Breeding for Parasite Resistance

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Wisconsin Sheep and Wool Festival
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Outline

- Background
- Our Approach
- Fecal Egg Counts
- Breed Data
- FEC EPDs
- Immune Competence
- Strategies

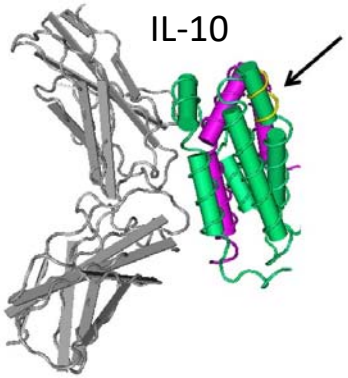
Background

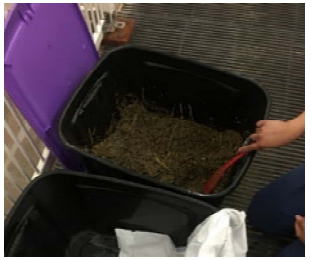
- 1990s Antoniewicz Open Lambing Barn, Shearing Barn assistant, sheep research
- Owned sheep since 2001, goats since 2008
- Always forage-fed, used for vegetation management
- UW-Madison: B.Sc. Wildlife Ecology 2000, M.Sc. Agroecology 2019, Dissertator Dairy and Animal Sciences 2020
- Taught AnSci Lab, UW Short Course grazing, organic small ruminants, many invited presentations at conferences, hosted pasture walks
- 130 acre farm, Dodgeville, WI
- 150 sheep, 150 goats, 53 horses, 7 adult LGDs, 2 donkeys, 30 layers

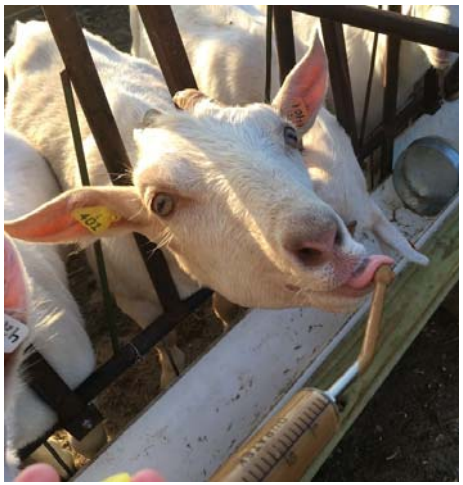
Sheep research
Glitter on corn, fed to sheep, to estimate transit time and duration of glitter passing; model for CWD spread from piles of deer corn. Sheep in harness diapers to collect glitter poo at UW-Madison.

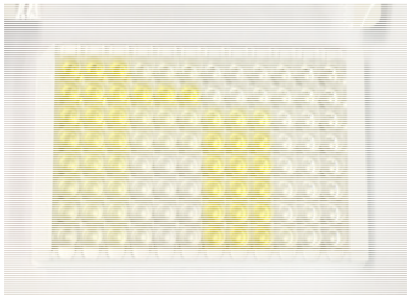
Egg-based Antibodies Against Goat, Beef Parasites

- Doctoral research
- Nutrition
- Immunology
- Parasitology



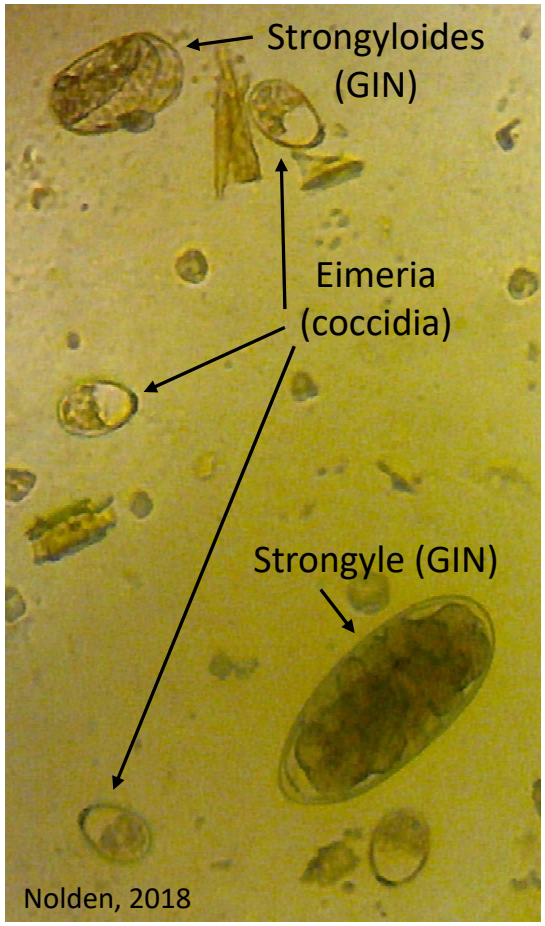






Gastrointestinal Nematodes (GIN), Helminths

- Major constraint of small ruminant livestock production[1]
- Significant economic loss to ruminant production worldwide[2]
- Treatment with synthetic chemical molecules has become less efficient due to the GIN's acquisition of resistance to these molecules[3]
- New approaches are needed
- Parasite resistance linked to immune competence[4]



[1]Jackson and Coop, 2000; Hoste et al., 2010; Mavrot et al., 2015.
[2]Grisi et al., 2014; Perry and Randolph, 1999
[3]Jackson and Coop, 2000; Kaplan, 2004; Papadopoulos et al., 2012; Mahieu et al., 2014.
[4] Bowdridge et al., 2024, 2025

What is Parasite Resistance in Sheep?

- Sheep's immune response to a parasite infection:
  - Resists becoming infected by parasites
  - Reduces the fecal egg count produced by those parasites, and the negative impact of the infection on the sheep
  - Does not fully clear the parasite infection; natural and needed
- Different from Resilience:
  - The ability to withstand an infection by parasites
  - Sheep's immune system and plane of nutrition can tolerate a parasite load that sheds a high egg count in the manure with minimal negative effects.
  - Problem: high shedding = high pasture contamination, stress = parasites become a problem
- Different from Dewormer Resistance – This is referring to the worms; the worms are resistant to being killed, paralyzed by the dewormer
  - Created by overuse of simple chemical dewormers
  - Adaptation of parasites to simple environmental toxins
  - Parasites have not become resistant to immune response due to it's complexity

Benefits of Resistant Sheep

- No need to deworm, or minimal
  - Save time (handling, checking, deworming)
  - Save $ on inputs (dewormer chemicals, herbs, pasture plants, fungi, eggs)
  - Reduce chemical resistant population of worms
    - Easy and inexpensive recovery of affected sheep
- Low cost feed: pasture, that doesn't concern itself with avoidance grazing
- Improved health of sheep; correlation of lambs bred for low parasite susceptibility are also less prone to mastitis, foot rot, and being culled for other health problems
- Improved lamb growth
- Marketing advantages
  - Organic, grain-free, regenerative

https://www.davis.wvu.edu/news/2022/03/11/sheep-vs-parasite-how-immune-responses-in-sheep-breeds-can-improve-the-species

What would that level of increase look like in reality?

If we are feeding Corn/SBM mixed at 14%CP then MP = 9.6%
To achieve requirements by feeding Corn/SBM alone you'd need:

	Normal Ewes		Parasitized Ewes		
	MP Req (lbs)	Feed Req (lbs)	MP Req (lbs)	Feed Req (lbs)	Normal vs Parasitized
Late Gestation	0.31	3.2	0.51	**5.3**	**+2.1 lbs**
Early Lactation	0.49	5.1	1.2	**12.5**	**+7.4 lbs**

WV EXTENSION

April 2025 Dr. Bowdridge https://youtu.be/jYQcijycbYY?si=03fcpD5b5yDwmcwY

Parasite Resistance

- Low Fecal Egg Count
  - Heritability 0.05-0.55, moderate
    - 0.2-0.3 ave for wool breeds
    - 0.48-0.54 for Katahdins
  - Variable mechanisms by breed and selection history
  - Range of resistance in every breed
    - Selectable: 15 years in AU Merinos, 50% improvement
    - 20,000-30,000 epg FEC documented
  - Immune Competence
- Environment
  - 70-80% of effects in wool breeds, 46-52% in Katahdins
  - Forage/Feed quality, protein
  - Water/minerals/vitamins/salt
  - Diseases
  - Humidity, heat, season length
  - Pasture management/confinement/Avoidance grazing
  - Stressors (predators, ammonia, etc)

https://katahdins.org/wp/wp-content/uploads/2023/02/notter_etal_historicepdforpr_2007.pdf

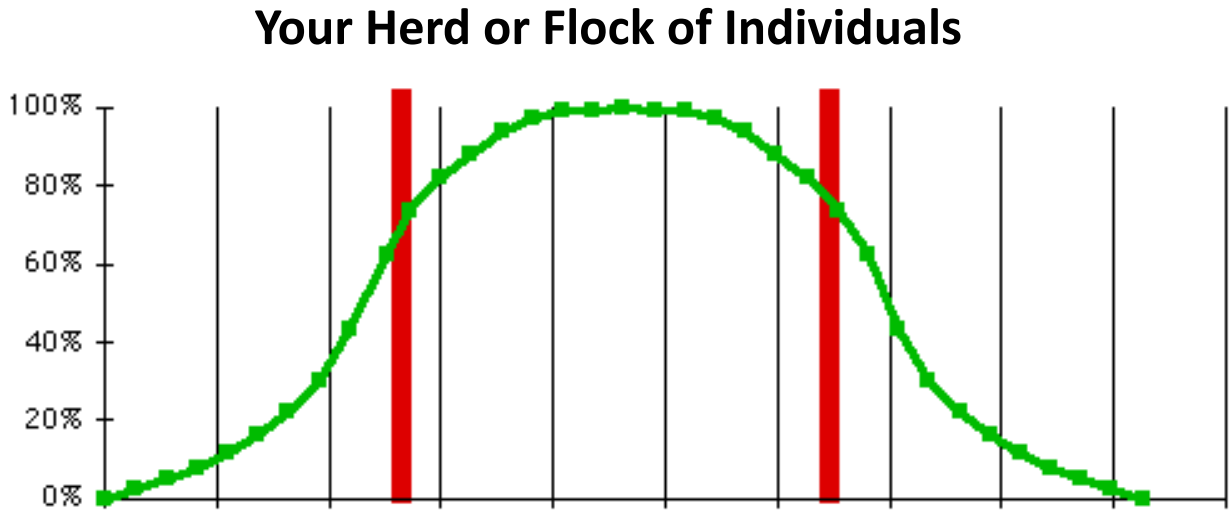
https://www.apsc.vt.edu/content/dam/apsc_vt_edu/extension/sheep/programs/shepherds-symposium/2010/04_strategies_for_genetic_improvement.pdf

Our Selection Approach

- Observe our animals, identify goals
- Manage how we want to manage, not avoidance grazing
- Grow our flock mostly from within
- Cull heavily
    - Fit animals to our environment and management
    - No deworming, hoof trimming, health treatments, birthing assistance, jugs, flushing, grain, castrating, disbudding, tail docking, boluses, injections, etc.
- Buy young, low-cost rams from similarly managed flocks
- Test them for 1-2 years in our system before using them to breed
    - Expose to heavily parasitized pastures, graze short, lambs, ewes and rams challenged (not just rams, like many people do)
    - Most are culled before breeding
    - Still spend less than the $2-7k pricetag of rams with FEC EBV data
    - Have not been tracking FEC recently, may start again
    - May order larvae for challenge test – Dr Bowdridge
    - Won't likely use ELISA CD&T titer indicator (we don't vaccinate due to hardly any cases of tetanus or clostridum over a decade of not vaccinating, and our treatment for our very few tetanus cases works well)
- Assess offspring of challenged rams and ewes in the same manner

Genetic Selection

- Rarely simple traits
- Given same context:
- Given same cohort:



Metabolic efficiency:	Poor-doers	Average	Easy-keepers
Parasite effects:	Affected	Average	Not affected
Parasite egg count:	High	Average	Low
Hooves:	Ski/flared	Average	Never trim
Temperament:	Reactive/aggressive	Average	Calm/easy/cooperative
Post-ingestive feedback:	Under-consume	Responsive	Over-consume
Birthing:	Required assistance	Average	No assistance
Accept kids/lambs:	Required assistance	Average	No assistance
Raised to weaning:	All died	Average	Raised all kids
Mature size/ADG	Small (<80 lb, <0.1 ADG)	Moderate	Large (>170 lb, >0.6 ADG)
Teat shape	Small/no orifice	Average	Torpedo/blown
Multiples w/o flushing	Single	Twins/triplets	Quads

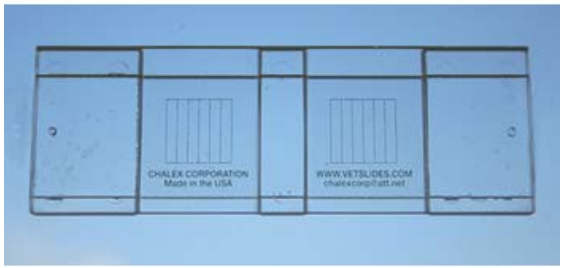
How to Test for Desired Traits – Genetic Selection

Example – Parasite Resistance

- Stop deworming individuals unless they show negative effects of parasite infection:
  - Indicators: a combination of bad coat, bad body condition, lethargic behavior, ears/head down, poor FAMACHA score, poor rumen fill, frequently sick, and/or scouring, slow growth, don't settle, flounder post lambing, poor milk production with a high fecal count
- Pull out individuals that need deworming, or do an inoculation challenge
  - Manage them in an area that can be decontaminated or won't be grazed by the good members of the flock because the parasites they shed will be more resistant to whatever chemical dewormers you used
  - Consider feeding BioWorma to this small group to reduce pasture contamination
  - Cull these individuals, or breed them to a much better ram and only keep the lambs that inherited the better traits
- Watch for individuals that continue performing well
  - Keep these for breeding and producing the future flock
  - Send those through a contaminated, overgrazed pasture to expose them to parasites
  - Keep the individuals that aren't excessively negatively affected, don't need to be dewormed, and have low FECs
- Select offspring that perform well in those same challenging conditions
- Select offspring that are better than their parents
- Do this selection every generation
  - Although parasite resistance is heritable, not all kids from great parents will inherit the good stuff and they need to be culled
  - Grow the herd from those who inherited the traits you want

Fecal Egg Count Procedure

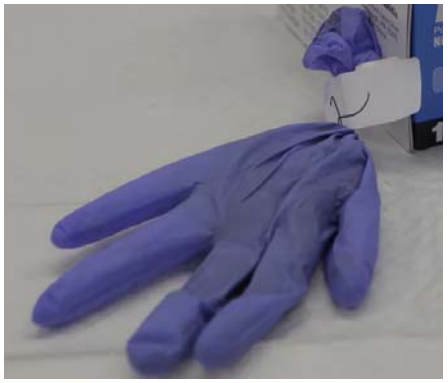
- Supplies



McMaster Slide, $22
https://www.vetslides.com/2-chamber-slides

100x (10 x 10)
Adjustable stage
Light below stage

40x-1000x
Advanced ...
$124.98
AmScope



Disposable Slides, coverslips, $10, slightly different procedure, longer count time/animal or per sample
http://www2.luresext.edu/goats/library/fec.html, Video on FEC procedure: https://youtu.be/ZZQymZKe_hs?si=gI8sKdc3nqWZMtNQ

Labs for Low Cost FEC testing

Texas A&M AgriLife Research and Extension Center

c/o Dr. Jake Thorne

7887 US Highway 87 N

San Angelo, Texas 76901

(325) 653-4576

$5/sample

Virginia Tech

Ramirez Parasitology Laboratory

c/o Roger Ramirez-Barrios

Center for One Health Research

1410 Prices Fork Road

Blacksburg, Virginia 24061

parasites@vt.edu

$7/sample

West Virginia University

Division of Animal and Nutritional Sciences

c/o Dr. Scott Bowdridge

1194 Evansdale Drive

2213 Ag Science Bldg.

Morgantown, WV 26506

(304) 293-2003

$5/sample

https://www.wormx.info/lowcostfec

Breed Differences in Parasite Management

- Texel, Suffolk, St. Croix, Katahdin
- Low FEC mechanism
  - Minimize L3 larvae attachment, St. Croix
  - Minimize adult larvae egg production, Texel
  - Suffolk rarely have either strategy; high FEC
  - Katahdins can have low or high FEC
- Low FEC sheep resist other diseases better
  - Hoof rot, mastitis, clostridium, LPS recovery
- Serum IgA important for resistance
  - High protein diet and minerals needed

https://onlinelibrary.wiley.com/doi/10.1111/pim.12876, Dr Bowdridge research

Genetic Selection

501 Scottish Blackface lambs, 1 month old

Sampled monthly for 6.5 months

Ostertagia circumcincta predominant, 25/lamb measured

Worm fecundity limitation is heritable

- Host heritability of worm length is highly heritable at h^2=0.62 ± 0.20
- Worm length is correlated with egg production (r=0.7, P<0.0001)
- Host heritability of number of parasite eggs per worm is highly heritable at h^2=0.55 ± 0.19
- Host immune function limits worm length and fecundity, via quantity and specificity of parasite-specific IgA
- No evidence that number of worms is influenced by the host h^2 0-0.14

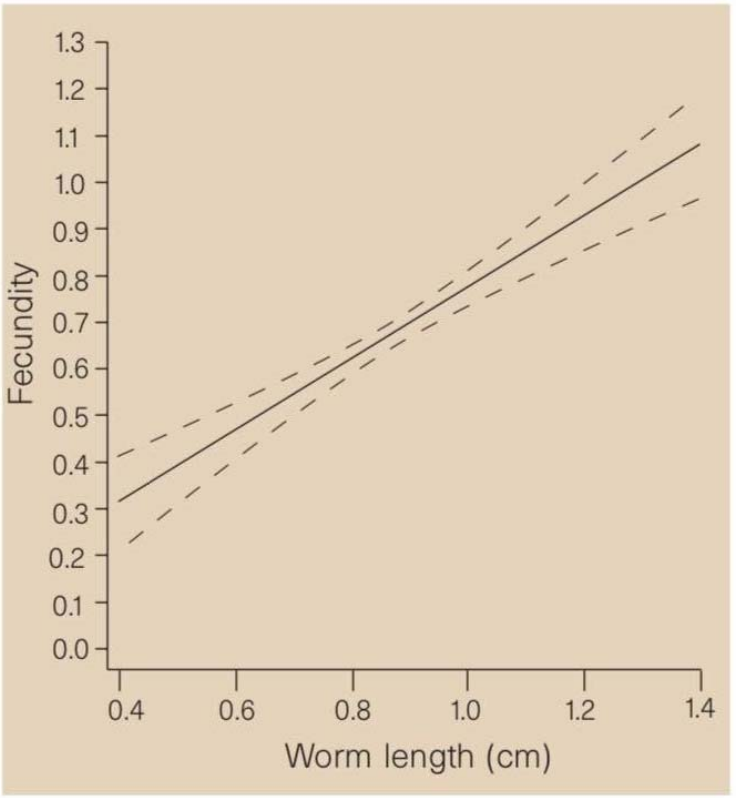


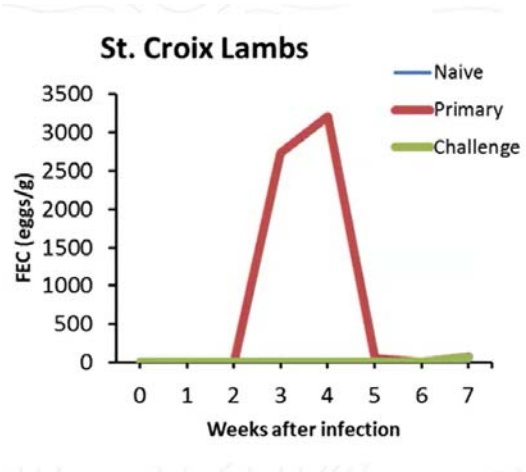
Figure 1 Relationship between worm fecundity and mean worm length. Fecundity was estimated from the log-transformed faecal egg count at slaughter divided by the log-transformed adult worm burden. The 95% confidence limits are shown.

Stear et al., 1997. How hosts control worms. Nature.

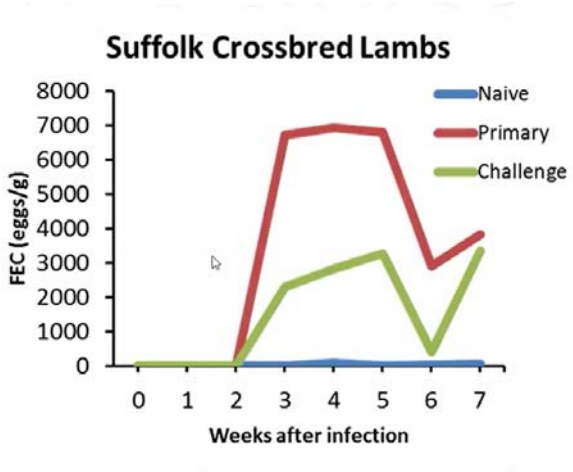
Image courtesy of Dr. Ruthanne McCaslin

Breed Our Way Out of Parasite Problems

- Development of genetic resistance values (FEC EBV) facilitates sustainable pasture-based and organic sheep production
  - Reduces GIN infection
  - Reduces need for deworming
  - Coupled with growth, reproductive and maternal traits, permits development of economically productive, parasite-resistant flocks



- Innate immunity takes care of Primary exposure
- Adaptive immunity prevents FEC spike with subsequent challenge



- Innate immunity allows 2x FEC with Primary exposure
- Adaptive immunity allows large FEC spike with subsequent challenge

https://projects.sare.org/media/pdf/O/S/1/OS19-124-Journal-Article.pdf

United Suffolk Sheep Association, 9-17-2024 webinar, https://youtu.be/UxYLADnfToY?si=EHr_Gw_gKsKxqLg3

NC STATE EXTENSION

Estimated Breeding Values

- Predictor of genetic merit
- Numerical representation of genotype
- More accurate than:
  - Raw performance data
  - Adjusted performance data
  - Ram tests
- Best tool in the toolbox
- "Estimated" not "true" breeding value
  - Associated accuracy value

NSIP National Sheep Improvement PROGRAM

Phenotype = Genotype + Environment

May 2025 EAPK Webinar - Understanding EBVs for Katahdin Genetic Improvement https://youtu.be/D1Vmgh4lBP8?si=frMvGrNnHhJKeWLN

NC STATE EXTENSION

Phenotype = Genotype + Environment

Breeding Value =

Selection Differential X Heritability

Breeding Value =

Selection Diff. X (Genotype / Phenotype)

We are left with the genetic difference between an individual and its contemporaries

May 2025 EAPK Webinar - Understanding EBVs for Katahdin Genetic Improvement https://youtu.be/D1Vmgh4lBP8?si=frMvGrNnHhJKeWLN

NSIP: FEC Estimated Breeding Value

- **What Data to Collect:**
- There are 2 different Estimated Breeding Values (EBVs) for parasite resistance offered to members of NSIP:
  - These EBVs are reported as a *percent reduction* in fecal egg count relative to the base average of the respective breed at the particular time period.
  - Weaning Fecal Egg Count (**WFEC**) (**42-90 days of age**)
  - Post Weaning Fecal Egg Count (**PFEC**) (**91-304 days of age**)
  - Fecal egg counts reported in **eggs per gram** as determined by McMaster Method.
  - Ensure lambs have been exposed to parasites at least 3 weeks prior to collection. Need min 500 epg cohort average.

Protocol downloadable at: http://nsip.org/nsip-resources-2/estimated-breeding-values/

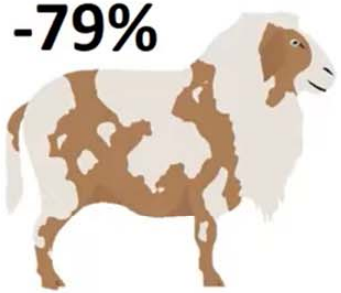
NC STATE EXTENSION

Lets compare a ram at the 90th percent to one at the 50th percentile....

Weaning Fecal Egg Count EBV

WFEC Expected Progeny Difference

-79%



-39.5%

EPD = (½)EBV

Expected FEC difference between lambs sired by these rams is 20%

-39%

-19.5%

13

May 2025 EAPK Webinar - Understanding EBVs for Katahdin Genetic Improvement https://youtu.be/D1Vmgh4lBP8?si=frMvGrNnHhJKeWLN

Example of Genetic Change

100 Katahdin ewes with a avg. FEC of -30

Purchased a ram with -80 FEC

GC=(-80+-30)/2=-55 FEC in resulting lamb crop

Kept all the daughters, purchased another -80 ram

GC=(-80+-55)/2= 67.5 FEC

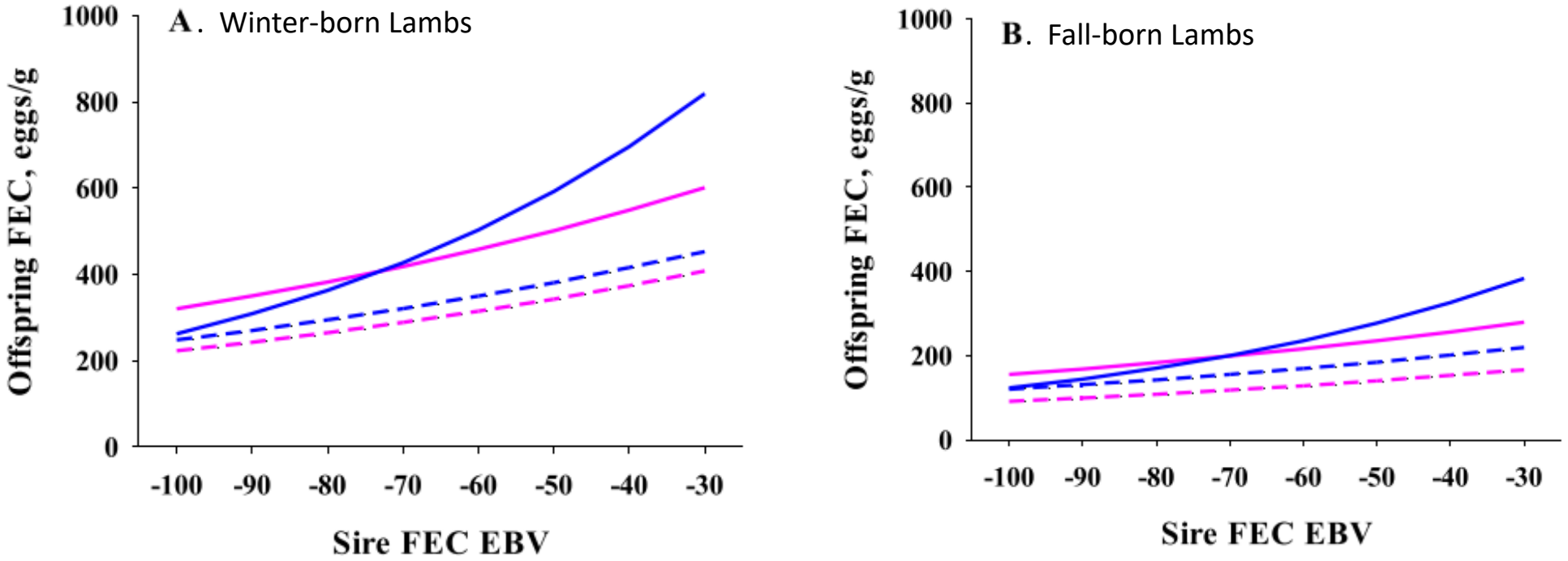
Selection differential of mature ewe verses ewe lambs

SD=(55-30)= 25

April 2025 EAPK Webinar - The Value of Genetic Selection in Katahdin Sheep https://youtu.be/Dwsv1I1c1UY?si=JxYoZz-Lgjq6SFG5

Lamb FEC vs Sire Weaning FEC EBV, Season

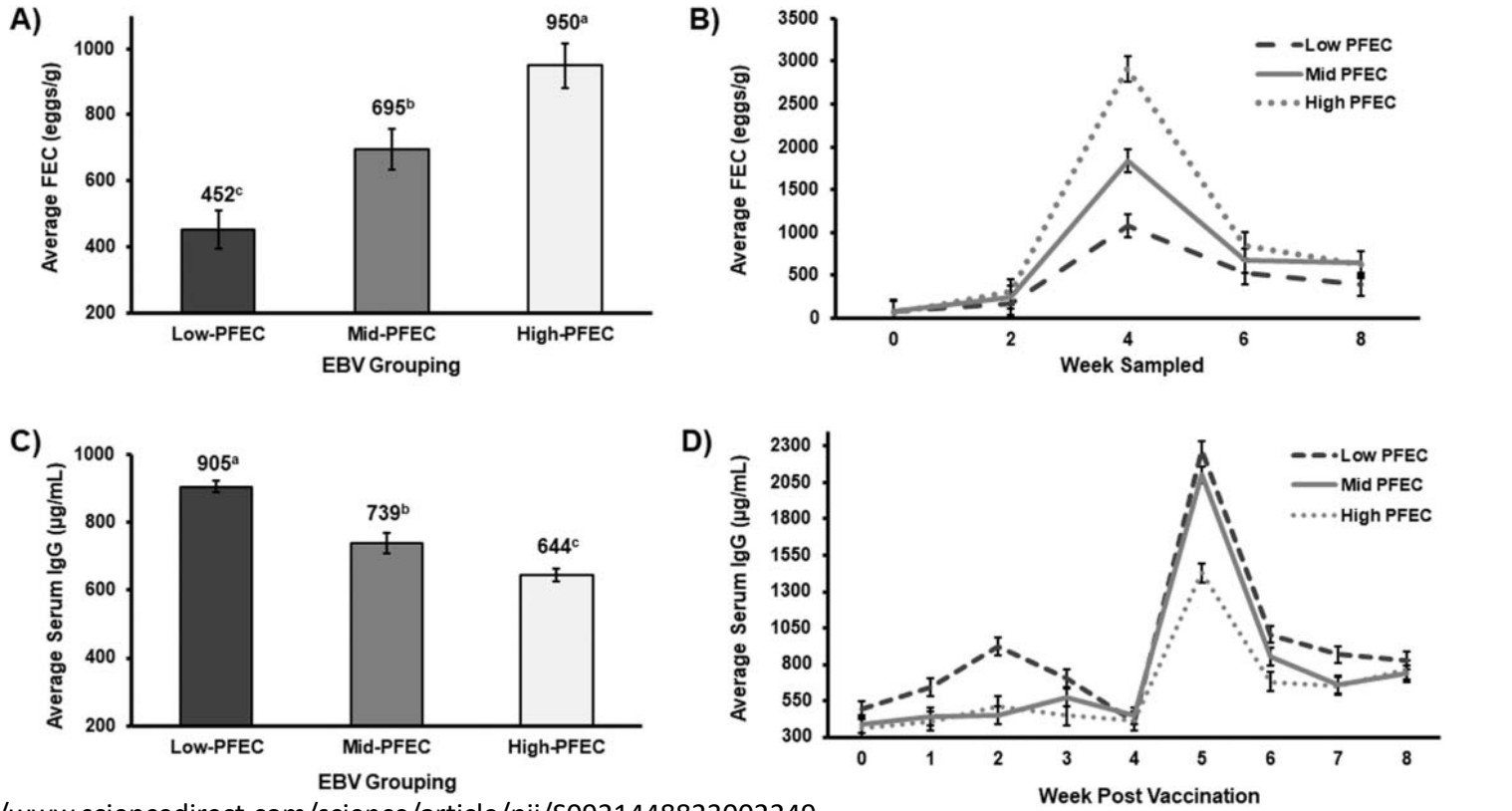
Performance-based EBV (WFECP; pink line)
Genome-enhanced EBV (WFECG; blue line)



There was a more rapid increase in FEC of offspring when sire WFEC (both pedigree and genomic) ranged between − 100% and − 70%, suggesting that selection of sires for GIN resistance was most effective among sires with the most extreme favorable EBV

Burke et al., 2022. Small Ruminant Research 216. https://projects.sare.org/media/pdf/O/S/1/OS19-124-Journal-Article.pdf

Dr. Bowdridge Research – FEC & Immune Function



https://www.sciencedirect.com/science/article/pii/S0921448823002249

Fig. 2. Average FEC and IgG of Katahdin lambs based upon PFEC (Post-weaning Fecal Egg Count) grouping.

(A) Average FEC of lambs by PFEC grouping. Different letters denote significance among the lamb PFEC groupings ($P < 0.05$).

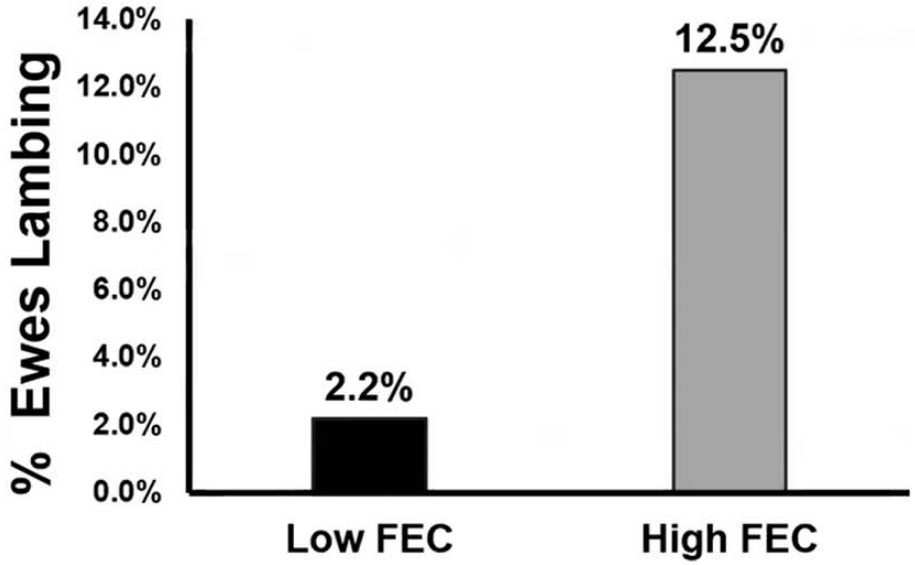
(B) Average FEC of lambs by PFEC grouping across week. All lambs were weaned on week 3.

(C) Average IgG (µg/mL) of lambs by PFEC group. Different letters denote significance among the lamb PFEC groupings ($P < 0.0075$).

(D) Average IgG (µg/mL) of lambs across weeks post vaccination by PFEC grouping.

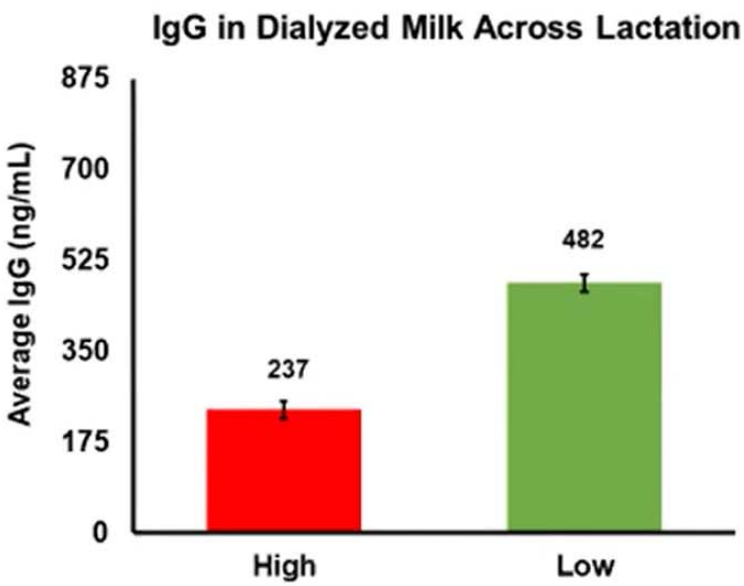
Culling based on mastitis in Katahdin ewes

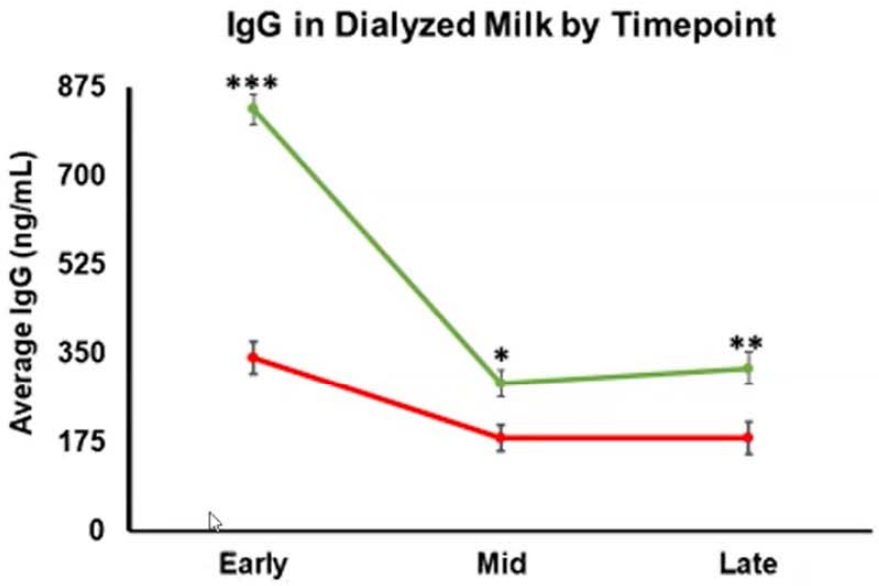
10.3% fewer ewes need culling for mastitis if they've been selected for low FEC



9/2024. United Suffolk Sheep Association. **Scott Bowdridge, West Virginia University.** https://youtu.be/UxYLADnfToY?si=qgHPvEtrnAvKwJ0J

Results – Milk IgG





Group	$P < 0.0001$
Time	$P < 0.0001$
Group*Time	$P < 0.0001$

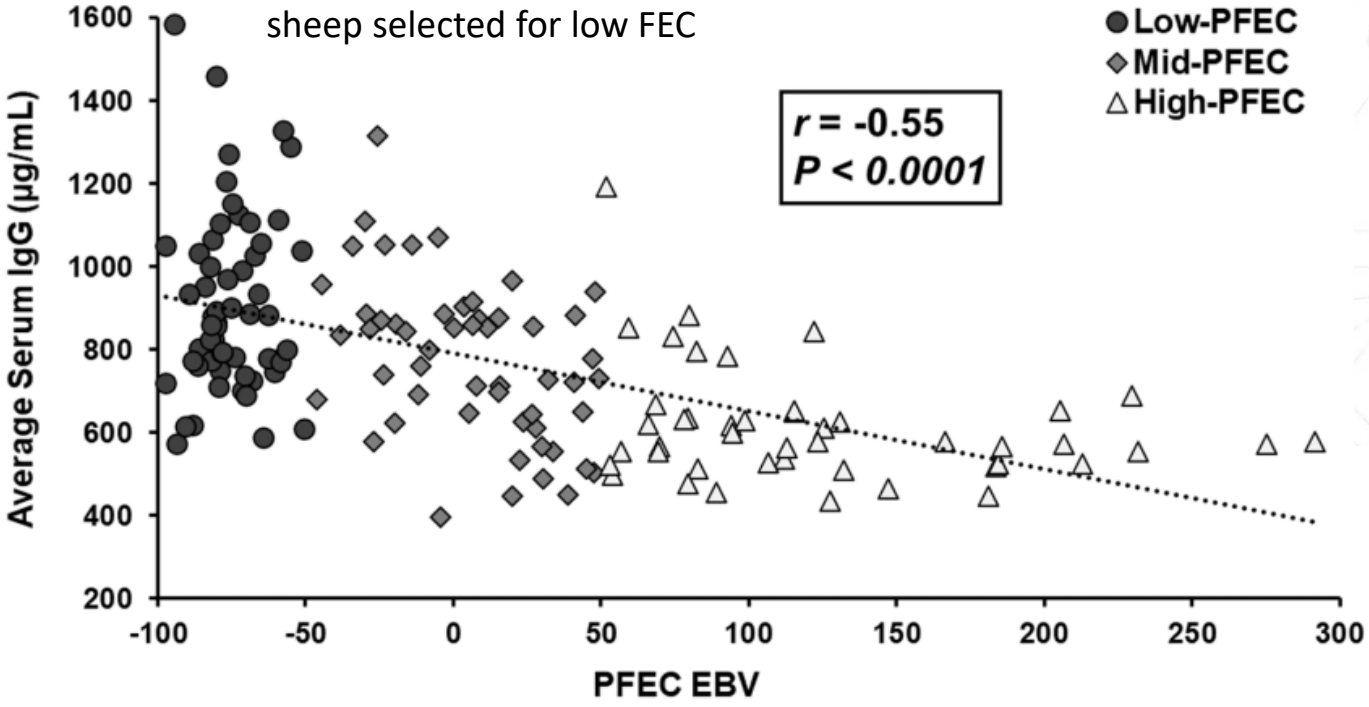
Colostrum and milk antibodies are significantly higher from ewes selected for low FEC

DAVIS COLLEGE OF AGRICULTURE AND NATURAL RESOURCES | SCHOOL OF AGRICULTURE AND FOOD SYSTEMS

9/2024. United Suffolk Sheep Association. **Scott Bowdridge, West Virginia University.** https://youtu.be/UxYLADnfToY?si=qgHPvEtrnAvKwJ0J

Dr. Bowdridge Research – FEC & Immune Function

Titer response to vaccination is higher in sheep selected for low FEC



- Serum samples have been collected from sheep with PFEC EBV:
  - Dorper sheep in TX
  - NC State Flocks
  - VT Glade Spring Flock
  - VA Producer (Katahdin)
  - All Rams on VT Performance Test
  - OH Producer (Katahdin)
  - Shropshire sheep in WI
  - University of Wisconsin Polypay Flock
- A lot of IgG ELISA's (@1,000 samples)

9/2024. United Suffolk Sheep Association. **There's more to parasite resistance than just worms. Scott Bowdridge, West Virginia University.** https://youtu.be/UxYLADnfToY?si=qgHPvEtrnAvKwJ0J

Fig. 3. Correlation between average serum IgG and lamb PFEC EBV value. Spearman's rank correlation to assess the relationship between total serum IgG (Y) and PFEC EBV (X) of Katahdin lambs. Different shapes denote the different grouping criteria for PFEC EBV.

https://www.sciencedirect.com/science/article/pii/S0921448823002249

Context for Parasite Resistance

- Metrics/Indicators/Factors
  - FEC post parasite exposure, EBV from NSIP
  - IgG titer response magnitude post stress, ELISA, immune competence
    - Correlated with FEC EBV, easier to measure? More reliable, less context-dependent?
  - Colostrum IgG, color intensity metric?
    - Pregnant ewe exercise 30 d prepartum improves colostrum and lamb serum IgG
  - Forage/Feed quality relative to metabolic need
  - Protein availability, adapted to need
    - RUP/Bypass, Alanine (BFT, lespedeza, fish meal, plantain, chicory, oak, aronia, etc)
  - Minerals and vitamins
  - Bioactive plant compounds, toxins
  - Humidity, heat, season length
  - Pasture contamination level, avoidance grazing management
  - Multiple parasite species; *H.contortus* or *coccidia* focus
- Single trait selection
  - Merinos in AU, resistance created, autoimmune issues
  - St Croix, natural selection, whole animal functionality
  - Texel, seasonal exposure, different mechanism than St Croix
- For us: Do they and their offspring survive and reproduce well?

https://library.ndsu.edu/server/api/core/bitstreams/ebffd976-3930-4c91-a261-b9a846687d22/content

Strategies

- Buy resistant sheep initially
  - Ram tests
  - EBV flocks
  - Other sheep graziers with similar selection criteria
- Improve existing flock
  - Breed to resistant rams
  - Retain offspring that inherited parasite resistance
    - Provide a parasite challenge
      - Natural infected pasture
      - Coproculture and dose a known number of L3 larvae
    - Recover challenged sheep
      - Deworm all and market those with high FEC
      - Deworm just the high count and retain low count lambs
  - Feed through bioworma or dedicate paddock to challenge area
  - Keep ewes exercising while pregnant

end, continue

A quote to ~~begin~~ our discussion

*"…after symptoms of this infection (Haemonchosis) have been seen, the time necessary for fattening lambs is greatly increased and requires the use of more expensive grains for finishing than in non-parasitized lambs…**therefore the prime requisite of economical sheep production is raising sheep that do not suffer from parasitism."***

Veterinary Helminthology (1949)

2015, Sustainable Appalachia webinar: https://youtu.be/lX9TT25A4VI Dr Scott Bowdridge

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Wisconsin Sheep and Wool Festival
September 5-7 2025