diameter variation coefficient (CV%  $\pm \text{SD}$ ) of vicuñas negative to *Eimeria* infection, mono-infected and co-infected.

	Eimeria infection		
	Negative	One species	Co-infection
Diameter ( $\mu\text{m}$ )	14.01 $\pm$ 1.15 <sup>a</sup>	14.30 $\pm$ 1.19 <sup>a</sup>	12.55 $\pm$ 0.44 <sup>b</sup>
CV (%)	22.77 $\pm$ 2.89 <sup>a</sup>	24.10 $\pm$ 1.41 <sup>a</sup>	29.55 $\pm$ 5.24 <sup>b</sup>

<sup>ab</sup>Rows with distinct superscripts indicate statistical difference.

**Table 5.** Fibre diameter ( $\mu\text{m} \pm \text{SD}$ ) and diameter variation coefficient ( $\text{CV}\% \pm \text{SD}$ ) comparison of means for each parasite found in vicuñas of the Cusco Region, Peru, ( $n=22$ ).

	<i>E. macusaniensis</i>	<i>E. lamae</i>	<i>E. alpecae</i>	<i>E. punoensis</i>	<i>N. spathiger</i>	<i>N. lamae</i>	Strongyle-type egg	<i>Trichuris</i> spp.	<i>L. chavez</i>
Positive animals									
Male	3	1	1	4	2	2	5	0	3
Female	3	1	0	8	1	0	7	4	2
Diameter ( $\mu\text{m}$ )									
Positive	$13.26 \pm 0.89$	$12.38 \pm 0.49^a$	13.75*	$13.45 \pm 1.34$	$14.12 \pm 1.12$	$13.04 \pm 1.00$	$13.75 \pm 1.12$	$13.73 \pm 0.82$	$13.64 \pm 0.82$
Negative	$13.84 \pm 1.25$	$13.86 \pm 1.13^b$	$13.67 \pm 1.20$	$13.94 \pm 0.94$	$13.61 \pm 1.08$	$13.73 \pm 1.19$	$13.60 \pm 1.27$	$13.66 \pm 1.25$	$13.68 \pm 1.27$
P value	0.2805	0.0375	0.7534	0.3137	0.4967	0.4333	0.7682	0.9155	0.9443
CV (%)									
Positive	$27.94 \pm 1.65^a$	$32.03 \pm 7.91$	25.23*	$27.25 \pm 4.86$	$25.16 \pm 1.01$	$26.05 \pm 1.17$	$26.55 \pm 5.49$	$27.66 \pm 2.35$	$25.27 \pm 1.01$
Negative	$25.02 \pm 4.87^b$	$24.99 \pm 3.02$	$25.90 \pm 4.46$	$24.25 \pm 3.18$	$25.97 \pm 4.66$	$25.85 \pm 4.56$	$25.19 \pm 2.93$	$25.51 \pm 4.62$	$26.03 \pm 4.89$
P value	0.0069	0.2619	0.4787	0.1245	0.7699	0.7939	0.4355	0.1409	0.5338

<sup>a</sup>Columns with distinct superscripts inside each category indicate statistical difference. <sup>b</sup>Values without standard deviation indicate a single sample.

In addition, any threaten to fibre quality is an obstacle in the marketing of vicuña fleece, linked to the lack of an offer in foreseeable quantity and large fluctuations in the price due to volatile demand that hinder the guarantee of income for producers and communities (Quispe et al., 2009). These results reflect the health status of the group of vicuñas evaluated and the relationship of parasitism with the quality of fibre production, a valuable resource for Andean communities and an important factor in vicuña conservation and sustainability, providing data for disease surveillance and representing a basis in the application of appropriate control measure.

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