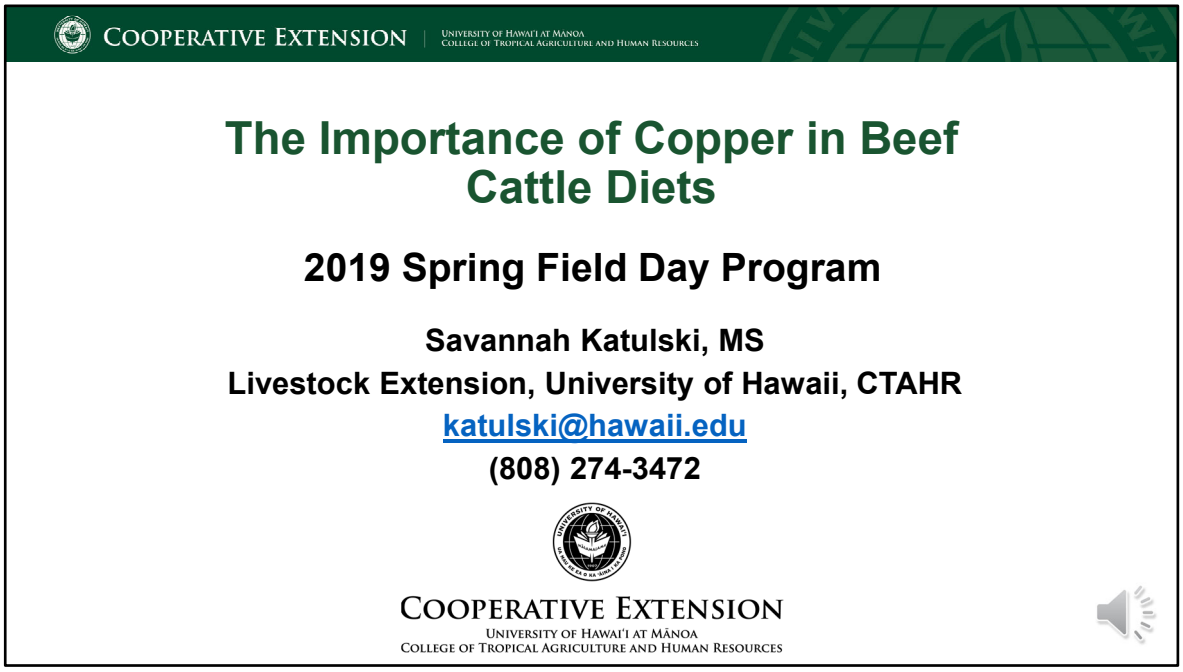


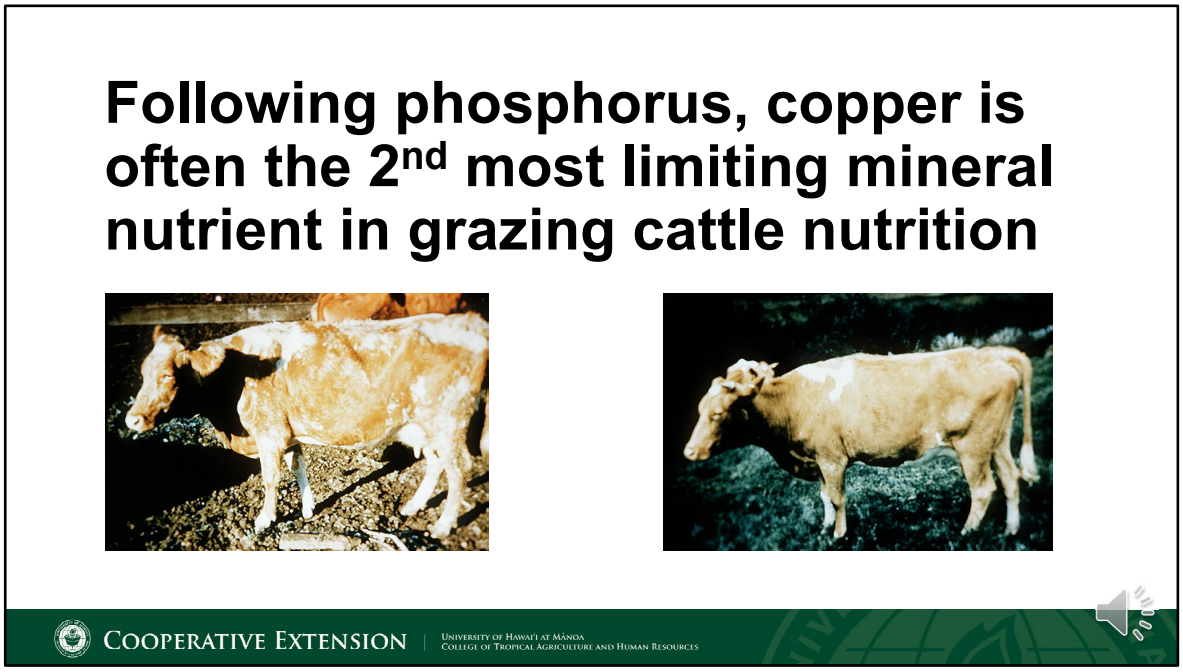
Hi everyone. First off, I want to thank you for taking time out of your busy schedule to tune in to this webinar series. The webinar serious was developed in order to offer an online version of the 2019 Spring Field Day Program that was conducted in June. My name is Savannah Katulski and I am a Livestock Extension Agent for the University of Hawaii CTAHR and I am based on Kauai. I am a bit of a mineral nerd, and spent most if not all of my time researching minerals, and specifically copper in my graduate program. So, I am pretty excited to be able to take some time to share some of my knowledge on minerals with you. This aspect of the webinar will dive deeper into the role of copper in cattle diets as well as discuss some of the nutritional interactions that are important in understanding copper nutrition for cattle in the state of Hawaii.

Minerals: Macro vs. Micro

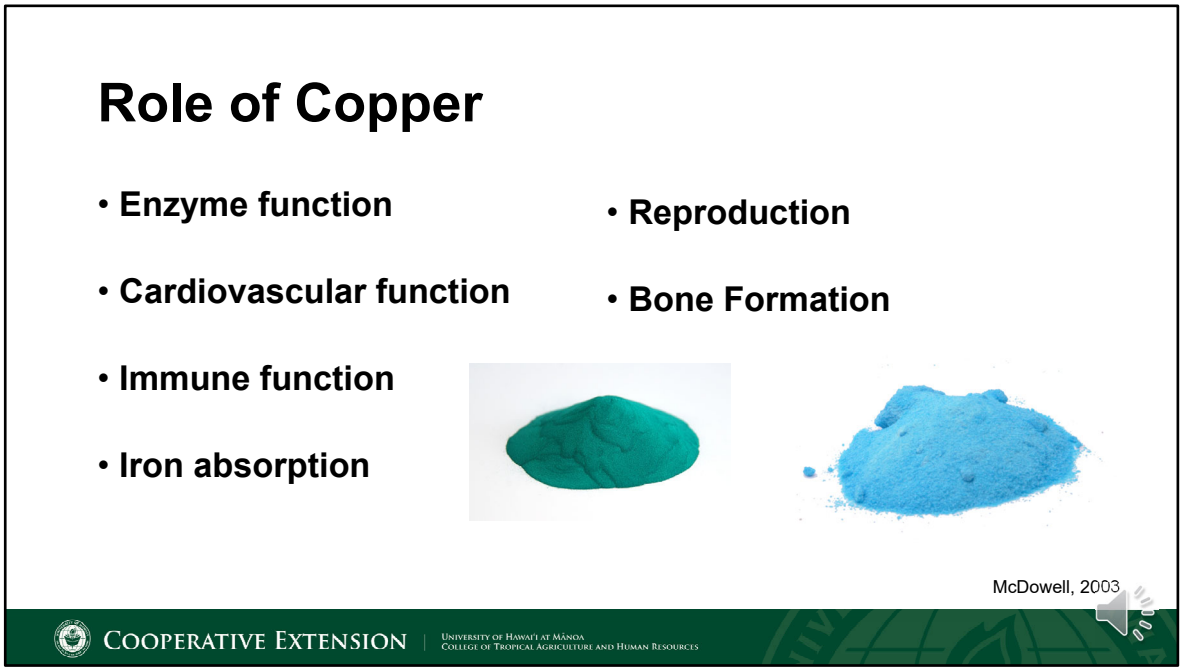
- Macrominerals: Ca, P, Mg, S, Na/Cl
  - Needed in larger quantities
- Microminerals: Cr, Co, **Cu**, I, Mn, Mo, Se, Zn
  - Needed in trace amounts
- **Regardless of amount required, ALL are necessary for normal body function and efficient production.**

When discussing mineral nutrition of livestock, we typically divide minerals into two classifications: macro and micro minerals. Macro-minerals are minerals that are needed in higher quantities in the diet and are often reported as a percentage of the diet. Examples of macro-minerals consist of Ca, P, Mg, S, and Na/Cl. Micro-minerals, on the other hand, are needed in smaller or trace quantities of the diet which is why they are commonly referred to as trace minerals. These are often reported as ppm in forage analysis, feed tags, or on mineral bags or tubs. Minerals in this classification include: Cr, Co, Cu, I, Mn, Mo, Se, and Zn. Don't let their names fool you, just like protein and energy; minerals, no matter if they're considered a macro or micro mineral, must be balanced in a diet. A shortage of any of these minerals can limit animal productivity and result in an inefficient cow herd. Just like you would make sure there is enough protein in your forages, you must make sure your cattle are consuming sufficient amounts of minerals in order to capitalize on their productivity potential.

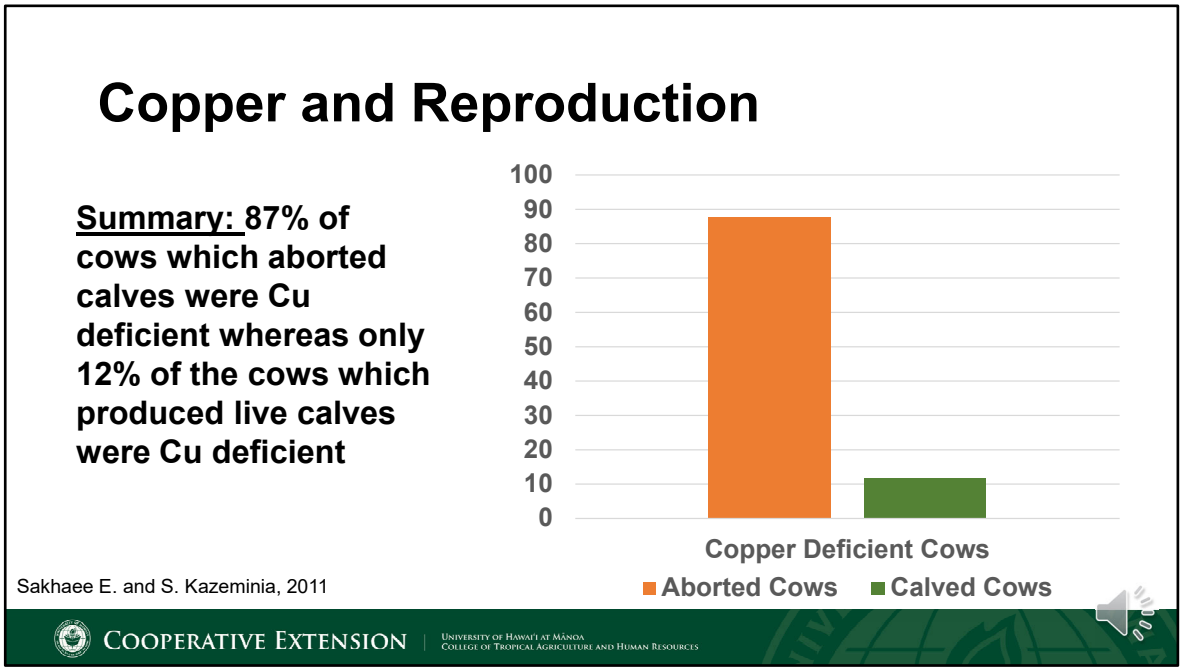
Minerals are provided to cattle in a variety of methods. Typically, the feed or forage in the case of most cattle producers in Hawaii, is the first source of mineral for cattle. The grasses or legumes in your pastures are the first thing a producer should look at when determining mineral levels in the diet. In terms of mineral supplements, there are many products available. The most common method is loose or bagged mineral such as the Purina bag pictured here. The Hawaii Mineral Mix is the most common loose mineral that I have observed being used on many operations in the state, although you can work with companies in order to develop a custom blend. Other delivery methods include trace mineral blocks, which contain no macro-minerals and only contain trace minerals, or molasses-based blocks, which are growing in popularity across the country. These products are easier to use, however one comment I would make when it comes to molasses blocks is that many of them are being used as a protein block, which is the most expensive form of protein you can provide to your herd. Be sure to pencil it out and make sure that those products will work for your operation from a financial standpoint. There are many companies which manufacture molasses-based blocks that are strictly mineral supplements, without the added protein and those products might be a good fit for your operation.



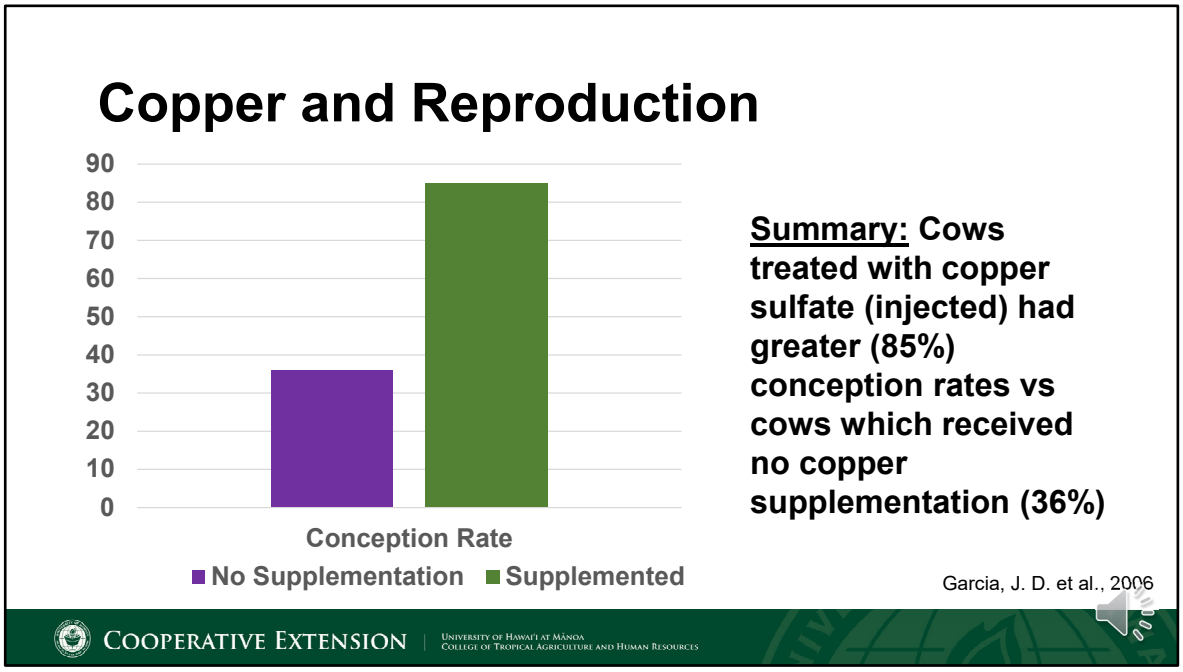
As mentioned throughout this field day webinar series, copper deficiency is quite common, and I suspect that this is likely the largest mineral deficiency on ranches in Hawaii. There are others that are observed and those will be discussed further in Dr. Odanis talk. These photos are classic examples of copper deficiency. These two photos represent the same animal, the one on the left has discolored, missing, patchy, and rough hair and is copper deficient. The photo on the right is the same cow after copper treatment and as you can see, the hair is shinier, has grown back, and overall the cow looks healthier; don't judge her based on her frame, this is clearly an example of an older styled cow. Dr. Odani will go into more detail on the clinical signs of copper deficiency as well as multiple other mineral deficiencies. But I do want to point out that oftentimes the first sign of copper deficiency you will see in your cattle is a discoloration of the coat. It often looks like sun bleaching but most times this is due to a deficiency in copper.



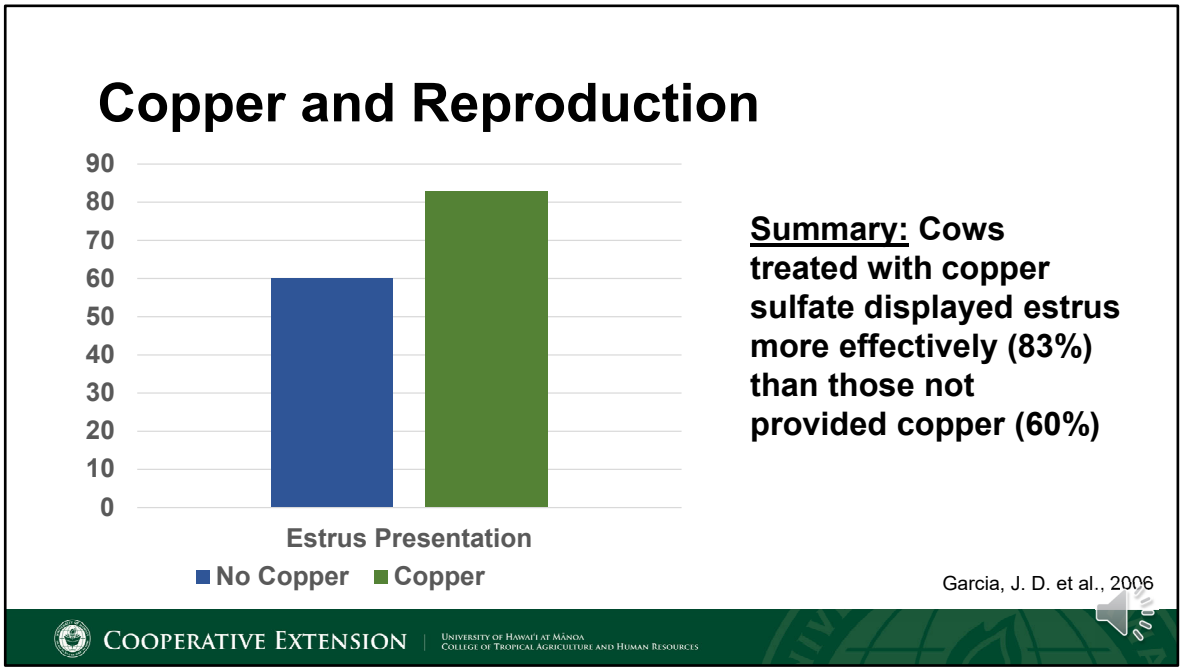
The role of copper in basic body function in cattle is extensive, and we won't get into everything in this webinar, but there are a few things that are important to note. There are many copper-containing and copper-dependent enzymes and the functions of these enzymes include cellular function, neural transmitting, and antioxidation. There are many other enzymes that either contain copper or require copper in order to facilitate their function. Copper is also important in cardiovascular function, due to its role in connective tissue metabolism and cardiac failure has been reported to be caused from extreme copper deficiency. This was historically referred to as "Falling Disease" where cattle in New Zealand were dropping dead out of nowhere in pastures due to ruptures in their aortas. Further inspection indicated that these cows were in fact extremely copper deficient and therefore unable to maintain the integrity of the blood vessels and heart tissue. Similarly, bone formation requires adequate copper level mostly due to its role in tissue and bone metabolism and Dr. Odani will discuss some of these clinical signs in further detail in her talk. Copper and iron now, they have a love hate relationship. Copper is necessary for Fe absorption and animals that are deficient in copper will eventually become anemic as well. However, high levels of iron in the diet can inhibit copper from being properly absorbed by the animal and therefore these two minerals must maintain a delicate balance. Can you see why I love talking about minerals? Their roles in the body are so intricate. Now, all of that is well and good, but let's be honest here, if you're in the cow/calf business, reproduction and immunity are likely big priorities for you and maintaining cows with huge reproductive success and calves with sufficient immune systems is imperative. We are going to discuss those a little further in the following slides.



This is a summary of a survey study where blood samples were taken from 318 cows. It was noted which cows aborted their calves and which had a calf on the ground and compared this to their copper status. From there they collected both blood and liver samples from these cows in order to evaluate copper status. Of the cows which aborted calves, just over 87% of them were copper-deficient, whereas only 12 % of cows which carried calves to term were copper-deficient. These results indicate a relationship between copper deficiency and the ability of a cow to drop a calf on the ground, which is likely one of the top priorities of a ranch.



The next two slides are summarized from the same study which used 120 cows to study the impact of copper deficiency on multiple aspects of reproduction. The authors of this study designed it so all of the cows on trial were on a copper deficient diet, however, half of the animals received an injection of copper sulfate in order to maintain sufficient copper status, whereas the control group was copper deficient due to the diet they were consuming and a lack of the copper injection. These animals were then placed in a reproductive-focused study. The results indicated that animals which were treated with an injection of copper sulfate, or copper sufficient group, had an 85% conception rate, whereas those cows in the control, or copper deficient group, had a 36% conception rate. Now I am guessing when you heard me say a 36% conception rate, you got a little concerned or maybe your eyes bulged a bit. Frankly, it is unacceptable and not profitable to have conception rates that low for a primarily cow/calf operation. The goal would be a 100% conception rate in your cow herd, because as we all know an open cow is a cow that isn't earning her place in the herd and is simply just an expense to your operation.



The same study I just discussed also observed the impact of copper deficiency on the cows ability to display estrus. Only 60% of the copper deficient cows presented estrus, while 83% of the copper injected group expressed estrus. So not only did the group forced into copper deficiency have more open cows, but they weren't even successful at presenting estrus. This function is another often overlooked but yet still very vital aspect of a successful and productive cow herd.

- **Copper deficiency can impact:**
  - **Calving rates**
  - **Conception rates**
  - **Ability to express estrus**
  - **Limited data on cattle specific impacts, but many studies report reproductive failure during copper deficiency**

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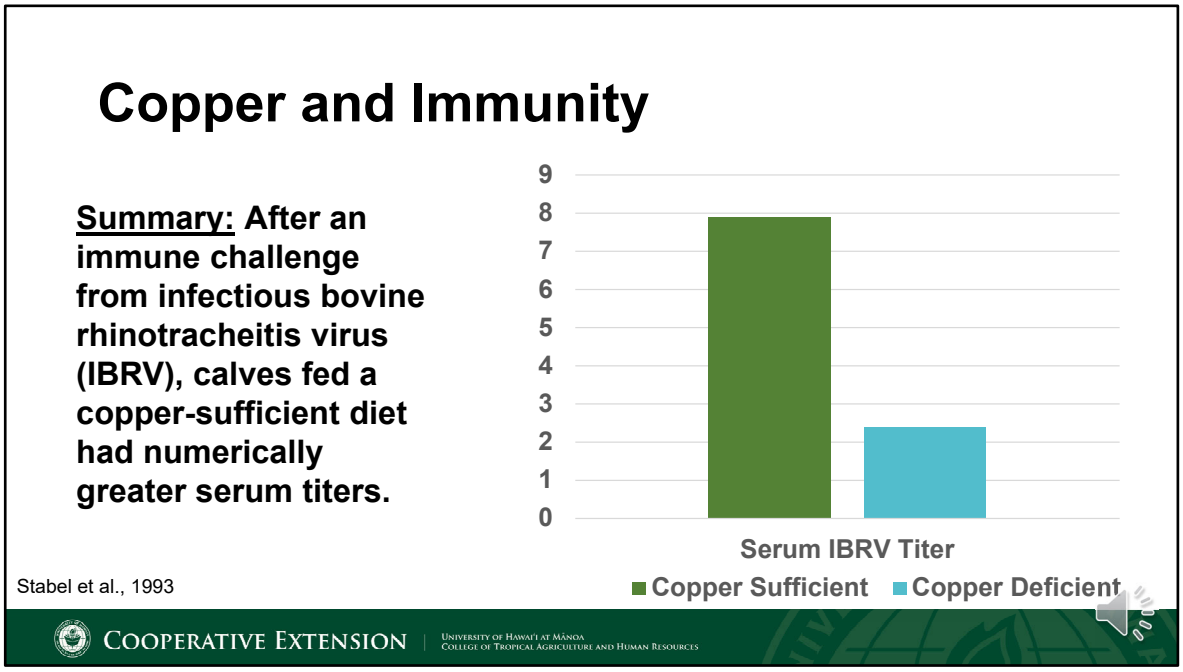
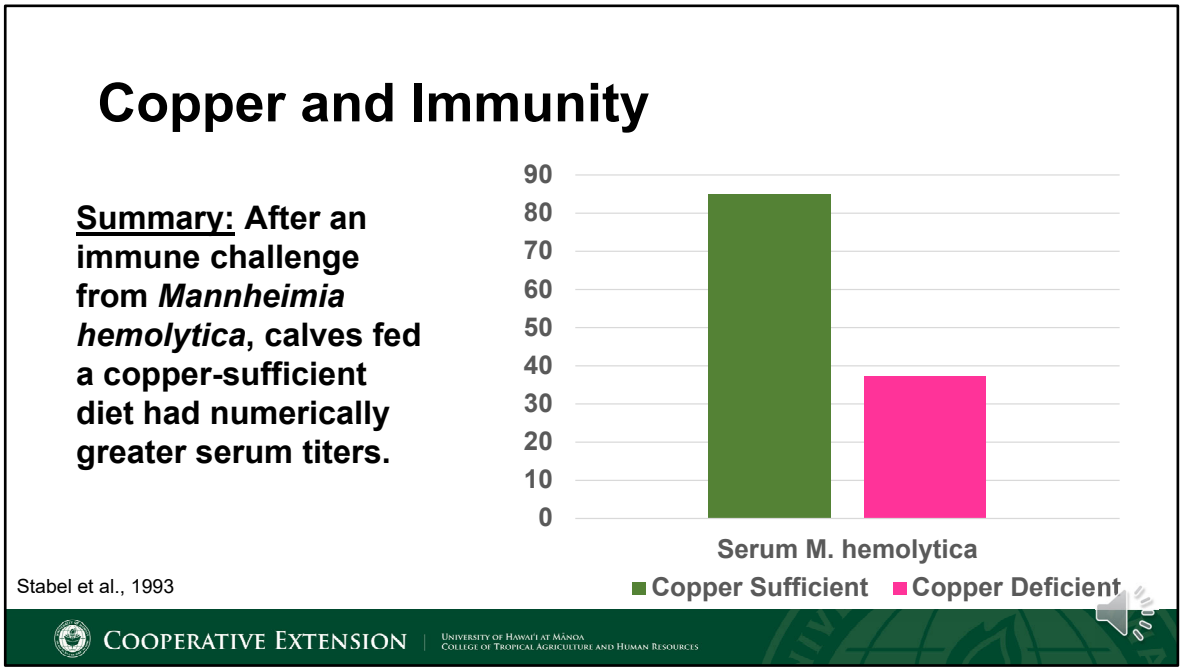
In summary, copper is linked to the cows ability to express estrus and therefore gain the interest of the bull, conception rates, and calving rates and the ability of a cow to carry the calf to term. If you have a cow/calf operation, these 3 aspects of reproduction are the drivers of your operation and dictate your ability to make a profit off of your herd.



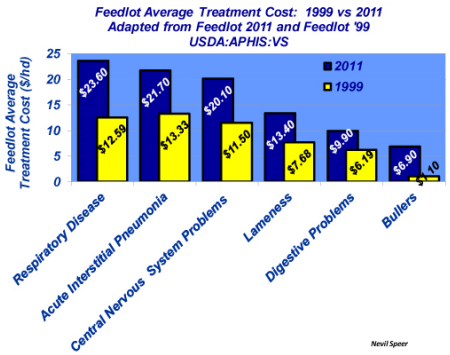
Switching gears, we are going to discuss the relationship between copper and immunity. This is one that has been established for decades with research done on mice, rats, pigs, and cattle. For a rancher, once that calf is on the ground, the next goal is to ultimately get the calf shipped off, placed into a grass finishing program, or sold through some other avenue. The goal is to do this with the least amount of inputs possible in order to have a greater net profit off of each calf. Proper immune function can significantly affect this. In this study, there were two groups of calves, a copper sufficient group and a copper deficient group. Both groups were exposed to infectious bovine rhinotracheitis virus (IBRV), which is one of the viral components of the bovine respiratory disease (BRD) complex. The calves that were copper sufficient had greater serum titers. For those of you who don't know, titers are the goal of a vaccine. When we expose an animal to a pathogen via a vaccine we want as many titers present in the blood after this exposure so that when exposed to the pathogen again in the future, and IBRV will always be one that calves are exposed to, they will be better equipped to fight off the disease. These results indicate that the copper sufficient calves will be less likely to be impacted by an IBRV immune challenge in the future compare to their copper deficient counterparts.



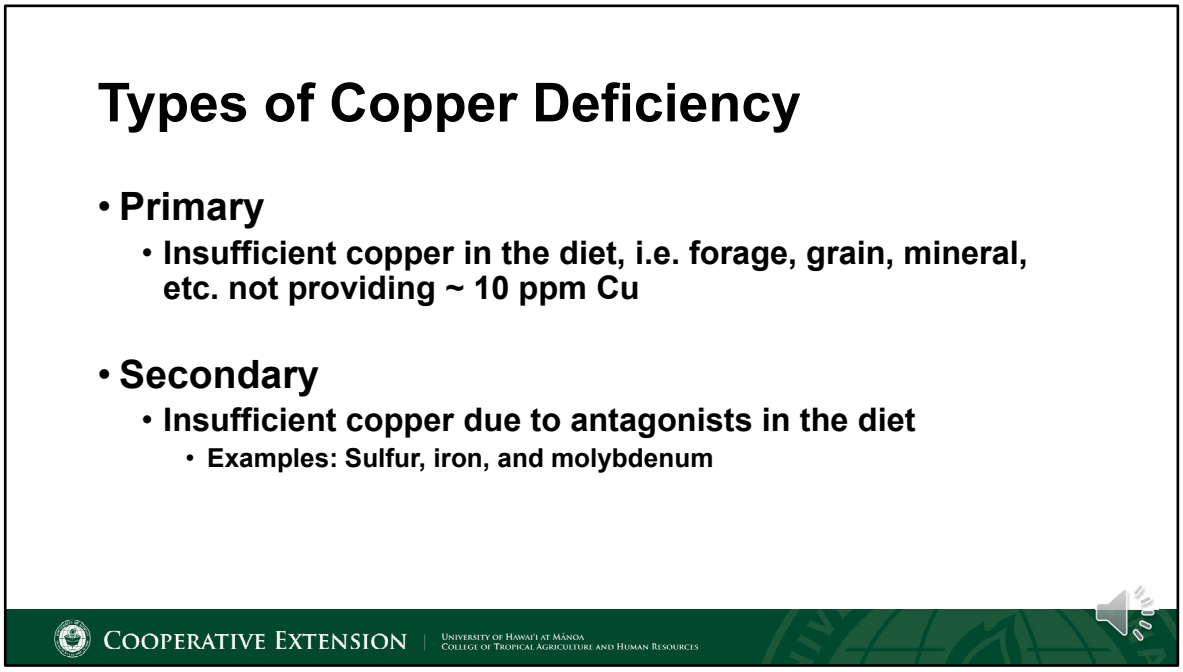
In this same paper, researchers again had a group of copper sufficient and deficient calves. However, instead of IBRV these calves were exposed to Mannheimia hemolytica, a big player in the BRD complex and is the major bacterial pathogen which causes BRD. Again, calves which were copper sufficient had greater serum titers after this immune challenge, indicating a greater ability to handle any future Mannheimia hemolytica challenges in the future.

Copper and Immunity

- **Copper deficiency impacts:**
  - **Initial immune response**
  - **Efficacy of vaccines**
  - **Future immune responses**
  - **Immune cell regulation**
  - **Inflammatory response**



In the top right of this slide I put a chart which is summarized from USDA APHIS data, which indicates the greatest treatment costs for a feedlot is BRD, at $23.60. A survey of ranchers last year indicated on average $26 was spent per calf treating BRD. I can imagine with the increased cost of labor and medications, this number is much higher for Hawaii. Now, if we can decrease the need to round-up and treat calves for things such as BRD by simply having adequate mineral nutrition, that would mean more money in your pockets at the end of the day on a per calf basis. In summary copper deficiency can impact vaccine efficacy as seen in the studies I presented, initial immune response, future immune responses, and I didn't touch on this but it has long been linked to immune cell regulation and function as well as the efficacy of an inflammatory response.



So now that I've given you the reason for why copper is important, lets transition into some of the nutritional aspects of copper nutrition in the beef cow. When we discuss copper deficiency there are two types: a primary copper deficiency which is caused from insufficient copper in the diet, which would be anything less than 10 ppm; and a secondary copper deficiency which is caused from antagonists present in the diet which limit the ability of the animal to absorb the copper provided to it. This means that the cattle may be consuming 10 or more ppm of copper, however, they are not able to absorb and therefore utilize the copper and it is essentially excreted and unused. In the case of copper, these antagonists are sulfur, iron, and molybdenum. And unfortunately for livestock producers in Hawaii, all three of these minerals are an issue in the state.

Copper Antagonists

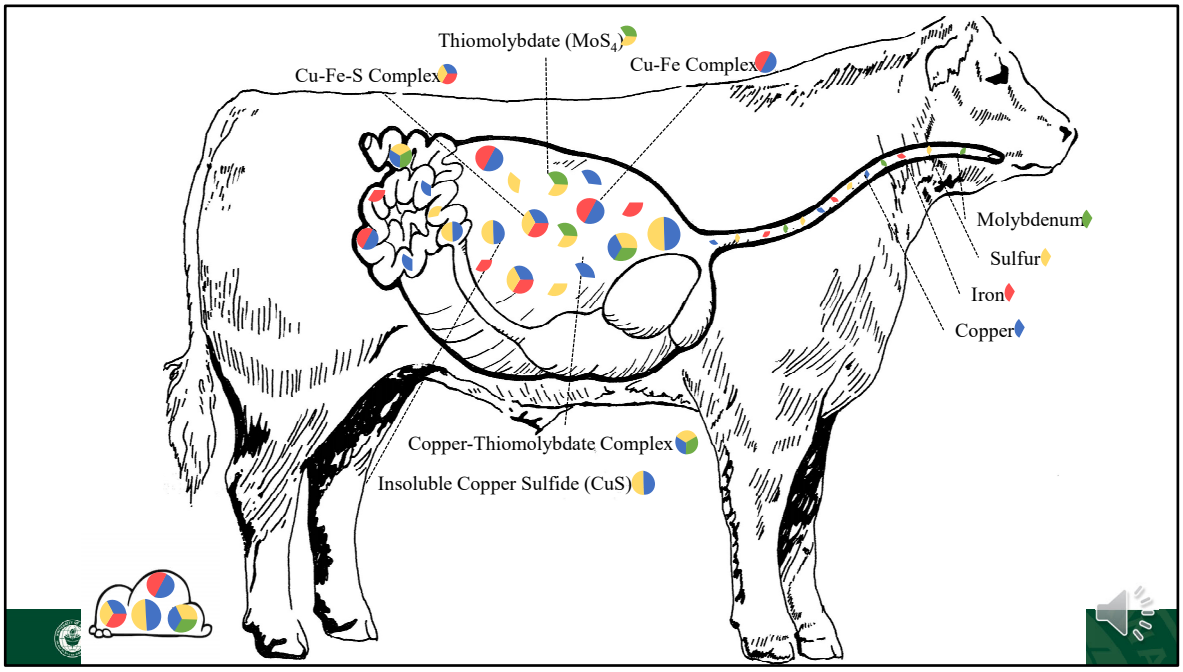
When it comes to minerals and ruminants, what goes in isn't always useable by the animal

- **Copper & Iron**
  - **Cu=Fe absorption but…**
  - **Impedes Cu at 200 ppm**

- **Copper & Molybdenum**
  - **Often associated with sulfur**
  - **Thiomolybdate-copper complexes**

- **Copper & Sulfur**
  - **Copper sulfide & copper bound thiomolybdates**

As a ruminant nutritionist by trade, I always like to poke a little fun at monogastric nutritionists because animals like poultry and hogs are so cut and dry. But, when it comes to ruminants, such as cattle, what goes in isn't what is necessarily absorbed and made available to the animal. There is a lot of modification and interactions that occur in the rumen, both good and bad. As I mentioned before, copper and iron have an interesting relationship. They need each other, but iron levels over 200 ppm can impede copper absorption. The specific mechanisms for how this happens are still being explored but some of the ways it impacts Cu availability is by directly binding to copper, dissociating from sulfur, if it is in the form of ferrous sulfide, and the sulfur binds to copper, or it can compete for absorption sites and therefore can kick the copper out of the site of absorption in both the rumen and small intestine. Sulfur and molybdenum like to gang up to ruin coppers day. Molybdenum alone doesn't greatly impact copper availability but molybdenum and sulfur together form thiomolybdates, which are copper-hungry. These compounds then seek out copper and bind to it. Once this happens, the copper cannot be absorbed and is excreted in the feces. Sulfur on its own can also bind directly to copper and form an insoluble form of copper sulfide and is again unabsorbed and excreted.



This graphic illustrates everything I just talked about in a more visual way. What happens is the animal consumes feed containing various minerals, such as sulfur, iron, molybdenum, and copper. Those minerals are often bound to an inorganic compound, such as sulfates in the case of copper sulfate or ferrous sulfide and they quickly dissociate, or break apart in the rumen. In the case of copper, this allows it to carry a charge and attract things such as sulfur, iron, or thiomolybdates. Once they are bound, they are near impossible to break apart and the copper passes out of the rumen, through the intestine where it cannot be absorbed, and is essentially excreted out of the body into manure.

Copper Antagonist	Deficient	Ideal	Antagonistic Level**		MTC*
			Marginal	High	
Iron (ppm)	< 50	50-200	> 200 -400	> 400	1000
Molybdenum (ppm)	Not Established	< 1	1-3	> 3	5
Sulfur (% DM)	< 0.10	0.15 – 0.20	> 0.20 – 0.30	> 0.30	0.40

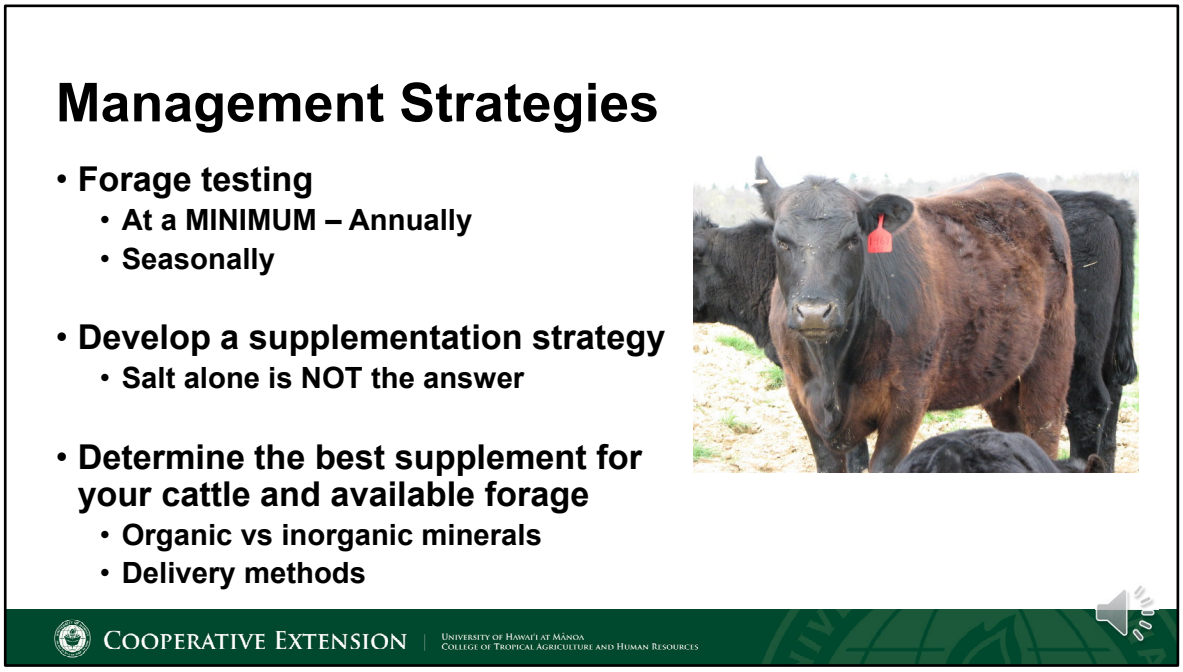
*Maximum Tolerable Concentration
** Levels above these can potentially adversely affect copper availability.

You have likely seen this chart in others' presentation, but as we can see here iron, molybendum, and sulfur all of an ideal concentration in the diet and are therefore always needed, however if it reaches levels greater than these listed here, it can impact copper absorption. For iron, that is anything great than 200 ppm, molybdenum anything greater than 1 ppm, and for sulfur anything greater than 0.2 ppm.

Characteristics of Hawaii's Forages

Season	Sample Size	% DM	% CP	% Ca	% P	% Mg	% K	% Na	Fe ppm	Zn ppm	Cu ppm	Mn ppm	Mo ppm	% S	Ca:P	Cu:Mo
10.11-11.11 Fall	n=9	**23.0**	**15.3**	**0.3**	**0.4**	**0.3**	**3.0**	**0.1**	**458.0**	**48.3**	**8.9**	**144.7**	**0.3**	**0.2**	**0.9**	**69.6**
		2.1	2.3	0.0	0.1	0.0	0.6	0.0	327.3	7.4	0.8	43.0	0.1	0.0	0.2	33.7
12.11-2.12 Winter	n=9	**24.1**	**20.4**	**0.4**	**0.4**	**0.3**	**2.3**	**0.1**	**492.7**	**38.4**	**11.2**	**127.6**	**0.9**	**0.2**	**1.1**	**13.4**
		6.7	2.6	0.0	0.0	0.0	0.1	0.1	298.0	8.9	1.4	46.7	0.3	0.1	0.1	3.1
3.12-5.12 Spring	n=6	**28.8**	**20.1**	**0.4**	**0.3**	**0.3**	**2.3**	**0.1**	**810.8**	**36.7**	**10.5**	**130.5**	**0.5**	**0.3**	**1.2**	**29.0**
		1.7	1.7	0.0	0.0	0.0	0.5	0.0	855.3	11.5	1.9	83.9	0.3	0.0	0.1	20.6
6.12-8.12 Summer	n=9	**23.8**	**18.9**	**0.3**	**0.3**	**0.3**	**2.7**	**0.1**	**180.8**	**38.1**	**11.3**	**225.1**	**0.1**	**0.2**	**1.0**	**0.0**
		5.2	1.1	0.0	0.0	0.0	0.4	0.1	49.3	5.9	1.3	63.0		0.0	0.2	39.4

Again, this is a slide you have likely seen before, but Hawaii's forages contain extremely high levels of iron, well above the antagonistic level, and depending on the season, both molybdenum and sulfur flirt with or at the antagonistic level. We can see that during a majority of the year, iron levels are well above the 200 ppm cutoff for antagonism. All three of these are a perfect storm, or a recipe for disaster when it comes to supplementing copper to your herd.



So, what does this mean for you as a producer? How can you make sure your herd is copper sufficient? The single most important thing you can do is know the nutrient profile of your feedstuffs. For most of you, that is the forage. At a minimum, forages should be sampled annually and a full panel should be done which includes protein, NDF, ADF, etc. as well as all macro and microminerals. Keep in mind that simply knowing how much copper is in the forages is NOT sufficient because we have antagonists present in our forages. Ideally, I would like to see forage samples collected and tested seasonally. We can see from the data on our forages that mineral content is heavily influenced by season and namely rainfall. If you ever need to be trained on forage testing or have any questions about where to send it, what to have analyzed, how to collect it or anything else, do not hesitate to contact either your county agent or an extension specialist and any of us would be more than willing to assist you with that. After you've had your forages tested, next is developing a supplementation strategy. One size does not fit all so it's important to try and tailor your supplementation for your pastures. Keep in mind that salt alone is not sufficient in order to have a nutritionally balanced diet for your herd. I want to take a moment to have a brief discussion on inorganic vs organic minerals. Now by organic I don't mean USDA certified organic, I am talking about minerals that are combine with an organic compound such as an amino acid. Organic minerals include chelates, proteinates, polysaccharide complexes, and amino acid complexes. Inorganic minerals are the commonly known minerals such as sulfates, chlorides, and oxides. So what's the big deal about organic minerals? Well they have a completely difference chemical makeup than inorganic minerals. Organic minerals are more tightly bound, meaning that when they enter into the rumen they dissociate to lesser degree in the rumen, versus copper sulfate which is almost 100% dissociated. This means that oftentimes the organic copper can pass through the rumen without binding to any of the antagonists and a greater amount is absorbed. These products are often more expensive than inorganic minerals, and may not work for every operation or may not even be needed if there are little to no antagonists in your feedstuffs. I highly recommend penciling out the use of these minerals, and weighing out the inputs and outputs of their use, maybe even using the risk tool that John will discuss in his talk. Again, if you ever have any questions about mineral types I would be more than happy to discuss this with you, clearly, I love to talk about minerals and nutrition.

With that I want to thank you all for listening. If you have any questions about what I discussed please feel free to send me an email or give me a call and we can discuss. Enjoy the remainder of the talks in this webinar series and I hope that you can join us in person at our next field day program this fall.