Seafood Processing Waste for Nutrition and Disease Control in Organically-Grown Potatoes

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I'd like to get into a couple of years of work we've been doing on applying seafood waste, particularly lobster waste, as a soil amendment in potato production, not only as a source of plant nutrition but also for disease control. That's the area that I'm specifically going to concentrate on because I'm a pathologist working on the disease aspects of this system.

Why look at this in the first place? Well, whenever you look at the waste from one industry potentially having benefits for another, it makes good environmental sense. So I think that's really the justification for beginning to look at some of this work. Also, there has been some historical work done in other crops looking at various seafood products and their impacts on the system that have shown some success, not only in disease control but also, of course, as a source of nutrition. Applying material from the sea to the land is a centuries-old practice, but it's only now that it's being looked at in some more detail, and some more specific science is being applied to try to figure out perhaps what some of the impacts of doing this really are. So some of the objectives of our work were to determine if the seafood waste, particularly lobster waste in this case, although we have been using crab too, when used as a soil amendment, is effective as a source of plant nutrition and also as a biocontrol method for some of the soilborne fungi pathogenic to potatoes. Also, we were interested in seeing what was causing the disease suppression, if there was any, and if it was related to any of the complex of soil microorganisms that are present in our ecosystems here.

As I mentioned, there has been previous work done. As an example, in 1997 a study by Pleban et al. looked at a bacterium producing chitinase which was shown to significantly protect cotton seedlings from root rot cause by *Rhizoctonia solani*. I'm going to be focusing on *Rhizoctonia* a little bit in this talk, as you'll see. There was also another study in 1999 of another bacteria producing a chitinase enzyme which reduced rice sheath blight caused by *Rhizoctonia solani* again. The hypothesis we had here is that lobster and crab shells are made predominantly of chitin and also another element, chitosan. These components are also found in the cell wall of many of the fungal pathogens of potatoes, so if you add this material to the soil and are able to stimulate bacteria and fungi in the soil that produce chitinase, which is the enzyme that breaks down these lobster and crab cells, perhaps you can then get a secondary effect by having these organisms break down the fungal cell walls of our pathogens and get some control of the pathogens in that way. So that was one of the main mechanisms that we were hoping to look at in this work.

So just describing our field trials, here's what the raw product looks like, right from the processor, and I was actually surprised at first at how much meat was in that. I thought I might bring a fork and some mayonnaise to the next planting. But actually after a couple of hours it gets much less appealing. This is a composted product that we worked with as well, and Roger Henry, who I believe is here, was predominantly responsible for developing this product. This was developed in the previous year, and we used it in the spring for planting. It's something that is ongoing, and the evolution of the compost is something that he's working on.

The raw product is quite coarse; it hasn't been crushed any specific amount. You can see that there are entire claws and carapaces present in that material.

We established these field trials out at the Harrington Research Farm. We applied the material both in a broadcast manner in the plots as well as in the furrow in a band. These were then incorporated into the soil with the roto-tiller, as you can see here. I must add that any odour issues that you might think of with this waste are quickly gone once you incorporate it. So it's virtually an odourless system once it's incorporated into the soil. Here you can see the composted product being applied, as well as some of the people who helped this year. We used cultivar Superior, cut seed, for our variety. The main treatments we looked at were the raw lobster waste, the composted product, and a conventional fertilizer as a control. We tried to equilibrate nitrogen (N) levels across the treatments, basically at a 60 kg/hectare level. Then we applied in either a banded or broadcast application and we had 4 applications in a randomized design.

Here you can see a plant emerging amongst the raw lobster waste that has been applied as a soil amendment. You can see that this material became bleached, and this happened within a couple of weeks of application. I want to comment here that the first year we did this, which was in 2002, the application in furrow actually caused phytotoxicity, and we didn't get any emergence in that application. When you're adding the amounts of material that we did right next to the seed piece you can get, as that material breaks down, some toxic chemicals being produced, such as ammonia, for example, which we believe was responsible for the phytotoxicity in that treatment. But the next year we simply covered those seed pieces with some soil before applying the band, and then we eliminated that problem.

Here is some pH data. We did look at the pH of the soil, because that has some significant impacts for fertility and also for disease aspects, and consistently we found that there was a significant increase in the pH with the compost application. The raw product was not significantly different from the fertilizer control.

We used a chlorophyll meter just as one way of getting an indication of how these amendments were affecting crop nutrition, and this basically is an indication of the chlorophyll production or the greenness of the crop. You can see here the difference between this plot which is looking quite lush and dark green when compared to a lighter-coloured plot here. We did find that in each year that we looked at this, the raw product was either better or similar to the fertilizer. It is really a measure of the ability to give nitrogen (N) into the system, and the composted product was poor or poorer. I'll talk about that in more detail in a minute.

One of the main pathogens and diseases we were looking at is *Rhizoctonia* stem canker and black scurf, and I was interested to hear Carlos this morning speak about the increasing problems with *Rhizoctonia* in the UK. We certainly have that as an issue here too. You can see a couple of the impacts here. There is a stem lesion and also the stolon is often lesioned too. Those symptoms can certainly cause yield reduction. As well, we have the black scurf phase later in the season when the tubers are harvested, and that has impacts for marketability and quality, particularly of seed and table market potatoes. As Carlos mentioned too, we are looking at both seed inoculum and soilborne inoculum, and what we are finding with some other work is that if you control your soilborne inoculum using good rotations and so on, the seed inoculum becomes more important. Whether seed or soilborne inoculum becomes most important in your system depends on how you're managing your land. The more potatoes that are cropped in a particular piece of land, the more problems you have with soilborne inoculum.

In July we destructively sampled some of the plants in the plot and looked at stolon canker.

What we found was that the raw product gave us a significant reduction in stolon canker in the banded application. We didn't get any significant results in the broadcast application. In most years we are getting a trend toward lower levels of stem canker where the material has been applied, compared to the fertilizer control.

This is November 2002 data on black scurf. We got about 5% scurf on the fertilizer, banded, and broadcast applications; we got significantly less scurf in the raw broadcast application. This past season we didn't have very high scurf levels in our trials, so we didn't get significant differences. You can see that here. If you look across instead of down, the black scurf levels were not significantly related to treatment, and that was also true for some of these other pathogens we were looking at–*Fusarium*, *Helminthosporium* causing silver scurf, and the common scab. There were pretty low levels this last year, but we have seen some reductions in previous years with some of these other soilborne pathogens.

In terms of yield, as I mentioned before, in 2002 we had that problem with the banded application in the raw material causing phytotoxicity. However, once that was corrected, we are really showing that the raw product is an excellent source of plant nutrition and consistently yields the same or better than the conventional fertilizer. The composted product didn't generally do as well; however, I just want to mention that there are a number of potential reasons for that. The compost is constantly being treated to improve its ability to release N, and also, as Carlos mentioned, the soil characteristics in terms of the microflora activity. We are working in soils here that really are not organic production soils, so they probably have a way to go in improving the soil health in terms of microbial activity to contribute to that compost being utilized better.

We're also noticing a significant increase in things like calcium (Ca) in the tuber tissues themselves. You can see from this 2002 data that we have significant increases in the Ca content of tubers when this material is applied. So that can have some positive benefits not only for human nutrition but also for disease control, because there have been some studies showing that increased Ca does contribute to better storage life and disease control of potatoes in storage.

Let's briefly look at some of the microbial work. Basically these are the colony-forming units of total bacteria grown on a medium called triptych soy agar. It's just a general look at the numbers of bacteria in the soil with the different treatments. Although some of these results weren't significant, we do get a trend for increasing total numbers of organisms, particularly the bacteria, when this material is applied. But the more interesting stuff comes when we look at chitin-amended media. This is basically growing out soil samples that have been shaken from the roots of plants, so we're looking at the roots' own soils to see whether the organisms in those soils were encouraging the breakdown of chitin–the chitinolytic ones. What we're finding is that indeed we have encouraged those organisms by adding these amendments. So here you can see the bacteria. In 2002 there were significant increases with the compost and the raw applications of chitinolytic bacteria in those soils. In 2003 we didn't get significance, but the trends were there. Similarly, for fungi we got significant increases in 2002 and 2003 of chitinolytic fungi in these soils.

The zones of clearing are a measure of how much of this chitinase enzyme is being produced, and again what we're finding is that we're getting some increases in this enzyme production in these soils where the amendments have been added, especially when you look at the fungi. That gives us some confidence that some of our disease control is coming from the production of chitinase.

Another thing we quickly looked at was antagonism, so we took some of the bacteria that we isolated from the soils and plated them onto this medium with a pathogen growing in the centre. This is *Rhizoctonia* here, and we also did this with *Fusarium*. We tried to measure whether there was any antagonism. You can see that there is some antagonism here, and really no antagonism there. We measure that on a 1-4 scale, and what we found was that where the amendments were added we got significant antagonism by the organisms in the soil toward those pathogens. So that is another mechanism of activity that may be operating. That was with *Fusarium*. Here is some data with *Rhizoctonia*, again showing significant antagonism.

So there are some different mechanisms that might be contributing to the control that we're finding, and we've been looking at chitinolytic species and direct antibiosis. There are other things such as competitive effects and production of toxic chemicals that are toxic to the microbes. This last one is interesting too. There has been some evidence that you can stimulate host resistance by applying chitin, because chitin does occur in fungal cell walls. By giving this to the soil system where the plant is growing, it can actually mimic a fungus, and the plant then develops its own resistance mechanisms against that and you get some disease control that way. That's one of the things that we're going to be looking at more closely in the future.

So, in summary, we are finding that this lobster waste product is a good source of plant nutrition, it does develop enhanced communities of beneficial soil microorganisms, we are seeing some soilborne disease suppression, and it might have a nice fit in an organic system.

Q: How long before the N from the chitin is available?

A: What we're finding is that where the raw product is applied, it's an excellent source of N for plant growth, so it seems to happen fairly quickly. I can't give you a figure, but it seems to be a very rapid release in that system.

Q: Did you observe any difference in the attractiveness to insect pests?

A: That's interesting. No, we wouldn't have observed that.

Q: (inaudible)

A: He made a comment that chitinase decreases the attractiveness to insect pests. We haven't looked at that specifically, but it certainly sounds like a good way to collaborate with an entomologist.

Q: How do you determine the rate at which the material is applied?

A: Basically we just tried to equilibrate that with the synthetic fertilizer rate, and I know that was hard to do. This was in the initial stages of this work, so we weren't really sure, especially with the composted product or the raw product, what the mineralization rate would be or any of those details. So that's something that we need to hone as this work progresses.

Q: Was there any increase in the number of pigeons and crows and seagulls?

A: Not that I noticed, but that's a good question. I know that over at AgriTECH, I believe they had some problems with crows impacting on their potato production there. But no, I didn't really notice that in these trials.

Q: What does a chlorophyll meter measure?

A: It's basically a measure of the amount of chlorophyll present in a plant by measuring the amount of light that is transmitted through a leaf. It essentially determines how "green" a plant is.