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# Bone Broth Analyzed

## *Investigation and Discussion*

### *The Premise:*

Bone broth is one of the most mineral rich foods you can make right? OK, I'll buy that. I've read it in many threads online and in many written publications discussing nutrition based on traditional, ancestral, whole-food, paleo, primal and low-carb concepts. Common sense dictates that it *should* be true, as after all, the process of making bone broth essentially consists of dissolving bones in water (at least partially). Well, if that's truly the case then where is the evidence?

I looked everywhere, but couldn't find a single stich of information that wasn't simply inference or conjecture (i.e. "Bone broth is rich in minerals, especially calcium and phosphorus"). Where are the facts, the hard numbers? Is it possible that the idea of bone broth being rich in minerals is so credible that nobody's ever bothered to prove it? Has no one been curious to see just how many minerals there are in bone broth? I know I have.

I really wanted to scratch this itch, but even Google wasn't helping me. Admittedly I am a bit of a data freak; I like knowing the details. That isn't to say that I'm a "doubting Thomas"; more like "curious George". I was already a *believer* in bone broth. I consumed it regularly and promoted it to others. I already *assumed* that there must be a cornucopia of unique health promoting compounds in bone broth, from the obvious minerals and gelatin to possibly more mysterious and elusive compounds like trace minerals, nucleotides, sulfates, long-chain fatty acids, fat soluble vitamins, co-factors, growth factors, glycosaminoglycans and a range of other potential molecules coming from such precious stores as marrow, connective tissue, bone and even spinal cord (if using back-bone segments).

While I didn't need convincing, I still wanted numbers and values. If not to *prove* the concept, then at least to compare bone broth to other foods and otherwise satisfy my curiosity. I was left with no other choice than to do my own tests. And so it began.

### *The Protocol:*

If I was going to make bone broth and have it tested by a lab, I wanted it to be the best bone broth possible. Surely there would be a sliding scale of mineral concentration that would depend on such factors as bone type, size, quality, PH and cooking time. I wanted my broth to be in the upper limits of this scale. I also wanted the broth to be reproducible and therefore representative of what at least some people are already doing out there.

I decided to use venison bones. I live on a small island in the Pacific Northwest and we have an abundance of mule deer. Over the winter I had hunted a nice young buck and kept all his bones for future broths. Since the mule deer are quite small here, the bone yield is about as much as you'd get from a big lamb. As the bones weren't very big I decided to make a mix, using every part of the body possible; long bones including joints, from the limbs (to get that nice soft marrow), hip bones, shoulder blades and backbone segments which included some nice spinal cord (no CWD to worry about in these parts). The bones were all scraped clean of meat and either cut or broken up to increase surface area. Deer bones are also quite thin so after cooking they easily fall apart.

I weighed the bones and measured the amount of water used to make the broth and carefully timed the cooking process to achieve the highest level of accuracy possible. I used a small pressure cooker (12 psi) in order to reduce the cooking time as well as to reduce water loss through steam. When all was said and done I took a sample of it and sent it to a local lab for analysis. I also took a sample of the water I used to have analyzed as the control. Here is the summary of that experiment.

| Bone Broth Protocol | |
|---|---|
| **Water**<br>(well water, filtered & UV treated, from the tap) | 2.25 L |
| **Bones**<br>(deer bones, scrapped, cut/broken, mixed types) | 3 lbs |
| **Cooking Method** | Pressure Cooker (12 PSI) on propane stove |
| **Cooking Time** | 8 hours (7 under pressure) |
| **Sample Taken** | 125 ml |

| Water Sample Analysis | |
|---|---|
| *Calcium (Ca)* | 36.1 mg/L |
| *Copper (Cu)* | 0.05 mg/L |
| *Iron (Fe)* | 0.05 mg/L |
| *Magnesium (Mg)* | 1.1 mg/L |
| *Manganese (Mn)* | <0.01 mg/L |
| *Potassium (K)* | 0.2 mg/L |
| *Sodium (Na)* | 53.0 mg/L |
| *Zinc (Zn)* | 0.05 mg/L |

So far, so good. I had what I believed to be a reasonable experiment for extracting a maximum amount of minerals without hitting a point of diminishing returns, i.e. before starting to over-degrade the quality of other important compounds more organic in nature like proteins and fatty acids. Let's see what the lab had to say about it.

| Bone Broth Analysis | | |
|---|---|---|
| Minerals | Amounts | Factor of Increase |
| *Calcium (Ca)* | 111.6 mg/L | 3.1 x |
| *Copper (Cu)* | 0.08 mg/L | 1.6 x |
| *Iron (Fe)* | 2.43 mg/L | 48.6 x |
| *Magnesium (Mg)* | 19.0 mg/L | 17.3 x |
| *Manganese (Mn)* | 0.04 mg/L | > 4 x |
| *Potassium (K)* | 416.0 mg/L | 2080 x |
| *Sodium (Na)* | 668.0 mg/L | 12.6 x |
| *Zinc (Zn)* | 0.59 mg/L | 11.8 x |
| *Total Nitrogen* | 7.8 g/L | N/A |
| *Total Protein** | 48.75 g/L | N/A |

Is it just me, or are these results totally unimpressive? I cooked 3 pounds of bones in a pressure cooker for 8 hours and all the calcium I managed to extract was 75.5mg? Granted, the total amount of minerals increased a fair bit, but the starting point was very low so the end result is still a far cry from being a mineral-rich food. You're likely to get more minerals from a small serving of Kale. Call me naïve, but I was expecting at least 10 times that amount (at least for something like calcium since it is the dominant mineral in bone).

*Total Protein is calculated from Total Nitrogen using an accepted quotient as these are intrinsically linked. When calculating protein content from animal sources Total Nitrogen is multiplied by a factor of 6.25.

The only impressive, even surprising result was the total protein content of the broth. At nearly 50g per liter (of clear broth), it's even more than you get from the average protein shake.

Protein is great, but it's the minerals I was after. I decided I must have not cooked the bones long enough. After all, stories are told of people cooking them for days on end until nothing is left but thick gritty sediment at the bottom of your pot. I had to try again.

*The New Protocol:*

Since I considered my first experiment to be less than successful, I decided to take it up a notch. I needed to increase the cooking time for sure, but I also decided to add vinegar to the broth to reduce PH and sent the samples to a bigger, more professional lab in the hopes of getting the most accurate results.

I used store-bought bones from grass-fed bison and cooked them for a total of 24hrs. I also used this opportunity to take a sample of broth midway through the boil (at 12hrs) to see the progression. I wondered if there was perhaps a "critical point" when the bones really started to shed their minerals; i.e. was the progression fairly linear or was it perhaps exponential beyond a certain point?

Of course, I would again send a sample of the water I used as a control; both to establish the mineral starting point of the broth and to compare the results with the other lab's values to either validate or refute them.

Due to my newfound doubt regarding the mineral prowess of bone broth, I also decided to send a sample of the most mineral rich vegetable broth I could make for comparison. Again I aimed for the highest values possible so I used an unreasonable amount of two of the most mineral rich plants nature provides: Nettles and Dandelions. I say "unreasonable" because I can't believe that anyone has ever or would ever use as much of these greens as I did to make a soup. This was going to be interesting; I was excited again.

*Summary and Results:*

| Bone Broth Protocol | |
|---|---|
| **Water**<br>(well water, filtered & UV treated, from the tap) | 2.25 L |
| **Bones**<br>(grass fed bison, 3 large bones with a bit of meat still on them) | 3.5 lbs |
| **Vinegar**<br>(white vinegar, 5% acetic acid) | 30 ml |
| **Cooking Method** | Pressure Cooker<br>(12 PSI)<br>on propane stove |
| **Cooking Time** | 25 hours<br>(24 under pressure) |
| **Samples Taken** | 250 ml after 12hrs<br>250 ml after 24hrs |

| Vegetable Broth Protocol | |
|---|---|
| **Water**<br>(well water, filtered & UV treated, from the tap) | 2.0 L |
| **Greens**,<br>Stinging nettle tops, fresh. | 250 g |
| **Greens,**<br>Dandelion Leaves, dried. | 52 g*<br>(*Equivalent to about 350g of fresh leaves) |
| **Cooking Method** | Pressure Cooker<br>(12 PSI)<br>on propane stove |
| **Cooking Time** | 3 hours<br>+ Left to steep overnight, no heat. |
| **Sample Taken** | 250 ml |

I sent the 4 samples to a bigger and more experienced lab this time; in operation for 30 years, specialized in water, soil and food analysis and using the most up to date techniques and equipment. Instead of being limited to the previous 8 minerals, I was able to order an analysis of over 30 minerals on each sample (though I am only including the 14 most relevant for this discussion). I was confident and excited to see the results. As you'll see however, what I got was even more disappointing and confusing than my first results.

| Water Sample Analysis | |
|---|---|
| *Boron (B)* | <0.05 mg/L |
| *Calcium (Ca)* | 29.5 mg/L |
| *Chromium (Cr)* | <0.01 mg/L |
| *Copper (Cu)* | 0.032 mg/L |
| *Iron (Fe)* | 0.034 mg/L |
| *Magnesium (Mg)* | 1.2 mg/L |
| *Manganese (Mn)* | <0.004 mg/L |
| *Phosphorus (P)* | 0.193 mg/L |
| *Potassium (K)* | 2.90 mg/L |
| *Silicon (Si)* | 16.5 mg/L |
| *Sodium (Na)* | 45.3 mg/L |
| *Strontium (Sr)* | 0.11 mg/L |
| *Sulphate (SO4)* | 11.2 mg/L |
| *Zinc (Zn)* | 0.05 mg/L |

So far, so good. The water analysis was very similar to my first sample. Such small variances have to be expected from well water.

The shock and confusion came with the analyses of my 3 broth samples, seen below.

| Bone Broth Analyses | | |
|---|---|---|
| Minerals | **12hr Broth** | **24hr Broth** |
| *Boron (B)* | <0.05 mg/L | <0.05 mg/L |
| *Calcium (Ca)* | 6.61 mg/L | 27.2 mg/L |
| *Chromium (Cr)* | <0.01 mg/L | <0.01 mg/L |
| *Copper (Cu)* | 0.017 mg/L | 0.035 mg/L |
| *Iron (Fe)* | 0.125 mg/L | 0.245 mg/L |
| *Magnesium (Mg)* | 11.1 mg/L | 14.7 mg/L |
| *Manganese (Mn)* | <0.004 mg/L | <0.004 mg/L |
| *Phosphorus (P)* | 64.6 mg/L | 68.0 mg/L |
| *Potassium (K)* | 420 mg/L | 668 mg/L |
| *Selenium (Se)* | 1.43 mcg/L | 0.35 mcg/L |
| *Silicon (Si)* | 9.90 mg/L | 16.8 mg/L |
| *Sodium (Na)* | 534.0 mg/L | 1060.0 mg/L |
| *Strontium (Sr)* | 0.011 mg/L | 0.030 mg/L |
| *Sulphate (SO4)* | 39.3 mg/L | 64.2 mg/L |
| *Zinc (Zn)* | 0.075 mg/L | 0.158 mg/L |
| *Total Nitrogen* | 9.208 g/L | 18.983 g/L |
| *Total Protein* | 57.5 g/L | 118.6 g/L |

| Nettle/Dandelion Broth Analysis | |
|---|---|
| Minerals | Amounts |
| *Boron (B)* | 0.655 mg/L |
| *Calcium (Ca)* | 237.0 mg/L |
| *Chromium (Cr)* | <0.01 mg/L |
| *Copper (Cu)* | 0.093 mg/L |
| *Iron (Fe)* | 0.204 mg/L |
| *Magnesium (Mg)* | 73.2 mg/L |
| *Manganese (Mn)* | 0.556 mg/L |
| *Phosphorus (P)* | 88.5 mg/L |
| *Potassium (K)* | 1850.0 mg/L |
| *Selenium (Se)* | <0.50 mcg/L |
| *Silicon (Si)* | 88.0 mg/L |
| *Sodium (Na)* | 70.8 mg/L |
| *Strontium (Sr)* | 1.21 mg/L |
| *Sulphate (SO4)* | 111 mg/L |
| *Zinc (Zn)* | 0.59 mg/L |
| *Total Nitrogen* | 0.448 g/L |
| *Total Protein* | 2.7 g/L |

I think a pattern is developing here; bone broth is decidedly not going to reveal itself as a mineral rich food; at least not for the minerals you'd expect like Calcium. The nettle/dandelion broth was the clear winner between the three, but even that seemed to be on the low side considering the amount of leaves used. A quick reference to a nutritional data compendium will show that you can expect to get a lot more minerals by simply eating the leaves. Of course, I didn't expect that my broth would be able to extract *all* the minerals from these greens, but I did expect it to obtain more than it did. Something else seems to be at play here that goes beyond the idea that we can simply extract minerals from things into solution by boiling the crap out of them.

A few things caught my attention in particular when looking at these results. For one, the calcium content in both of the bone broth samples is actually *lower* than it was in the water I started with! How can that be?

Another interesting thing is that most minerals (and nitrogen) seemed to have increased linearly through the boiling process, meaning that they more or less doubled from the 12hr point to the 24hr point. This would seem to suggest that the longer we cook, the more we get. Too bad it didn't apply to the calcium, magnesium, phosphorus and selenium, and too bad it's all fairly meaningless as most of these amounts are barely beyond trace levels.

Again, the protein content of the broths were the most impressive. I would've never thought you could squeeze 118g of protein into a liter of clear broth, and it looks like it might've been even more had I cooked it longer still.

At this point I was frustrated enough to get on the phone with the lab and demand a retesting of my samples. I explained my incredulity, using the calcium scores as my basis as these were the most obviously irreconcilable. The lab kindly obliged and ensured that their senior chemist oversaw the analyses. After a few days of waiting, the results came in: Original Analysis Confirmed. That means they got the same results the second time around.

I spoke at length to a senior staff member there about my perplexing results, and she explained that *she* wasn't surprised at all! Molecularly speaking, bone broth is a very complex thing. Who knows what is going on in there; what molecules are possibly reacting with others? Also, just because you are breaking down the physical structure of bones using heat and water, doesn't mean that any "released" minerals will automatically go into solution (in ionic form). This is apparently hard to do unless you use industrial strength acids. She told me that many food companies face similar problems when formulating new recipes and trying to achieve consistent nutritional profiles. Any new ingredient, substitution or change in process can have a big influence on the end result, often in unpredictable ways.

*<u>Two likely explanations:</u>*

1. The minerals are being bound out of solution through chemical reactions in the broth. I.e. perhaps the minerals are reacting with certain proteins or other structures and precipitating out of the broth. *This would explain why the calcium values were actually lower in the broths than in the plain water. It also explains why it seemed to affect some minerals more than others; perhaps there is a chemical affinity for some minerals in this particular environment due to their unique chemical properties.*

2. The minerals are not actually being "released" from their glyco-protein matrixes in the bones and other tissues. The macro structure of the bone is breaking down, but only into smaller micro structures that simply sink to the bottom of the pot; not small enough to be dissolved or kept in suspension.

Put simply, most of the minerals were likely in the sediments at the bottom of the pot. This is not news to anyone who's made bone broth and experienced the soft sand-like grit waiting for you at the bottom of each bowl. Of course, it wasn't news to me either, but I still expected the broth itself to be quite rich in minerals. The fact that it is not, and even that it's mineral poor, *was* news.

I couldn't stop there; I had to know how many minerals were in the sediments. I decided I would make yet another batch of broth, but this time separate the sediment from the broth and have both analyzed separately. I used the same protocol as above, but used 3lbs of locally pastured grass-fed cow bones and cooked them for 9hrs in my trusty pressure-cooker. When it was done cooking, I let it cool and removed all the bones from it. Once everything was settled, I carefully ladled all of the broth out until I was left with only the sediment layer. I scraped and poured all of it into a jar (only about 60ml or 2oz worth). I sent this jar along with a sample of the broth to the lab for analysis.

Bingo! While it's no surprise that this is where most of the minerals would be found, the results still don't make bone broth a particularly mineral rich food (unless your layer of sediment is more considerable than mine). Though that 60ml sample is fairly mineral rich, it doesn't go very far toward balancing the rest of the broth once you divide it by its total volume (at least 2 liters). Remember that these values are expressed in mg/L, but my sample was only 60ml. You have to multiply these numbers by 0.06 (60ml is 6% of a liter) to get the actual amounts of minerals in that sample. Now take those numbers and divide them by about 2 (2 L) to account for the whole broth. Not so impressive anymore, is it? See the table here for the actual values contributed by the sediment to 1L of broth.

**Bone Broth & Sediment Analyses**

| Minerals | **9hr Broth** | **Sediment** | **Total** (Broth + Sediment) |
|---|---|---|---|
| *Boron (B)* | 3.59 mg/L | 4.92 mg/L | **3.74 mg/L** |
| *Calcium (Ca)* | 16.7 mg/L | 2764.0 mg/L | **99.62 mg/L** |
| *Chromium (Cr)* | 0.011 mg/L | 0.039 mg/L | **0.012 mg/L** |
| *Copper (Cu)* | 0.109 mg/L | 0.148 mg/L | **0.113 mg/L** |
| *Iron (Fe)* | 0.485 mg/L | 5.29 mg/L | **0.634 mg/L** |
| *Magnesium (Mg)* | 5.27 mg/L | 68.6 mg/L | **7.33 mg/L** |
| *Manganese (Mn)* | 1.51 mg/L | 1.47 mg/L | **1.55 mg/L** |
| *Phosphorus (P)* | 45.4 mg/L | 1010.0 mg/L | **75.5 mg/L** |
| *Potassium (K)* | <0.03 mg/L | 398.0 mg/L | **11.97 mg/L** |
| *Selenium (Se)* | <0.01 mg/L | <0.01 mg/L | **<0.01 mg/L** |
| *Silicon (Si)* | 9.03 mg/L | 8.81 mg/L | **9.29 mg/L** |
| *Sodium (Na)* | 428.0 mg/L | 511.0 mg/L | **443.33 mg/L** |
| *Strontium (Sr)* | 0.025 mg/L | 2.25 mg/L | **0.093 mg/L** |
| *Zinc (Zn)* | 0.231 mg/L | 5.04 mg/L | **0.38 mg/L** |
| *Total Nitrogen* | 12.2 g/L | N/A | **≈12.2 g/L** |
| *Total Protein* | 76.25 g/L | N/A | **≈76.25 g/L** |

*Discussion and Conclusion:*

By now, one thing should be clear: bone broth is *not* as rich in minerals as we've made it out to be. What *is* rich in minerals is bones themselves. If you want to obtain the minerals from the bones, you're going to have to eat them one way or another. That means either cooking the bones until they are soft enough to chew or long enough until they break down into bone sand to enrich your soups and stews, though the texture may not be as appetizing.

This may be true, but it remains that from a historical and even nutritional perspective, this fact is more or less insignificant. I'm sure it is quite a rarity that bone broth was/is ever consumed by itself; probably at least accompanied by a mixture of some kind of vegetation. It is therefore moot to say that the broth itself is low in minerals when the end-product soup supplies many minerals in relative abundance, via the other foods added to it.

It is not for *nothing* that bone broth has stood the test of time as a health promoting food across diverse populations worldwide. The health benefits of bone broth may have never hinged on its supposed mineral repletion, though it might have been believed to be (at least in part). Bone broth obviously supplies a host of other important nutrients which have been responsible for its enduring popularity (not to mention its flavour). I might add that some of these nutrients are not likely to be found anywhere else in our diets. The combination of fresh roots & greens, herbs, meat and bone broth is still hard to beat as a nutritionally complete and health promoting food.

I started out this investigation as a bone broth enthusiast curious about its professed mineral profile. In the end, I came out of it as the same bone broth enthusiast only more educated on its intrinsic value and how to profit from it optimally. Even though my nutritional expectations of it have been mitigated somewhat, my appreciation for it has only grown. I hope this information will do the same for you.

*Recommendations:*

- Bones have a lot of "life" in them, so use them up to their fullest potential. My experiments have shown that high amounts of protein (amongst other things I'm sure) can still be extracted even after 24hrs of cooking. If you're the type of person that usually cooks their bones for 8-12 hours, make sure you save your bones and use them again. You'll likely get as much protein out the second and third boil as from the first (even if your bones look "dry" after the first boil).

- In fact, even if you're the type of person that usually cooks their bones for 24hrs or more, it might still be a better idea to do so in 8-12hr segments in order to obtain the highest quality nutrients possible. That is, cook your bones for 8-12hrs, then remove the broth and replace it with fresh water. Repeat this until you've achieved your desired total cooking time. This will protect the nutrients extracted in your first boil from being further denatured by excessive exposure to heat. Case in point: though my 24hr broth from above had the highest levels of protein, its structure was actually considerably weaker than the 12hr sample of the same broth. It did not hold into as strong of a "gel" and remained somewhat more fluid. Its color was also considerably darker than the 12hr sample, which itself was darker than both of my other broths cooked for 8 and 9hours respectively. The weaker structure suggests that the gelatinous proteins and glycans were getting denatured and losing their properties. The darker color might suggest a similar situation, akin to the browning of foods as they oxidize, cook and caramelize, though this is only speculative as it is too difficult to account for any other contributing factors (like concentration through evaporation).

- Finally: Get your minerals from the foods themselves. This applies to herbal teas as well. For those of you hoping to boost your iron levels by drinking nettle tea, consider eating the nettles in the tea bag when you're done infusing. Better yet, buy them in bulk and add them to your soup. Though boiling water does seem to extract *some* of the minerals, it seems most of them stay in the food. So have your tea and eat it too!

*Please see Appendix 1 for a comparative table of all my analytical results.

For more information on these bone broth experiments, please contact me at bonebrothinfo@gmail.com.