

Determining the Effectiveness of Types of Copper Against Sheep Parasites



Sayward, Melissa. Personal Photograph. 2013.

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ABSTRACT

The purpose of this project was to determine the effectiveness of different types of copper against parasites in Icelandic sheep. Due to the concern of copper toxicity in sheep, chemical anthelmintics, commonly called dewormers, became the method of choice for treating sheep parasites. Over time parasites have built up resistance to the chemical dewormers. Scientists are now recommending shepherds employ a varied approach for treating parasites, including the use of copper in the form of copper oxide wire particles. This project looks at the effectiveness of copper oxide wire particle (COWP) boluses and chelated copper in loose minerals to treat parasites in Icelandic sheep. We predicted that there would be a dramatic decrease in the parasite loads of a sheep receiving any form of copper and an increase in parasite load for sheep receiving no form of copper. Sheep receiving minerals with copper were suspected to have the best results as the copper in the minerals is bio-available and therefore will affect the parasites right away. Since COWP are slowly released in the blood stream, it was suspected they would not be as effective as the loose minerals containing high levels of copper. The data showed that copper was effective, but the COWP produced the quickest decrease while loose copper minerals produced better long term results. Based on the analysis of the data of this one month study, Icelandic sheep farmers should give sheep COWP boluses when the sheep have a significant parasite load. The farmer should then use loose minerals containing copper to keep the parasite load below significant levels.

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1.0 Purpose

The purpose of this project was to determine the effectiveness of different types of copper against parasites in Icelandic sheep. Copper had been used in the past as an effective agent against parasites. Due to the concern of copper toxicity in sheep, chemical anthelmintics, commonly called dewormers, became the choice method for treating sheep against parasites. Today, parasites have built up resistance to the chemical dewormers. Scientists are now recommending shepherds employ a multifaceted approach for treating parasites. Generally, sheep can only be given copper wire oxide particles (COWP), since most breeds cannot tolerate the levels of copper found in other treatments. However, Icelandic sheep have greater tolerance of and need for copper. There are several formats in which copper can be delivered. This study looks at the effectiveness of COWP bolus versus chelated copper in loose goat minerals to treat parasites in Icelandic sheep.

One of the researchers lives on a farm raising Icelandic sheep. Parasites are of great concern. The family has experienced death of sheep due to parasite loads, but has anecdotal success with copper. The study aims to quantify the success with copper and determine which form of copper is most beneficial to the sheep.

2.0 Hypothesis

We predict we will see a dramatic decrease in the parasite loads of a sheep receiving any form of copper and an increase in parasite load of sheep receiving no form of copper. We predict that the sheep receiving the loose minerals with copper will have the best results against parasites. The copper in the goat minerals is bio-available and therefore will affect the parasites right away. Copper oxide wire particles (COWP) are designed to dissolve slowly, which makes them excellent for most breeds of sheep where copper toxicity is a concern. Therefore, we suspect they will not be as initially effective as an anthelmintic as the goat minerals will be. We do expect the COWP to be just as effective as the minerals toward the end of the one month study.

3.0 Background Research

3.1 Parasites in Sheep

There are many parasites that affect sheep. The most common parasites are the barber pole worm (*haemonchus contortus*), the stomach worm (*teladorsagia circumcincta*, also known as ostertagia), black scour worm (*trichostrongylus supp*), thread neck strongyles (*neamtorius spp*), *moniezia* (tapeworms), *eimeria supp* (coccidia), *trichuris ovis* (whipworm) and the fasciola hepatica (common liver fluke). (Schoenian, 2012) The largest health threat to sheep is the *Haemonchus contortus* parasite, part of the family of parasites referred to as intestinal trichostrongyles. Infestation of *Haemonchus contortus*, a bloodsucking parasite, causes many deaths each year. (Zajac, 2002)

IMAGE 1: Picture of *Haemonchus Contortus*



Schoenian, Susan. *Barber Pole Worm*. Digital image. *Sheep 2--1*. University of Maryland Extension, 8 Dec. 2013. Web. 16 Mar. 2014.

The *Haemonchus contortus* is a stomach parasite residing in the abomasum that sucks up to ten percent of the total blood volume of the sheep each day. (Hutchens, 2004) The parasite has a very short four-stage life cycle and produces thousands of eggs each day. Sheep with a parasite load of ten thousand adult worms are at risk of death. (Burke, 2005) "The eggs are deposited in the feces, hatch on pasture and the life cycle begins again. Outbreaks are worst when warm summer rains break up the fecal pellets and create a moist environment for the hatched larvae." (Burke, 2005) With wet pastures, the animals are more susceptible to the *Haemonchus contortus* infestation. (Hutchens, 2004)

Sheep having a *Haemonchus contortus* infestation also usually have secondary infestations of the *teladorsagia circumcincta* (ostertagia) and *trichostrongylus supp*. These parasites cause lack of appetite, weight loss, scours, decreasing wool production and death. For the *trichostrongylus*, death is only occasional. Although *nematodirus* is seen in the United States, it only causes minor issues: dehydration, lack of appetite and weight loss. Coccidia normally only affects young lambs, leading to failure to thrive, weight loss and death. (Schoenian, Parasite Chart, 2012)

3.2 Parasite Management

Today parasites have developed resistance to every chemical dewormer currently available. Parasites are partially resistant to some while they have a full resistance to others. (Burke, 2005) "'Many North Country (NY) sheep and goat farmers already report barber pole parasite resistance to multiple conventional deworming medications' says Betsy Hodge, livestock educator with Cornell Cooperative Extension of St. Lawrence County." (Hodge and Stanton, 2014) Research conducted at the University of Maryland in 2002 evaluated the conventional parasite dewormers: Ivomec, Tramisol and Valvazan, one dewormer from each class. There are currently three classes of dewormers: benzimidazoles, nicotinic agonists, and macrolytic lactones. (Zajac, 2002)

Overall, Ivermetin, TRA, and Valvazn was effective (> 95% egg reduction) in 33.3% (5/15), 13.3% (2/15), and 40.0% (6/15) of the treated animals, respectively with no differences among treatments, indicating overall reduced drug efficacy. (Fletcher, Jackson and Whitney, 2002)

Due to the known resistance, when chemical dewormers are used, the class of dewormers should be rotated.

There are ways to treat parasites without using chemical dewormers, including feeding tannin-rich forages such as sericea lespedeza, using copper oxide wire particles, employing mixed species grazing, encouraging the grazing of browse rather than grass, and increasing supplemental feeding. Mixed species grazing involves using sheep, along with cows, horses, or poultry. Goats are affected by the same parasites as sheep and should not be used in mixed grazing situations. It is possible, however, to use other breeds of sheep or goats that are naturally resistant to parasites in mixed species grazing. St. Croix, Barbado Blackbelly, Gulf Coast or Florida Natives, and Katalin are all sheep considered to be naturally parasite resistant. (Burke, 2005) Increasing the amount of land used to graze helps reduce parasite load. "Under more primitive conditions the level of parasitism in animals would probably be limited by their tendency to roam over greater areas." (Zajac, 2002) For maximum reduction to parasite loads on a pasture, pastures should be used only once a season. Providing extra feed to maximize sheep nutrition has been shown to be effective against parasites. Protein, minerals and energy all allow the sheep to generate new red blood cells to replace the ones destroyed by the parasites. Extra nutrients boost the immune system, allowing the sheep to better resist the parasites.

3.3 Parasite Management Through Use of Copper

Although scientists are not completely sure how copper kills the *Haemonchus contortus* parasite, it is generally believed the parasites die from copper poisoning. Numerous studies in the last twenty years show that copper is effective as an anthelmintic. Copper sulphate, a mineral substance that already meets organic farming specifications for plant production, has a strong deworming action against certain parasites, particularly *Haemonchus contortus*. (Duval, 1996) There are many ongoing studies showing the effectiveness of using COWP against the *Haemonchus contortus*. Despite the information on copper, it is only in the last few years that farmers have been really encouraged to reconsider copper, specifically in the form of copper oxide wire particles, as a major part of their parasite management. "Copper oxide is very different from copper sulfate, which when fed to sheep can quickly lead to copper toxicity." (Burke, 2005) Because the copper in COWP is in a different form than the copper sulfate, the copper in COWP is poorly absorbed by the sheep. (Hale, 2007)

Copper oxide is given to animals as a bolus (not more than 2 grams) and should not be used more than one time per year per animal for sheep until more is learned on reducing the potential for copper toxicity during its use. In some areas of the U.S. copper oxide should not be used because of the high levels of copper in the environment. (Burke, 2005)

COWP has shown to be effective for a four week period. It is thought to be effective only on *Haemonchus contortus* and too slow to work in severe cases of parasite infestation. (Burke, 2005) "Copper boluses (Copasure®) are available for use for copper deficiency in cattle. These boluses can be repackaged into much smaller dosages (usually 0.5 to 2 g) for use in sheep and goats." (Schoenian, 2012)

The early results suggest that 0.5 grams of COWP per animal can be effective at controlling the barber pole worm in

growing lambs and 2 grams per doe is as effective as higher levels of COWP to reduce worm loads by 50% in lactating does,” Thoney says, “however we would like to replicate the success on more farms statewide, including Northern New York, to provide definitive recommendations. (Stanton and Hodge, 2014)

The boluses can be administered with a pill or balling gun. The FAMACHA system should be used to determine which animals should receive a COWP bolus. Any sheep with a score of 4 or 5 should receive COWP. (Schoenian, 2012)

FAMACHA is a method to determine if a sheep or goat is anemic because it has an infestation of the *Haemonchus contortus*. FAMACHA stands for **FA**ffa **MA**lan **CHA**rt. The method was named for its originator, Francois Malan, a South African livestock parasitologist. (Hutchens, 2004) The FAMACHA method is only effective for determining the parasite load of *Haemonchus contortus* as other parasites do not cause anemia in the same manner as *Haemonchus contortus*.

In the FAMACHA system the eyelid color is matched up with a scorecard that ranks color on a 1 to 5 scale. A dark red eyelid membrane color is a 1 and indicates no significant anemia. A white color is a 5 and indicates severe anemia. The light red, pink and pinkish white colors in between indicated by scores 2 through 4, indicate increasing levels of anemia that generally correspond to the parasite burden the animal is carrying. (Lewandowski, 2010)

Animals that score 3 should be considered for deworming. Animals scoring a 4 or 5 should be dewormed. “By deworming only those animals that need it, selection of drug resistant strains of worms is slowed and the life of a given dewormer on a given farm can be prolonged.” (Hutchens, 2004) For FAMACHA to be accurate, sheep and goat eyelids should be checked at least every 7-10 days at minimum. Because lambs have smaller blood volumes, lambs “with heavy infections can go from apparently healthy to death’s doorstep in 10 to 14 days.” (Lewandowski, 2010) The FAMACHA system must be used correctly to be effective. This requires taking a FAMACHA training course and learning how to compare sheep eye-lids with the laminated color chart. The method is simple to use if two properly trained people work together. (Hutchens, 2004)

In the last several years, researchers have begun re-evaluating copper sulfate as a dewormer. (Schoenian, 2012) Scientists believe copper sulfate is safe when given in proper proportion to molybdenum, which binds to copper and prevents copper toxicity.

The ratio of copper (Cu) to molybdenum (Mo) is the most important dietary factor affecting copper toxicity in sheep. Ratios of 10:1 or less will prevent toxicity in most cases. This is because molybdenum forms an insoluble complex with copper which prevents copper from being absorbed. Sulfur further complicates the

Cu:Mo relationship by binding with Mo. (Schoenian, 2012)

The form of copper sulfate used in the study is chelated copper, which is an organic form of copper. Chelated minerals are fed to make them more bio-available than standard non-organic minerals.

3.4 Use of Copper in Sheep

Copper is one of the key trace minerals and is critical for life. Copper is needed for healthy nervous and immune systems and for healthy wool development and is stored in a sheep's liver. (Schoenian, 2009)

Copper is required for the activity of enzymes associated with iron metabolism, elastin and collagen formation, melanin production, and the integrity of the central nervous system. Ceruloplasmin, a copper-containing transport protein, is required for normal red blood cell formation by allowing iron absorption from the small intestine and release of iron in the tissue into the blood plasma. The process of normal hair and wool pigmentation requires copper. It is also believed that copper is a component of polyphenyl oxidase, which catalyzes the conversion of tyrosine to melanin and is involved in the incorporation of disulfide groups into keratin in wool and hair. (Blezinger, 2004)

3.5 Copper Deficiency in Sheep

Most sheep get copper from mineral supplements, but copper may also be absorbed from pastures that have been fertilized with large amounts of poultry manure. Copper deficiency is common in sheep when pastures are low in copper and high in iron, molybdenum and sulfur. Signs of copper deficiency include anemia, brittle or fragile bones, loss of hair or pigmentation loss, and poor wool growth. Copper deficiency in ewes during mid-pregnancy may lead to swayback in lambs. Swayback refers to a condition in which a sheep's back is not straight. (NADIS, 2001)

3.6 Copper Toxicity

There are two types of copper poisoning: chronic copper toxicity and acute copper toxicity. Acute copper toxicity occurs when copper is injected in the sheep, while chronic copper toxicity results when the liver cannot handle all the copper, causing a release of copper into the blood stream. Copper in the blood causes jaundice and destruction of red blood cells. "Excess copper is stored in the liver....The storage level in the liver can take months or even years to reach a toxic level (> 1,000 ppm). Even then, it needs stress to release the copper into the bloodstream." (Schoenian, 2012) Copper poisoning in sheep may be caused by consumption of trace mineral supplemental salt that is formulated for cattle or horses, vitamin and mineral supplements for other livestock, or grazing pasture that has been fertilized with swine manure or poultry litter. (Schoenian, 2009) Copper toxicity may be discovered by evaluating the eyelids and mouth, looking for yellow coloring. (Sargison, 2014) Signs of poisoning include weakness, panting, dull attitude, pale mucous membranes, yellow discoloration of the eyes, or

gums. (NADIS, 2001)

In most breeds of sheep, copper is used in the diet at about 8-11 parts per million. It will be toxic to sheep at 15-20 parts per million. Different breeds of sheep respond to copper differently. Finnsheep are the least likely to suffer from copper poisoning. (Bagnall, 2001) Icelandic sheep are part of the North European Short Tailed grouping and are related to Finnsheep, Romanov, Shetland, Spelsau sheep and the Swedish Landrace. Texel sheep tend to “accumulate more copper in their livers” than other breeds. (Schonian, 2012)

4.0 Materials

- Official FAMACHA Anemia Card
- Clipboard with list of sheep ear tag numbers
- Back in Balance Goat Minerals
- Back in Balance Sheep Minerals
- COWP Bolus (2 gm)
- Mineral feeders
- Camera
- Computer
- Icelandic sheep
- Disposable aprons
- Microscope—scientific with three objectives
- Three beam scale
- Glass stirring rod
- Salt
- Water
- Small plastic weigh trays
- Plastic spoon
- Eyedropper
- Examination gloves
- Pipettes
- Graduated pipettes
- Plastic 50 ml sterilized test tubes with seal-able caps
- Para-film
- Parasite egg chart from University of Rhode Island/SARE/Virginia Tech
- Notebook
- Plastic sandwich bags
- Pencil, pen, permanent marker

5.0 Procedures

One of the students took a FAMACHA class and was certified to perform FAMACHA eyelid checks on sheep and goats in November 2013. Both students attended the yearly winter lecture on Wednesday December 3, 2014 led by Betsy Hodge that provides farmers with the latest research and information from across the nation related to sheep and goats. Betsy Hodge, the livestock educator in Saint Lawrence County for Cornell Cooperative Extension, runs the Extension Learning Farm and is

The sheep were each given a number. A correlation to ear tag was recorded in the science notebook. The sheep were divided into 4 groups: A, B, C, and D. Each group received a separate treatment. There were four treatments given:

- IMAGE 2: Back-in-Balance Goat Mineral Label**



IMAGE 3: Back-in-Balance Sheep Mineral Label

Boreal Balance, LLC Back in Balance Minerals

Back in Balance Sheep Mineral	
Back in Balance Sheep Mineral to be fed free choice to sheep in all life stages. This mineral can be fed to sheep on pasture or confined to dry lot feeding.	
GUARANTEED ANALYSIS	
Calcium (Ca), minimum.....	8.00%
Calcium (Ca), maximum.....	10.00%
Salt (NaCl), minimum.....	1.00%
Salt (NaCl), maximum.....	3.00%
Sulfur (S), minimum.....	10.00%
Magnesium (Mg), minimum.....	4.90%
Potassium (K), minimum.....	50%
Zinc (Zn), minimum.....	935 ppm
Manganese (Mn), minimum.....	521 ppm
Cobalt (Co), minimum.....	100 ppm
Iodine (I), minimum.....	200 ppm
Selenium (Se), minimum.....	17 ppm
Vitamin A, minimum.....	350,000 Int.Units/Lb
Vitamin D3, minimum.....	30,000 Int.Units/Lb
Vitamin E, minimum.....	2,000 Int.Units/Lb
GUARANTEED INGREDIENTS	
Magnesium limestone, Kelp meal, Sulfur, Zinc polysaccharide complex, Manganese polysaccharide complex, Cobalt glucoheptonate, Selenium yeast, Vitamin A acetate, Vitamin D supplement, Vitamin E supplement, Hydrated calcium aluminosilicate, Hydrated sodium aluminosilicate, Diatomaceous earth (flow agent), Origanum oil, Dried & cured meal (Fusaceae, Bangiaceae, Ulvacae), Roughage products, Chicory root, Red pepper, Saccharin sodium, Fenugreek flavor extract, Anise oil, Cloves, Hemiodilute extract, Garlic, Lemongrass oil, Cobalt carbonate, Lactic acid, Organic soy oil, Organic rose hip powder.	
FEEDING DIRECTIONS	
This mineral is a complete mineral containing calcium, magnesium, essential trace minerals and vitamins.	
Provide salt free choice	
Expected consumption is 1 to 1.5 ounces per head daily.	
Feed requirements may differ by farm. For feeding advice contact Alethea Kenney	
You can find her contact information at www.backinbalanceminerals.com	
Manufactured by	
North Central Feed Products / Gervick, Minnesota 56644 / Telephone No. 218-487-6040	Lot. No. _____
Product# BBSM	25 Lbs (11.34 kg) Net Weight or Bulk

Kenney, Alethea. *Back in Balance Sheep Mineral Label*. Digital image. *Back In Balance*. 2014. Web. 10 Mar. 2015.

The project supervisor determined which group would receive what treatment to prevent the two researchers from being influenced when doing the fecal egg counts. All groups of sheep were given Back-in-Balance Minerals, either goat minerals (containing extra copper) or sheep minerals (containing no copper). Since the two minerals appear to be the same, the researchers did not know which each group received. The project supervisor administered copper bolus to two groups after the initial fecal sample were collected. The supervisor filled the mineral carrying containers so the researchers did not know which minerals were administered to which group. The minerals were administered in free choice containers every 1-3 days based on the consumption rate of the minerals. Feed rate for minerals is 1 oz per head.

All fecal samples were collected from each sheep during feeding time. The samples were put in plastic sandwich bags, labeled with the sheep tag number, and stored in the refrigerator until they were evaluated. Fecal samples were collected in the beginning, in the middle, and the end of the study. The students were trained to perform fecal egg counts by a sheep farmer and teacher trained in FAMACHA and fecal evaluation. Large animal veterinarian Dr. Sarah McCarter said fecals with less than 500 eggs per gram were considered to have negligible/insignificant parasite loads. To be considered effective the parasite load needed to show a reduction of at least 90%.

The fecal samples were evaluated using a fecal float egg count and McMaster Slides. Using a sample of feces, the researcher needs to be sure that the feces came from the correct sheep. A plastic weigh boat was placed on a triple-beam scale to measure 2 grams of feces. The researcher added feces until the scale indicated that the weight was correct. The two grams of feces were then added to 28 milliliters of water in a test tube. The researcher used a glass stirring rod to break up the feces and mix the solution thoroughly. Solution was drawn up into a plastic pipette from the top of the test tube close to the side to minimize the amount of debris taken without missing the eggs. The researcher then placed the tip of the pipette on the side of the

McMaster slide and slowly released the solution into the first well. The researcher filled both wells as carefully as possible to avoid mixing in air bubbles, which replace solution that would have potentially contained eggs. More air bubbles make the egg count too small, introducing bias into the data. After the McMaster slide was filled, the researcher waited five minutes to allow the eggs to rise to the top and the solution to settle.

A McMaster slide acts as both slide and coverslip. The roof is attached at the ends and in between the wells. Above each well, lines are etched into the roof, forming a grid. The researcher looks through the grid and counts only the eggs within the grid lines. The number of eggs from the two wells are added together and multiplied by fifty to determine the total number of eggs/gram in the sheep's feces.

$$Eggcount(grams)=(Well1+Well2)\cdot 50$$

6.0 Data

The following table shows the fecal egg counts for each sample. The number of eggs shows the total number of eggs in the two wells. The group letter indicates the group the sheep was a member of.

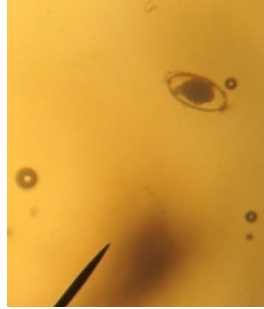
TABLE 1: Results of Fecal Egg Counts

Name	Group	Initial #Eggs	Fecal Initial	2nd #Eggs	Fecal Mid-point	3rd #Eggs
1	A	0	0	12	600	1
2	A	7	350	8	400	3
3	A	10	500	2	100	4
4	A	13	650	0	0	1
5	A	13	650	9	450	25
6	A	40	2000	0	0	12
7	A	50	2500	10	500	2
8	A	75	3750	10	500	1
9	B	35	1750	10	500	3
10	B	71	3550	31	1550	48
11	B	20	1000	10	500	37
12	B	12	600	2	100	27
13	B	173	8650	17	850	0
14	B	30	1500	141	7050	160
15	C	11	550	0	0	6
16	C	1.5	75	5	250	1
17	C	39	1950	0	0	6
18	C	40	2000	14	700	3
19	C	49	2450	17	850	3
22	D	30	1500	5	250	9
23	D	13	650	10	500	1
24	D	9	450	20	1000	1
25	D	11	550	3	150	0
26	D	103	5150	8	400	2

TABLE 2: Type of Parasite Seen in Each Sample

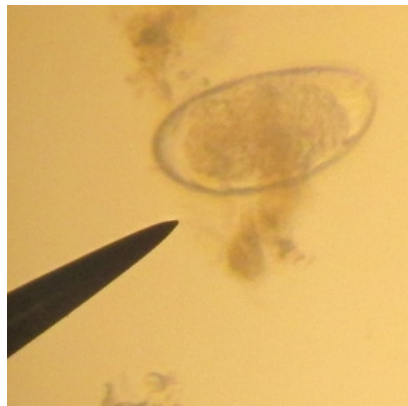
	Strongylids			Nematode			Aoncotheca			Trichuris			Coccidia			Moniezia			Spyrokites			Ostertagia			Other		
SHEEP #	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3
1	9	--	--	--	--	--	3	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2	--	4	1	--	--	--	--	--	--	--	--	--	2	2	2	--	--	--	5	2	--	--	--	--	--	--	--
3	4	--	--	--	--	--	--	--	--	--	--	--	5	2	4	--	--	--	--	--	--	1	--	--	--	--	--
4	15	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5	10	7	7	--	--	--	--	--	--	--	--	--	3	1	18	--	1	--	--	--	--	--	--	--	--	--	--
6	40	--	11	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7	50	10	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
8	74	7	1	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--	1	--	1	--	--
9	35	2--	1	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
10	61	3--	42	--	--	3	--	--	--	--	--	2	--	1	--	9	--	1	--	--	--	1	--	--	--	--	--
11	29	9	6	--	--	--	--	--	--	--	--	--	1	1	6	--	--	--	--	--	--	--	--	--	--	--	1
12	2	--	24	--	--	--	--	--	--	1--	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
13	137	16	--	--	--	--	--	--	--	--	--	--	15	1	--	21	--	--	--	--	--	--	--	--	--	--	--
14	29	133	155	1	7	5	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
15	11	--	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16	--	--	1	--	--	--	--	--	--	--	--	--	2	5	--	--	--	--	--	--	--	--	--	--	--	--	--
17	39	--	6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18	33	4	2	--	--	--	--	--	--	--	--	--	5	9	--	--	--	1	--	--	--	2	--	--	--	--	--
19	42	2	2	--	--	--	--	--	--	--	--	1	7	11	--	--	--	--	--	--	--	--	--	--	--	--	--
20	--	13	2	--	--	--	--	--	--	--	--	--	--	14	--	--	--	--	--	--	--	--	--	--	--	--	--
21	--	36	10	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
22	29	4	9	--	--	--	--	--	--	--	--	--	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--
23	12	1	1	--	--	--	--	--	--	--	--	--	1	9	--	--	--	--	--	--	--	--	--	--	--	--	--
24	3	18	1	--	--	--	--	--	--	5	2	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	11	3	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	101	8	2	1	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

IMAGE 4: Nematodirus Egg Under Microscope Using 10X



Sayward, Liam. Personal Photograph. 2015

IMAGE 5: Strongylid Egg Under Microscope Using 10X



Sayward, Liam. Personal Photograph. 2015

CHART 1: Fecal Egg Counts For Group A Over Time

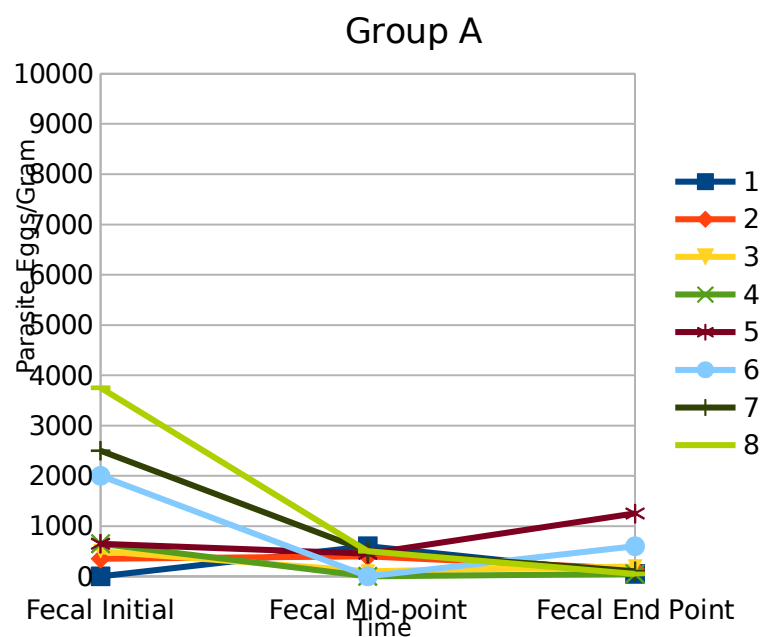


CHART 2: Fecal Egg Counts For Group B Over Time

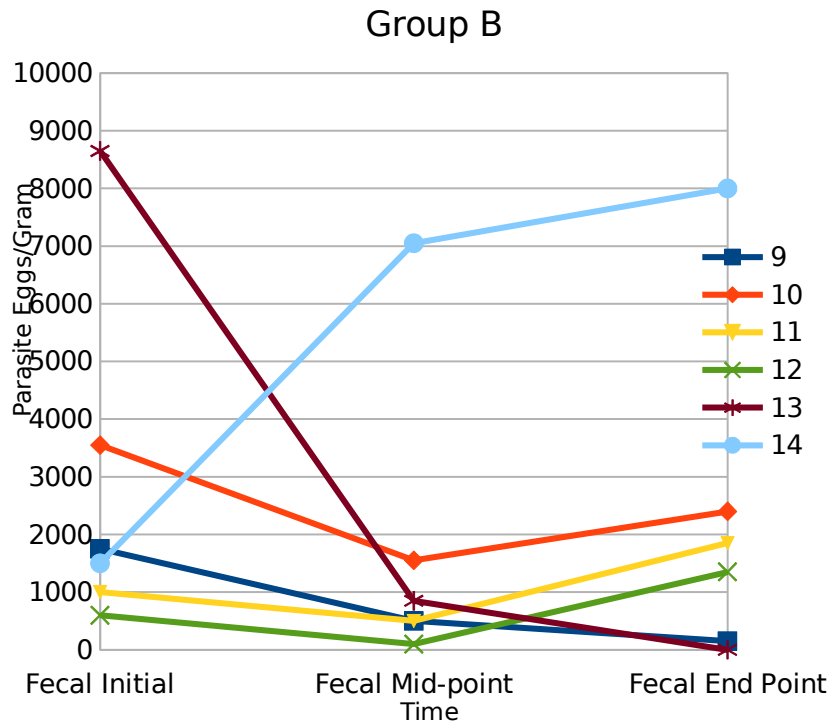


CHART 3: Fecal Egg Counts For Group B Over Time

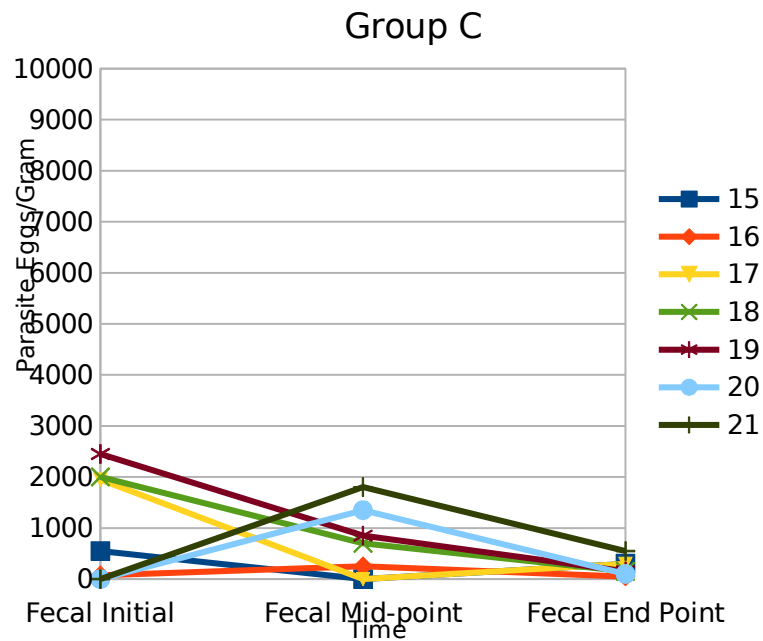
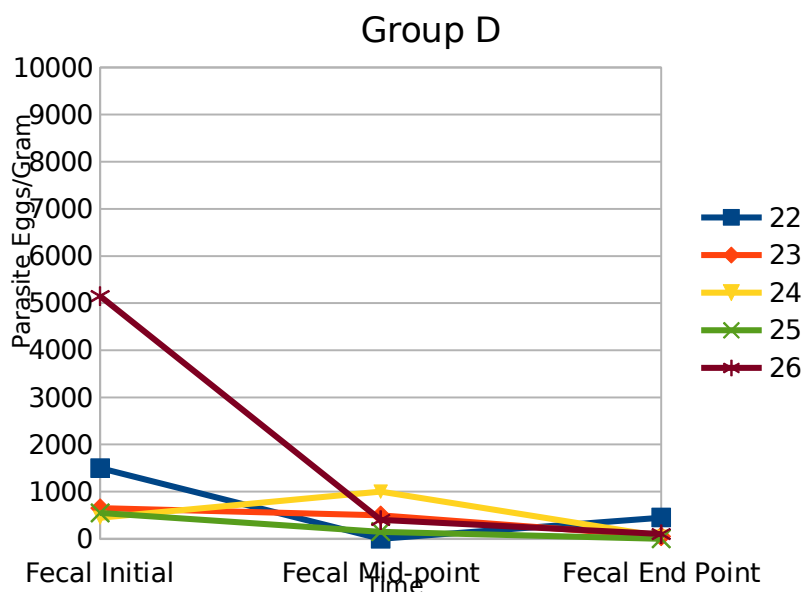


CHART 4: Fecal Egg Counts For Group B Over Time



7.0 Analysis

Reviewing the initial samples, four of the twenty-six sheep (Sheep 1, 2, 16, and 24) had egg/gram counts of 500 or below and therefore (based on information from large animal veterinarian Dr. Sarah McCarter, DMV) had parasite loads that were not significant. At the end of the study, all four still had parasite loads that were insignificant. These sheep were removed from the analysis because although there was fluctuation in the data, overall they remained below the level considered to be carrying a parasite load. Two sheep (Sheep 20 and 21) were removed from analysis because they did not have initial fecal samples.

Efficacies were calculated by comparing the second and the final egg/gram count to the initial egg/gram count. To determine efficacy, we used the following equation (Fletcher, Jackson and Whitley, 2002):

$$\text{Percent Efficacy} = \frac{(\text{Sample initial} - \text{Sample final})}{\text{Sample initial}} * 100$$

GROUP A

Two weeks after the treatment, all the sheep in Group A (6 sheep) with a parasite load had egg counts of 500 or less. Therefore, 100% of sheep carrying a parasite load responded to treatment in two weeks. At the end of the study, four of the six (67%) had insignificant parasite loads. Sheep 5 started with a parasite load of 650 eggs/gram and went down to 450 eggs/gram at 2 weeks post treatment, but then she ended at 1250 eggs/gram. Sheep 6 went from 2000 eggs/gram initially to 0 eggs/gram at 2 weeks but then rose to 600 eggs/gram at the end of 4 weeks.

TABLE 3: Efficacy of Treatment for Group A

Sheep Number	Efficacy of Treatment at 2 Weeks	Efficacy of Treatment at 4 Weeks
3	80.-00	60.00%
4	100%	92.31%
5	30.77%	-92.31%
6	100.00%	70.00%
7	80.00%	96.00%
8	86.67%	98.67%

Overall for Group A, the treatment was effective for two weeks. Although the efficacy data only shows the treatment being effective for 2 sheep (where efficacy is greater than 90%), all the sheep actually ended the two weeks with insignificant parasite loads.

GROUP B

After treatment, at the two week point, 5 of the 6 sheep in Group B had a decrease in parasite load. Three of these sheep (50%) had a parasite load that was now considered insignificant. At the four week point, only two sheep (33.33%) had insignificant parasite loads. The other sheep had an average increase in egg/gram of 334.58%. Therefore, 50% of sheep carrying a parasite load responded to treatment in two weeks and 33.33% in four weeks. Sheep 14 never showed any improvement. Sheep 14 started with a parasite load of 1500 eggs/gram and went up to 7050 eggs/gram at 2 weeks post treatment, and ended at 8000 eggs/gram.

TABLE 4: Efficacy of Treatment for Group B

Sheep Number	Efficacy of Treatment at 2 Weeks	Efficacy of Treatment at 4 Weeks
9	71.43%	91.43%
10	56.34%	32.39%
11	50.00%	-85.00%
12	83.33%	-125.00%
13	90.17%	100.00%
14	-370.00%	-433.33%

Overall for Group B, according to the efficacy equation, the treatment was effective for 16.67% sheep at 2 weeks and 33.33% effective at 4 weeks. Compared with chemical dewormers, this treatment was similar to use of a chemical dewormer.

GROUP C

The 4 sheep in Group C all had significant parasite loads. After treatment, at the two week point, all 4 of the sheep in Group C had a decrease in parasite load. Two of these sheep (50%) had a parasite load that was now considered insignificant. At the four week point, all 4 sheep (100%) had insignificant parasite loads. Both Sheep 15 and Sheep 17 did have a rise in parasites from week 2 to week 4 but their end egg/gram number was still considered to be an insignificant number of parasites.

TABLE 5: Efficacy of Treatment for Group C

Sheep Number	Efficacy of Treatment at 2 Weeks	Efficacy of Treatment at 4 Weeks
15	100.00%	45.45%
17	100.00%	84.62%
18	65%	92.50%
19	65.31%	93.88%

Overall for Group C, according to the efficacy equation, the treatment was effective for 50% of the sheep at 2 weeks and 4 weeks. Compared with chemical dewormers used in the University of Maryland study, the treatment Group C received was more effective at treating parasites.

GROUP D

After treatment, at the two week point, all 4 of the sheep in Group D had a decrease in parasite load. All 4 of these sheep (100%) had a parasite load that was now considered insignificant. At the four week point, all 4 sheep (100%) had insignificant parasite loads. Sheep 22 had an increase in parasites from week 2 to week 4 but its end egg/gram number was still considered to be an insignificant number of parasites.

TABLE 6: Efficacy of Treatment for Group D

Sheep Number	Efficacy of Treatment at 2 Weeks	Efficacy of Treatment at 4 Weeks
22	83.33%	70.00%
23	23.08%	92.31%
25	72.73%	100.00%
26	92.23%	98.06%

Overall for Group D, according to the efficacy equation, the treatment was effective for 25% sheep at 2 weeks and 75% at 4 weeks. Compared with chemical dewormers

used in the University of Maryland study, the treatment Group D received was more effective at treating parasites.

Comparing the efficacies, the treatment that Group D received was the most effective. All the sheep in this group had a decrease in parasites such that the egg/gram count at week 2 and week 4 were below the 500 egg/gram threshold and were considered insignificant.

In reviewing the data, it appears that Group B got sheep minerals because they maintained high fecal counts and as an entire group they had the lowest efficacies. It is believed that groups A, C, and D all received one form of copper as their overall parasite egg numbers decreased.

Two of the lambs in the Group B did have a decrease in their eggs even though they were not receiving copper. They were receiving supplementary feeding as part of another science project. It is known that sheep receiving more energy will be able to resist parasites better. The two sheep that decreased were the two largest sheep in the pen. They tended to eat more than the other lambs.

In reviewing the type of parasites seen in the study, most of the eggs were *haemonchus contortus*. Sheep 2 had Spyrokites in her initial and second sample. These are consistent with sheep who have experienced a spontaneous abortion. She is known to be bred. In May, after lambing season, the correlation to the presence of Spyrokites to abortion can be confirmed.

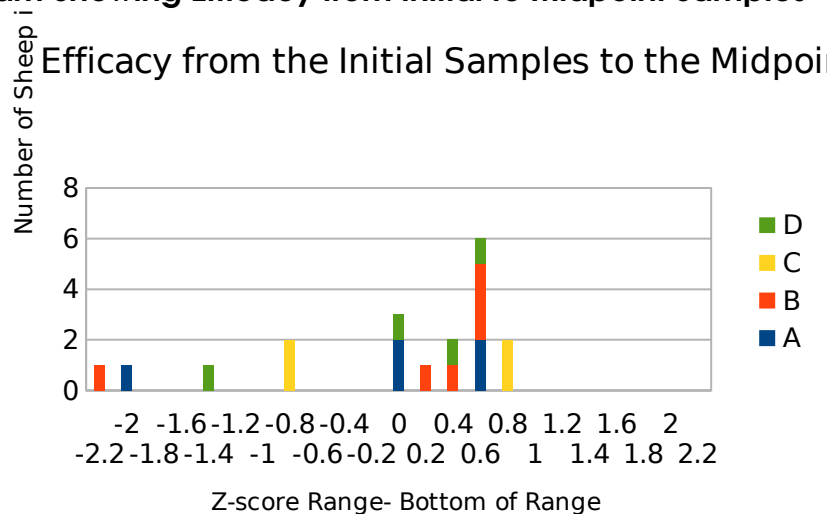
The numbers of coccidia tended to be higher for sheep with heavy parasite loads or sheep who had a dramatic decrease in parasite loads. The coccidia is a primary issue for young lambs.

Using the efficacies from the set of data, a mean and standard deviation was calculated for each group of sheep.

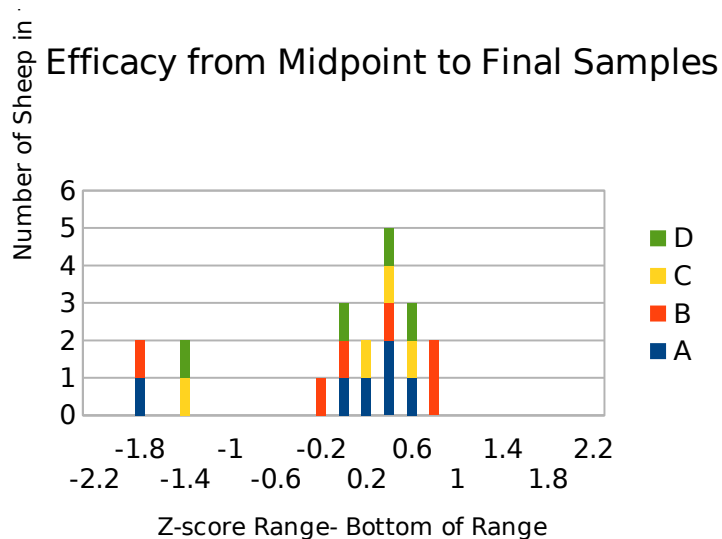
$$Z = \frac{Efficacy - MeanEfficacy}{SampleStandardDeviationofEfficacy}$$

A histogram of the z-scores was plotted. The results are shown here.

GRAPH 1: Histogram Showing Efficacy from Initial to Midpoint Samples



GRAPH 2: Histogram Showing Efficacy from Midpoint to Final Samples



The histogram shows a multi-modal curve. The efficacy equation is based on the assumption that the z-scores are distributed over a normal bell curve, but we did not see a normal bell curve because there is too little data. Therefore, the study showed better anecdotal evidence than statistical evidence. To see more statistically valid evidence, we would need to include more sheep in the study.

Following the analysis of the data, the supervisor revealed the treatments by group.

TABLE 7: Sheep Treatment Groups

Sheep Group	Treatment
A	COWP + Back-In-Balance Sheep Mineral
B	Back-In-Balance Sheep Mineral
C	Back-In-Balance Goat Mineral
D	COWP + Back-In-Balance Goat Mineral

8.0 Conclusion

Based on the analysis of the data of this one month study, Icelandic sheep farmers should give sheep COWP boluses when the sheep have a significant parasite load. The farmer should then use minerals containing copper to keep the parasite load below significant levels.

The study shows that all breeds of sheep would benefit from a good quality sheep mineral that would bolster the sheep's immune system. Pat Colby, the author of *Natural Sheep Care*, advocates that sheep given proper minerals will not have problems of parasites. She does assume that "proper" minerals involves use of copper. (Colby, 2006). The Back-In-Balance sheep minerals provide sheep with similar benefits of the chemical dewormers Ivermectin and Valvazn. Unlike the dewormers, minerals do not carry the risk of generating parasite resistance.

The copper results cannot be directly extrapolated to all breeds of sheep due to the sensitivity of sheep to copper. Shepherds need to consider their individual breed's sensitivity to copper and the level of copper in the soil.

Further study needs to be done to determine the frequency of minerals that is needed to maintain the parasite load below the detectable levels. The maximum time between offering the minerals containing copper should be determined to see if offering them less often still maintains the effectiveness while reducing the exposure to copper. During the in-between times, sheep mineral could be offered to maintain the sheep's immune system.

Additional study should be conducted with the COWP to determine the rate at which it acts. It would be helpful to collect samples every few days to see exactly how fast COWP works and know better whether you could use COWP to save a sheep if it was dying of parasites.

Annotated Bibliography

Bagnall, Alicia, Luke VanNatter, and David Lee. "Copper Toxicity in Sheep." *Sheep Management*. Purdue University School of Agriculture, Spring 2001. Web. 11 Mar. 2014.

This article talks about copper toxicity. Copper is stored in a sheep's liver. Different breeds respond to copper differently. Finnsheep are the least likely to suffer from copper poisoning. Copper is used in the diet at about 8-11 parts per million. It will be toxic to sheep at 15-20 parts per million. The mucus membranes and skin will turn a yellowish brown.

Blezynger, Stephen B. "High Levels of Sulfur in a Cow's Diet Can Affect Copper Absorption." *Cattle Today*. Cattle Today, Inc., 2004. Web. 21 Feb. 2014.

"Copper is required for the activity of enzymes associated with iron metabolism, elastin and collagen formation, melanin production, and the integrity of the central nervous system. It is required for normal red blood cell formation by allowing iron absorption from the small intestine and release of iron in the tissue into the blood plasma. Ceruloplasmin is the copper-containing transport protein. The process of normal hair and wool pigmentation requires copper. It is believed that copper is a component of polyphenyl oxidase which catalyzes the conversion of tyrosine to melanin and for the incorporation of disulfide groups into keratin in wool and hair."

Bowman, Dwight. *Worms, Goats, Sheep & Copper Wire Particles*. Ithaca: Cornell University College of Veterinary Medicine, 2013. Print.

This is a presentation which provides extensive information of what the vet school knows about the effect of copper on parasites. It includes information on use of copper sulfate.

Burke, Joan. *Management of Barber Pole Worm in Sheep and Goats in the Southern U.S.* Booneville: USDA, ARS, Dale Bumpers Small Farms Research Center, Feb. 2005. PDF.

"The adult female can lay thousands of eggs daily and can consume 200 microliters of blood daily. An average of 10,000 adults is enough to kill a sheep or goat. The female's prodigious output of eggs is partly responsible for the explosive nature of outbreaks, especially in favorable weather conditions. The eggs are deposited in the feces, hatch on pasture and the life cycle begins again. Outbreaks are worst when warm summer rains break up the fecal pellets and create a moist environment for the hatched larvae. During drought or very cold conditions, a majority of larvae become dormant or die and transmission to the animal is very low."

Colby, Pat. *Natural Sheep Care*. Austin, TX: Acres U.S.A., 2006. Print.

This book teaches the shepherd how to raise sheep without the use of chemicals or medications. The importance of giving sheep adequate copper is stressed. The author claims that sheep given accurate minerals will not have a parasite load.

Duval, Jean. "The Control of Internal Parasites In Ruminants." *The Ecological Agriculture Projects*. McGill University, 1996. Web. 16 Dec. 2013.

"Copper sulphate, a mineral substance that already meets organic farming specifications for plant production, has a strong deworming action against certain parasites, particularly *Haemonchus contortus*."

Fletcher, C. M., D. J. Jackson, and N. C. Whitley. "Efficacy of Anthelmintics Against Gastrointestinal Parasites Among Young Small Ruminants on the Eastern Shore of Maryland." University of Maryland, 2002. Web.

This abstract reported the results of the study of chemical dewormers. "Overall, Ivermetin, TRA, and Valvazn was effective (> 95% egg reduction) in 33.3% (5/15), 13.3% (2/15), and 40.0% (6/15) of the treated animals, respectively with no differences among treatments, indicating overall reduced drug efficacy."

Fox, Mark T., PhD. "Gastrointestinal Parasites of Sheep and Goats." *Gastrointestinal Parasites of Ruminants: Merck Veterinary Manual*. The Merck Veterinary Manual, Sept. 2014. Web. 18 Feb. 2015.

Hale, Margo, Joan Burke, Jim Miller, and Tom Terrill. *Tools for Managing Internal Parasites in Small Ruminants: Copper Wire Particles*. ATTRA: National Sustainable Agriculture Information Service, 2007. Print.

This article provided information about parasite management and using copper oxide wire boluses (COWP). It has been discovered that copper oxide wire particles (COWP) reduce parasite overload in sheep and goats. COWP was developed to meet the needs of copper deficiency in sheep and cattle without causing copper toxicity. "The form of copper used in COWP is poorly absorbed. The exact mechanism of how copper wire particles control internal parasites is not yet fully understood. Researchers believe copper has a direct effect on internal parasites."

Hatfield, P. G., C. K. Swenson, R. W. Kott, R. P. Ansotegui, N. J. Roth, and B. L. Robinson. "Zinc and Copper Status in Ewes Supplemented with Sulfate- and Amino Acid-Complexed Forms of Zinc and Copper." *Journal of Animal Science* 79 (2001): 261-66. Web. 1 Mar. 2014.

This study showed that the chelated mineral form of copper was better absorbed than the sulfate.

Hodge, Betsy. "Integrated Parasite Management and FAMACHA Training." FAMACHA Workshop. Cornell Cooperative Extension of Essex County, Essex. 16 Nov. 2013. Lecture.

I took this class to learn how to use the FAMACHA system. I learned all about parasites, how to perform fecal egg counts, and how to evaluate live sheep using FAMACHA.

Hutchens, Terry, Dr. Monty Chappell, and Dr. Marion Simon. *Kentucky Cooperative Extension Service Evaluates FAMACHA*. Lexington: University of Kentucky Cooperative Extension Services, 2004. Print.

The FAMACHA method was named for the originator- Francois Malan, a South African livestock parasitologist. The method is simple to use if two properly trained people are working together. "10% of the total blood volume may be consumed by the parasites each day." Animals that score 3, the animal should be considered for deworming. If an animal is a 4 or 5, deworming should occur. "By deworming only those animals that need it, selection of drug resistant strains of worms is slowed and the life of a given dewormer on a given farm can be prolonged." With wet pastures, the animals are more susceptible to barber pole worm.

Hutchinson, Tom C., and M. Sheena Symington. "Differences in the Copper Tolerance of British Sheep Breeds and the Possible Relationship to the Soil Chemistry of the Regions of the Origin of the Breeds." Trent University, Environmental and Resource Studies Program, Peterborough. 14 Mar. 2014. Speech.

The speakers think that some sheep developed in areas with high copper in the soil so they are able to tolerate more copper than sheep that developed in areas with low copper soil. "An interesting aspect of copper in wool analysis is that coloured or black wool has been known for at least a century to respond to copper applications. Copper deficient wool loses its crimp while copper deficient black wool loses both its crimp and its colour. It becomes white. In a recent experiment at Leeds University, a number of Black Welsh Mountain sheep were subjected to a low copper diet and basically became white. Shepherd's showing sheep in coloured classes at shows in Canada used a potentially lethal mixture of nicotine sulphate and copper sulphate in the diet a few weeks before shows to maximize pigmentation (but, they emphasized that you had to be careful with it.)"

"Icelandic." *Breeds of Livestock*. Oklahoma State University, 2008. Web. 19 Dec. 2013. Icelandic sheep are part of the North European Short Tailed grouping and are related to Finnsheep, Romanov, Shetland, Spelsau sheep and the Swedish Landrace.

Kenney, Alethea. *Restoring and Maintaining Health*. Shevlin: Boreal Balance, 2013. PDF.

Sheep that have poor health will have issues like poor wool quality, hoof conditions, low lambing percentages and difficult births, poor weight gain and milk production, diseases and parasites. Many farms are deficient in several key trace minerals. Some trace minerals are needed in small amounts and they may be the limiting factor in life or death. Copper is associated with poor nerve function and swayback disease. Copper is important for immune health and the ability to use iron. You should consider copper first when talking about parasites because of its use as copper oxide wire particles to kill parasites. Mineral blocks contain high amounts of salt. Sheep only need a small amount of salt so they self regulate the intake. This means they do not get all the

nutrients they need. Sheep should be fed loose minerals. Chelated minerals are easier to digest and absorb over mineral blocks. "Because chelated minerals are so easily digested (sometimes close to 100% useable by the body), they can help offset situations where other minerals cause elimination or poor absorption of the needed mineral." Molybdenum added to minerals interferes with the absorption of copper.

Lewandowski, Rory. "Use FAMACHA Correctly." *OSU Sheep Team RSS*. Ohio State University Extension, 16 June 2010. Web. 17 Feb. 2014.

FAMACHA is a way to determine if your sheep is anemic. An anemic sheep is suffering from an infestation of the barber pole worm. You need to use the system correctly and not guess. FAMACHA is recommended for small to medium herds. If you have a large herd, look at a portion of the sheep rather than all of them. "In the FAMACHA system the eyelid color is matched up with a scorecard that ranks color on a 1 to 5 scale. A dark red eyelid membrane color is a 1 and indicates no significant anemia. A white color is a 5 and indicates severe anemia. The light red, pink and pinkish white colors in between indicated by scores 2 through 4, indicate increasing levels of anemia that generally correspond to the parasite burden the animal is carrying." It is only effective when used on a regular basis. Sheep cannot have barber pole one day and then an infestation a few days later. "Due to their smaller blood volumes, lambs and kids with heavy infections can go from apparently healthy to death's doorstep in 10 to 14 days. This means that animals should be FAMACHA scored every 7-10 days during this period."

"McMaster Egg Counting Technique: Principle." *McMaster Egg Counting Technique: Principle*. Royal Veterinary College, n.d. Web. 12 Dec. 2014.

Nolan, Thomas, Dr. "McMaster Egg Counting Technique." *McMaster Egg Counting Technique*. University of Pennsylvania School of Veterinary Medicine, 2006. Web. 12 Dec. 2014.

This article teaches about doing fecal egg counts.

Sargison, Neil, BA VetMB DSHP FRCVS. "Copper Poisoning in Sheep." *National Animal Disease Information Service*. National Animal Disease Information Service, UK, 2014. Web. 21 Feb. 2014.

This article talks about the effect of copper poisoning on sheep. There are two types of copper poisoning: chronic copper toxicity and acute copper toxicity. Chronic copper toxicity happens when the liver cannot handle all the copper. This causes a release of copper into the blood stream which causes jaundice and destruction of red blood cells. Some breeds get copper toxicity more than others. It can be determined by evaluating the eyelids and mouth, looking for yellow coloring. Acute copper poisoning occurs when copper is injected in the sheep.

Schoenian, Susan. "Copper Toxicity in Sheep." *Small Ruminant Info Sheep*. University of Maryland Extension, 21 Dec. 2009. Web. 16 Mar. 2014.

This article talks about copper toxicity in sheep. The signs of copper deficiency are: anemia, brittle or fragile bones, loss of hair or pigmentation loss, and poor wool growth. Copper is one of the key trace minerals and is critical for life. A sheep can get copper poisoning by: trace mineral salt formulated for cattle or horses, vitamin and mineral supplements for other livestock, or a pasture that has been fertilized with swine manure or poultry litter.

Schoenian, Susan. "Internal Parasite (Worm) Control." *Sheep 2001: A Beginner's Guide to Raising Sheep*. University of Maryland Extension, 8 Dec. 2013. Web. 16 Mar. 2014.

This article talks about internal parasites. They are the biggest threat to sheep health. The barber pole worm sucks blood in the abomasum. The barber pole worm is the deadliest parasite to sheep. It has a very short life cycle and produces lots of eggs. Integrated Parasite Management involves many methods working together to control parasites. Methods include rotational grazing, using dry lots, multi-species grazing, using pasture plants that have anthelmintic properties, nutritional management, anthelmintics, and FAMACHA.

Schoenian, Susan. "The Internal Parasites That Affect Sheep and Goats." *Sheep and Goat*. University of Maryland Extension, 2012. Web. 18 Feb. 2015.

This is a chart that shows all the sheep parasites.

Schoenian, Susan. "Revisiting copper toxicity in sheep" *Small Ruminant Info Sheet*. University of Maryland Extension, 22 Dec. 2012. Web. 15 Jan. 2015.

This article talked about the concern about copper toxicity in sheep. It discussed using COWP and copper sulfate and how the copper can help against parasites.

Simpson, Melinda M. "Use of Copper to Control *Haemonchus contortus* Infestation in Hampshire Ewes." Thesis. University of Kentucky, 2011. *Use of Copper to Control *Haemonchus contortus* Infestation in Hampshire Ewes*. University of Kentucky UKnowledge, 2--11. Web. 5 Dec. 2--14.

Smith, Barbara, Mark Aseltine, and Gerald Kennedy. *Beginning Shepherd's Manual*. Ames: Iowa State UP, 1997. Print.

Stanton, Tautiana, PhD, and Betsy Hodge. "NNYADP Renews Funding for Parasite Control

Project, Releases 1st-Year Results." Northern New York Agricultural Development Program, 30 May 2014. Web. 15 Dec. 2014. This press release reports the results of the COWP usage study conducted in Northern NY.

"Trace Element Deficiencies in Sheep." *NADIS National Animal Disease Information Service*.

National Animal Disease Information Service, UK, 2014. Web. 17 Feb. 2014.

This article talks about the trace mineral deficiency in sheep. One deficiency is

for copper. It talks about the signs and how it can be prevented. Copper deficiency is most common when pastures are low in copper but higher in iron, molybdenum and sulfur. The symptoms of copper depend on where you live. Signs include poor wool quality, anemia, and poor bone mineralization. Copper deficiency in ewes during mid-pregnancy may lead to swayback in lambs.

Van Wyk, Jan A., and Gareth F. Bath. "The FAMACHA System for Managing Haemonchosis in Sheep and Goats by Clinically Identifying Individual Animals for Treatment." *Veterinary Research: A Journal of Animal Infection* 33.5 (2002): 5--9-29. *National Center for Biotechnology Information*. U.S. National Library of Medicine, 2002. Web. 7 Mar. 2014.

This study proves that the FAMACHA system is very reliable for those who take the class. However, FMACHA does not work as well with goats as it does the sheep.

Zajac, Ann. "Controlling Goat Parasites -- Is It a Losing Battle?" *Controlling Goat Parasites*. Virginia Tech, Web. 08 Dec. 2014.

This article written by a vet talks about the types of worms sheep have and all the methods of controlling them. We used the quote, "Under more primitive conditions the level of parasitism in animals would probably be limited by their tendency to roam over greater areas."

Images

Crain, Andrea. Personal Photograph. 2015.

Kenney, Alethea. *Back in Balance Goat Mineral Label*. Digital image. *Back In Balance*. 2014. Web. 10 Mar. 2015.

Kenney, Alethea. *Back in Balance Sheep Label*. Digital image. *Back In Balance*. 2014. Web. 10 Mar. 2015.

Schoenian, Susan. *Barber Pole Worm*. Digital image. *Sheep 2001*. University of Maryland Extension, 8 Dec. 2013. Web. 16 Mar. 2014.

Sayward, Liam. Personal Photograph. 2015.

Sayward, Melissa. Personal Photograph. 2013.