Dear Friends and Colleagues,

It is my great pleasure to welcome you to Georgia and the campus of Fort Valley State University for the 10th Anniversary Conference of the American Consortium for Small Ruminant Parasite Control (ACSRPC). The theme of this conference is “Training-the-Trainer” in integrated parasite management (IPM) technologies. Veterinarians, country agents, and university extension educators will then train individual small ruminant producers all across the country and around the world in the application of IPM principles on-farm. In addition to hands-on training in IPM techniques, conference attendees will have ample opportunities to discuss parasite management issues while they listen to and share their questions with some of the world’s foremost experts in IPM research and outreach.

I want to extend my sincere gratitude to the speakers who have come to this conference from as far away as South Africa and Greece, and attendees from all across the country, including Washington State, Connecticut, Texas, and everywhere in between. You have picked a wonderful time of year to visit Georgia, the “Peach State”. The azaleas are in full bloom, and while you are here, be sure to sample early peaches and our world famous Sweet Vidalia Onions, which are harvested throughout the month of May.

Of course, none of this would be possible without the financial support of our sponsors, and to each of them, I extend a most sincere thank you for caring about and supporting programs aimed at sustaining family farms. I am also grateful for the many, many hours of hard work put in by staff from the Office of Sponsored Programs at FVSU, and for the tremendous support from all levels of administration at the University, as well as from faculty, students, and staff at the College of Agriculture. I am also sincerely thankful for my colleagues at the 25 other institutions that make up the ACSRPC for their devotion to research and extension programs that help small ruminant producers keep their animals and their bottom line healthy!

A key to the success of the first 10 years of the ACSRPC has been our willingness to interact and share ideas with each other and with farmers, researchers, and extension personnel outside of our consortium, and it is in this spirit that we welcome attendees to this conference. We hope you will use this opportunity to learn, to interact and to make connections that will have a lasting impact on sustainability of small ruminant production across this nation and around the world.

Let’s have a great conference!

Thomas H. Terrill
ACSRPC Coordinator
May 20, 2013

To All ACSRPC Members:

What a delight it is for me to welcome you to "The Valley" for your 10th Anniversary Conference!

Telling you that Fort Valley State University stands proud of our association with ACSRPC and of its many accomplishments of significance is something I personally feel able to do. My own association with FVSU began way back in 1969 when I arrived as a freshman. Thirty-seven years later it was my honor to assume the position of this historic institution's presidency.

Through the interim I maintained close connections with many faculty and staff, including the outstanding scholars and researchers who make up what we now call the College of Agriculture, Family Sciences and Technology. Word of the increasing success of our Small Ruminant Research and Extension Center came as most-welcome news. Then, in 2003 with the founding of the American Consortium for Small Ruminant Parasite Control, opportunities opened up for my beloved university to join with an elite group of other institutions to further coordinated inquiries leading to substantive practical benefits to Georgia and all areas where the small ruminant industry existed. It is one of those ideas that we now look back upon asking why we did not join together earlier. It is an idea that has been tested by time and found solid and enduring. It is an idea that is making a difference.

We here in "The Valley" see ACSRPC on its 10th anniversary as standing of the threshold of ever-greater accomplishment and ever-higher levels of service. FVSU stands ready to partner in that service. Meanwhile, we take pride in your presence among us and in the close ties and friendships this partnership has brought.

Please accept my wish that this conference stands out for you as the greatest so far.

Sincerely yours,

Larry E. Rivers
President
May 20, 2013

Greetings to ACSRPC Representatives!

On behalf of the faculty of The Fort Valley State University, it is my pleasure to offer a warm Wildcat welcome to all those attending the 10th Anniversary Conference of the American Consortium for Small Ruminant Parasite Control.

Here at FVSU we are committed to the greatest traditions of scholarly research, and nowhere on our campus does that fact find greater application than in the fields of agriculture and animal husbandry. That our scholars can join with those of twenty-seven other institutions from around the nation and world to further small ruminant parasite control research exemplifies to me and to us the finest aspects of that commitment to service. That FVSU can do so as lead institution brings even more satisfaction.

No one can deny that, over the past ten years, ACSRPC has worked tremendous impact on the small ruminant industry. That result would not have been possible had not the top talents in the field been open to productive cooperation and mutual support. Even more exciting is what will come in the future. The success of this mutual endeavor is only beginning. There will come a future time when we all look back on this grand 10th anniversary occasion and recall how very much has come to fruition since 2013. Proud now; we will be even prouder then.

I have been honored to come to know many of you in the past few years. I hope to renew those acquaintances at the 10th Anniversary Conference and to make even more. As I do, please let me know how Fort Valley State University can be of greater service to you and to ACSRPC.

Permit me to close by extending my personal thanks to all FVSU researchers and scholars who have contributed to the work of our Small Ruminant Research and Extension Center and to the American Consortium for Small Ruminant Parasite Control.

Respectfully yours,

[Signature]

Canter Brown, Jr.
Executive Vice President and
Interim VP for Academic Affairs
Message from the Dean

Since establishment of the Georgia Small Ruminant Research and Extension Center (GSRREC) in 1986, Fort Valley State University (FVSU) has been a leader in small ruminant research and outreach activities. The overall goal of FVSU agricultural research is to empower small and limited resource farmers worldwide by providing the knowledge needed to sustain successful agricultural enterprises.

Accordingly, the GSRREC faculty and staff have been addressing production-related problems encountered by goat and sheep producers through applied research, and offering practical solutions via hands-on training programs, extension publications, and site visits. These solutions have included economically viable nutritional strategies for small ruminant production, improving reproductive efficiency in goats, disease management, and methods for processing goat products, and for their packaging, preserving, and marketing.

An important impediment faced by meat goat producers in the southeastern US and other regions around the world with a high temperature-humidity climate is controlling gastrointestinal worms. The formation of the parasite control consortium, presently called the American Consortium for Small Ruminant Parasite Control (ACSRPC), was a major step in tackling this global issue faced by small-holder farmers. I am glad that this team, comprised of small ruminant researchers and extension specialists, veterinarians, forage specialists, agricultural economists, and others, had the insight and forethought to take this initiative some ten years ago, and I am proud that FVSU is the lead institution in this effort.

Dr. Thomas Terrill, an FVSU professor, forage scientist, and coordinator of ACSRPC, has done an outstanding job directing activities of the consortium. The success of the Consortium is a testament to his commitment, leadership, and interpersonal skills. The work of this team has immensely benefited numerous small ruminant producers around the world.

I congratulate Dr. Terrill and the consortium on their tenth anniversary and wish success with the conference that is being conducted in conjunction with this celebration.

Govind Kanna
Dean and Director
Message from Assistant Vice President for Land Grant Affairs:

As Assistant Vice President for Land Grant Affairs, Extension Administrator, and an alumnum of the College of Agriculture, Family Sciences and Technology, it is my distinct honor to welcome producers, veterinarians, extension agents, scientists, and industry representatives from across the country and the world to our campus for the 10th Anniversary Conference of the American Consortium for Small Ruminant Parasite Control.

Fort Valley State University (FVSU) is one of two Land-Grant Universities in the state of Georgia, and as such, is dedicated to improving the lives of individuals, families, and communities throughout the state of Georgia and across the nation through cutting-edge research, teaching, and outreach programs. Throughout the history of this distinguished University, we have been committed to serving the economic, social, and educational needs of limited-resource families and under-represented individuals. Sustaining the family farm during these uncertain economic times is one of the most critical issues facing our nation, and the agricultural researchers and extension specialists at FVSU are committed to this cause.

With a distinguished record of research and outreach focused on development, validation, and on-farm implementation of sustainable small ruminant parasite control programs, special emphasis is placed on small and limited resource farmers. The American Consortium for Small Ruminant Parasite Control shares our University's values, and we are proud of the commitment this organization has in serving small ruminant producers and agricultural industries throughout our state, across the country, and around the world.

Enjoy the conference!

Sincerely,

Mark Latimore, Jr., Ph.D.
Assistant Vice President for Land Grant Affairs (Interim)
and Extension Administrator
latimorem@fvsu.edu
(478) 825-6296
American Consortium for Small Ruminant Parasite Control
10th Anniversary Conference • May 20-22, 2013

~ Program ~

Monday, May 20

8-8:30am  Registration

8:30-9:15 am Introduction
Dr. Thomas H. Terrill, ACSRPC Coordinator, Assistant Professor, Fort Valley State University

Welcome
Dr. Canter E. Brown Jr., Vice President of Academic Affairs, Fort Valley State University

Greetings
Dr. Larry E. Rivers, President, Fort Valley State University

Remarks
Congressman Sanford D. Bishop Jr., Representing 2nd District of Georgia

SESSION I
Session Chair: Dr. Jorge A. Mosjidis, Professor Emeritus, Auburn University

9:15-9:45am Train-the-Trainer: Transfer of Research Knowledge to Farm Application –
Dr. Seyedmehdi Mobini, Professor, Fort Valley State University

9:45-10:15am Overview of ACSRPC – Dr. Thomas H. Terrill, Assistant Professor, Fort Valley State University

10:15-10:45am Southern Region SARE funding opportunities – James H. Hill, 1890 Land-Grant Liaison, Southern Region SARE

10:45-11am Break

SESSION II
Session Chair: Dr. James E. Miller, Professor of Veterinary Medicine, Louisiana State University

11-11:30am Biology of Parasites – Dr. Ann Zajac, Associate Professor, Virginia Tech

11:30am-12:15pm Anthelmintic Resistance and New Anthelmintics – Dr. Ray M. Kaplan, Professor of Parasitology, University of Georgia

12:15-1:30pm LUNCH – C.W. Pettigrew Farm & Community Life Center

Speaker: Gareth F. Bath
Emeritus Professor, Faculty of Veterinary Science
University of Pretoria, South Africa
### SESSION III
**Session Chair:** Dr. Felipe Torres-Acosta, Professor of Veterinary Parasitology, Autonomous University of Yucatán, Mérida, Mexico

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<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
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<tr>
<td>1:30-2pm</td>
<td>Extending the Efficacy of Dewormers/Smart Drenching</td>
<td>Dr. Lisa Williamson, Associate Professor, University of Georgia</td>
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<tr>
<td>2-2:30pm</td>
<td>The FAMACHA® System – An Aid in the Management of Haemonchosis in Small Ruminants</td>
<td>Dr. Adrian Vatta, Manager, Antiparasitics, Zoetis, Kalamazoo, MI</td>
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<td>2:30-3pm</td>
<td>Copper Oxide Wire Particles</td>
<td>Dr. Joan M. Burke, Research Animal Scientist, USDA, ARS, Dale Bumpers Small Farms Research Center, Booneville, AR</td>
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<td>3- 3:30pm</td>
<td>Break</td>
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### SESSION IV
**Session Chair:** Dr. Anne Zajac, Associate Professor, Virginia Tech

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<th>Time</th>
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<tr>
<td>3:30-4pm</td>
<td>Sericea lespedeza</td>
<td>Dr. Thomas H. Terrill, Assistant Professor, Fort Valley State University, and Dr. Jorge A. Mosjidis, Professor Emeritus, Auburn University</td>
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<tr>
<td>4-4:30pm</td>
<td>Mechanism of Action of Tannins</td>
<td>Dr. Herve Hoste, Senior Researcher, University of Toulouse, France</td>
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<td>4:30-5pm</td>
<td>Fungus and Vaccines</td>
<td>Dr. James E. Miller, Professor of Veterinary Medicine, Louisiana State University</td>
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<td>5-5:30pm</td>
<td>Herbal Dewormers</td>
<td>Dr. Enrique Nelson Escobar, Small Ruminant Specialist, University of Maryland Eastern Shore</td>
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<tr>
<td>5:30-6pm</td>
<td>Round Table Discussion/Q&amp;A</td>
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**Tuesday, May 21**

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<th>Time</th>
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<tr>
<td>8-8:30am</td>
<td>Registration</td>
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### SESSION V
**Session Chair:** Dr. Joan M. Burke, Research Animal Scientist, USDA, ARS, DBSFRC, Booneville, AR

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<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
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<tr>
<td>8:30-9am</td>
<td>Nutrition and Pasture Management</td>
<td>Dr. Jean-Marie Luginbuhl, Professor, North Carolina State University</td>
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<td>9-9:30am</td>
<td>Genetic Selection for Resistance</td>
<td>Dr. David Riley, Associate Professor, Texas A&amp;M University</td>
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<tr>
<td>9:30-10am</td>
<td>Importance of Host Response in Resistance to Nematode Parasites</td>
<td>Dr. Jorge Gonzalez, Senior Research Fellow, University of Las Palmas de Gran Canaria, Canary Islands, Spain</td>
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10-10:30am  Extension's role in parasite control – Dr. Niki Whitley, Animal Science Specialist, North Carolina A&T State University, and Susan Schoenian, Sheep & Goat Specialist, University of Maryland

10:30-11am  Break

SESSION VI  
Session Chair: Dr. Thomas H. Terrill, Assistant Professor, Fort Valley State University

11-11:30am  Leave the Best, Treat the Test - Targeted Selective Treatment for the Resource Poor in Africa – Dr. Jan van Wyk, Extraordinary Lecturer, University of Pretoria, South Africa

11:30-12pm  International Perspectives, Europe – Dr. Smaragda Sotiraki, Veterinary Research Institute of Thessaloniki, Greece

12-12:30pm  A New Paradigm for the Control of Gastrointestinal Nematodes in the Tropics – Dr. Felipe Torres-Acosta, Professor of Veterinary Parasitology, Autonomous University of Yucatán, Mérida, Mexico

12:30-2:30pm  LUNCH & TOURS – Lane Southern Orchards

SESSION VII  
Session Chair: Dr. Ray M. Kaplan, Professor of Parasitology, University of Georgia

2:30-3:30pm  Integrated Parasite Management - Panel of Speakers from Day 1 and 2

3:30-4pm  Round Table Discussion/Q&A

4-6pm  Hands on FAMACHA® Training  
(Those that attended both days get integrated parasite management (IPM) trainer or FAMACHA® certification)

Wednesday, May 22

8-8:30am  Registration

SESSION VIII  
Session Chair: Dr. Jean-Marie Luginbuhl, Professor, North Carolina State University

8:30-12pm  Integrated Parasite Management (IPM) Training

12-1:30pm  LUNCH – C.W. Pettigrew Farm & Community Life Center

SESSION IX  
Session Chair: Dr. Jan van Wyk, Extraordinary Lecturer, University of Pretoria, South Africa

1:30-3pm  Hands on FAMACHA® and Five Point Check® Training/Trainer Certification

3-5pm  Fecal Egg Count Laboratory Training
Gareth Bath
Emeritus Professor
Sheep and Goat Health and Production
Faculty of Veterinary Science
University of Pretoria
Private Bag x04
Onderstepoort 0110
South Africa
+27(12) 529 8038 (work)
+27 82 82 2526 (cell)
Gareth.bath@up.ac.za

BRIEF BIOGRAPHY

Gareth Bath has had wide experience of most aspects of sheep and goat health and production since 1970 and has published extensively in scientific journals and other scientific publications including several books and chapters in books. Internationally, he has made contributions in Namibia, Zimbabwe, Zambia, Tanzania, Kenya, Uganda, Ghana, Tunisia, Egypt, Italy, France, Greece, Britain, Norway, Belgium, India, Malaysia, Japan, Australia and New Zealand, as well as the United States of America. He has been involved in several major international projects involving parasite control, including those funded by the FAO and EU. From 2006 onwards, he has been a foreign member of the ACSRPC, and in 2008 was elected the first South African to join the European College of Small Ruminant Health Management, a specialist body. He is co-developer of the internationally acclaimed FAMACHA© system and the initiator of the FIVE POINT CHECK© for the targeted selective treatment of small ruminants, as well as designing and promoting sustainable, holistic, integrated parasite management systems for sheep and goat farmers world-wide.
Dr. Joan M. Burke
Research Animal Scientist

USDA, Agricultural Research Service
Dale Bumpers Small Farms Research Center
6883 South State Highway 23
Booneville, AR 72927

(479) 675-3834 x325
Joan.burke@ars.usda.edu

**BRIEF BIOGRAPHY**

Dr. Joan M. Burke is a Research Animal Scientist with the USDA, Agricultural Research Service, Dale Bumpers Small Farms Research Center in Booneville, Arkansas. She received a Ph.D. in reproductive biology at Oregon State University, a Master's in animal science from the University of Maine and a Bachelor's degree from Cornell University. Dr. Burke has been with ARS since 1999 where she has conducted research on the control of gastrointestinal nematodes in sheep and goats. Her program focuses on Smart Drenching, alternatives to synthetic anthelmintics, nutrition, and genetic selection for parasite resistant animals. She was co-recipient of a patent on the use of sericea lespedeza to control parasites in animals. More recently, she conducted team research on the control of *Eimeria* spp. by feeding sericea lespedeza in sheep and goats. She works closely with producers conducting research and disseminating results. She has been a member of the American (formerly Southern) Consortium for Small Ruminant Parasite Control since its beginning.
Dr. Enrique Nelson Escobar
Small Ruminant Specialist

University of Maryland Eastern Shore
Princess Anne, Maryland

(410) 651-7930
enescobar@umes.edu

BRIEF BIOGRAPHY

Dr. Enrique Nelson Escobar joined the University of Maryland Eastern Shore (UMES) as an assistant professor and extension specialist in small ruminants in July 2009. Dr. Escobar obtained an agricultural engineering degree from the University of El Salvador and his M.S. and Ph.D. degrees from the University of Maryland. He supervises the operation of the UMES small ruminant farm, and conducts research and extension programs for Maryland sheep/goat producers, and collaborates with University of Maryland Extension on statewide small ruminant program events, including the Maryland State Fair. He has collaborated with local, state, and national teams to develop projects managing goats to utilize unwanted vegetation, thus improving land vocation and value. Internationally, Dr. Escobar has collaborated with teams in Central America, Haiti, the Dominican Republic, Armenia and Nepal. Dr. Escobar coordinated small farm and sustainable agriculture programs in Oklahoma. At the USDA/Cooperative State Research, Education, and Extension Service (CSREES-now NIFA), Dr. Escobar assisted in supporting the activities of the CSREES Small Farms Program and also functioned as the Executive Director of the USDA Advisory Committee on Small Farms. Dr. Escobar has continued the effort at UMES toward the research and adoption of integrated parasite management practices in small ruminants.
**Dr. Jorge Francisco González**  
Senior Research Fellow  
Project Leader: Genetic resistance to nematodes in small ruminants

Parasitology Unit, Department of Animal Pathology  
Veterinary Faculty,  
University of Las Palmas de Gran Canaria, Arucas 35413  
Canary Island, Las Palmas (Spain)  
Phone: +34 928 457242  
Email: jfgonzalez@dpat.ulpgc.es

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**BRIEF BIOGRAPHY**

Dr. Jorge F. González obtained his first degree in Veterinary Sciences in 1996 at the University of Las Palmas de Gran Canaria (ULPGC). He was awarded a competitive National Fellowship at the Department of Animal Pathology at the ULPGC in 1997. However, by September, 1997, he was appointment Associate Professor at the Parasitology Unit of the Veterinary Faculty of ULPGC and embarked on a PhD about immune response against gastrointestinal nematodes in goats within this research group. He was appointment Senior Research and Lecturer Fellow in 2011. He has visited several national and international research laboratories and he has established collaborative work with many of them. He is the principal investigator for several competitive and industry supported grants. His current main research aim is identified why the Canaria Hair Breed sheep is more resistant to gastrointestinal nematode infections than local Canaria sheep.
Dr. Hervé Hoste graduated as a DVM in 1982. He obtained his PhD in 1987 and then his HDR (Habilitation à Diriger la Recherche) in 1997. He has been appointed by INRA since 1983 and he is now an INRA Senior Researcher within the UMR 1225 IHAP in Toulouse, which is a joint research unit between INRA and the Toulouse Veterinary School (ENVT). INRA is the largest Research Institute in Europe dedicated to Agricultural Research. ENVT is one of 4 French Veterinary Schools. The UMR IHAP’s research focuses on interactions between host animals and pathogens. Within IHAP, Dr Hoste’s team works on the “Interactions between Nematodes and the Digestive Environment”.

Hervé Hoste has conducted research in Veterinary Parasitology, especially on Gastrointestinal Nematodes of sheep and goats, for 30 years. His main scientific researches aimed at better understanding the pathophysiological and pathogenic mechanisms explaining the disturbances and damages due to GINs in small ruminants and more recently to analyse the influence of gut environment on GINs, in relation with animal feed (nutraceuticals). However, strong links have always been maintained between these basic researches and more applied ones with potential farm applications, in particular in the field of alternative approaches to commercialised synthetic anthelmintics in the control of GINs, in a context of wide spread resistance to these AHs in worm populations.
Dr. Ray M. Kaplan  
Professor of Parasitology  
Department of Infectious Diseases  
College of Veterinary Medicine  
University of Georgia  
Athens, Georgia 30602

**BRIEF BIOGRAPHY**

Dr. Ray M. Kaplan is a Professor in the Department of Infectious Diseases in the College of Veterinary Medicine at the University of Georgia. Prior to his position at University of Georgia, Dr. Kaplan served in the Army Veterinary Corps at the Walter Reed Army Institute of Research, where he was Chief of Parasite Biology in the Division of Experimental Therapeutics. Dr. Kaplan received his bachelor's degree from Virginia Tech and his DVM from Virginia Maryland Regional College of Veterinary Medicine. He worked as a clinical veterinarian in a mixed-species private practice in Pennsylvania for several years before leaving practice for the University of Florida, where he earned a PhD in Veterinary Parasitology. Since 1998, he has been in his current position where he teaches and performs research and service in veterinary parasitology. Dr. Kaplan's research program is focused on measuring, understanding, and solving the problem of drug resistance in helminth parasites. He is a Diplomate of both the American College of Veterinary Microbiologists (Parasitology) and the European Veterinary Parasitology College, is the former director of the Filariasis Research Reagent Resource Center (FR3), and is the current director of the Athens Parasitology Diagnostic Laboratory. He also is recipient of the Pfizer Award for Research Excellence and the University of Georgia Charles N. Dobbins Award for Excellence in Service.
Dr. Jean-Marie Luginbuhl, Professor of Crop Science and Animal Science at North Carolina State University, has been leading the Meat Goat and Forage Systems Research and Extension Program since October 1995. In this position, Dr. Luginbuhl is responsible for conducting research with meat goats and guiding development of the North Carolina meat goat industry. His research program emphasis and goals include developing sustainable forage and browse-based feeding systems for meat goats, using goats as bio-agents to control invasive herbaceous weeds and woody vegetation in pastures, forest land and other areas when grazing alone or in combination with cattle, evaluating the browse potential of fodder tree species in silvopastoral systems for meat goats, and exploring non-pharmaceutical approaches to treating meat goats with traditional anthelmintics. In the past, Dr. Luginbuhl has worked with small farmers in the Peruvian Andes, and his other international experiences include Costa Rica, Honduras, Mexico, Spain, Morocco, Indonesia, Switzerland, Uruguay and Venezuela. Dr. Luginbuhl is presently a member of the board of directors of the International Goat Association. Dr. Luginbuhl grew up on an integrated livestock-crop farm in a small rural community located near the city of Neuchâtel in the French part of Switzerland, and he speaks English, French, and Spanish fluently.
Dr. James E. Miller

Everett D. Besch Professor of Veterinary Medicine
Interim Associate Dean for Research and Advances Studies

Department of Pathobiological Sciences
School of Veterinary Medicine
Louisiana State University
Baton Rouge, LA 72927, USA
(225) 578-9652
jmille1@lsu.edu

Dr. James E. Miller is a faculty member in the Department of Pathobiological Sciences, School of Veterinary Medicine at Louisiana State University. He is author and/or coauthor of over 90 refereed journal articles, numerous technical/report papers, proceedings papers, and abstracts, and 7 book chapters. He is a research collaborator with numerous national and international organizations. He is a co-founder of the American Southern Consortium for Small Ruminant Parasite Control. The Consortium's primary purpose is to evaluate and promote alternative nonchemical methods for controlling nematode parasites. Dr. Miller is the principal investigator for several competitive and industry supported grants studying the epidemiology, control, and genetics of ruminant nematode parasitism. His research program focuses on improving ruminant production using an integrated approach to controlling parasites. His area of special expertise is small ruminant gastrointestinal nematode parasitism, which is one of the most serious constraints affecting production worldwide. Dr. Miller's research is directed at developing alternative strategies for control. His current research program is two-fold: 1) to determine why, and/or how, Gulf Coast Native sheep are relatively more resistant to gastrointestinal nematode infection than Suffolk sheep, and 2) to evaluate alternative (nonchemical) approaches for protection against nematode infection.
Dr. Seyedmehdi Mobini

DVM, MS, Dipl. ACT

Professor and Head
Department of Veterinary Science
Fort Valley State University
Fort Valley, Georgia 31030

mobinis@fvsu.edu

BRIEF BIOGRAPHY

Dr. Seyedmehdi Mobini has 35 years of experience as a veterinarian and educator. His expertise is in the area of sheep and goat disease prevention, surveillance, treatment, herd health management, and reproductive management. For the past 23 years, he has been involved in the development of sheep and goat industry in Georgia and Southeast serving as State of Georgia Small Ruminant Extension Veterinarian. He also works with the Georgia State Veterinarian and USDA/APHIS/VS Area Veterinarian in Charge as a Small Ruminant Disease Specialist. Dr. Mobini has published numerous scientific and extension publications on sheep and goat herd health management and reproduction. He is the editor of “Smart Drenching and FAMACHA Integrated Training for Sustainable control of GI Nematodes in Small Ruminants”. He has been exposed to veterinary practice in Iran, Ireland, Jordan, Afghanistan and the United States of America.
Dr. Jorge A. Mosjidis
Professor Emeritus
Auburn University
Department of Agronomy and Soils
Auburn, AL 36849
(334) 844-3976
mosjijai@auburn.edu

BRIEF BIOGRAPHY

Dr. Jorge A. Mosjidis is a Professor Emeritus at Auburn University and the Alabama Agricultural Experiment Station at Auburn, Alabama. He has an agronomy degree from the University of Chile, Santiago, and a Ph.D. from the University of California, Riverside. He recently retired but remains partially active. He is a geneticist and plant breeder. As a plant breeder he developed new forage crop cultivars that are more productive and persistent for use in pastures. The new cultivars are also used as cover crops for the protection and conservation of soil and water resources, reduction of surface water pollutant transport, improvement of soil productivity, preservation of a favorable balance between pests and predators, and enhancement of biological diversity. In addition, some of the cultivars have ornamental value for roadsides or for the production of bioenergy. Species bred are sericea lespedeza, sunn hemp, common vetch, hairy vetch, crimson clover and red clover. He collaborates in investigations that explore the parasite control properties of sericea lespedeza.
**Dr. David Riley**

Associate Professor

Department of Animal Science  
Texas A&M University  
College Station, TX 77843

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**BRIEF BIOGRAPHY**

**Dr. David Riley** is an associate professor of animal breeding and genetics in the Department of Animal Science at Texas A&M University. He received his bachelor's degree in agricultural economics in 1984, his master's degree in animal breeding in 1997, and his Ph.D in genetics in 2000, from Texas A&M University. Dr. Riley specializes in quantitative genetic approaches to livestock improvement, including crossbreeding programs, selection programs, and genomic evaluation. He completed sabbatical work with geneticists at CSIRO in Australia in 2008. His current research focus includes the incorporation of information about inherited molecular material in the prediction of genetic merit to improve the performance, efficiency, adaptability, health, and reproduction of livestock.
Susan Schoenian
Sheep & Goat Specialist

University of Maryland Extension
Western Maryland Research & Education Center
18330 Keedysville Road
Keedysville, Maryland 21756

(301) 432-2767 x343 (office)
sschoen@umd.edu

BRIEF BIOGRAPHY

Susan Schoenian is a Sheep & Goat Specialist at the University of Maryland's Western Maryland Research & Education Center. She has been with University of Maryland Extension since 1988. Susan holds B.S. and M.S. degrees in Animal Science from Virginia Tech and Montana State University, respectively. Susan conducts the Western Maryland Pasture-Based Meat Goat Performance Test, which seeks to identify meat goat bucks that are resistant and resilient to internal parasites. She is the author of several web pages pertaining to small ruminants, including the Maryland Small Ruminant Page and Sheep 101. Susan is the current web master for the web site of the American Consortium for Small Ruminant Parasite Control.
Dr. Smaro Sotiraki
Senior Researcher
Head of Veterinary Medicine

Veterinary Research Institute
Hellenic Agricultural Organization - Demeter

BRIEF BIOGRAPHY

Dr. Smaro Sotiraki, Senior Researcher, Head of Veterinary Parasitology at the Veterinary Research Institute, Hellenic Agricultural Organization - Demeter and has significant managerial experience in research projects. Overall, she has participated in more than 20 major R&D programs under Structural Funds and EU FP schemes, and currently she is the National Coordinator of a FP7-CP "LowinputBreeds" and Chair of the FA0805 COST Action "CAPARA-Goat Parasite Interactions - from Knowledge to Control". She holds doctorate degrees in Veterinary Medicine and Parasitology from the Aristotle University, Greece and conducted post-doctoral research at the Life University, Denmark (2002-2004). She is a de facto member and a member of the Educational Committee of the European College for Veterinary Parasitology, has 20 years experience in Veterinary Parasitology, and has held two Marie Curie Fellowships.
Dr. Thomas H. Terrill
Assistant Professor of Animal Science

Fort Valley State University
Agricultural Research Station
1005 State University Drive
Fort Valley, Georgia 31030

(478) 825-6814
terrilt@fvsu.edu

BRIEF BIOGRAPHY

Dr. Thomas H. Terrill is an Assistant Professor in Animal Science at Fort Valley State University (FVSU), Fort Valley, Georgia. He earned a Ph.D. degree from The University of Georgia, a Master's from Virginia Tech, and Bachelor's degree from The Pennsylvania State University, all in Forage Agronomy. He completed a Post-Graduate Fellowship in Animal Science from 1989-1990 at Massey University in Palmerston North, New Zealand, and has been at FVSU since 1992. His research and outreach program has focused on feeding of tannin-rich forages for improved nutrition and parasite control in sheep and goats, as well as other novel (non-chemical) parasite control methods. Dr. Terrill was a co-founder of the American (formally Southern) Consortium for Small Ruminant Parasite Control and has served as its coordinator since it was first started in 2002.
Dr. Juan Felipe Torres-Acosta received his veterinary degree from the Yucatan University, Mexico, his MSe from the University of Edinburgh Scotland, and his PhD from The Royal Veterinary College, University of London, England. He is Professor of Veterinary Parasitology and Small Ruminant Production and Health in the Department of Animal Health at the Faculty of Veterinary Medicine, Yucatan, Mexico (Universidad Autónoma de Yucatan). He conducts research on sheep and goat production in the tropics, focusing on the development of knowledge, technology, and skills aiming at enhancing the sustainability of small ruminant production under commercial and subsistence farming systems. His research interests include the epidemiology of parasite resistance against anthelmintic drugs, as well as different novel approaches to control gastrointestinal nematodes. His work has been directed at implementing agro-ecological approaches to improve health and productivity of small ruminants under tropical conditions. The aim is to improve understanding of local resources and then direct that knowledge to match end-users’ (farmers) resources (i.e. local feed resources) to meet the needs of local animals in an economically viable way. His work has emphasized the importance of enhancing nutrition of local tropical animals to achieve good levels of health and productivity. In addition, he has evaluated sustainable selective anthelmintic treatment schemes aimed at reducing dependence on anthelmintics, and determined the direct impact of local anthelmintic plants against parasites.
Dr. Adriano Vatta qualified as a veterinarian in 1998 from the University of Pretoria, South Africa and obtained an MSc (Veterinary Sciences) degree from the same university in 2001. In 2008, he was awarded a PhD (Rural Resource Management) from the University of KwaZulu-Natal, South Africa. Adriano spent ten years in research in parasitology at Onderstepoort Veterinary Institute, South Africa, with an emphasis on the diagnosis, treatment and management of gastrointestinal parasites of goats and sheep. His work focused on testing and validating technologies for worm control for use by small-scale farmers. This work included some of the first studies on the use of the FAMACHA© system for the management of barber pole worm infection in goats. Adriano also developed information materials for farmers to use to improve the overall management and health of their small ruminants. Subsequently, he spent two years in academia as an Assistant Professor of Parasitology at Ross University School of Veterinary Medicine, St. Kitts. After a brief period at the University of Georgia, where he worked on anthelmintic resistance in sheep parasites as well as the interaction of ivermectin and immune cells on heartworm in vitro, Adriano took up the position of Manager, Antiparasitics at Pfizer Animal Health in Kalamazoo, Michigan. Here he currently works in the clinical development of antiparasitic products for livestock and companion animals.
Jan van Wyk
Extraordinary Lecturer

Department of Veterinary Tropical Diseases
Faculty of Veterinary Science
University of Pretoria
Private Bag x04
Onderstepoort 0110
South Africa

+27(12) 529 8380 (work)
+27 82 82 2527 (cell)
jan.vanwyk@up.ac.za

BRIEF BIOGRAPHY

Jan van Wyk has been in helminth research since 1968, with an initial focus on schistosomosis and later, management of nematodes in small ruminants. Past service includes field work as a State Veterinarian in South Africa and Namibia for five years, followed by research at the Onderstepoort Veterinary Institute and the University of Pretoria. His Research, now largely conducted with teams from outside of South Africa, is focused principally on development of sustainable integrated parasite management (IPM) systems for countering development of drug resistance, with emphasis on targeted selective treatment (TST) using systems such as FAMACHA© and the Five Point Check©, and decision support automation with electronic systems, including mobile phones and animal activity monitoring devices.
Dr. Niki Whitley
ANR Program Leader and Animal Science Specialist
North Carolina A&T State University
The Cooperative Extension Program
PO Box 21928
Greensboro, NC 27420
(336) 285-4684
ncwhitle@ncat.edu

BRIEF BIOGRAPHY

Dr. Niki Whitley graduated with B.S. and M.S. degrees in Animal Science from the University of Georgia, and a Ph.D in Animal Physiology from Mississippi State University. She conducted a post-doctoral fellowship at the University of Missouri, working with various livestock species, including sheep. Dr. Whitley is currently an Animal Science Specialist, Adjunct Associate Professor and the Agriculture and Natural Resources Program Leader at North Carolina Agricultural & Technical State University. She has been working in NC since 2008. Prior to that time, she was tenured at the Associate Professor level at the University of Maryland Eastern Shore, with research, teaching, and extension duties. Dr. Whitley has developed programs in livestock integrated parasite management (IPM), including goat and sheep training, and general small-scale pasture livestock production. Dr. Whitley has many research papers, abstracts and presentations and is a successful grant writer. In addition, Dr. Whitley is a member of the eXtension Goat Industry Community of Practice and the American Consortium for Small Ruminant Parasite Control. She is also the faculty coordinator in charge of the NC A&T State University Small Ruminant Demonstration Site in Reidsville, North Carolina.
Dr. Lisa Williamson
Associate Professor

Department of Large Animal Medicine
College of Veterinary Medicine
University of Georgia
Athens, Georgia 30602

lisa1@uga.edu

BRIEF BIOGRAPHY

Dr. Lisa Williamson is an Associate Professor in the Department of Large Animal Medicine at the University of Georgia College of Veterinary Medicine. She received her bachelor's degree in 1978, her DVM in 1981, and her master's degree in Physiology in 1990, from the University of Georgia. She became a diplomate of the American College of Veterinary Internal Medicine in 1991. Dr. Williamson worked in large animal private practice in Virginia and New York, and as a clinical instructor at the University of Wisconsin before joining the faculty at the University of Georgia College of Veterinary Medicine in 1989. Dr. Williamson is currently a field service clinician who works with all large animal species. One of her favorite challenges is assisting small ruminant and camelid owners with parasite management. Her research efforts have been directed at characterizing anthelmintic resistance in sheep and goats, and most recently, camelids. She has organized and conducted many FAMACHAC® workshops in Georgia since 2006, and is the vice president of the Alpaca Research Foundation. Dr. Williamson joined the American Association for Small Ruminant Parasite Control shortly after its inception in 2002.
Dr. Anne Zajac
Associate Professor

Department of Biomedical Sciences and Pathobiology
Virginia/Maryland Regional College of Veterinary Medicine
Virginia Tech
Blacksburg, Virginia 24061

BRIEF BIOGRAPHY

Dr. Anne Zajac is a faculty member at the Virginia/Maryland Regional College of Veterinary Medicine at Virginia Tech. She is a Michigan native and received her DVM from Michigan State University and a PhD in parasitology from Ohio State University. She has been a faculty member at Virginia Tech since 1986. Dr. Zajac teaches parasitology to both veterinary and undergraduate students and supervises the parasitology diagnostic lab in the veterinary hospital. Her principal research interest is the biology and control of gastrointestinal parasites of small ruminants and camels. She is a past president of the American Association of Veterinary Parasitologists and a charter member of the parasitology specialty in the American College of Veterinary Microbiology.
American Consortium for Small Ruminant Parasite Control: The First Ten Years

Thomas H. Terrill
Agricultural Research Station,
Fort Valley State University,
Fort Valley, GA 31030, USA

Introduction

The American (formerly Southern) Consortium for Small Ruminant Parasite Control (ACSRPC) was officially formed in 2003, with a mission of 1) developing novel methods for sustainable control of gastrointestinal nematodes (GIN) in small ruminants, and 2) educating stakeholders in the small ruminant industry on the most up-to-date methods and recommendations for control of GIN (ACSRPC.org). The past 10 years have coincided with a seismic change in producer attitudes towards parasite control in sheep and goats, from prophylactic use of broad-spectrum anthelmintics on all the animals in the herd or flock to ‘targeted selective treatment’ of only those animals that need it most. The previous practice led to a world-wide epidemic of anthelmintic-resistant sheep and goat GIN (Kaplan, 2004), while the latter approach, combined with strategies to maximize the usefulness of still-effective anthelmintics (‘Smart Drenching’) and use of novel, non-chemical control technologies, has resulted in more sustainable and profitable sheep and goat production systems in the United States (U.S.) and around the world. This overview will describe the history, current status, and future plans of the ACSRPC and the role it played in this global shift toward more sustainable GIN control strategies by small ruminant producers.

Background

Small Ruminant Production

Small ruminant production has been a major component of livestock agriculture throughout the world for millennia and remains a primary resource for food and income for farm families in many developing countries. Production of small ruminants is a growing industry in the U.S. due to stable ethnic markets, rapidly increasing demand for grass-fed or organically-produced livestock (Greene and Kremen, 2003), and the growing popularity of specialty meat-type goat and sheep breeds. A major challenge to continued growth of this industry is infection with GIN, particularly Haemonchus contortus (barber pole worm), the predominant blood-feeding parasitic nematode throughout tropical and subtropical regions of the world.

Anthelmintic Resistance

For the last fifty years, the predominant GIN control strategy on sheep and goat farms in the U.S. has been prophylactic treatment of all animals in the herd or flock as often as every 3-4 weeks using broad-spectrum anthelmintics. Although initially an effective strategy, treating the whole herd or flock kills off susceptible GIN, leaving a few drug-resistant parasites, which then reproduce, increasing as a percentage of the GIN population (Kaplan, 2004). Inevitably, the GIN population in a herd or flock becomes predominantly drug-resistant, leading to anthelmintic
failure on individual farms. Mirroring similar trends world-wide, reports on multiple anthelmintic-resistant goat and sheep GIN in individual herds in the U.S. started appearing 10-15 years ago, and more recently in on-farm prevalence studies (Kaplan, 2004; Howell et al., 2008). Even before this, it became obvious to scientists in the U.S. and overseas that small ruminant industries were headed for a crisis if alternatives to exclusive use of anthelmintics to control sheep and goat GIN were not quickly developed. This lead to the first Novel Approaches to the Control of Helminth Parasites of Livestock meeting, held in Armidale, Australia, in April, 1995. By the time the second Novel Approaches meeting was held three years later, at Louisiana State University (LSU) in Baton Rouge, in March, 1998, research on alternative methods of parasite control was underway at various institutions world-wide, but there were few attempts to integrate these methods into a coordinated program. At the Baton Rouge meeting, scientists from Fort Valley State University (FVSU), LSU, and the Danish Centre for Experimental Parasitology at the Royal Veterinary and Agricultural University (RVAU) in Copenhagen, Denmark, met and began planning to develop funding proposals to support research on sustainable parasite control in small ruminants in the U.S. Subsequently, cooperative projects between FVSU, LSU, and RVAU were funded by USDA Scientific Cooperation and 1890 Institution Capacity Building Program grants in 1999 and 2000, respectively, and focused on documentation of anthelmintic resistance in goat herds in GA and on validation of the use of nematode-trapping fungi as an alternative GIN control method in sheep and goats.

American Consortium for Small Ruminant Parasite Control (ACSRPC)

History

The foundation for the eventual development of the ACSRPC was laid at FVSU on June 7-8, 2001, in a meeting funded by a USDA Sustainable Agriculture Research and Education (SARE) Planning Grant. Parasitologists (3), forage scientists (4), animal nutritionists (2) and extension specialists (1) from Georgia, Florida, Alabama, Louisiana, U.S. Virgin Islands, Denmark, and New Zealand met for two days to brainstorm ideas for future directions of research and outreach for sustainable parasite control in small ruminants. At this meeting, several conclusions were drawn: 1) that the concept of an anthelmintic ‘silver bullet’ was no longer viable as the sole strategy for sustainable parasite control in small ruminants, 2) that sustainable parasite control required a combination of different strategies in an integrated program, and 3) that development and validation of such a program would require cooperation between many different institutions and disciplines, as well as between university/USDA research programs and on-farm outreach. After a second planning meeting at FVSU in August, 2001, a full SARE proposal entitled ‘Novel Methods for Sustainable Control of Gastrointestinal Nematodes in Small Ruminants’ was submitted in November, 2001, which included research initiatives on use of nematode-trapping fungi and copper oxide wire particles (COWP) to reduce GIN infection in sheep and goats, and producer workshops on FAMACHA® and Smart Drenching. This project, for which funding was initiated in September, 2002, was a collaboration between scientists, veterinarians, and extension specialists from FVSU, LSU, the University of Georgia (UGA), Auburn University, the University of Florida, USDA/ARS in Brooksville, FL, and Booneville, AR, the University of the Virgin Islands, RVSU in Denmark, and the Onderstepoort Veterinary Institute in South Africa, and set the pattern for research and outreach for the ACSRPC for the next decade.
Over the past 10 years, ACSRPC research efforts have focused primarily on validation and on-farm implementation of novel GIN control technologies, including the FAMACHA® system for identification of anemia (as a result of *H. contortus* infection) in sheep and goats, grazing or feeding of dried forms of anti-parasitic plants, including the tannin-rich forage sericea lespedea (Lespedeza cuneata (Dum-Cours.) G. Don.), use of copper oxide wire particles (COWP) given in bolus form or mixed with the feed ration to kill *H. contortus* in the abomasum, biological control using nematode-trapping fungi to kill infective nematode larvae in feaces on pasture, and vaccines against *H. contortus* (Terrill et al., 2012). These and other techniques, including grazing strategies (Burke et al., 2009), use of improved nutrition and breeding to enhance overall herd or flock resilience and resistance, respectively, to GIN infection ( Torres-Acosta et al., 2004), and the Five Point Check© system of targeted selective treatment (Bath and van Wyk, 2009) have been the basis for development of integrated ‘basket of best options’ GIN control programs around the world (Jackson and Miller, 2006).

Outreach of the ACSRPC has focused on effectively delivering information on integrated parasite management (IPM) principles and the skills needed to properly implement them to producers through producer workshops (Smart Drenching, FAMACHA®, IPM), as well as through the internet and other electronic means.

Support for this work has come from USDA SARE, 1890 Institution Capacity Building, Organic Research and Outreach Initiative, and Small Business Innovation Research grants, and from administrators, faculty, staff, and students at 25 institutions across the U.S. and the world.

**Current Status**

From its official inception 10 years ago, the ACSRPC has maintained a singular focus and a consistent approach. Our focus is on assisting small ruminant producers in acquiring information on sustainable parasite management and implementing validated novel GIN control technologies on-farm. Our approach has been multi-institutional and multi-disciplinary, combining the expertise of parasitologists, forage scientists, animal scientists, veterinarians, and extension specialists in developing research and outreach initiatives on integrated parasite management. This concept of using a holistic, integrated approach to sustainable parasite control using simple, inexpensive diagnostic systems (FAMACHA® and the Five Point Check©) combined with novel GIN management strategies (COWP, feeding or grazing of tannin-rich forages, breeding to improve herd or flock resistance to GIN infection) has application to small ruminant producers worldwide, in developing as well as developed countries, and to organic, reduced input (grass-fed), and conventional livestock production systems. As such, this work has positively impacted thousands of producers in the U.S., Puerto Rico, and the U.S. Virgin Islands and has the potential to impact millions more small ruminant producers across the globe.

**Future Directions**

As infection of small ruminants with *H. contortus* is no longer primarily a southern U.S. problem, demand for FAMACHA® workshops has spread across the country, with the system now in use in 46 out of 50 states and even into Canada. There have been more frequent reports of anthelmintic resistance in sheep and goat herds outside of the southern U.S. as well, including
the Mid-Atlantic (O'Brien et al., 2011) and northern U.S. (Grosz, 2012). To address this challenge, our Consortium has expanded its membership to include scientists and extension specialists from these regions and changed our name from the Southern Consortium to the American Consortium for Small Ruminant Parasite Control. The current conference reflects our new emphasis on having a more national, as well as international reach as an organization, and we will continue in this effort to provide information on sustainable parasite management to the producers who need it, wherever they may be.

References


Biology of Parasites

Anne M. Zajac, DVM PhD, Dipl. ACVM-Parasitology
Department of Biomedical Sciences and Pathobiology
Virginia/Maryland Regional College of Veterinary Medicine,
Virginia Tech, Blacksburg VA 24061-0442. Email: azajac@vt.edu

Sheep and goats in the U.S. and around the world are infected with a wide range of internal and external parasites. In many regions of the world, the most important parasites are gastrointestinal nematode worms. The most important of these worms all belong to the same taxonomic group and are often referred to collectively as “trichostrongyles”. All grazing sheep and goats are infected with a community of trichostrongyle parasites that can contribute to disease and production loss. With the recent development of high levels of parasite resistance to commercial dewormers, successful control of these parasites now requires integrated management programs that incorporate basic knowledge of the biology of trichostrongyle parasites.

Although all grazing sheep and goats are infected with some level of trichostrongyles, low worm numbers will usually have little impact on animal health. As worm numbers increase, however, reduced weight gain and decreased appetite may occur. The most severely affected animals will show signs that can include weight loss, diarrhea, anemia and bottle jaw (hypoproteinemia). Camelids (llamas and alpacas) can also be infected with these parasites and suffer the same signs of disease when parasite numbers are high. Adult cattle and horses, however, do not become infected with most sheep and goat trichostrongyles and usually kill any ingested infective larvae.

While all the trichostrongyle parasites can contribute to disease in sheep and goats, there is one worm that dominates in importance in the eastern and midwestern U.S. and in many other countries. This parasite is *Haemonchus contortus*, known as the barber (or barber’s) pole worm or wireworm. The remainder of this presentation focuses on the biology of *H. contortus*, but the details of the life cycle of other trichostrongyle parasites (*Teladorsagia, Trichostrongylus*, etc) are very similar.

*Haemonchus contortus* adults are found in the abomasum, or true stomach, of small ruminants. In camelids, the parasites are found in C3, the camelid equivalent of the abomasum. Female worms reach about 1 inch (3 cm) in length, making this species one of the largest of the trichostrongyles (Figure 1). Unlike other trichostrongyles that feed on intestinal tissue or fluids, barber pole worm feeds directly on host blood. The parasite has a small “tooth” that is used to lacerate the stomach and cause surface bleeding, with the worm ingesting released blood. When large numbers of parasites are present significant loss of red blood cells and blood proteins occurs resulting in anemia and bottle jaw, which may be fatal if untreated. Severe infections are most likely to occur in young sheep and goats before immunity has developed.

Once barber pole worm or other trichostrongyle larvae infect a sheep or goat host they complete their development to the adult stage; this process usually takes two to three weeks. Once male and female worms are mature they mate and females begin to produce eggs. Barber pole worms are remarkably prolific and each female worm can produce up to 10,000 eggs/day. It is not unusual
for sheep or goats to be infected with hundreds or thousands of parasites that could daily produce millions of eggs. Individual adult worms have a limited life span and usually survive for only a few months.

Eggs of _H. contortus_ and other trichostrongyles are shed in the manure of infected sheep and goats (Figure 2). Development of eggs occurs in the manure, which provides some protection from environmental conditions. The cells inside the egg form a larva (first stage or L1) that hatches out of the egg. After hatching, larvae feed on bacteria and go through two molts to reach the infective third larval stage (L3). These third-stage larvae make their way out of the fecal material and onto the forage where they are ingested by sheep and goats (Figure 3).

Environmental conditions determine the rate of development of trichostrongyle larvae, their survival in the environment and ultimately impact the level of infection in sheep and goats. Different trichostrongyle parasites have different environmental preferences, which also determines their relative importance in different regions of the U.S. and the world. In general, development of trichostrongyle eggs and larvae occurs in a temperature range of approximately 50°F -96°F. One of the main reasons that _Haemonchus contortus_ is so important in small ruminants in the U.S., is that the climate in much of the country has a period of warm, moist conditions that are highly favorable for development and survival of infective larvae. The southeastern U.S., in particular, with its hot, humid summers and long grazing season, is very well suited to _H. contortus_. Optimum conditions for transmission of _H. contortus_ were found from mid-March to mid-October in Columbus, Georgia. _Haemonchus contortus_ eggs and larvae do not tolerate cold and freezing temperatures well. However, members of ASRPC have found that even in New England, _H. contortus_ is the predominant parasite egg in fecal samples in the summer grazing season. Although in western states cold winters and dry summers make _H. contortus_ less important, irrigation can make conditions suitable for transmission. The minimum length of time required for the development of _H. contortus_ L3 in hot summer weather is about 3-4 days. However, in cool spring or fall weather it may take several months for L3 to develop.
Once L3 larvae have formed and moved out of the fecal pellets, their ability to migrate on forage is affected by air temperature, soil moisture, and relative humidity. Larvae usually remain within inches of the fecal pellets and also do not migrate more than a few inches vertically on grass blades.

The length of time that L3 larvae can survive on pasture is also dependent on environmental conditions. Infective larvae are unable to feed and survive on existing metabolic reserves. Once those are exhausted, the larvae die. The hotter the weather, the faster they use their reserves and
die. In the temperate portions of the U.S., a pasture may need to be rested for 6 months during cool weather to remove most parasite larvae. In hot weather, most larvae may be cleared from pasture in 3 months.

A final element of parasite biology that plays a major role in the successful transmission and survival of trichostrongyles is arrested development (hypobiosis). Following infection of a sheep or goat, a larva may go into a state of “arrest” where it does not continue development and is metabolically inactive for a period that may last several months. Following this period of arrest, the parasite larva resumes development and becomes an adult. Usually, the greatest proportion of arrested larvae is found in animals during times of the year when eggs and larvae do not survive well in the environment and thus allows worms to delay adulthood and egg production to a more favorable time of year for their offspring. In areas with cold winters, *Haemonchus* survives the winter months primarily as arrested larvae in animals. In lambs examined in Ohio, Maine, and Virginia more than 80% of *Haemonchus* were present as arrested larvae in winter. Where winters are very mild, hypobiosis appears to be less important in the epidemiology of parasite transmission. In Louisiana, levels of hypobiotic larvae were never substantial, although the highest proportion of hypobiotic larvae tended to be in the fall.

In areas where winter arrest of parasite larvae occurs, emergence and development of adult worms in late winter and spring are followed by an increase in fecal egg counts. The rise in egg counts is magnified in lambing ewes by a relaxation of immunity around lambing called the Periparturient Egg Rise (PPR). The PPR is well documented in sheep, but may not be as important epidemiologically in goats.

References


Biology of Anthelmintic Resistance: These Ain’t Your Father’s Parasites

Ray M. Kaplan, DVM, PhD, DipACVM, DipEVPC
College of Veterinary Medicine
University of Georgia, Athens, GA

Introduction

Anthelmintic resistance is defined as a heritable genetic change in a population of worms that enables some individual worms to survive drug treatments that are generally effective against the same species and stage of infection at the same dose rate. In practical terms anthelmintic resistance is present in a population of worms when the efficacy of the drug falls below that which is historically expected, when other causes of reduced efficacy have been ruled out. Parasitic nematodes have many biologic and genetic features that favor the development of drug resistance. Short life cycles, high reproductive rates, rapid rates of evolution, and extremely large population sizes combine to give many parasitic worms an exceptionally high level of genetic diversity. This leads to certain worms having gene mutations that reduce their susceptibility to the drug.

Amplification of resistance within a worm population to clinically relevant levels is a slow and gradual process, requiring numerous generations under drug selection (usually taking several to many years). Thus, from a practical perspective, the genetic phase of resistance develops slowly over time during which it is impossible to detect, but then increases very rapidly in its later phase, where it is then perceived as a clinical event. This has great clinical relevance because resistance can transition from undetectable, to clinically important levels over a very short period of time. Consequently, unless a surveillance program is in place that closely monitors the effectiveness of drug treatments over time, resistance will not be noticed clinically until levels of resistance are extremely high. There is also very strong evidence that once resistance is diagnosed as a clinical problem “reversion” to susceptibility likely will never occur.

The Scope and Prevalence of Resistance

For many years, worms were controlled in small ruminants by the frequent use of anthelmintics, and this approach was quite effective. However, we now know that this strategy has turned out to be shortsighted and unsustainable. The prevalence of multi-drug resistant gastrointestinal nematodes (GIN; particularly Haemonchus contortus but also others) is extremely high any we are at risk of having no effective anthelmintics to use in the near future. Prior to 2000, there was little data on the prevalence of anthelmintic resistance in the US. There had been a few published reports over the years, but the state of the problem was unknown. In an initial collaboration between University of Georgia and Fort Valley State University, goatherds at the respective institutions were tested for resistance against multiple anthelmintic drugs. To our great surprise, at both sites H. contortus were multiply resistant to all 3 available drug classes (benzimidazoles, avermectins, levamisole); only moxidectin was effective but it had never been used at either farm (Terrill et al., 2001). The results of this study raised serious concerns and led
to a larger study on 18 goat farms in Georgia. This larger study confirmed the serious nature of the problem; >90% of farms had resistance to both albendazole and ivermectin and 1/3 had resistance to all 3 major drug classes (plus levamisole) (Mortensen et al., 2003). These findings pointed to the severity of the problem and served as an important impetus to the development of further collaborations, which ultimately contributed to the formation of the SCSRPC (which later became the ACSRPC). The SCSRPC then conducted a 46-farm region-wide study throughout the southern US investigating the prevalence of anthelmintic resistance on both sheep and goat farms (Howell et al., 2008). In that study, *H. contortus* from 45 (98%), 25 (54%), 35 (76%), and 11 (24%) farms were resistant to benzimidazole, levamisole, ivermectin, and moxidectin, respectively. Resistance to all 3 classes of anthelmintics was detected on 22 (48%) farms, and resistance to all 3 classes plus moxidectin was detected on 8 farms (17%). Thus on almost 20% of all farms tested, resistance was detected to all available anthelmintics; a situation referred to as “Total Anthelmintic Failure”. A more recent study performed by some ACSRPC members from 2007-2009 in the mid-Atlantic region found a further escalation of moxidectin resistance; 39% of farms had resistance (Jackson-O'Brien, submitted).

The rapid increase in moxidectin resistance is not surprising given the fact that ivermectin and moxidectin are closely related drugs that have the same (or very similar) mechanisms of action and resistance; resistance to one drug in this class confers resistance to all of them. The reason that moxidectin remains effective against ivermectin-resistant worms appears to be simply a matter of potency. Moxidectin is just a more potent drug against *H. contortus*, so that therapeutic doses are still capable of killing worms that have become resistant to ivermectin. Unfortunately, this efficacy has proven to be short-lived, therefore use of moxidectin must be carefully monitored and managed to maintain its efficacy. The reality is that moxidectin is no longer effective on a high percentage of sheep and goat farms in the eastern and southern US.

**New Drugs and the Future of Parasite Control Using Anthelmintics**

One bright spot in this gloomy situation is the recent discovery of a novel anthelmintic class (amino-acetonitrile derivatives; AAD) (Kaminsky et al., 2008) and its introduction as Zolvix® (Monepantel) by Novartis in New Zealand, Australia, and several European countries. It is not known when or even if the FDA will approve Zolvix, but one could reasonably expect Zolvix will be approved and sold in the US in the relative near term. However, excitement regarding this new anthelmintic (the first new anthelmintic drug class for use in livestock introduced in more than 30 years) should be tempered by the lessons learned regarding the development of resistance to all drugs. Thus, if and when this new drug is approved, it must be used carefully and sparingly to guard against the rapid development of resistance.

Clearly then, major changes need to be made in the way that GIN control is practiced on many farms. Anthelmintics can no longer be thought of as an inexpensive management tool to be used as needed to maximize animal productivity and maintain herd health. Instead they must be thought of as extremely valuable and limited resources that are not readily renewable or replaced. We must balance our desire to maximize animal health and productivity with the reality that effective long-term control of *Haemonchus* will only be possible if anthelmintics are used less frequently, as well as intelligently, with prevention of resistance as a goal. To address this issue, a concept referred to
as ‘Smart Drenching’ has been introduced. Smart drenching is an approach whereby we use the current state of knowledge regarding host physiology, anthelmintic pharmacokinetics, parasite biology, dynamics of the genetic selection process for resistance, and the resistance status of worms on the farm to develop strategies that maximize the effectiveness of treatments while also decreasing the selection of drug resistance. One of the most important aspects of smart drenching is a selective treatment approach based on the use of FAMACHA®. These topics will be addressed in other papers presented at the meeting.

**Diagnosis of Anthelmintic Resistance**

Before developing an effective control program for *Haemonchus* or any other GIN parasite, it is extremely important to know if resistant worms are present on a particular property, and if present, to which drugs. This can only be done 2 ways: (1) by performing a fecal egg count reduction test; or (2) by performing an *in vitro* larval development assay (LDA). The FECRT is the most readily available means for resistance diagnosis since it can be performed on any farm; but this test is labor intensive and requires performing many fecal egg counts making it expensive and inconvenient to perform. An alternative to the FECRT is the LDA (DrenchRite®), however, the test can only be performed in a specialized parasitology diagnostic lab. A single DrenchRite test can detect and measure resistance to benzimidazoles, levamisole, ivermectin and moxidectin from a single fecal sample. The Kaplan laboratory currently offers this test for a fee ($450). This cost reflects the significant equipment and supply needs, as well as the great deal of technical expertise and labor required to perform the DrenchRite assay. Requests for information about the DrenchRite test and current pricing should be sent to Sue Howell at jschb@uga.edu.

**References**


Extending the Efficacy of Anthelmintics

Lisa H Williamson, DVM, MS, DACVIM
University of Georgia College of Veterinary Medicine

Anthelmintic Use

Anthelmintics, commonly referred to as “dewormers” and “drenches” are compounds used to kill gastrointestinal parasites (worms) without harming the host. Effective anthelmintics are a precious commodity, as decades of nonselective use (whole herd treatment using calendar based intervals) have promoted drug resistance in worm populations. It is important that producers use anthelmintics judiciously with the goal of not only preserving productivity of their livestock, but also with the goal of preserving efficacy of the anthelmintics. The first step to using anthelmintics wisely is to know the basics about these drugs. The three classes of anthelmintics commonly used in small ruminants are (1) the benzimidazole class, (2) the imidazothiazole/tetrahydropyrimidin (membrane depolarizing) class, and (3) the macrocyclic lactone class. A new anthelmintic class, referred to as the amino-acetonitrile derivatives, was recently introduced, but is not yet labeled for use in the United States. Small ruminants are food animals, so veterinarians and producers must be mindful of Food and Drug Regulations withdrawal times for meat and milk. A veterinarian-client-patient relationship must exist when using anthelmintics in an extra-label manner, which is often necessary, because so few anthelmintics are labeled for small ruminants. Information concerning label use can be accessed through the Food Animal Residue Avoidance Databank at www.farad.org. Questions regarding extra-label use can be directed to usfarad@gmail.com.

Benzimidazole Class

Members of this class include albendazole (Valbazen®), fenbendazole (Panacur®, Safe-Guard®), oxibendazole (Anthelcide®) and oxfendazole (Synanthic®). These anthelmintics are often referred to as the “white dewormers” because of their appearance. Benzimidazoles kill nematodes by disrupting cellular energy metabolism. This class of anthelmintics generally has a wide margin of safety. The efficacy of a benzimidazole can be improved by fasting the animal 12 hours prior to treatment. Fasting slows gastrointestinal transit time, thereby allowing more contact time with the medication. Also, delivery of medication close to the pharynx (over the tongue) promotes better contact with the gastrointestinal tract because delivery deep into the oral cavity does not stimulate closure of the esophageal groove. Syringes with adapters that facilitate deep delivery of an anthelmintic in the oral cavity should be used when dosing small ruminants. A unique feature of the benzimidazole is that the duration of exposure has a marked effect on efficacy. Longer exposure times are associated with greater nematode-killing capacity. As a result, giving a second full dose of a benzimidazole such as fenbendazole 12 hours after the first dose will increase lethality. A study conducted on goats with benzimidazole resistant Haemonchus contortus showed that two consecutive-day doses of fenbendazole reduced the fecal egg count (FEC) by 92%, whereas a single dose had only achieved a 50% fecal egg count reduction. The goats and sheep can be fed between the first and second dose of benzimidazole. The benefit of multi-day dosing on nematode populations with emerging benzimidazole resistance is expected to be short-lived, because resistance will progress to total failure of
benzimidazoles with repeated exposures. Currently, high level benzimidazole resistance is prevalent in *Haemonchus contortus* and *Trichostrongylus colubriformis* isolated from sheep and goats in the southeastern United States. Veterinarians should not rely on the benzimidazoles for control of these worms unless prior susceptibility testing indicates that this class is efficacious. Fenbendazole is labeled for sheep at 5 mg/kg orally; meat withdrawal time is 6 days and milk withdrawal is zero days. Fenbendazole is used extra-label in goats at 10 mg/kg orally, and has a 16-day meat withdrawal and 4-day milk withdrawal time. Albendazole is the most potent member of the benzimidazole class. It should not be used in the first 30 days of pregnancy because it is teratogenic. Great caution should be taken with repeated dosing of albendazole on consecutive days, particularly in camelds, as it can induce fatalities in crias at high doses. Albendazole is approved for sheep at 7.5 mg/kg orally, with a 7-day meat withdrawal time and no milk withdrawal. Extra-label use of albendazole in goats at 20 mg/kg orally calls for a 9-day meat withdrawal and 7-day milk withdrawal time (FARAD).

**Imidazothiazole/tetrahydropyrimidine Class**

Members of this class include levamisole (Tramisol®, Prohibit®), morantel tartrate (Rumatel®), and pyrantel pamoate (Strongid®). Levamisole is an imidazothiazole drug that kills nematodes by depolarizing nicotinic neuromuscular junctions. It also acts as a cholinergic agonist in mammals, which is the reason for its narrow therapeutic index. Therefore, animals need to be weighed and dosed carefully. Also, animals should not be fasted prior to treatment. The oral route is safer than the injectable route. The dose should be delivered deep into the oral cavity. Toxicity can occur with as little as a 30% overdose, and symptoms such as hyper-excitability, salivation, trembling, ataxia, urination, defecation, collapse and death can occur within a few hours after treatment. Atropine sulfate (0.6 mg/kg SQ) can alleviate side effects if given promptly. Approximately half of the *Haemonchus contortus* isolates from sheep and goats are still sensitive to levamisole, perhaps as a result of the infrequent use of this anthelmintic as safer products came on the market. Levamisole is labeled for use in sheep at 8 mg/kg orally; it has a 3-day meat withdrawal and zero day milk withdrawal. Levamisole is used extra-label in goats at 12 mg/kg orally. FARAD recommends a 4-day meat withdrawal and a 3-day milk withdrawal. Morantel tartrate and pyrantel pamoate are tetrahydropyrimidine drugs that also act as cholinergic agonists, but they are less potent than levamisole. On the positive side, they are also less toxic and therefore have a wider margin of safety. Pfizer, Inc. indicates that goats can receive Rumatel® 88 (morantel tartrate) at 10 times the recommended dose for 3 consecutive days without suffering any ill effects. Morantel tartrate is more effective in ruminants than pyrantel pamoate. Morantel tartrate is recommended in goats at a dose of 10 mg/kg, orally, with a 30-day meat withdrawal and a zero day milk withdrawal time.

**Macrocyclic Lactone Class**

The macrocyclic lactone (ML) chemical class consists of the avermectins and milbemycins. Avermectins include ivermectin (Ivomec®, eprinomectin (Eprinex®), and doramectin (Dectomax®). Moxidectin is an example of a milbemycin drug. The anti-parasitic effect is mediated through selective binding to glutamate-gated chloride ion channels. Despite the fact they are lipid soluble, the macrocyclic lactones do not readily cross the blood brain barrier in mammals. As a result, they have a wide margin of safety in most situations. Ivermectin is labeled
for sheep at 0.2 mg orally with a meat withdrawal of 11 days and no milk withdrawal. Ivermectin is used extra-label in goats at a dose of 0.4 mg/kg orally; FARAD recommends a meat withdrawal time of 14 days and a milk withdrawal of 9 days. Moxidectin is a more potent, lipophilic macrocyclic lactam than ivermectin, so it will kill ivermectin resistant nematodes for a while. However, side resistance will develop in ivermectin-resistant intestinal nematodes within 1-2 grazing seasons with nonselective use. Many *Haemonchus contortus* isolates from small ruminants are already ivermectin resistant, and and moxidectin resistance is on the rise. Food animal moxidectin products include Cydectin® Oral Drench for Sheep (1 mg/ml), Cydectin® Pour-On for Cattle (5 mg/ml), and Cydectin® Injectable for Cattle (10 mg/ml). Moxidectin is labeled for sheep at 0.2 mg/kg orally; meat withdrawal time is 14 days. FARAD has assigned a very conservative milk withdrawal time of 60 days because moxidectin residues persist in milk. However, milk testing can be performed to determine if moxidectin levels are in an acceptable range earlier. Testing is available at Iowa State University (http://vetmed.iastate.edu/diagnostic-lab/cycads). When using oral moxidectin in an extra-label fashion in goats, the dose is doubled to 0.4 mg/kg orally. FARAD has assigned a meat withdrawal time is 23 days. Milk withdrawal time is 60 days (FARAD personal communication, April 2013).

Ivermectin and moxidectin should be administered orally rather than by any other route for gastrointestinal nematode control. When oral and injectable routes were studied in lambs, oral administration of ivermectin resulted in higher concentrations of ivermectin within the *H. contortus* abomasal populations. Pour-on products formulated for cattle are not recommended for small ruminant gastrointestinal nematode control, topically or orally. A few years ago, the American Consortium For Small Ruminant Parasite Control members recommended using subcutaneous moxidectin in goats, but this recommendation has been withdrawn for several reasons. Oral treatment is more likely to achieve higher concentration of drug in the worms, and FARAD recently issued a very long meat (132 days) withdrawal for subcutaneous moxidectin use in goats. As is the case with the benzimidazole drugs, efficacy of the macrocyclic lactones can be maximized by fasting animals 12 hours prior to treatment, and by dosing deep into the oral cavity.

### Simultaneous Use of Anthelmintics from 2-3 Different Classes

Treatment of animals with 2-3 anthelmintics from different classes can be advantageous when low-level resistance exists to the various drugs, because synergism can enhance the overall killing effect on multi-drug resistant worms. The simultaneous administration of anthelmintics does NOT promote resistance. In fact, this strategy is much less likely to worsen resistance than when a single drug treatment is used (rotating between the classes) through the grazing season. The dose of each medication used in the combination drench should not be decreased. However, it is recommended that the medications not be pre-mixed in the same syringe. Meat and milk withdrawals should be assigned based on the medication used in the combination that has the longest withdrawal times.

### Recommendations

1. Know what worms are in your herd or flock test (faecal egg count reduction test or larval developmental assay) to determine which anthelmintics are effective.
2. Treat only the animals that need it based on low body condition scores, high FAMACHA scores, and prevailing circumstances (time of year, use and age of the animal, and condition of the rest of the herd or flock).
3. Weigh animals and use a treatment chart to ensure proper dosing.
4. Use oral anthelmintics, and use medications formulated for oral use.
5. Dose deep into the oral cavity.
6. Remember that goats require a double dose for most anthelmintics, the exception being levamisole: goats require 1.5 times the sheep dose.
7. Withhold feed for 12 hours prior to treatment. Levamisole is the exception: do not withhold feed prior to dosing.
8. Use a combination of anthelmintics from several different classes when low-level multi-resistant worms are present.
9. Store medications properly and do not use them past their expiration date.

References


The FAMACHA® System – an Aid in the Management of Haemonchosis in Small Ruminants

Adriano F. Vatta
Zoetis, 333 Portage Street, Kalamazoo, MI 49007
Email: adriano.vatta@zoetis.com

Introduction

The FAMACHA® system is a technique used in small ruminants to assess the level of anemia resulting from infection with Haemonchus contortus, the barber’s pole worm. The system allows a decision to be made with regard to anthelmintic treatment on an individual animal basis as opposed to treating all the animals in the herd or flock, and application of the method leads to a large reduction in anthelmintic use when compared with conventional drenching approaches. It is a method of ‘targeted selective treatment’ which refers to the identification and treatment of those individuals that truly require it while leaving the rest untreated (Besier, 2008). The system was developed in South Africa (Malan et al., 2001) to provide an alternative approach to the common practice of frequent drenching of sheep, which has been associated with the widespread emergence of anthelmintic resistance. The system has since been adopted for use worldwide, including in the United States, where anthelmintic resistance in small ruminants is common and widespread (Mortensen et al., 2003; Howell et al., 2008).

Haemonchus contortus is an abomasal parasite that follows a direct nematode life cycle. It is a voracious blood-sucker, and the main effect on the host is anemia, which can be evaluated clinically by examining the mucous membranes of the host. Named for its originator, the FAffA MALaN CHealthAssessment (FAMACHA®) system consists of a card with five color categories which is compared with the color of the conjunctival mucous membranes of the sheep or goat. The animal is classified into one of the five color categories, from 1 (non-anemic) to 5 (severely anemic). A decision to treat the animal or not is then made based on the FAMACHA® score, the age and production status of the animal, and general recommendations for the climatic region.

The use of a selective treatment strategy is founded on the concept that parasites are not equally distributed in host populations (Barger, 1985). Twenty to thirty percent of the animals harbor most of the worms and are responsible for most of the eggs deposited in the feces on pasture. If this group of animals can be identified and treated, this will greatly reduce the daily pasture contamination. In the case of haemonchosis, FAMACHA® score has been shown to be negatively correlated with packed cell volume (higher score, lower packed cell volume) and positively correlated with fecal egg count (Kaplan et al., 2004). In practice, this means that the system may be used as an effective tool to identify those animals that are clinically most affected by the parasitism, or less ‘resilient’. It should be noted, however, that the system has been validated in small ruminants for the control of H. contortus infection only.

Development and Validation of the FAMACHA® System

The first experiment, which led to the development of the actual FAMACHA® card, was conducted on a sheep farm near Badplaas, South Africa, in a climatic zone characterized by hot,
wet summers and mild winters (Malan et al., 2001). Haemonchus contortus was the predominant gastrointestinal parasite on the farm and the parasite population was highly resistant to multiple anthelmintics with only levamisole and morantel remaining effective. Furthermore, the sheep were maintained on irrigated pastures. Researchers, in collaboration with the producer, decided to test the possibility of grading the color of the ocular mucous membranes of the sheep as an indication of the extent to which animals were affected by H. contortus infection. From March to July 1991, routine drenching was stopped. Three hundred eighty-eight sheep were examined at weekly intervals and classified as red (subsequently designated FAMACHA® score 1), red-pink (2), pink (3), pink-white (4) or white (5). If the animal’s mucous membranes were white or pink-white, or if the animal had submandibular edema (‘bottle jaw’), its packed cell volume was determined, and if this was <15%, the sheep was treated with levamisole. In this manner, drenching was reduced by 90% compared with previous practices. Seventy per cent of the animals did not require drenching, 20% required one drench, 7% required two drenches, 2% required three drenches, and 1% required four drenches. The percentages of sheep requiring one or more drenches were higher in lactating and pregnant animals when compared with “dry” animals. Following this study, the chart itself was developed and tested further.

The first studies with the FAMACHA® system in goats were conducted in indigenous goats in South Africa (Vatta et al., 2001, 2002). Animals were scored with the card every 2-4 weeks during the late spring, summer, and early fall periods of 1998/1999 and 1999/2000, and blood samples for packed cell volume were collected. Goats were treated if scored as 4 or 5. Tests for sensitivity and specificity were applied to the data. Sensitivity is defined as the proportion of diseased individuals that test positive (Smith, 1995), or, in the case of the FAMACHA® system, the proportion of anemic animals (packed cell volume <19%) that are correctly identified as being anemic. Specificity is defined as the proportion of disease-free individuals that test negative, or, in the case of the FAMACHA® system, the proportion of non-anemic animals that are categorized as such. The data indicated that the sensitivity of the system was between 23.0% and 28.4%, and the specificity between 90.4% and 91.3%, when the packed cell volume cut-off for an anemic animal was considered to be <19%. However, when the animals scored as 3s, 4s, and 5s (as opposed to only 4s and 5s) were considered anemic and included in the analyses, the sensitivity improved to between 75.7% and 85.1%, but the specificity decreased to between 52.0% and 55.3%.

The FAMACHA® system was subsequently validated in the United States by members of the American Consortium for Small Ruminant Parasite Control. Kaplan et al. (2004) determined the sensitivity of the system was 92.2% for sheep and 93.9% for goats when animals with packed cell volumes ≤19% and FAMACHA® scores of 3, 4, and 5 were considered anemic. The corresponding values for specificity were 59.2% and 35.5%. This was based on data from Arkansas, Georgia, Louisiana, Florida, and the Virgin Islands, and the scoring was done by scientists. However, Burke et al. (2007), applying the same cut-offs, found that the values for sensitivity in the hands of producers in Georgia, Louisiana, Florida, and Puerto Rico were 59.2% and 66.3% for sheep and goats, respectively. The specificities were 68.8% and 64.5%, respectively. Maheiu et al. (2007) determined a sensitivity of 63.4% and a specificity of 71.3% for goats in Guadeloupe, French West Indies, when the scoring was done jointly by two technicians.

The FAMACHA® system has been further tested and/or adopted in several other countries,
including Brazil (sheep: Molento et al., 2009; sheep and goats: Sotomaior et al., 2012; goats: Vilela et al., 2012), Morocco (sheep: Ouzir et al., 2011), Kenya (goats: Ejlertsen et al., 2006), Italy (sheep: Di Loria et al., 2009; Cringoli et al., 2009), and Switzerland (goats: Scheurle et al., 2010).

Recommendations for Use

Recommendations were developed for the use of the FAMACHA© system in the southern United States (Kaplan et al., 2004). Briefly, these include the following:

- Examine the animals at least every 2-3 weeks at the beginning of the expected period of Haemonchus challenge in climates where a seasonal incidence of infection occurs.
- During critical periods, examine the animals on a weekly basis.
- In adult animals, treat the 4s and 5s, but ensure that the flock or herd is in good body condition and good overall health.
- Specifically identify and treat animals that are unthrifty, anorexic, lagging behind the flock or herd, or have submandibular edema.
- If the flock or herd is not in good body condition and good overall health, treat the 3s as well.
- In lambs, kids, and periparturient animals, always treat the 3s.
- If ≥5-10% of the animals are anemic (4s and 5s), treat the 3s, 4s, and 5s, and change the pasture, if possible.
- Also treat the 3s when scores shift, indicating the outbreak of disease, for example, when a rapid downward trend in the 1s is seen, and there is a reciprocal increase in the 2s and 3s.

The recommendations that concern good husbandry, such as identifying unthrifty animals, are important because, while the FAMACHA© system has relatively good sensitivity in sheep and goats, there is a small possibility that anemic animals may be missed. The system must, therefore, be used in conjunction with other parasite control and good husbandry measures, including good grazing management, especially where non-Haemonchus infections occur. Currently, the system is increasingly being used within integrated parasite control programs (see, for example, Vatta et al., 2007; Miller et al., 2011; Spickett et al., 2012).

Advantages and Concluding Remarks

Use of a selective drenching approach will lead to reductions in anthelmintic treatment when compared with conventional drenching practices, and should slow down the development of anthelmintic resistance. This reduction in drenching was dramatically demonstrated in the Badplaas study (Malan et al., 2001). In the study by Mahieu et al. (2007), only 37.3% of the does scored according to FAMACHA© system required treatment. There were 0.57 doses administered per doe in the FAMACHA© group compared with 3 doses per doe in the controls.

Producers should be aware, however, that the benefits of reduced drenching may be somewhat offset by potential production losses. Van Wyk (2008) reported some production losses in two of three trials; in one of these, the losses were approximately 4.85 lb (2.2 kg) per sheep. On many farms, however, sparing use of remaining effective anthelmintic groups remains the only
manner in which anthelmintic resistance may be managed into the future.

The FAMACHA© system may be used to identify animals that repeatedly require treatment, to enable culling of those animals. Heritability of FAMACHA© scores has been shown to be relatively good (Riley and Van Wyk, 2009), and Burke and Miller (2008) were able to identify a superior sire for parasite resistance/resilience through the use of FAMACHA© scores.

The FAMACHA© system also has the potential to be used, following validation, as a diagnostic tool for anemia in other livestock species. It has been tested in camelids (Williamson et al., 2009) infected with *H. contortus*, as well as in cattle infected with trypanosomes (Grace et al., 2007).

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Copper Oxide Wire Particles to Control *Haemonchus contortus* in Sheep and Goats
Joan M. Burke, Research Animal Scientist, USDA, ARS, Arkansas
James E. Miller, DVM, MPVM, PhD, DipACVIM, Louisiana State University
Thomas H. Terrill, Professor, Fort Valley State University, Georgia

Introduction

The American Consortium for Small Ruminant Parasite Control (ACSRPC) began to examine the use and safety of copper oxide wire particles (COWP) as an anthelmintic for sheep and goats in 2003 due to the universal prevalence of anthelmintic resistance. COWP are available commercially to alleviate copper deficiency in ruminant livestock. COWP can be included in an integrated gastrointestinal nematode (GIN) control program, specifically to control *Haemonchus contortus* (Burke et al., 2004, 2007b; Burke and Miller, 2006a; Spickett et al., 2012). Because sheep are susceptible to copper toxicity, caution must be employed if COWP is used as an anthelmintic.

Efficacy against GIN

Bang et al. (1990a) reported a 96% reduction in adult *H. contortus* and 56% reduction in *Teladorsagia circumcincta* (another abomasal nematode) in lambs administered COWP. However, Chartier et al. (2000) reported a 75% reduction in *H. contortus* and little effect against *T. circumcincta* or *Trichostrongylus colubriformis* (intestinal nematode) in goats administered COWP. Knox (2002) observed an anthelmintic effect of COWP against developing larvae, but other studies showed limited or no effect (Waller et al., 2004; Burke et al., 2007b; Vatta et al., 2009). Soli et al. (2010) determined that efficacy of COWP to reduce *H. contortus* was similar between lambs and kids. Doses of COWP as low as 0.5 g administered to lambs (Burke and Miller, 2006a) or kids (Burke et al., 2007b), and 1 g to mature ewes (Burke et al., 2007a) was effective in reducing an infection of *H. contortus*.

Mode of Action

COWP administered as a bolus or in the feed (Burke et al., 2010a, b) quickly moves through the rumen and much is retained in the folds of the abomasum, where *H. contortus* develops to its adult stage. The bioavailability of copper in the gastrointestinal tract is sensitive to pH. Bang et al. (1990b) determined that copper from COWP in the abomasum was insoluble at pH greater than 3.4, which often occurs in GIN infects lambs (pH of uninfected lambs was less than 1). It was thought that COWP could be indirectly acting on adult nematodes throught the increased copper status of the host, or directly due to increased copper in the abomasum, which could potentially penetrate the cuticle of *H. contortus*. Moscona et al. (2008) found evidence of a direct effect of COWP on *H. contortus*. The Louisiana State University group determined through transmission electron microscopy that cuticle lesions occurred on *H. contortus* from COWP treated lambs, with the greatest frequency of lesions observed within 12 hours post-treatment, but still present 84 hours later. Concentrations of copper were also higher in *H. contortus* from COWP treated than untreated lambs. Even though particles can be found in the abomasum for several weeks (Judson et al., 1984; Burke et al., 2004), anthelmintic activity does not persist more than 21 days (Burke et al., 2007b) or 41 days (Vatta et al., 2012).
Forms of Copper

Copper sulphate was used as an anthelmintic before synthetic anthelmintics were developed (Wright and Bozicevich, 1931). However, we found no value in including copper sulphate in the mineral or feed of growing goats for control of *H. contortus* (Burke and Miller, 2008). We reported a reduction in fecal egg counts in goats treated with a sustained-release multi-trace element/vitamin ruminal bolus that contained 3.7 g copper as copper oxide (Burke and Miller, 2006b). An industrial form of COWP was examined for the control of *H. contortus*, but failed to reduce fecal egg counts (Burke and Miller, unpublished data). The COWP available for the treatment of copper deficiency in cattle (Copasure; Animax Ltd., Suffolk, England) was used in nearly all of the ACSRPC research. Recently, the same company offered a similar product for lambs and kids in 2 g and sheep and goats in 4 g, which would be a dose used to treat copper deficiency, but too high for repeated anthelmintic use. Other commercially available forms of COWP recently commercialized in the U.S. have not been examined for the control of *H. contortus* in sheep and goats, but experiments are pending. It is important to conduct trials with a known *H. contortus* infection; otherwise, results can be misleading (Burke et al., 2010a).

Other Research

Burke et al. (2005b) noted that COWP did not adversely affect the ability of *Duddingtonia flagrans*, a nematode trapping fungus, to reduce larval development. There were no adverse effects of administering COWP (2 g) to pregnant Katahdin ewes or their offspring (Burke et al., 2005a). The safety of using COWP in lactating Polypay ewes and their offspring occurred in collaboration with Iowa State University; no signs of copper toxicity or reduction in lamb production were observed (Burke et al., 2007a). There was evidence that a combination strategy using both COWP and sericea lespedeza was more effective than either strategy alone (Burke et al., 2012). Currently an experiment is being conducted to examine long term effects of COWP administered every 4 to 6 weeks to sheep during their productive stage (before and during lactation in ewes; post-weaning to lambs) conducted during a three year period (Burke, Miller, Terrill, Mosjidis). Lamb production appears to be similar between the COWP and a control group using synthetic anthelmintics.

Summary

While the risk of copper toxicity should always be evaluated before a decision to use COWP as an anthelmintic, especially for sheep, low doses of COWP are an effective means to control *H. contortus* in the face of anthelmintic resistance. At present, COWP is allowed as an anthelmintic by organic certifiers in the U.S., giving an alternative to organic producers and those wishing to minimize chemical use in small ruminants. Producers should always consult a veterinarian, livestock specialist, or professional in formulating a GIN control strategy best suited to their production system.

1 Mention of trade names or commercial products in this manuscript is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.
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Sericea Lespedeza

Jorge A. Mosjidis ¹, and Thomas H. Terrill ²,

¹Dpt. Agronomy and Soils, Auburn University and Ala. Ag. Expt. Stn., Alabama, ²Fort Valley State University, Georgia

Sericea lespedeza [Lespedeza cuneata (Dumont) G. Don] is a widely-adapted, non-bloating warm season perennial legume that can be used for grazing, hay, or as a conservation plant. It is a deep rooted plant that although it does best on deep, well-drained upland soils, it can be grown on a wide range of soil types and sites. It is particularly well adapted to acid, infertile soils commonly found in the southeast of the USA. Sericea lespedeza is tolerant of aluminum-toxic conditions; therefore, it is especially valuable in soils with a pH below 5.0 where aluminum toxicity is a problem.

History of Sericea Lespedeza

Sericea lespedeza became one of the most commonly used species for planting on strip mine spoils, road banks, and other disturbed or eroding areas. The widespread efforts to conserve soils in the 1930's through 1950's used the sericea lespedeza plant material available at the time. That was the cultivars Arlington, released in 1939, and Okinawa that was made available in 1944 (but was not formally released), both of which have very thick stems. Auburn University started a breeding program in the 1950's aimed at improving some of the characteristics of the sericea plant. The improved cultivars of sericea lespedeza (Serala and Interstate), released by Auburn University in the 1960's, continued to play a major role in conservation of natural resources in the Southeast. Disturbed soils from surface-mined coal sites were stabilized by planting sericea lespedeza, a practice that continues up to now.

Sericea lespedeza was seen as low quality forage because of frequent but not always poor animal performance. Poor animal performance was ascribed to low nutrient intake caused by low palatability and low digestibility of sericea lespedeza forage. Low palatability has been thought to be due to high tannin content and to coarse, thick stems. At the time it was recognized that over-mature plants were a major problem affecting forage palatability and quality. The recommendation was to graze the plants when they were less than 15 cm (6 in) tall, but it was acknowledged to be unrealistic because of reduced stand longevity. The development of the cultivar AU Grazer™, released in 1997 by the Ala. Ag. Expt. Station and Auburn University, represented a turning point for the crop. AU Grazer™ is the cultivar that was selected under grazing conditions and is the first cultivar tolerant to grazing.

Many pharmaceutical anthelmintics for ruminants have become ineffective due to increased gastrointestinal parasite resistance worldwide. Cooperative research conducted by Fort Valley State University, Louisiana State University, the USDA-ARS-Arkansas and Auburn University with the cultivar AU Grazer™ determined that the small ruminant industry can feed AU Grazer™ to protect animals against internal parasites that cause economic damage and animal death. Research has demonstrated that feeding sericea lespedeza is particularly effective against infection by the barber's pole worm Haemonchus contortus and has other positive effects on ruminants and the environment. This plant benefits the health of ruminants because besides
helping to reduce gastrointestinal parasites, it is effective in reducing protein degradation, improves nutrition and prevents bloating.

ACSRPC Sericea Lespedeza Research

The anti-parasitic properties of sericea lespedeza were first documented in grazing trials with goats in Oklahoma (Min et al., 2003; 2004) and with hay-feeding trials with goats in Georgia (Shaik et al., 2004; 2006) and sheep in Louisiana (Lange et al., 2006). The anthelmintic effect of sericea hay was unexpected because of earlier work showing that drying of this forage reduced its content of extractable condensed tannins and improved intake in sheep (Terrill et al., 1989). In fact, the initial trial, completed in Georgia in fall, 2003, in which ground AU Grazer™ lespedeza and bermudagrass [Cynodon dactylon (L.) Pers.] hays were fed as 75% of the diet to parasitized goats (25% grain-based supplement), was only completed because of unavailability of sericea grazing paddocks at Fort Valley State University. To our surprise, the sericea-fed goats had significantly lower fecal egg counts (FEC) than the goats given the bermudagrass diet. In a follow-up study with uncut hay, FEC of goats fed sericea were 80% lower than control animals 7 days after feeding was started, and this difference was maintained throughout the 6-week trial. The sericea-fed goats also had 70% less adult H. contortus in their abomasum than goats on the bermudagrass hay diet. Numbers of small intestinal worms (Trichostrongylus colubriformis) were also lower in these animals, as well as the percentage of parasite eggs successfully developing into larvae (Shaik et al., 2006). Similar results were reported in a sheep trial completed around the same time in Louisiana (Lange et al., 2006), with FEC reductions of 67-98% in the sheep fed a sericea diet compared with control animals.

Since these initial sericea lespedeza hay trials, subsequent experiments have included evaluation of ground sericea leaf meal and pellets as the primary diet and as a supplemental feed for goats and sheep grazing grass pastures, and grazing trials with sericea, both in pure stands and in mixed sericea-grass pastures (Terrill et al., 2012). Additional tests of the anti-parasitic effectiveness of sericea lespedeza in combination with other novel GIN management strategies, including use of FAMACHA© (Miller et al., 2011) and copper oxide wire particles (Burke et al., 2010) have also been completed. Over the past 10 years, in every experiment in which H. contortus was the dominant GIN in sheep and goats, there has been a positive anti-parasitic effect of feeding or grazing sericea lespedeza, with either reduced FEC, lower adult worm numbers in the abomasum, or both (Terrill et al., 2012). The level of GIN reduction that has been reported for sericea compared with non-tannin diets, up to 98% for FEC (Lange et al., 2006), and 94% for adult H. contortus (Min et al., 2003), is often 2-3 times higher than that reported for other anti-parasitic plants. The reason for this is not completely clear, but may be related to the type of condensed tannin in sericea lespedeza, which is a more reactive type than other plant tannins, possibly allowing it to interact directly with the adult nematode in the abomasum. Evidence of this was recently provided by scanning electron micrographs of female H. contortus recovered from the abomasum of goats fed pelleted diets containing sericea lespedeza leaf meal or non-sericea commercial pellets. The worms from the goats fed sericea had a shrunken, shriveled appearance, while the control animal worms looked smooth (Kommuru et al., 2012).

Although sericea lespedeza has been most consistently effective against the blood-feeding H. contortus, the primary GIN infecting goats and sheep throughout the tropics and subtropics worldwide, sericea has also shown some anti-parasitic properties against other GIN as well,
Mechanism of Action of Tannins against Gastrointestinal Nematodes

H. Hoste$^{1,2}$, I. Mueller-Harvey$^3$, I. Fourquaux$^4$, C. Carlos-Sandoval$^5$, J.F.J. Torres-Acosta$^5$.

$^1$INRA UMR 1225 Interactions Hôte Agents Pathogènes. 23 chemin des Capelles F-31076 Toulouse Cedex, France
$^2$Université de Toulouse, ENVT. 23 Chemin des Capelles. F-31076. Toulouse, Cedex, France
$^3$School of Agriculture, Policy & Development, University of Reading, Reading, U.K
$^4$Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Yucatán, Km 15.5 carretera Mérida-Xmatkuil, Mérida, Yucatán, Mexico
$^5$Centre de Microscopie Électronique Appliquée à la Biologie, Université de Toulouse, Faculté de Médecine Rangueil, 133 route de Narbonne, F31062 Toulouse Cdx France

Summary

Parasitic infections with gastrointestinal nematodes (GINs) remain a major pathological threat in outdoor production systems of various livestock species. Up to now, the control of these parasitic diseases essentially relied on the use of commercial, anthelmintic (AH) drugs. However, resistance to these anthelmintics is now widespread amongst worm populations in sheep and goats across the world.

Recent results indicate that bioactive, tanniniferous plants represent a valuable option as an alternative to commercial drugs for the control of GINs. A well-targeted use of tannin containing fodders as nutraceuticals requires a better understanding of their modes of action against worms. This means that we need to understand (1) how to analyze the changes caused at the various parasitic stages and (2) to identify the nature and concentration of the active tannin molecules that are most appropriate for anthelmintic activity.

The effects on the various nematode stages (third stage larvae and adult worms) of *Haemonchus contortus* and *Trichostrongylus colubriformis* will be presented using data from two different models of tannin-containing plants, i.e. a temperate forage legume, sainfoin (*Onobrychis vicifoliae*), and a tropical legume tree (*Lysiloma latisiliquum*). These descriptions will mainly rely on results from scanning or transmission electron microscopy. The discussion will focus on the role of tannin concentrations versus tannin structures in terms of their AH properties. Besides condensed tannins, the possible role of some other polyphenols (i.e. flavonoids) against GI nematodes will be explored.

We will illustrate how information on the mode of action of tannins and flavonoids against GIN may prove useful for improved field/farm applications under entirely different environmental and epidemiological conditions within the context of small ruminant production systems. In the future, it will be also important to understand other factors that could lead to optimize the use of this type of nutraceuticals. These aspects that need further consideration include the feeding behaviour of infected and non-infected ruminants, the effect of ruminant species, etc. This needs to be explored with the animal breeds and the parasite isolates present under the different conditions of temperate and hot humid environments.
Vaccines and Nematode-Trapping Fungi

J.E. Miller, Louisiana State University; T.H. Terrill, Fort Valley State University

As anthelmintic resistance continued to become a problem worldwide, vaccines and nematode-trapping fungi have been investigated as a non-chemical means to help in the control of gastrointestinal nematode parasites.

There have been 2 successfully marketed vaccines, one for lungworm (cattle) and one for hookworm (dogs). Both of these used irradiated larvae as the antigenic source. Other attempts (irradiated larvae, excretory/secretory and/or somatic proteins) to develop vaccines for gastrointestinal nematodes in ruminants has had limited success with several that showed promise with efficacies of 30-60%. The most recent vaccine attempt has been with the natural hidden-gut Haemonchus contortus antigens HgalGP and H11. These antigens are extracted from the gut of H. contortus and when administered with the adjuvant Quil A, high levels of antibody production are stimulated. These circulating antibodies are ingested by H. contortus during blood feeding and interfere with the associated gut proteins to render the worm incapable of maintaining vital functions, thus the worms are expelled. Studies have shown the efficacy of this vaccine to be high, up to >90% in some cases, including studies done in the US. The problem with this vaccine is that the natural antigens are found in the gut of the worm and thus are “hidden” from the host’s immune system. Therefore, to generate continued protection, the vaccine has to be administered multiple times during the infection season to maintain antibody levels. The cost of extracting antigens from worms and having to administer multiple boosters made commercialization impractical. Attempts to develop a recombinant vaccine also met with disappointment in that the appropriate protein folding configuration could not be duplicated to retain efficacy. However, a recent attempt to enhance antigen extraction and finding that a much lower dose stimulated an adequate immune response has led to a potential commercial product, but as of now that product will only be available in Australia. Plans are not to market this vaccine in the US.

Nematode-trapping fungi have been evaluated as a means to help reduce infective larvae on pasture. Some common soil fungi form sticky loops which can “trap” infective larvae. Initial studies added chlamydospores of these fungi to feces where they germinated and trapped infective larvae as they moved through the fecal mass, thus essentially eliminating translation to the surrounding forage. This work was done primarily in Danish and Australian laboratories. The one obstacle to overcome was to find one of these fungi whose chlamydospores could survive passage through the gastrointestinal tract. Several species were evaluated and the one that had the greatest survival rate was Duddingtonia flagrans. After several feeding studies that showed a high level of germination and trapping activity in the feces of cattle, sheep and horses, a Danish pharmaceutical company embarked on commercialization of D. flagrans. After developing the product (chlamydospores adhered to millet seeds, as a feed top dress) and testing it successfully in many parts of the world, including the US, the company elected to stop production. Australian laboratories also dropped it as a viable option. The major obstacle was having to feed the product daily for an extended period of time, usually 8 weeks or longer to achieve the desired results. This treatment regime was impractical for large producers who did not or could not bring their animals up on a daily basis, and it may have been rather cost prohibitive for those who could.
This coupled with having to also deworm the animals to remove worms, added to the cost. Therefore, over the last decade to role of nematode-trapping fungi has received limited attention that has been pursued in Mexico and Brazil with local isolates of D. flagrans. Recently, an Australian company has revived this control approach and has been working on commercialization of a D. flagrans product for small farm producers. In the US, interest in revisiting the use of D. flagrans has targeted exotic hoofstock maintained on limited exhibit enclosures of zoos where anthelmintic resistance has led to high morbidity and mortality due to haemonchosis. In response to zoo requests, the Australian company has been involved in field studies to evaluate their product to control infective larvae in exotic hoofstock feces. Those studies showed high efficacy and they are now actively pursuing approval through the Environmental Protection Agency for marketing their product in the US. If they receive marketing approval, the product should also be available for use in livestock species. This revived effort could prove useful as one entity in an integrated control program for small ruminant producers in the US to help reduce pasture infectivity and reinfection over time.
Alternative Compounds to Commercially Available Anthelmintics to be used in Sheep and Goats

E.N. Escobar, Ph.D.
University of Maryland Eastern Shore
Princess Anne, Maryland 21853

Introduction

Helminthosis (worm burdens) in small ruminants is a problem within itself in all agro-climatic zones of the world. In addition, anthelmintic resistance (AR) is a global problem that threatens the welfare of sheep and goats and represents a challenge in eroding the productivity of small ruminants, thus affecting the survival of the sheep/goat farms. Most economic losses are due to what is known as “sub-clinical nematodosis,” which is not immediately observed and not even measured by sheep and goat ranchers. Jabbar et al., 2006 reviewed extensively the AR status in small ruminants. AR is identified when a previously used anthelmintic ceases to kill an exposed worm population at the therapeutically recommended dosage (Jabbar et al., 2006). In the United States, all the major groups of the commercially available anthelmintics have been reported to have developed variable degrees of resistance when used to protect small ruminants. One of the earlier reports on alternative use of plants with anthelmintic properties was presented by Kissam (1781) reporting that cow-itch (*Phaseolus zuratensis siliqua hirsuta*) could be used as a vermicide to treat children with worms instead of preparations of mercury, aloes, rhubarb, jalap (a dried tuberous root from *Ipomoea purga* syn. *Exogonium purga*, a plant in the morning-glory family), steel, tin, sulphur (sulfur)..."and others too tedious to mention". Kissam (1781) indicated that the hairy substance growing outside the pods was mixed with molasses or syrup and given to children and adults for 3 consecutive days at the rate of one teaspoon for children and double for adults. Efforts to reduce production losses caused by Gastrointestinal Nematode (GIN) parasitism in small ruminants (sheep and goats) have led to the investigation, development and implementation of a number of control methods to complement or replace commercially available anthelmintics. The need for alternative control measures stems from the development of anthelmintic-resistant GINs with reports of multi-class resistance to these drugs. The Anthelmintic Resistance (AR) has been very well documented all over the world. A number of these control methods such as predacious micro-fungi, protein supplementation, and plant parts or extracts in feed, additions to feed and vaccines have demonstrated potential to control infection but require development and examination under production conditions. In addition, demand for alternative dewormers originates from the organic small ruminant industry. Breeding for natural resistance to GIN infection has already shown success in controlling the infection under natural production conditions and that will be the topic for another occasion. In most cases researchers have used Packed Cell Volume (PCV) or hematocrit and Fecal Egg Count (FEC) as indicators of efficacy of the different tested compounds. This presentation will attempt to focus on “alternative compounds” to reduce GIN infection in sheep and goats. This effort started as a discussion on “herbal anthelmintics”, however the body of documented instances of the use of such products is negligible; therefore it was expanded to the current concept.
Diatomaceous earth

Diatomaceous earth (DE) is a powdered, fossilized, geological siliceous deposit, rich in unicellular marine or fresh water diatoms, which damages the invertebrate cuticle (arthropods and nematodes), increasing permeability and causing death by dehydration (McLean et al., 2005). DE with less than 7% composition of crystalline silica is generally recognized as a safe feed additive in Canada and the USA (Bennett et al., 2011, Köster, H, 2013). DE is used to control many invertebrate pests, including grain storage invertebrate pests and as an alternative anthelmintic product fed to domestic animals (poultry, sheep and cattle) for gastro-intestinal parasite control, although the small number of efficacy studies show mixed results (Fernandez et al., 1998 and McLean et al., 2005, Bennett et al., 2011). When naturally infected goats (Haemonchus contortus, Eimeria and Trichostrongylus spp.) were fed DE at 50, 100 and 150 μg/kg body weight, Bernard (2009) reported that DE did not show an anthelmintic effect as expressed by eggs per gram of feces.

Condensed Tannins

Tannins are natural polyphenols. Biosynthetically the Condensed Tannins (CT) are formed by the successive condensation of the single building blocks, with a degree of polymerization between two and greater than fifty blocks being reached. The coupling pattern of the catechin units in condensed tannins can vary considerably (Khanbabaee and van Ree, 2001). In forages (mostly leguminous plants), tannins are considered secondary compounds and in general herbivores avoid plants with excess tannin content. However, it has been reported by many investigators that CTs have beneficial effects relative to parasitized sheep or goats eating plants with CTs because CTs aid in the management of GIN infestations (Min and Hart, 2003; Coffey, 2007; Lisonbee et al., 2009; Novobilský et al., 2001; Juhnke et al., 2012; . In the United States, several plants are of interest to sheep and goat producers: Sericea lespedeza (Sericea cuneata), birdsfoot trefoil (Lotus corniculatus), chicory (Cichorium intybus) and sainfoin (Onobrychis vicifolia). In other regions in the world plants of the genera Acacia, Schinopsis, Leucaena, Salix have shown to have anthelmintic activities (Minho et al., 2008; Beserra de Oliveira et al., 2011; Mupuyo et al., 2011). However, the effects of feeding high tannin containing feeds have not always reduced parasite burdens. For example, Whitley et al. (2009) reported that high tannin sorghum rations did not affect FEC or PCV of goats eating the high sorghum diets. Also, Max et al., (2007) reported a slight FEC reduction (only 19%) in sheep and goats fed up to 170 g/animal/day of acacia leaf meal (Acacia polycantha) compared to control groups. Use of CTs as alternative anthelmintic has multiple research trials backing up claims of efficacy and has encouraged producers to the use of lespedeza as a component of integrated parasite management plans.

Other “herbal dewormers” and anthelmintic compounds

At least two commercial herbal dewormers have been tested in research trials. Burke at al. (2009) did not find any indication, after a 112 day trial, that a commercially available herbal dewormer controlled GIN in goats. Yoder (2011) tested Plumbagin in sheep and reported that treated sheep and control sheep did not show any difference on parasite burden as expressed by PCV and FEC. Garlic, papaya seeds and pumpkin seeds have been used in trials with sheep and goats and have not been found to enhance PCV or reduce FEC in the treated sheep and/or goats.
(Burke et al. 2009; Gooden 2012, Escobar et al. unpublished data). However, Stickland et al. (2009) reported 64.4% reduction in FEC in sheep using garlic and 65.5% reduction in FEC when pumpkin seeds were fed. Diehl (2004) published an extensive report of 60 plants in the Ivory Coast that have shown larvicidal activity against _H. contortus_. Several parts of plants were extracted with 90% ethanol and 25.6% of the extracts showed a high activity. Oil and seed paste of _Chenopodium_ spp. (epazote, wormseed, erva de Santa Maria) has been used to treat worm infections in animals and humans for centuries, however the margin of safety is very narrow and _Chenopodium_ may cause adverse reaction and even death to the treated animals (Cornell University, 2013). Other relevant alternative plants are included in the enclosed table.

Discussion

The list of reports on the use of alternative anthelmintics for use in sheep and goats is overwhelming; however, the methods for analysis are ingenious but not standardized. It seems that the compounds tested may reduce larval activity in-vitro but when tested in-vivo the results from treated animals are not different than results from the control ones. One difficulty which is very common is the proper identification of the plants. The scientific name plus the variety should be included in reports. For example, pumpkin’s scientific name is _Cucurbita pepo_; however there are at least 5 varieties commercially cultivated in the US. Another underlying situation exists when researchers need to decide between running an in-vitro trial or an in-vivo trial. Both complement each other providing information to better understand the results in the field and to make recommendations. Once more there is the need of collaborative studies and the contribution of chemists, botanists and animal scientists in order to identify alternative compounds to control worms in sheep and goats.
<table>
<thead>
<tr>
<th>Small Ruminant Species</th>
<th>Name of the Alternative Dewormer</th>
<th>Parasite species</th>
<th>Test Conducted</th>
<th>Results</th>
<th>Reference</th>
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<tr>
<td>Sheep</td>
<td>Jujube (Bark, crude methanolic extract) - <em>Ziziphus nummularia.</em></td>
<td><em>H. contortus</em></td>
<td>In-vitro: • adult motility assay • egg hatch • larval development In-vivo</td>
<td>Effective</td>
<td>Bachaya, et.al, 2009.</td>
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<td>Sheep</td>
<td><em>Acacia nilotica</em> - pods with seeds - crude methanolic extract</td>
<td><em>H. contortus</em></td>
<td>In-vitro: • adult motility assay • egg hatch • larval development In-vivo</td>
<td>Effective</td>
<td>Bachaya, et.al, 2009.</td>
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<td>Sheep</td>
<td><em>Chenopodium album</em></td>
<td><em>H. contortus</em></td>
<td>In-vitro: • adult motility assay • egg hatch In-vivo, reduced FEC</td>
<td>Effective, LC$_{50}$=0.449 mg/mL 93.9% reduction</td>
<td>Jabbar et al., 2007</td>
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<td>Sheep</td>
<td><em>Caesalpinia crista</em></td>
<td><em>H. contortus</em></td>
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<td>In-vivo, reduced FEC</td>
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<td>Effective, LC&lt;sub&gt;50&lt;/sub&gt; = 0.134 mg/mL</td>
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<td>82.2% reduction</td>
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<td>Sheep</td>
<td><em>Wormwood</em> - <em>Artemisia absinthium</em></td>
<td><em>H. contortus</em></td>
<td>In-vitro:</td>
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<td>In-vivo, reduced FEC</td>
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<td>80 to 83% reduction</td>
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<td>Sheep</td>
<td><em>Banana leaves</em></td>
<td><em>H. contortus</em></td>
<td>In-vitro:</td>
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<td>In-vivo, reduced FEC</td>
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<td>Reduced 97% larval development</td>
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<td>Reduced 58%</td>
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<td>Jabbar et al., 2007</td>
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<td>Tariq et al., 2009</td>
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<td>Oliveira et al. 2010</td>
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Grazing and Pasture Management

J-M. Luginbuhl\textsuperscript{a}, H.M. Glennon\textsuperscript{a}, J.E. Miller\textsuperscript{b}, T.H. Terrill\textsuperscript{c}

\textsuperscript{a}North Carolina State University, Raleigh, NC 27695, USA, \textsuperscript{b}Louisiana State University, Baton Rouge, LA 70803, USA, \textsuperscript{c}Fort Valley State University, Fort Valley, GA 31030, USA

Introduction

The biggest threat to the profitability of goat operations world-wide is gastrointestinal nematode (GIN) infections. Poor growth, low feed efficiency and/or mortality are typically seen in parasitized animals. Decades of chemical anthelmintic use have led to resistance in all three major classes of anthelmintics (Zajac and Gipson, 2000; Terrill et al., 2001). The development of alternative non-chemical GIN control methods is critical for the goat industry to survive. The most damaging parasite, the barber-pole worm, \textit{(Haemonchus contortus}, HC) thrives in the warm, humid climate of the southeastern United States. Summer pastoral conditions are ideal for HC infections. The high condensed tannin (CT) legume sericea lespedeza ([\textit{Lespedeza cuneata} (Dum.-Cours) G. Don]; SL) also grows well in the southeastern United States and has been successful in reducing GIN infections in small ruminants. Fecal egg count (FEC) and larval development have been significantly reduced in goats grazing SL (Min et al., 2004) and goats in confinement eating SL hay (Shaik et al., 2006) or SL hay pellets (Terrill et al., 2007). Upon slaughter, the number of adult HC worms in the abomasum of animals eating SL was also significantly lower (Shaik et al., 2006; Terrill et al., 2007). The objective of these three experiments was to evaluate SL as a summer forage for grazing meat goats and its effects on GIN infection.

Materials and Methods

\textit{Experimental design and protocol.} Three grazing experiments were conducted during the summers of 2008, 2009 and 2010 at North Carolina State University in Raleigh, NC. The sericea lespedeza (var. AU Grazer) plots were established with a no-till drill in March 2007 at a rate of 39 kg/ha. The pearl millet (PM) plots (\textit{Pennisetum glaucum} var. Tifleaf III) were planted annually in May and fertilized with ammonium sulfate at rate of 56 kg N/ha 2-4 weeks after planting. Each of the nine grazing plots measured 0.13 ha.

In Experiment 1, 36 boer cross kids (BW 17.3 kg) were stratified by FEC and sorted into 9 groups of 4 animals in a randomized complete block design with 3 replications. Kids had been dewormed 11 d prior with moxidectin (Cydecin oral sheep drench, 0.04 mg/kg) and housed in a slotted floored pen until the trial started. Due to anthelmintic resistance, animals were still carrying a natural infection of parasites at the beginning of each experiment. In Experiment 2, 45 Boer cross kids (BW 17.6 kg) were dewormed orally at weaning with moxidectin (Cydecin pour-on, 0.05 mg/kg), grazed on SL for 16 d and then stratified by FEC and sorted into 9 groups of 5 animals in a randomized complete block design with 3 replications. In Experiment 3, 45 Boer cross kids (BW 18.5 kg) were dewormed with moxidectin (Cydecin oral sheep drench, 0.04 mg/kg), grazed on a contaminated grass pasture for 7 days and then stratified by FEC and sorted into 9 groups of 5 animals in a randomized complete block design with 3 replications. In
Expt 1 and 2, animals were strip grazed on SL, PM, or rotated (ROT) between SL and PM. In Expt 1, ROT animals started on SL and switched treatments on d 14, d 28 and d 42. In Expt 2, ROT animals started on PM and switched treatments on d 18 and d 32. In Expt 3, animals grazed either SL or PM or had access to both SL and PM (SLPM). At the end of Expt 1 (d 49 – d 77), Expt 2 (d 46 - d 67) and Expt 3 (d 35 – d 56) kids were housed together in a building having a slotted floor. Kids had ad libitum access to fescue hay and were fed a corn/soy hull concentrate at 1.5% BW. Then, kids were slaughtered at a USDA approved abattoir.

**Sampling procedures and analyses.** For all experiments, feces was collected weekly from the rectum of individual animals for determination of fecal egg count using a modified McMasters technique (Paracount EPG, 1984) and reported in eggs per gram feces (egp). Blood was collected weekly by jugular venipuncture from individual animals using 5 ml EDTA vacutainer tubes for packed cell volume (PCV) determination. FAMACHA scores were also recorded weekly. If an kid received a FAMACHA score of 4 or lower or their PCV dropped below 16%, they were given an anthelmintic and no further samples were taken from that animal for the trial even though they remained on the plots as grazers. At slaughter, adult worms were recovered from the abomasum and small intestine for identification and enumeration as described by Shaik et al (2006). The L4, L5 and adult worms were then identified and counted.

**Statistical analyses.** FEC, PCV and FAMACHA data were analyzed as a randomized block design using repeated measures in PROC MIX (SAS, 2003). Adult worm counts were analyzed in Proc GLM. FEC values were log transformed ln(FEC +10) before analysis but untransformed least squares means were presented.

**Results**

**Experiment 1.** Treatment and treatment x time effects were significant (P < 0.01) for FEC. During the 49 d grazing period, SL was lower than ROT (P < 0.06) and PM (P < 0.01) and ROT was lower than PM (P < 0.05) (avg: SL 376 epg; ROT 581 epg; PM 1,484 epg). Mean FEC was similar on d 0 between SL (1,590 epg), ROT (808 epg) and PM (1,895 epg). FEC of kids grazing solely SL decreased within 7 d and stayed lower (P < 0.01) from d 7 through d 49 than the PM goats. The FEC of the ROT kids increased from 395 epg to 1025 epg (P < 0.06) within 7 days of grazing on PM and then decreased from 995 epg to 330 epg (P < 0.001) when switched to SL on d 28. FEC of all animals rose once they were placed in the barn on d 49. On d 77, ROT kids had higher FEC (ROT 7,347 epg; SL 3,717 epg; PM 2,870 epg; P < 0.05). While grazing, 7 of the 12 kids on the PM and 1 on the ROT paddock had to be dewormed. While in the barn, 1 ROT goat received anthelmintics.

There was no overall treatment effect on PCV or FAMACHA scores of the goats but time and treatment x time were significant (P < 0.01). After the goats were placed in the barn on d 49, the PCV of all treatments declined through the end of the trial. FAMACHA scores from all treatments rose after animals were taken off pasture. No difference was observed in the adult worm count taken from the abomasum or small intestines of the kids. *H. contortus* was the dominant nematode recovered.

Average daily gain (ADG) was measured only on animals that had not been dewormed by the
end of the trial. ADG was similar in all treatments (SL: n = 12, 110 g/d; ROT: n = 10, 91 g/d; PM: n = 5, 102 g/d).

**Experiment 2.** Treatment and treatment x time effects were significant (P < 0.01) for FEC. During the 46 d grazing period, SL was lower than ROT (P < 0.05) and PM (P < 0.01) and ROT was lower than PM (P < 0.05; avg: SL 202 epg; ROT 1,203 epg; PM 1,851 epg). Mean FEC were similar on d 0 between SL (255 epg), ROT (155 epg) and PM (189 epg). These initial values are low because in addition to be dewormed, all animals were grazed on SL for 16 days before the start of the trial. The FEC of kids grazing solely SL decreased within 11 d and stayed lower (P < 0.05) from d 11 through d 46 than the PM animals. The FEC of the ROT kids decreased from 2,855 to 568 epg (P < 0.001) within 7 d of grazing SL and increased from 60 to 1,065 epg (P < 0.001) within 7 d when switched again to PM paddocks. FEC of the SL and ROT kids rose after they were placed in the barn, and FEC of PM was lower (P < 0.01) on d 67 (SL 3,421; ROT 5,350; PM, 938). While grazing, 9 PM, 6 ROT and 4 SL goats had to be dewormed. While in the barn, 4 SL, 2 ROT and 1 PM goat were drenched with an anthelmintic.

There was no overall treatment effect on PCV or FAMACHA scores of the goats but time and treatment x time were significant (P < 0.01). Following barn feeding on d 46, PCV values for all treatments decreased and FAMACHA scores increased.

There was a treatment effect (P < 0.05) on the number of *H. contortus* (SL, 40 vs PM, 63) and number of *T. colubriformis* (SL, 134; ROT, 121 vs PM, 6) found in the abomasum and small intestines of the kids. The % *H. contortus* was lowest in SL (21.7%) and highest in PM (91.9%) with ROT (39.5%) being intermediate.

ADG measured only on animals that had not been dewormed by the end of the trial did not differ between treatments (SL: n = 11, 61 g/d; ROT: n = 9, 64 g/d; PM: n = 6, 78 g/d).

**Experiment 3.** Treatment and treatment x time effects were significant (P < 0.01) for FEC. During the 35 d grazing period, PM was higher than SL (P < 0.01) and SLPM (P < 0.05) (avg: SL 463 epg; SLPM 673 epg; PM 2,598 epg). Mean FEC was similar on d 0 between SL (1,688 epg), SLPM (1,525 epg) and PM (1,838 epg). FEC of kids grazing SL and SLPM decreased within 7 d (SL: 1688 to 178; SLPM: 1525 to 493) and stayed low from d 7 through 35. FEC of all kids rose after they were placed in the barn. The FEC of SL was lower (P < 0.01) only on d 42 (SL 415; SLPM 1479; PM 2,955). While grazing, 8 PM, 2 SL and 1 SLPM goats had to be dewormed. None received anthelmintics while in the barn.

There was no overall treatment effect on PCV or FAMACHA scores of the goats but time and treatment x time were significant (P < 0.01). During the barn feeding period (d 35-d 56), the PCV value for SL decreased (P < 0.01) while the other 2 treatments did not change. No difference was observed in the adult worm count taken from the abomasum or small intestines of the kids, but a trend for the GIN population to shift to *T. colubriformis* in animals eating SL was observed.

ADG were highest for SLPM (n= 13, 122 g/d), intermediate for SL (n=12, 96 g/d) and lowest for PM (n=6, 64 g/d), and differed between SLPM and PM (P < 0.5).
Discussion

Grazing SL forage was effective at reducing GIN infection in young meat goats. Animals grazing only SL consistently had lower FEC than animals grazing only PM and effects could be seen in as little as 7 days. SL reduced FEC during the grazing periods by 75%, 89% and 82% over PM (Expt 1, 2 and 3 respectively), thus effectively reducing pasture contamination. Animals that grazed both forages during the experiments had intermediate FEC. When goats were removed from SL forage, FEC increased quickly and became pathogenic in some cases. These results are consistent with Min et al. (2004) who reported an increase in FEC after goats were switched from grazing SL to rye/crabgrass and vice versa. Lange et al. (2006) also reported a diminished anthelmintic effect of SL after switching animals from SL hay to bermudagrass (Cynodon dactylon [L.] Pers.) hay. This increase in FEC indicates SL causes suppression of GIN fecundity and not necessarily larvae mortality. Over the course of the current three experiments, more kids grazing PM had to be treated with anthelmintics (n = 25, 60%) than the SL (n = 10, 24%) or ROT/SLPM (n = 11, 26%). Although PCV and FAMACHA were not affected by treatment, treatment x time effects were seen. At times, SL animals had higher PCV and lower FAMACHA scores indicating a possible decreased effect by H. contortus. This may be due to an inhibition of blood feeding and/or shift in nematode population in the GI tract. Adult worm counts indicated that animals grazing SL had a lower H. contortus and higher T. colubriformis infection in Expt 2. In Expt 3, there was a trend for the GIN population to shift to T. colubriformis in animals eating SL. Conversely, in Expt 1 no difference was observed with H. contortus the predominant nematode recovered (98-100%), regardless of treatment. Terrill et al. (2007) found a 75% and 38% reduction in H. contortus infection in animals eating SL pellets and SL hay compared to BG hay. Shaik et al (2006) reported a decrease in H. contortus, Teladorsagia circumcincta and T. colubriformis adult nematodes in animals on a SL hay diet.

The absence of nematode population shift in our experiments cannot be readily explained. Nevertheless, the fact that all 3 experiments were conducted sequentially on the same fields and that the grazing period of Expt 3 was the shortest (35 days vs 49 and 46 days for Expt 1 and 2, respectively) are perhaps factors to take into consideration.

Conclusions

Sericea lespedeza is a high-quality summer legume forage for goats that also provides some natural anthelmintic properties. Because the GIN are only inhibited in blood feeding and egg laying and not necessarily killed when animals graze SL, producers should be cautious when taking goats off SL pastures.

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Genetics of Parasite Resistance in Small Ruminants

David Riley and Lauretta Ngere
Department of Animal Science
Texas A&M University

Introduction

Since the detrimental influence of internal parasites in small ruminants is substantial world-wide, all possibilities for countering those effects should be considered seriously. Use of anthelmintics cannot be the only option; there is appropriate concern about the development of resistance to the effects of anthelmintics by internal parasites. If climate change is a reality, we should expect corresponding changes to influence the demographics of internal parasite populations, although predicting those changes will never be simple. Genetic control strategies through the hosts (small ruminants) are appropriate for consideration. The objective of this paper is to discuss the possibilities to genetically influence small ruminant traits related to internal parasites.

Broad Aggregate of Genotypes = Breeds

Somewhere in history, livestock breeders began to use genetic principles that resulted in the formation of breeds or races. In those early years breeders were to some degree isolated; the ability to add unrelated animals to their flocks or herds was limited. This resulted in the concentration of alleles (versions of genes) identical by descent (inbreeding). These breeds were strongly influenced by geography and became adapted to the conditions that they and their ancestors lived in. Many of these breeds are maintained today as well, and those adaptation attributes acquired through their history are still valuable today for livestock producers. The simple use of genetics to affect traits of importance constitutes breed selection. There are documented breed differences in resistance to the effects of internal parasites. Examples of breeds with greater resistance (relative to other breeds) to gastrointestinal nematodes include Florida Native, St. Croix, Gulf Coast Native, Red Maasai (Kenya), Santa Inês (Brazil), and Katahdin.

Crossbreeding

Maybe the greatest advantage of crossbreeding is the generation of heterosis, also known as hybrid vigor, for many economically-important traits. Heterosis is defined as the mean difference of crossbred animals relative to the weighted mean of the pure breeds that are present in the crossbred animals. It is experimentally calculated as

\[ \text{Heterosis} = \text{Crossbred mean} - \text{Purebred mean} \]

For example, in Table 1, values are given for means of 3 traits in Suffolk, Gulf Coast Native, and first crosses (F₁, the filial 1 generation). Li et al. (2001) detected significant heterosis for packed cell volume (PCV) and fecal egg count (FEC). The value for FEC, though numerically negative, is favorable: crossbred lambs had lower FEC than the average of the purebred lambs.
Table 1. Breed group means and estimates of heterosis for blood packed cell volume (PCV) and fecal egg count (FEC) at 20 wk age in lambs (adapted from Li et al., 2001)

<table>
<thead>
<tr>
<th>Group</th>
<th>Packed cell volume</th>
<th>Fecal egg count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suffolk</td>
<td>18.2</td>
<td>7,289</td>
</tr>
<tr>
<td>Gulf Coast Native</td>
<td>25.5</td>
<td>952</td>
</tr>
<tr>
<td>Purebred average</td>
<td>21.85</td>
<td>4,120.5</td>
</tr>
<tr>
<td>F1</td>
<td>26.1</td>
<td>1,966</td>
</tr>
<tr>
<td>Heterosis, trait units</td>
<td>4.25</td>
<td>-2,154.5</td>
</tr>
<tr>
<td>Heterosis, % PB avg</td>
<td>19.4%</td>
<td>-52.3%</td>
</tr>
</tbody>
</table>

Can heterosis be used to improve parasite resistance in small ruminants? It looks like it; however, we should be careful in its interpretation. Sometimes heterosis can be detected in harsh environments primarily because one parent breed is not well-adapted to the environment, drastically influencing the purebred mean. For example, in the Louisiana results in Table 1, the Suffolk means for PCV and FEC are extremely unfavorable relative to the other breed groups. The F1 FEC mean is much higher (worse) than the Gulf Coast Native, yet enormous heterosis was detected. In this case, if we were only considering this trait, we should compare the F1 to the Gulf Coast Native. However, heterosis favorably influences other traits, especially reproduction, and the value of heterosis across all traits should benefit the entire production system. Heterosis may not always be favorable; an example in beef cattle production would be that heterosis for birth weight could result in larger calves at birth and consequently greater calving difficulty and death loss.

Selection

First consider a hypothetical quantity individual genetic merit for a trait of choice. This value is not palpable or observable, but we assume that every animal that could be considered a potential parent has such a value for our trait of interest. If we knew these values, we would rank the potential parents by these values. Statistical regression on an individual’s phenotype (record for the trait we are considering) can be used to estimate these values. Since the 1960s, livestock breeders have utilized a statistical tool Best Linear Unbiased Predictions (BLUP) for estimating genetic merit for individual animals, which include pedigree information and records of relatives. The more records used in these analyses the more accurately genetic merit can be estimated. These estimates of genetic merit (expected progeny differences, EPD) represent differences among mean values: the expected mean of an individual’s progeny minus the population mean.

These EPD are estimates of additive genetic merit and are therefore highly dependent upon the heritability of the trait. Heritability ($h^2$) represents the proportion of trait variation that is caused by the additive genetic variance. Heritability ranges theoretically from 0 to 1, and higher values result in more accurate estimation of EPD. Typical values for common traits in livestock, e.g., weight or milk production traits range from 0.2 to 0.4

Could parents be identified to improve traits related to internal parasite resistance using this methodology? Yes. Estimates of heritability for such traits can be seen in Table 2.
An important result from this work is that selection for improvement of FAMACHA<sup>®</sup> score is possible using EPD, since $h^2$ in this Merino flock in South Africa was as high as the more expensively measured traits: hematocrit values (PCV) and FEC.

Table 2. Estimates of heritability from analyses of moderate and peak worm challenge data in which records from treated lambs were either excluded or penalized (adapted from Riley and Van Wyk, 2009)

<table>
<thead>
<tr>
<th></th>
<th>Excluded</th>
<th>Penalized</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moderate worm challenge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAMACHA&lt;sup&gt;®&lt;/sup&gt;</td>
<td>0.08 ± 0.04</td>
<td>0.11 ± 0.04</td>
</tr>
<tr>
<td><strong>Peak worm challenge</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAMACHA&lt;sup&gt;®&lt;/sup&gt;</td>
<td>0.19 ± 0.054</td>
<td>0.25 ± 0.054</td>
</tr>
<tr>
<td>Hematocrit</td>
<td>0.21 ± 0.059</td>
<td>0.22 ± 0.058</td>
</tr>
<tr>
<td>Fecal egg count</td>
<td>0.19 ± 0.061</td>
<td>0.23 ± 0.065</td>
</tr>
</tbody>
</table>

Estimates of heritability appear to be dependent upon the worm environment, that is, the severity of the worm burden to which animals are exposed. In this study, moderate and peak worm challenge levels were determined by the number of lambs requiring treatment. Estimates of heritability were largest under severe worm challenge environments. A harsh environment permits differential expression of resistance by animals, allowing identification of superior individuals; obviously, it would be undesirable to permit a flock to deteriorate under severe challenge just to facilitate that identification. Because there was a strong genetic correlation of FAMACHA<sup>®</sup> scores taken in harsh and moderate environments EPD values can be generated under less than severe worm challenge environments and still achieve effective selection. Equally important results from this work were the strong genetic correlations of FAMACHA<sup>®</sup> with hematocrit value and FEC. This implies that selection for FAMACHA<sup>®</sup> would result in favorable correlated response in both other traits.

The necessity of treatment of individual lambs to minimize economic loss will influence the kind of genetic analyses employed. Treatment dramatically improves the worm environment of those individuals that are treated, and consequently the traits measured, to their advantage relative to untreated lambs. In the process, valuable information is generated about the genetic merit for lamb resistance, but typically such records are excluded from genetic analyses. Numbers of observations are reduced, and the treated animals and their relatives are unfairly advantaged, resulting in incorrect estimation of genetic merit. Penalization (using a scheme for altering observed records based upon treatment status and date), rather than exclusion, may be a better way to incorporate valuable resistance information into genetic analyses. Inclusion of penalized records increased the estimates of heritability from these data (Table 2).

**Genomics**

Tremendous effort has been expended in the last decade to incorporate genomic information in livestock improvement programs. At this point, it should be difficult to claim success.
**Traits controlled by a single (or a few) gene.** Examples include the callipyge and the Booroola Fecundity (FecB) genes in sheep, and the coat color genes such as Melanocortin 1 Receptor in cattle. Traits that fall into discrete categories (double-muscled vs. normal muscling) are often controlled by one or a few genes. Most of these are easy to identify and we know specifically the different alleles (versions of the gene) and can identify the genotypes (allelic content at a gene = 2 alleles) of individuals. Many of the tests that genetic companies offer are limited to these types of traits, e.g., scrapie susceptibility.

**Traits controlled by a large number of genes,** each with a small but cumulative contribution to the trait. Traits that are continuous (measured on an infinitely-divided number line; e.g., body weight) in nature are often controlled by many genes. In many cases there is probably a subset of genes that are mostly responsible. These are more difficult to identify, and especially arduous to establish causation (that is, the actual genes responsible are known and mapped).

In most cases markers (physical modifications of sequence of nucleotides, which are the building blocks of DNA, within the genome), rather than the causative genes themselves are tracked. One especially helpful marker is the single nucleotide polymorphism (SNP). If we could have enough SNP located across the genome (the genome consists of the DNA present across all 27 and 30 pairs of chromosomes in sheep and goats, respectively), then we could assume that the causative genes would be linked (located near enough to each other on the chromosome that the recombination process that normally occurs in the formation of sperm and ova seldom separates the two) to the SNP, and we could therefore monitor the inheritance of the unseen, unknown genes with the seen, known markers.

The development of high density SNP arrays (like the OvineSNP50 BeadChip http://www.illumina.com/products/ovinesnp50_dna_analysis_kit.illumina) has greatly facilitated investigation of these concepts. Annealing DNA from a single animal to a chip that has short target sequences of nucleotides for over 50,000 SNP loci (plural of locus, which is a physical place in the genome) would result in learning the genotypes at all of those SNP. Genotypes are then statistically associated with trait variation using regression theory, and estimates of that association at each locus are produced. Those estimates (or a subset of the most strongly associated) can be summed into a single value representing genetic merit for a trait. Researchers in dairy production in the United States, Europe, and Australia are probably most involved in this process (genomic selection using molecular breeding values—a breeding value is an EPD doubled) at the moment. There are a number of serious issues that could influence the validity of these, and there has not been pronounced success in this area. It is appropriate to be cautious with adoption of selection using such values today, but there is potential that this could impact selection of small ruminants for parasite resistance. Regions on two sheep chromosomes have been detected as associated with resistance to *H. contortus* (Marshall et al., 2012).

**All the Easy Research Has Been Done**

Our opinion is that it is worth the effort to document gene expression in some body tissue relating to a specific trait and then assemble genotypes for that gene and predict genetic merit using those rather than markers. Probably all of our efforts as geneticists to date are naïve, that
is, things are considerably more complex than we ever thought. Without doubt, EPD today have value that can be used to successfully select parents. We have very bright people working on implementation of genomic information into predictions of genetic merit for livestock. However, we could never imply that we are on the verge of accomplishing this.

References


Importance of Host Response in Resistance to Nematode Parasites

Jorge F. González, Departamento de Patología Animal, Facultad de Veterinaria, Universidad de Las Palmas de Gran Canaria, Trasmontaña s/n, Arucas, Las Palmas, 35413. Spain

Introduction

Gran Canaria is one of the seven volcanic islands of the Canarian Archipelago. It is located in the Atlantic Ocean about 150 km from Northwest cost of Africa. Although it is a tiny island, with only 1,560 km², it is popularly called “miniature continent” due to the different climates and diversity of landscapes founds on it. Variation in local weather is mainly the consequence of the global effect of the Alisios winds, local sea current, big mountains (volcanoes) and the proximity to the Sahara desert. Two basic climatological zones have been proposed: the dry and the temperate. They are further subdivided to give a total of four isoclimates zones organized in concentric circles on the Island: dry desert, dry steppe, temperate mild and temperate cold (Rodriguez-Ponce et al, 1995).

Obviously, this great difference in weather has an impact on small ruminant parasite prevalence. In general, there are more gastrointestinal nematodes (gi) in sheep and goats in temperate than in dry areas, and also worm species are different depending on isoclimates zones (Molina et al, 1997; Hernández et al, 2012).

Two main local breed of sheep has been exploited by local farmers almost exclusively: the Canaria Hair Breed (CHB) and the Canaria sheep (CS). The CHB sheep are short haired breed sheep predominantly reared for meat and manure production while the CS are predominantly utilized for milk production. Differences in trichostrongylid egg counts in faeces between breeds have been consistently observed in routine analysis carried out for the Parasitology Unit of the Veterinary Faculty of Las Palmas de Gran Canaria University, even though animals from both breeds were co-habited the same grazing areas. In last few years, we have carried out several trials in order to demonstrate differential resistance to *Haemonchus contortus* in this two breed of sheep.

In these trials, several animals (8-11 months old) have been inoculated with 20,000 L3 of an *H. contortus* strain donated by Dr. Knox and Dr. Bartley (Moredum Research Institute, Edinburg, Scotland). Animals have been slaughtered at different days post infections. Several parasitological and immunological techniques have been carried out. Some of the results obtained in these trials are presented herein.

Results and Discussion

Mean egg per gram (EPG) and number of eggs in female worm in uterus have been significantly lower in CHB sheep than in CS. There were also clear trends for a reduction in adult worm burden. Adult worm burden was 50% lower when compared with mean worm counts in CS at 28 dpi, although it was not statistically significant (p=0.06) (González et al, 2008). These data suggest that CHB sheep is more resistant than CS to *H. contortus* infections. Interestingly, there were no significant differences between breeds in larval counts and length at 7 dpi which suggest
that protective mechanism(s) in resistant (CHB) sheep were mainly directed against the adult parasite (González et al, 2011).

In the susceptible (CS) breed, at 28 dpi, there was a significant and positive correlation between worm burden and length, as well as between eggs in uterus and worm length. EPG were also correlated with adult worm counts. These correlations have been shown in several experimental infections in sheep in both *Teladorsagia circumcincta* (Stear and Bishop, 1999) and *H. contortus* (Lacroux et al, 2006) infections. In all these studies, the early parasitic stages are proposed as the target of immunity. However, no such correlations were observed in resistant CHB sheep, in which the adult stage seems to be the target of the immune response. These suggest that resistance mechanism(s) in this sheep breed may be different to those previously studied in commercial breed of sheep (González et al, 2011).

No quantitative differences between breeds were observed in immune cell populations quantified at the abomasal wall at different killing points (7, 21 and 28 dpi). The only exception was the eosinophil. A significant reduction in this granulocyte population was detected only in the susceptible breed of sheep at 28 dpi. Abomasal eosinophil number was two-fold higher in the resistant CHB than in CS at 28 dpi, suggesting that CHB sheep have increased recruitment of eosinophils in abomasal tissues, when adult parasites are present. Eosinophils have been demonstrated to surround larvae *in vivo* and to damage larvae *in vitro*, and this cell is probably involved in a delayed-larvae rejection (Rainbird et al, 1998; Meeusen and Balic, 2000; Balic et al, 2006). There is no clear evidence in its role against adult to date.

A significant negative correlation between abomasal CD4+T cells with worm burden and length at 28 dpi was observed in the CS breed, suggesting that this cell may be relevant in modulating parasite establishment, in agreement with several previous studies (Gill et al, 1993; Peña et al, 2006). However, no such significant correlative response was found in the CHB sheep. In contrast to CS breed, eosinophil and gd T cells were negatively correlated with epg at 28 dpi only in CHB sheep, but not with worm burden or length, suggesting that these cells may play a role in modulating fecundity against *H. contortus* (González et al, 2011).

**Conclusions**

In conclusion, with these trials, we have demonstrated disparate immune responses between two breeds of sheep native to the Canary Islands. These results—in addition to other experiments developed with other local breeds of sheep—strongly suggest that ancient breeds may hold the key to identify the resistance pathways of host against parasitic diseases. This information may be potentially useful for identify new pharmacological targets or immunization strategies. Obviously, first step is preserved this endangerment resource. Local and national government and international agencies must promote and protect these indigenous animal breeds (Piedrafita et al, 2010).

**Acknowledgement**

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References


Extension’s Role in Parasite Control

Susan Schoenian
Sheep & Goat Specialist
University of Maryland Extension

Dr. Niki Whitley
Extension Animal Scientist
North Carolina A&T University

History of Extension

Cooperative Extension (Extension) is a nationwide, informal educational network that brings the research and knowledge of the land grant university to people in their homes and on their farms. It links over 2,900 county extension offices, more than 100 land grant colleges and universities, and the federal government.

In 1862, the Morrill Act established land grant universities to teach citizens about agriculture, home economics, mechanical arts, and other practical professions. Extension was formalized in 1914 by the Smith-Levels Act, which established a partnership between land grant colleges and the U.S. Department of Agriculture to provide extension work.

Throughout its history, Extension has played a vital role in improving the efficiency of agricultural production. Today, while it serves a more diverse audience and operates with fewer resources, Extension continues to serve the educational needs of the public, including those of small ruminant producers. In fact, recognizing its continued importance, many federal grant programs now require an extension (outreach) component.

Internal Parasitism in Small Ruminants

Internal parasitism is the primary health problem affecting small ruminants in many regions of the United States. According to the 2011 NAHMS Sheep Health Report, internal parasitism accounted for 9.6 percent of non-predator sheep losses, with farms in the East experiencing almost 5 percent more losses (1). As for goats, necropsy records showed that internal parasites caused more goats to die in the Southeastern United States than the total of the next three leading causes (2).

The traditional approach to worm control has been to administer anti-parasitic drugs called anthelmintics (dewormers). Unfortunately, the worms have developed varying degrees of resistance to drugs in all three anthelmintic classes, with some farms in the Southeast experiencing total anthelmintic failure. Among livestock populations, anthelmintic resistance is the worst in sheep and goats, and has been documented in the camelid population.

American Consortium for Small Ruminant Parasite Control

The Southern Consortium for Small Ruminant Parasite Control (SCSRPC) was established in 2003 to address the growing problem of anthelmintic resistance in the small ruminant industry (5). In 2012, as the membership of the consortium expanded, the name was changed to the
American Consortium for Small Ruminant Parasite Control (ACSRPC), with the name change reflecting the national scope of the parasite problem.

The ACSRPC is a group of scientists, veterinarians, and extension specialists whose stated mission is to 1) Develop novel methods for sustainable control of gastrointestinal nematodes in small ruminants; and 2) Educate stakeholders in the small ruminant industry on the most-up-to-date methods and recommendations for small ruminant parasite control (3).

Since 2003, Consortium members have received grant funds in excess of $3.5 million to support the mission of the Consortium (4,5). Some of the initial research efforts involved documenting anthelmintic resistance and validating the FAMACHA® system for use in the United States. Other research projects have focused on novel methods of parasite control, including copper oxide wire particles, sericea lespedeza, and nematode-trapping fungus (4).

Extension (outreach) has been an important component of all grant-funded projects.

Web Site

In 2004, the Southern Consortium for Small Ruminant Parasite Control established a web site at www.scsrpc.org. Additional domain names (acsrpc.org, wormx.org, wormcontrol.org, and controlworms.org) were eventually purchased and re-directed to the original domain. The web site underwent significant redesigns in 2012 and 2013. It was moved to a new server and has a new webmaster.

The primary purpose of the web site is to provide small ruminant producers with information on sustainable gastro-intestinal parasite control. It is a place where members of the Consortium can share results of their research projects. The web site also provides access to train-the-trainer materials.

The web site currently has listings of approved FAMACHA® instructors and upcoming FAMACHA® trainings. Each month, a different member of the consortium provides a “Timely Topic” related to parasite control. Timely topics appear on the home page and are archived for continued access.

Train-the-Trainer Curriculum

In 2006, the Consortium received a grant to develop curriculum for FAMACHA® instructors (trainers) (5). Educational materials include a three-ring binder, CD-ROM, and PowerPoint (Flash) presentation. Materials contained in the binder and CD-ROM are available on the Consortium’s web site. Currently, the materials are in the process of being updated. Instructors are free to modify the materials to suit their own educational needs.

FAMACHA® Workshops

FAMACHA® (also called Smart Drenching and Integrated Parasite Management) workshops have been at the core of the Consortium’s outreach effort. The first FAMACHA® workshops were held in Georgia and Florida in the spring of 2003, followed by similar workshops in Alabama, Arkansas, Louisiana, Maryland, Oklahoma, Texas, Puerto Rico, and the U.S. Virgin Islands.
Islands (5). Since 2003, over 29,000 FAMACHA® cards have been sold to over 40 states and various Caribbean and Latin American countries (9).

Impacts

The impact of FAMACHA® workshops has been documented on at least two occasions (6,7,8). In 2004, ninety participants in FAMACHA® workshops, primarily in the Northeast, returned a mailed survey. According to the survey, 91.1 percent of producers were using the FAMACHA® system to make deworming decisions; 64.4 percent were having less problems with internal parasites, 77.8 percent were deworming their animals less often, and 75.6 percent reported spending less money on anthelmintics (6,7).

According to pre- and post-tests, workshop participants increased their knowledge of internal parasite control by 30 to 40 percent (6,7). In addition to using the FAMACHA® system, workshop participants were implementing various other management practices to control internal parasitism, including pasture rest-rotation, 61%; supplemental nutrition, 54%; periparturient dewormings, 51%; and animal selection, 49% (6,7).

In 2009, a larger, more formal survey was conducted by the American Consortium for Small Ruminant Parasite Control and published as an abstract in the Journal of Animal Science (8). Surveys were returned by 729 participants, primarily from southern and Midwestern states. According to survey results, 95 percent of respondents felt that the training made a difference in their abilities to control or monitor parasitism. Eighty-seven percent of respondents indicated they were using the FAMACHA® system to make deworming decisions. Seventy-four percent were deworming less frequently and 75 percent saved money in the first year after the training. In addition to FAMACHA®, the most popular practices being implemented were rotational grazing, 77%; and genetic selection, 53% (8).

Percent FAMACHA Workshop Participants

![Diagram showing the percentage of workshop participants using FAMACHA, deworming less, and saving money in 2004 and 2009.](image-url)
The results from both surveys clearly demonstrated that producers have benefitted from FAMACHA® trainings (6,7,8).

Future

According to the 2009 NAHMS Goat Report, only 14 percent of goat owners (in surveyed states) were using the FAMACHA® system to make deworming decisions (2). While it is likely that additional progress has been made in the past four years, this data shows that there is a continuing need for education, as being provided by the Consortium.

FAMACHA® workshops will continue to be held throughout the United States. Workshops will target all small ruminant producers (sheep, goat, and camelid), as well as veterinarians and animal health specialists. There is a strong need to certify more FAMACHA® instructors and to provide training to producers in the more northern and western states. There is also opportunity to provide education to small ruminant producers in other countries.

The role of the web site will continue to be expanded, with the opportunity to conduct trainings online. Online training would be particularly suitable for producers who lack qualified extension services in their county, state, or country. Online training for veterinarians and other agricultural professionals is another option being considered by the Consortium.

Additional educational materials, including research outcomes, will be posted to the web site as they become available.

References


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(5) Tom Terrill, personal communication (2013).


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Leave the Best, Treat the Rest - Targeted Selective Treatment for the Resource-Poor in Africa

J.A. van Wyk and G.F. Bath
Faculty of Veterinary Science,
University of Pretoria,
Private Bag X04, 0110
Onderstepoort, South Africa

Drug Resistance

Global indiscriminate use of and over-reliance on the wide array of chemicals for management of most pests, be they of import to plant, animal or man, has resulted in development of resistance to almost all of the substances involved in parasite and/or pest management, to the extent that in many instances agricultural production and medical health are progressively coming under threat. Hence development of sustainable methods for managing worm resistance remains one of the main incentives for research on gastrointestinal nematode infection in the veterinary field (Van Wyk & Reyneke, 2011. Vet. Parasitol., 177, 212-223).

Lack of Cooperation between Various Disciplines

Effective management of both internal and external parasites is essential for optimal, sustainable production of domesticated ruminants. Unfortunately, research on the parasites involved is too compartmentalised, resulting in clashes between management strategies for internal and external parasites, for instance regarding sustained efficacy of endectocides such as the macrocyclic lactones (MLs), and hence on the production of the hosts. Use of MLs at intervals as short as a few weeks for controlling ticks in cattle, or in winter in an attempt to eradicate sheep scab, selects very severely for resistance in Haemonchus contortus. Furthermore, there is too little research cooperation between forage and animal scientists and veterinary parasitologists for optimal animal production strategies.

Track Record of ACSRPC

One of the most important contributions of the ACSRPC in the decade of its existence has been the unique ability to integrate important research between veterinary, forage and animal scientists, centred on clinical evaluation of animals to enable Targeted Selective Treatment (TST), principally FAMACHA® non-invasive evaluation of anaemia, now included with nasal discharge-, body condition-, dags- and submandibular oedema scoring in the Five-Point-Check (“5.√”) system of clinical evaluation (Bath & Van Wyk, 2009. Small Rum.Res., 86, 6-13). South Africa contributed with development of FAMACHA® and the TST approach. In reaction to extreme levels of resistance that developed to the range of available anthelmintics, the TST approach was ushered in in South Africa with the so-called FAMACHA method of clinical evaluation of the anaemia of haemonchosis (Malan & Van Wyk, 1992. Proc. S.A. Vet. Ass. Bienn. Nat. Vet. Congr., Grahamstown, S. Africa, 7–10 Sept., 139; Bath et al., 1996. Proc. 7th Ann.Congr.Livestock Hlth Prod. Group S.Afr.Vet.Ass., Port Elizabeth), to be able clinically to detect anaemia and leave untreated any animals deemed unlikely to benefit from treatment, while the rest are dewormed (“Leave the best, treat the rest” – Bath, 2012. BIT’s Ann.Symp.Antiparasites, Guangzhou, China). In the process the untreated animals continue to
pass worm eggs onto pasture, adding to a build-up of an unselected population of worms, unexposed to the anthelmintic concerned and said to be in refugia.

FAMACHA, as Part of “5.✓” System for TST

The FAMACHA® system, comprising comparison of the colour of the conjunctivae of sheep and goats to a colour chart for clinical detection of anaemia in animals under severe challenge with *H. contortus*, was developed and widely tested and found to be useful for field application by trained farmers in South Africa (Bath et al., 2001. FAO Technical Cooperation Project No. TCP / SAF / 3321(A). 90+xxviii pp; Van Wyk & Bath, 2002. Vet. Res. 33, 509–529). Thereafter, following on training by members of the South African team in the Americas and elsewhere, testing and/or adoption of the system spread to over twenty countries (Van Wyk & Bath, personal records, 2012), amongst others and particularly the southern states of the USA, where dedicated teams of trainers facilitate use mostly by farmers with small flocks of small ruminants (Kaplan, R.M. et al., Vet. Parasitol., 123,105-120). And in Brazil Maia, Rosalinski-Moraes, Sotomaior et al. (March, 2013, personal communication, Sotomaior) recently completed a project which, over a period of two years, entailed theoretical and hands-on practical training of more than 1,100 persons in FAMACHA and the theory of TST in general.

Pros and Cons of FAMACHA®

From a considerable amount of field testing of the FAMACHA® system (Van Wyk & Bath, 2002), the following positives have been shown: On-farm clinical evaluation by the farmer; low initial input cost; slowing of development of anthelmintic resistance; success in application not related to level of education; good genetic correlation with breeding values for animal production; and promoting of frequent examination of the animals. In contrast, the disadvantages of the method include high labour requirements; hands-on pre-training; multiple possible causes of the anaemia that is detected; complexity of optimal timing of application in relation to worm challenge; especially applicability to haematophagous worm species only. When supported by the “5.✓” system of clinical evaluation of infection, including nasal discharge, and body condition, submandibular oedema and dags scoring in addition to FAMACHA®, the impact of major non-bloodsucking worm species as well as *Oestrus ovis* can be assessed, although not to the same degree of accuracy as for use of FAMACHA® for the anaemia of haemonchosis.

Five-Point-Check System in Practice

Especially the drawback of the labour involved in using the FAMACHA® and the “5.✓” system is reflected in its implementation mainly in countries such as Brazil and southern USA, where flocks and herds of small ruminants are relatively small or anthelmintic resistance is particularly prevalent and severe or labour is more available; it is certainly progressively less practical the larger the numbers of small ruminants involved. However, the level of education is not important to the success rate with application of FAMACHA®, with the implication that the system has the potential for application by resource-poor (R-P) communal farmers in South Africa and indeed the entire continent of Africa and elsewhere. However, the challenge now is to firmly establish its use among these farmers.
Five-Point-Check System for the Resource-Poor

For application by R-P farmers in Africa, need for experienced trainers and facilities for easy handling and clinical evaluation of animals need to be addressed for hands-on farmer training. Even for small numbers of animals, effective handling facilities are essential, otherwise clinical evaluation becomes difficult and discourages uptake of TST. However, using locally available material such as fence poles cut from local bushes and trees, can make it possible at low cost. In addition, the majority of R-P farmers in most communal farming regions possess cell (mobile) phones (Anonymous, 2005., Finance24, 17 April 2005, http://www.finance24.com), presenting a wonderful opportunity for education, training, and for reporting of clinical results of evaluation for central computation, interpretation and feedback. Presently interpretation and feedback are seriously limited, however, by a dearth of persons with the necessary experience in parasitology for advising more than a handful of R-P farmers or communities, and effectively to interpret the large volumes of data to be expected if roll-out and participation of R-P farmers were to be successful.

Farmer Uptake

Farmers often fail to adopt practices which could help to avert introduction of potentially economically crippling disease conditions. For instance, despite serious warnings over decades, many farmers continue to purchase animals at auctions, thus running severe risk of introduction of seriously deleterious animal health conditions such as venereal diseases and resistant worm populations, which are extremely difficult to eradicate once established. Furthermore, in Australia and New Zealand continual emphasis by very active extension teams on routine anthelmintic efficacy testing as an early indication of development of and hedge against anthelmintic resistance has resulted in only 31% of farmers having ever had tests for efficacy done by 2006 (Lawrence et al., 2007. NZ Vet. J., 55, 228-234) and Leathwick (2011, Rural News NZ, 7 June, 2011, p61) and Le Feuvre (2011, WormBoss, April, 2011) estimate that in New Zealand and Australia merely 10% of farmers do comply with the oft repeated, strong recommendations.

Automated Decision Support

One of the possibilities being investigated now for facilitating application is through mathematical modelling and associated software to build systems for automated evaluation of incoming data. Such models are in the process of development for risk assessment (Reynecke et al., 2011. Vet. Parasit., 177, 231-241). This progress to date was made possible by the fact that anaemia can be clinically graded on-farm by most people into the five different FAMACHA© categories, from 1 (denoting absence of anaemia) to 5 (severe anaemia) without any routine laboratory testing being required. Hence, for FAMACHA© only five different totals, corresponding to the range of FAMACHA© categories, need be submitted electronically to a central computer system, making it a very straight-forward procedure. And if all aspects of the “5.√” evaluation could be included, it would most often involve only another ten more totals for body condition- and dags scoring, since sub-mandibular oedema and Oestrus ovis infection, manifested as nasal soiling, are sufficiently covered by the standard operating instructions concerning the “5.√” system. In the favour of development of a central decision support system
is the fact that, despite a great deal of variation in details, much the same basic principles are involved in parasite management from place to place and in relation to farm management system. Hence development of the first automated system will largely put the structure in place, and can then be modified to accommodate other regions and management systems. (*Van Wyk & Reynecke, 2011. Vet. Parasit., 177,231-241*).

The necessary technology and voluminous metadata for development and initial validation of an automated decision system are available, and the main hurdle at present in the way of developing it is that it is a specialised and complicated undertaking.

**Potential of the Cellphone in Relation to Central Automated Decision Support**

Mobile phones have become so versatile in magnitude of functions, that they present an exciting range of possibilities for expansion of clinical evaluation systems to R-P farmers, first and foremost to serve as the essential link for two-way communication between the farmer and whatever central system is developed (*Van Wyk & Reynecke, 2011*):

- **Data submission**: Cellphones are admirably suited to data submission, even being able to function with relatively sophisticated software in disease-related surveys, for evaluating state of knowledge and levels of success with training of farmers, animal health technicians and other personnel.

- **Data interpretation**: Since most small ruminants are infected with gastrointestinal nematodes almost all the time (*Gordon, 1981 Proc.# 58. Refr.Course Sh. Univer.Sydney. Post-Grad.Comm.Vet.Sci.: 607-615*), worm numbers determine pathogenesis, requiring quantitative-, in contrast to a qualitative diagnosis that suffices for most infectious diseases such as bluetongue or paratuberculosis. This, and variation in seasonal effect on parasites and farm management systems, make data interpretation complex and time-consuming (*Van Wyk & Reynecke, 2011*). Consequently, central, automated decision support is needed for the required increase in the numbers of farmers who could be accommodated per experienced adviser with utilization of the potential of cellphones.

- **Farmer training**: The complexities mentioned mean that messages short enough to be read by most farmers are seldom specific enough for use as a comprehensive guide. In contrast, those messages that are more comprehensive are seldom read. Electronic aids fill this gap - it seems possible that short explanations in the form of cellphone messages explaining decisions on disease management, specific per set of current conditions, could be developed. In the case of R-P farmers the structure of many resource-poor communities lends itself to training of farmers, in that training could focus on members of central farmers’ committees existing in the communities and could, for instance, be maintained by pop-up cellphone messages.

- **Addressing poor farmer uptake into the future**: Practically the only feed-back that has been possible to date to farmers in relation to submitted diagnostic samples and data has
been generic, with little if any background explanation relating to recommendations made by advisers. We suggest investigation of the possibility that well designed explanatory feedback, automatically generated from farmer-derived, electronically submitted clinical data or sample analysis, could improve farmer uptake of such recommendations.

The Use of Forage with an Anthelmintic Effect

The use of such pastures shows promise. One of the best researched pastures, the legume *Lespedeza cuneata*, has been shown to contribute much to profitable farming. It can be used on the poorest soils, enriches them, is easily made into hay, and best of all, increases carrying capacity several fold. Trials by us in South Africa concentrated on the practical use of this forage plant as a green pasture, and confirmed its anthelmintic value, although at a lower level than in trials in the USA (*Bath, unpublished observations, 2012*). Although its implementation on communal farms has been investigated on relatively small scale with good results in Swaziland and Mozambique, considerably more investigation is required.

New Initiative

The latest South African initiative is a further attempt to help implement holistic, sustainable and integrated control measures for internal parasites, given the name “The Big Five” (*Bath, 2013. 8th Internat.Sheep Vet.Congr., Rotorua, N.Zealand*). The long list of known and proven measures for internal parasite management in sheep and goats has been repackaged into 5 groups of 5 measures each, much easier to remember than the long, disconnected list of 30 or 40 items. This enables farmers and advisors to concentrate on 5 major factors that determine success: (i) strengthening animals; (ii) controlling numbers; (iii) using pasture factors; (iv) monitoring the situation; and (v) effective drug use.

Preservation of Faeces for the Resource-Poor for Lab Analysis

Long distances and inadequate transport very much complicate submission of faecal samples by the resource-poor for worm egg counting (FEC), since the worm eggs in the faeces hatch within a few hours unless refrigerated. However, work in South Africa has shown that vacuum packing will preserve faeces for FECs for up to 3 weeks at room temperature. In lab trials faecal samples that were either vacuum packed and maintained at ambient room temperature (~18-30°C), were compared with others that were not vacuum packed and maintained either under refrigeration or at the above ambient room temperature, from which it is clear that vacuum packing was very effective for faeces preservation for up to 3 weeks for FECs (Fig. 1, left, below), but that unfortunately, the worm eggs failed to hatch after a period of a few days at ambient temperature (Fig. 2, right, below).

**Figure 1 (left) and 2 (right):** Respectively faecal egg counts and numbers of infective larvae of *H. contortus* recovered from faecal cultures (*Van Wyk, unpublished EU PARASOL report, 2008*)
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Goat–Parasite Interactions: from Knowledge to Control - The European Union COST Action CAPARA

Sotiraki, S. 1, Hoste, H. 2

1 Veterinary Research Institute, HAO-Demeter, Thermi, 57001 Thessaloniki Greece  
2 UMR 1225 INRA/ENVT, Ecole Nationale Vétérinaire de Toulouse, 23 Chemin des Capelles, 31076 Toulouse Cedex, France

Sustainable and fully integrated within the local rural development, goat farming plays a key environmental role. It aids the natural upkeep of less fertile areas and the preservation of environmentally fragile ecosystems. Natural spaces, such as pastureland, have been preserved for centuries thanks to such farming. The goat population is expanding rapidly because of goats’ economic value as efficient converters of low-quality forages into quality products, and thanks to farmers’ determination to be self-sufficient where resources are limited.

One of the main threats to outdoor breeding of goats is parasitism. Goats and sheep are infected with the same parasitic species. They provoke similar pathophysiological changes and economical consequences. However, until now, the majority of data on the host–parasite interactions have been accumulated from ovine studies. Comparison of the interactions between parasites in sheep and goats illustrates how the inference of data acquired from one small ruminant species compared to a second one can lead to errors. This sometimes causes dramatic consequences in the control of these infections. It also illustrates alternative potential approaches for control. If exploiting the immune response combined with strategic treatments seems an efficient option in sheep, exploiting the feeding behavior, including the potential to self-medicate on natural resources might be as valuable in goats.

CAPARA is an EU COST* Action (FA0805) which has been launched in 2009 to set up a multidisciplinary network of research teams. More precisely, the main CAPARA objective was to establish a network of European researchers working on various aspects of goats parasitology and health management to advance towards a better understanding of the different components explaining the specificities of goat-parasite interactions as well as to develop sustainable strategies to control parasitic diseases in goats. Moreover CAPARA aims to create links with other countries worldwide either because of the importance of goat production and/or because of similar approaches of control developed in sheep. CAPARA was presented as an instrument to diffuse the current state of knowledge of European groups towards developing countries. This Network has been in a large scale created including 33 countries in Europe and beyond (i.e. North Africa, South America, Australia, New Zealand) plus worldwide established connections with Mexico, USA, Canada, Brazil, Malaysia and others.

The Teams within the network are working on ways to a) propose improved integrated methods of control specifically adapted to goat parasite infections; b) provide better recommendations on the use of antiparasitic drugs resulting in reduced drug abuses and improved animal welfare at the farm level; c) harmonize drug regulations according to EU legislation; d) improve goat breeding and support EU policy for traditional farming and e) preserve the landscape, territory and European culture.
The project has been organized in Working Groups (WG) and Tasks as follows:

**WG 1: Specificity of goat behavior and epidemiology of parasite infections**

**Task 1: Specificities of goat behavior and parasite infection**
Goats are particularly a suitable host model to study parasite infection because of their diversity of food selection, their ability to exploit both grass and shrubs, and their adaptation to rangeland environment. The specificities of goat behavior are being studied in order to determine how this factor influences the pattern of infections, in terms of type, prevalence, and abundance of parasitic species. On the other hand, the goat behavior is being studied also taking into consideration the consumption of natural compounds (e.g. tannins), presenting antiparasitic properties.

**Task 2: Epidemiology of parasite infections in goats in Europe**
At present there are various ongoing epidemiological studies of goat parasitic diseases in partner countries. This is relying on the satellite based technologies and a special team has been created in order to coordinate those studies and exploit results under the title “Use of GIS technology for epidemiological studies”.
In addition, a wide questionnaire has been set up by one of our colleague from Italy to indentify extensively the occurrence and frequency of the main ecto and endo parasites of goats present in Europe. This project will soon create a map with all parasites of goats in Europe.
Last some surveys have been (or are planned) implemented to first examine or to complement the current data on the status of AH resistance in Europe.
Results of both approaches will provide a basis to identify the emergence and/or progression of parasitic agents within Europe and to understand better how the environmental changes contribute to the evolution of such phenomena.

**WG 2: Goat immune response to parasites. Pathological consequences**

**Task 1. Adapted diagnosis methods for caprine parasitic diseases.**
The diagnostic techniques for ruminant parasites are well-standardized in cattle and sheep but the tools available to diagnose parasitic infections for goats are much less developed and are generally relying on techniques standardized in sheep.
The objective of this task is to validate and standardize diagnostic techniques for goat parasitic diseases in caprine models, in order to improve the diagnostic tools, to study the immune responses and the dynamics of parasites in goats.

**WG 3: Pharmacokinetics and efficiency of Ahs**

**Task 1: Sustainable use of antiparasitic drugs in goats.**
To provide better recommendations on the use of antiparasitic drugs resulting in reduced drug abuses and improved animal welfare at the farm level;
To meet this objective it has been prioritized to test the presence of AH resistance in worm populations in goats. For this reason we are launching a FECRT ring-test between CAPARA laboratories which will follow by a field based FECRT.
Task 2: Commercial use and registration of antiparasitic drugs
This Task has been created in order to support the harmonization of drug regulation for a so-called minor species other than the main livestock species used in animal production. To meet this objective a special Team (Group) has been created under the title “The Use of antiparasitic drugs in goats in Europe”. An ongoing activity of this Team is a questionnaire survey between CAPARA members in order to define which compounds and under which scheme have been used so far nation-wide in goats. The data for this task have been collected and they are currently analyzed.

WG 4: Sustainable control of parasite infections in goats.

An integrated sustainable control of parasites supposes the evaluation of innovative methods of control assimilating the specificities of the goat-parasite interactions.

Task 1. Specificities of browsing caprine behaviour and use of non conventional, natural compounds with antiparasitic properties.
The need to find novel approaches to control parasites has given a strong, recent impetus to the scientific exploration of the antiparasitic properties of natural plant compounds. The highest ability of goat to tolerate the consumption of plant secondary metabolites compared to sheep means that a large range of plants deserve to be examined for their potential activities. This will be measured based first on in vitro screening methodologies, then in vivo experimental studies. Last, it will be validated in conditions of farm production. Hence, controlled and field trials with local breeds of goats are being carried out to identify and evaluate local bioactive plants containing secondary metabolites with antiparasitic properties.

The objectives of this task are also the standardization of methods to identify and characterize the active components, the understanding of the mode of action of plant-derived bioactive compounds, and the evaluation of the most beneficial methods to exploit those bioactive forages. Guidelines for field and laboratory assays for efficacy studies will be produced. Practical application of this knowledge in European countries would support integrating productive improved pastures with high nutritive value and natural vegetation that contribute to achieve sustainable goat production systems.

Collaborative studies within this task have led to the identification and or confirmation of natural compounds with AH properties against GINs especially in the Mediterranean area. Additionally some studies indicated that some of these substances might affect not only GINs but also the coccidia in kids. Also this approach has lead to a better understanding of the interactions between the caprine behavior, the efficacy of some plants and plant secondary metabolites and the activity against parasites.

The expected results of CAPARA are to generate direct data useful for goat industry and to provide comparative insights to better understand the balance between the various regulatory mechanisms to counteract parasite infections and how they interact depending on the host species. Overall, CAPARA aims at delivering holistic approaches including analysis of the host-parasite relationships and integrating environmental factors such as providing goats with the ability to browse.
*COST (European Cooperation in Science and Technology) is Europe’s longest running intergovernmental framework in science and technology cooperation, providing funding for cooperative research networking projects called ‘Actions’. Funded by the EU’s 7th Framework Programme, COST mobilises and connects extraordinary scientific potential within Europe and beyond.
A New Paradigm for the Control of Gastrointestinal Nematodes in the Tropics

J.F.J. Torres-Acosta¹, C.A. Sandoval-Castro¹, H. Hosté², P. Mendoza-de-Gives³, M.A. Alonso-Díaz⁴, A.J. Aguilar-Caballero¹, N. Ojeda-Robertos⁵, J.J. Vargas-Magaña⁶, J.I. Chan Pérez⁷, P. González-Pech¹.

¹FMVZ, Universidad Autónoma de Yucatán, Km 15.5 Carr. Mérida-Xmatkuil, Mérida, Yucatán, Mexico
²INRA UMR 1225 Interactions Hôtes Agents Pathogènes. 23 chemin des Capelles F-31076 Toulouse Cedex, France
³Université de Toulouse, ENVT. 23 Chemin des Capelles. F-31076. Toulouse, Cedex, France
⁵CEIERT-FMVZ, Universidad Nat. Autónoma de México, Km. 5.5 Carr. Federal Tlapacoyan-Martínez de la Torre, C.P. 93600 Veracruz, Mexico
⁷ESCA, Universidad Autónoma de Campeche, calle 53 s/n Escárrcega, Campeche, México.

Introduction

Sustainable production of sheep and goats in the tropics is possible. However, it will depend on respecting the balance between the quantity of foliage harvested, without affecting the field, and animal production. If the balance is right, the number of gastrointestinal nematodes (GIN) in the field and in the animals will be easy to tolerate by the animals. However, most production systems are still trying to obtain the highest production possible per hectare. As a result, the producers still rely heavily on commercial anthelmintic (AH) drugs to sustain such productivity. The problem of anthelmintic resistance (AR) is becoming more common in the humid and sub-humid tropics of Mexico. Thus, we need to reduce our dependence on conventional drugs. In the last 20 years Mexican researchers have investigated different alternative measures to control GIN in small ruminants. In this paper we summarize the work performed in Yucatán with different research groups in México and other countries of the world.

Anthelmintic Resistance in Mexico

Although the first cases of AR resistance were found early in the 1990’s, the first trials showing the number of farms with resistant worms were published in the first years of the 21st century (Torres-Acosta et al., 2012a). The current situation is still worsening and recent evidence shows that AH drugs fail to work in many farms of the humid tropics of Mexico. Thus, practical alternative measures to substitute commercial drugs are urgently needed.

What is More Important: Undernourishment or Parasitic Infection?

Practical field experience obtained from sheep and goats in the tropics of Yucatan showed us valuable lessons:
a) Animals require sufficient hours for browsing, even in the dry season. In the tropical deciduous forests it is not practical to "cut and carry" fodder even for a small herd. Thus, it is better to allow the animals to harvest their own food.

b) A reduction in feeding time immediately affects sensitive aspects such as milk yield. The recovery to "normal" production levels is unlikely even when feeding was re-established, similarly to what has been observed in other grazing-supplemented lactating cows.

c) Under the conditions of Yucatan, ruminants cannot satisfy their appetites only by grazing/browsing. Thus, supplementary feeding is needed.

d) A relatively small proportion of animals are clearly affected by undernourishment or GIN infections. However, it is difficult to define which of the two problems was more important.

With such background information, it was decided to start exploring the nutrition-parasite interactions under the browsing conditions of Yucatan. The first field trials showed that the negative effects of undernourishment and GIN infections (Haemonchus contortus, Trichostrongylus colubriformis and Oesophagostomum columbianum) were both affecting production and survival of kids almost equally. Those studies confirmed the positive economic benefit of supplementary feeding (improved resilience against GIN) during the wet and the dry seasons (Torres-Acosta et al., 2012b). After those first attempts, other studies showed that supplementary feeding was needed at all times during the year. Thus, undernourishment and GIN infections need to be tackled by constant supplementary feeding, and no carry-over effects can be expected (Aguilar-Caballero et al., unpublished).

Energy Supplementation and Resilience against GIN

Early field and pen trials were based on supplements containing protein or energy and protein. However, based on the conditions of the vegetation of Yucatan (abundance of legume trees with a high CP content), it was expected that resilience against GIN could also be improved by using energy feedstuffs (i.e., maize grain, sugar cane molasses). Field trials confirmed that energy supplements improved resilience against GIN in browsing goats and sheep (Retama-Flores et al., 2012). The effect was explained as the result of balancing both N and energy supply in the rumen.

Non-conventional Anthelmintic Materials

Copper oxide wire particles (COWP) were tested as non-conventional AHs against GIN in sheep and goats of Yucatan. The idea was to combine the COWP with the supplementary feeding to improve further the positive effects of energy / protein supplements. Trials in Yucatan showed that the improvement of resilience, above that of supplementary feeding alone, was not evident (Martinez-Ortiz-de-Montellano et al., 2007). Thus, the economic viability was unlikely. In spite of the modest effects on resilience, COWP showed to have a long persistent effect against H. contortus (at least 35 days post-treatment) (Galindo-Barbosa et al., 2012).

The direct AH effect of plant secondary metabolites from tropical plants (particularly condensed
tannins) against GIN, has been explored in Mexico in collaboration with the research group in Toulouse, France. The first in vitro evidence of AH activity of tropical tannin rich (TR) extracts was obtained with French isolates *H. contortus* or *T. colubriformis* (Alonso-Díaz et al., 2008a, 2008b) and Mexican *H. contortus* (Hernández-Orduño et al., 2008). The evaluation of these extracts against Yucatan isolates showed a lower susceptibility in the latter compared to other isolates previously tested (Calderón-Quintal et al., 2010). In spite of the latter, the in vivo trials showed that the consumption of tannin containing fodders affected the biology of GIN by reducing the establishment rates of larval stages (Brunet et al., 2008) or reducing either the fecundity or size of adult female worms compared to those parasites exposed to control tannin-free diets. Worms exposed to TR materials under in vitro and in vivo conditions showed lesions in the cuticle, the muscles and the intestinal cells (Martínez-Ortíz-de-Montellano et al., 2013). Currently, the feeding behavior of ruminants in the heterogenous vegetation of the forests of Yucatan is being investigated. Those studies aim to determine the quantity and quality of the diet consumed by ruminants, including the content of condensed tannins. The effect of ruminant species (sheep or goats) and GIN infection, on the feeding behavior of individual animals, is also being explored.

**Reducing the Risk of Infectivity in the Field**

The collaboration with CENID-PAVET, Mexico, is directed to explore the use of the Mexican strain of *Duddingtonia flagrans* against GIN. The efficacy of *D. flagrans* against natural GIN infections in goats was the first contribution. Later, the McMaster technique was found suitable to determine the number of spores reaching the feces of sheep (chlamydospores per gram of feces or CPG). This tool and other in vitro studies helped to confirm that a large proportion of spores dosed per os are destroyed in the digestive tract (nearly 90%) (Ojeda-Robertos et al., 2009). According to recent studies, the best proportion of spores:nematode eggs was 10:1 and a larger quantity failed to improve the trapping efficacy of *D. flagrans* (Ojeda-Robertos et al., 2008). The addition of chlamydospores into feed pellets as a practical spore-dosage mechanism is currently being investigated. The shelf-life studies (under refrigeration, room temperature and outdoors) showed that the spores contained in the pellets maintain the predatory activity against *H. contortus* L₀ for up to 8 weeks. The combined effect of spores and nutrition provided from the pellets is currently being explored.

**The Combined Targeted Selective Treatment (cTST) Scheme**

Although GIN infections in sheep and goats from Yucatan is present in more than 95% of the individuals, the majority of these animals show mild infections (Fecal egg counts) and only a small proportion of the population show high egg counts. Thus, a TST scheme seemed feasible in theory. In collaboration with Gareth Bath and Jan Van-Wyk, allowed to explore the use of FAMACHA® in goats and sheep of Yucatán. We showed that FAMACHA® and Body Condition Score helped to detect those animals at risk of suffering severe GIN infection. Those criteria can be used to choose animals for a fecal sample. The studies suggest treating with an efficacious AH drug only those animals above certain quantity of EPG (Torres-Acosta et al., sent for publication). This information can also play a vital role in the construction of breeding schemes based on the selection of those animals needing least number of AH treatments per year while producing lambs or kids as well as milk.

92
Conclusions

The search for novel approaches for the control of GIN of small ruminants has produced promising results. The work performed in Mexico has shown that it is feasible to reduce the dependence on conventional AH drugs. However, it is important to realize that the control will need to rely on a variety of tools, and each farm will need to adopt different tools according to the resources available. At present we are moving from the development of different tools to the application of those tools at farm level.

References


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