Designer Foods: Enhancing Nutrition with Biotechnology

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Briefing on Food Biotechnology

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Thank you very much for inviting me here today to talk about biotechnology. Peggy Lemeaux who was supposed to give the first talk on the nuts and bolts of the technology unfortunately her daughter wouldn't let her on a plane and she sends her apologies and I can totally appreciate her daughter's concerns.

So I'm going to take five minutes to cover what Peggy would've taken 15 minutes to do. And I understand Brian is copying, I sent a page of useful Web sites, I thought rather than sending a big handout this Web site list would be somewhere you can go to because it's assured that this is actually pure review documentation.

And of course with the web it's very difficult to discriminate between what's opinion and what's pure reviewed fact. So those Web sites I can assure you have pure review publications on them.

Everything I talk about today will be on my Web site, which I've listed there as well. I have a much broader version because the AMA told me to remove all text files so all the text slides are gone but they are on my Web site if you want to download them for more information.

So what I'm going to do is basically give a very short introduction, as I said, to the nuts and bolts of this technology. And I really wanted to put it in the context of historical perspective because as we all know we've been literally modifying the world around us for thousands of years, all (inaudible) to enjoy the products of biotechnology.

Every single day we eat bread, we eat cheese and very important microorganisms are used to brew beer. I'm Irish so this is a major component of biotechnology as far as I'm concerned.

The basics of the type of raw material, if you like, that biotechnologists work on is genetic information and some of the original work was done by Mendel who did lots and lots of experiments with lots and lots of peas. But the fundamentals that he developed, in fact, are the basis of all of the modifications that we have today.

They're far, far broader than just modern biotechnology, which is in the common parlance, called genetic engineering, from a scientific perspective it's called recombinant DNA technology. And I understand it was actually a science reporter that first coined the term genetic engineering. So you've made important contributions to the science.

So I'm going to give you a timeline here of the technology. A little bit of text because I needed to put it in context.

As you know modern day corn is descended from this skinny little ancestor here on the right. And all of the genetic information necessary to make modern day corn, in fact is available in that ancestor. It was just subject to many, many years of crossbreeding and selection based on mutations that were rising naturally to select the components that give you modern day corn.

But all of that, quote/unquote genetic engineering was done by Native Americans. So we've had biotechnologists in this country for literally thousands of years.

This century has taken on a new level of focus on the applications of technology to improve in crop agriculture. We're all aware of the selective breeding that was done by an individual called Luther Burbank and I have an interesting quote from him which I haven't used because it's a text quote.

It basically says we have now the power to manipulate nature in a way never intended by God. We must proceed with the utmost caution in the application of this newfound knowledge. And Luther made that statement in 1906.

And you have all eaten, maybe you haven't eaten, Burbank potatoes, I know I have. And he really gave the initial tools that are used for most of the crossbreeding and selection that's done.

But a lot of people aren't aware though is the amount of advanced technology that has been with us for the last 50 years. For example we can now do broad crosses. We can have two plants cross that would never come together in nature. They would have been inhibited through what's called sexual incompatibility. And people are often astounded by the notion that plants have sex but they do. If they didn't, we wouldn't have seeds or crop plants.

So scientists have gone in to stop this sexual incompatibility barrier and there are several products out there now that were produced using these wide crosses.

You've seen brocciflower; you know the green colored cauliflower? That's a wide cross between broccoli and cauliflower. And what scientists do, is normally the embryo is lost, they go in - take this embryo put it in nutrient media, grow it up and it bypasses the sexual incompatibility barrier.

Another technology I think that many people aren't aware of is that of using mutagenesis in selection whether it's either chemical or radiation mutagenesis where you literally are frying the genome using a mutagen and then selecting the phenotype that you want from that. But of course at the chromosome level you really have no clue how you've modified the genome and this again has been around for 50 years.

This technology took on a whole new perspective with the advent of recombinant DNA technology in the early 70's and specifically in the early 80's when it applied to plant systems. Because now we have the capability of modifying plants by taking genes from a very broad pool indeed, pretty much all kingdoms, plants, animal and microbial.

And to me the new modern technology is far more predicable, far more precise and far more controlled than using the traditional technology and I will show you. This is a graph I downloaded, a picture I downloaded from a Japanese site. I particularly picked the Japanese site but of course they have very stringent regulations regarding genetically modified food.

What you're looking at here is in a radiation breeding center and in the center of this field there's a Cobalt 60 source spewing out 89 terebecorals of radiation. And that's a hell of a whack of radiation. In fact it's so high that the core has to be pulled down into the field before anybody walks in there.

Then you collect the seeds, you grow them and again you select the phenotype because you are doing no molecular work here so you don't know what's happening at the chromosome level. And I'll give you an example of a plant that has been modified using this.

I don't know if you eat Asian pears. Every single Asian pear on the market today has been produced using a radiation breeding for selection against black spot disease. Now all we know is that by using this breeding we've made the plant resistant to black spot disease. We do not know at the molecular level how this has been modified. And this has been around for 30 years.

And I think if you're to look at a potential label for that, that's scientifically accurate and correct, but I think this is really misinformation as far as the public is concerned. You'd, I would think, possibly scare people if you put a label stating this pear was produced through radiation breeding in California.

It's absolutely scientifically correct but I don't think it's informative. And as I said this was not done through genetic engineering, this is all done through a radiation and mutagenesis.

You might have seen earlier this summer that the Minister for Agriculture in Italy was rather upset to see that a German newspaper was stating that the Durham wheat used to make Italy's famous spaghetti had been produced using mutagenesis. Now I don't know whether he was more upset by the fact that it was a German newspaper or by the statement that was being made. But he was a very upset man. But the reality is all of spaghetti is produced from Durham wheat that was bred through a radiation mutagenesis.

And I'll just give you a very, very basic science lesson on actual recombinant DNA technology. This is some work that was done by a famous Russian scientist called Vavlov who promised Stalin that he could double productivity by crossing a cabbage with a radish and getting the leaves of a cabbage and the roots of a radish.

Now Vavlov made a fantastic contribution to science. He introduced a brand new species, finobrasica. And for introducing this brand new species he was sent to Siberia because he ended up with the leaves of a radish and the roots of a cabbage. And instead of doubling productivity he quartered productivity.

Now that's a simplified statement on my part, Lukashenko had a lot to do with him going to Siberia as well. But really poor Vavlov's problem was he was dealing with tens of thousands of genes and he had no control at the molecular level as to how to manipulate these genes or how to bring them together to get the desired affect.

With genetic engineering, you see the little red dot there, you're just modifying one or two genes at a time and as I said in my opinion that makes it far more predicable, precise and controlled. And again I'll give you an example from Davis in a moment. I really apologize for this slide, I didn't realize how faded it was.

This is just in one graph how we do genetic engineering, the majority of genetic engineering and biotechnology of plants. There's a bacterium called agrobacterium tumefaciens that's a natural genetic engineer. It has been modifying plants literally for centuries.

You may have heard of crown gall disease. Well it has a piece of extra chromosomal DNA called the TI plasma, it's TI stands for tumor inducing. And using genetic engineering you can take out all the tumor inducing genes and you can swap in the gene you want to trick this bacteria into carrying into your plants and sure enough.

If you want to see how this is done in detail, if you go to my Web site I go step-by-step through the process of how this is done, with real people. And anyway as I said you can trick agrobacterium tumefaciens into carrying in your gene of choice into the plant and it will be stable incorporated using the system that has evolved over time by agrobacterium tumefaciens.

Now agrobacterium tumefaciens only works really well on broad-leafed plants on dichots so an effective way for a long time we couldn't modify cereals, which of course are very important.

So a very enterprising individual discovered that if you coat some tungsten pellets with DNA and initially they actually used gunpowder cartridge, a .22 cartridge to shoot these pellets right trough the tissue.

Now of course most of the cells were blasted to kingdom come but some actually took up the DNA. And, those that did, use what's called a reporter gene. In this instance it's called the gus gene and what this basically does is it reacts with the sub straight to give you a blue color. So you know whether you've got your genes in there and they're being expressed by virtue of the fact of having a blue color. So that's a very quick way to screen very quickly so you can get rid of all of the ones that have not taken up with the gene.

And I'll give you an example from Davis. Remember I was telling you about with using traditional breeding, at wide crosses you don't have any control of the chromosome level. Well in California tomatoes are king. They're very, very important and high soluble salads is sort of the golden grail of processing tomatoes because the more soluble salads you have, the more tomato you have.

Now the normal type of tomato like lycopersicum esculentum is what's called a hexes-accumulator. There's a wild variety of tomatoes called lycopersicum cumileski which is found in the Andes.

In fact all tomatoes and, this may come as a surprise, potatoes originated in the Andes, they did not originate in Ireland. And there's an incredible rich source of germ plasm in the Andes.

Now this character over here on the right has a lot of qualities you don't want. It has poor size, bad yield, bad taste and it's toxic. So I don't think toxic pizza --

The scientist, well the growers wanted to have this super (inaudible) characteristic (inaudible) into their own plants. So we literally had to do 19 years of back crossing to the normal cult of our (inaudible) to get rid of all of the characteristics that you didn't want.

But when you think about it because again through this traditional breeding you were not analyzing at the molecular level. We know it now no longer has the phenotype of toxicity but we don't know what genes are still in there. This is using traditional wide cross breeding.

Using genetic engineering, Alan Bennett in our lab succeeding in doing the same thing in one step because before this guy is a hexes-accumulator at the step before it's a silcros-accumulator. So he uses anti sense technology.

That is he didn't put any new genes in. He took the gene that was already in there, the enzyme that was already in there, turned around, put it in backwards, turned off the step and immediately got the same results.

Now if I was to ask you which of those is more substantially equivalent to the original. The one that has been intergressed with genes from a toxic plant or the genetically engineered one where no new genes have been inserted other than the selection gene.

In my opinion I think it's the latter and here you can see the nice firm tomato paste as opposed to the (inaudible) one. That's the end of the basic lesson.

What I wanted to do now is to focus on what I was asked to talk about on improved nutritional contents in plants. And I really want to emphasis the fact that this is the potential. I'm talking about potential here of what we can do.

The problem of course right now with this technology is the first generation is out there and it's been credibly successful. The agronomic traits that Dr. Riggs talked about. Through those we've had reduction of 17 million applied acres of chemicals by individuals who've adopted this technology. That's a huge savings to the environment.

Those that have adopted the Round-up Ready soybeans have saved 280 million dollars, this was in 1998 by reducing the complex cocktails of herbicides they had to use because now they just use one. And while I'm not supposed to talk about that today so I'll just leave it at that but if you want more information it's on the Web site.

Now if you look at the requirements we need to be healthy, they come at several levels and this is my version of a person there. That's supposed to be a hot dog. Sorry it looks more like a very big caterpillar he's eating.

But the main components are divided into macro and micronutrients and of course you're all very familiar with the macronutrients, the proteins, carbohydrates and fats. And I'll talk a little bit about the work that's being done in this area.

I think the greatest focus though, from a molecular biology point of view is in the area of micronutrients. As we become more aware of the fact that we should eat to stay healthy rather than always running to the doctor like to Dr. Riggs to get cures when we get sick although biotech of course has a lot of answers on that as well.

So what I'm going to do is just walk you through some of the potential products that can be produced using genetic engineering as I said. But keep in mind I'm talking about potential here. You can't, at this point in time, go to the store and buy any of these products but hopefully you will be able to in time.

And I'm not going to focus too much on the anti nutrients because Steve Taylor is going to focus on the allergens. The only one I will talk about a little bit is the phytate. And then on the novel crop products, I'll talk a little bit on products that can be used - the plants can be used as factories to produce that you would never at all have thought, in fact, plants would never have produced in nature. I won't talk on the therapeutics of vaccines because that will be covered later as well.

So this is one of the areas that we're focusing on. The engineers are working on the front and the biotechnologists are working on the back. That was a joke, sorry.

At the macro level proteins are one of the prime focus areas insofar as the development of a balanced diet. As you're very familiar, those of you who are vegetarians that you need to be very careful that you're able to ingest all of the essential amino acids to stay healthy. And of course no plant is perfect in that capacity.

So some of the work that is being done is looking on improving amino acid races of plants. For example, corn and the cereals are low in lysine so work that's being done by Brian Larkin is to try and increase the lysine content in cereals.

Soybeans are low in what's called sulfur-rich proteins like methionine and in fact that's one of the areas you might have seen a couple of years ago, one of the first statements where biotech is dangerous, the work that was done in this area. And in fact to me it shows how the checks and balances work.

That is they were trying to introduce sulfur-rich proteins into soybean from a really rich source of these proteins, that is Brazil nuts. They were aware, this was Pioneer, that these Brazil nuts do have a certain percentage of the population are allergic to it.

So the first thing they looked for was to see was the protein they were using one of these allergens and I'm sure Steve Taylor will talk more about this. But sure enough they are human, the one they were using that's the one that people were allergic to so they stopped it immediately.

And, as I said, that was put out there as a failure of biotech to me it's hey that's a success, it was trashed. It was never marketed, the checks and balances are working.

Work that's also being done in improving the protein content is actually looking at better ways to, for example, assimilate nitrogen. As you know nitrogen is a very important component of proteins especially if you look at glusmene asfargene and it's not very efficiently processed by metabolic pathways at this point in time. I need to speed up here.

And so some work that's being done, they've introduced glusmet dehydrogenes gene to increase the assimilation of nitrogen and they've actually succeeded in increasing the protein content by 15 to 20 percent. That's a big increase.

At the starch level some work that's being looked at is again to improve sucrose hydrolysis and starch by osenthysis by introducing a gene from e. coli called ADP glucose parafasfarlas, it more rapidly converts to sucrose into starch. This is especially important in the humble potato.

Those of you who remember your high school biology you know that a dark iodine color means that there's a lot of starch here. And, in fact, by putting this ADP glucose parafasfarlas under the control of the patent gene so it's only turned on in the potato you increase the starch content by 30 to 40 percent.

And the real advantage of this is not that you have more spud for your money but when you actually make your french fries or your chips because there's no moisture there, if there isn't much moisture to evaporate it doesn't take up oil. So it's in fact a low fat potato because there's no evaporation and take up of oil. So I think it's a much more healthful alternative than olestra because you don't have any problems with anal leakage and other things.

On carbohydrates you may be aware of the fact that individuals who eat beans sometimes have problems with the fact that this particular carbohydrate, here stackos, is not very easily digestible. It goes into our lower bowels and you get this full feeling and other things.

So by lowering the stackos level and increasing sucrose you can get sweeter soybeans but you also eliminate the unpleasant side effects of eating beans. And even more important from healthful point of view is the introduction of hifructones, work that was done in sugar beet. As you know sugar beet, especially in Europe, is one of the main sources of sucrose and some individuals in the Netherlands took a gene from a Jerusalem artichoke it's called sucra sucrose fructosaltransberrys. You don't have to remember these names. And it very effectively converted the actual accumulation from sucrose to fructose and fructose as you know is a very healthful oligo saciride. It can produce, what it really is good for the lower bowel again in that it helps to grow good bacteria, I suppose is a way to put it.

The production of (inaudible) fatty acids is really good for a healthy colon on several levels. One to prevent cancer development but also the fact that it lowers triglycerates to absorption into the blood stream itself. I need to speed up, I'll try and finish her.

These are some other really important micronutrients that we now have the potential to modify using an approach called nutritional genomics. As you're very well aware of the fact that the human genome is now supposedly totally sequenced, of course it's not.

The amount that's needed ought to be a value of sequence but there's still a way to go. But the capability of the technology that was developed for the human genome can now be applied to plants where you can look at global expression of genes to determine genes that are important in metabolic pathways for the production of these essential vital chemicals.

It's estimated there's between 80 to 100,000 secondary plant metabolites in plants. A large number of those vital chemicals have a real advantage and these are just some of them. Carotenoids obviously for preventing prostate and other cancers in addition to cardiovascular disease and when your mother told you to eat your carrots this is a good reason, macular degeneration is also protected.

Glucosonites, I know the former President Bush didn't like to eat broccoli but now using molecular genetics and nutritional genomics, we can modify pathways for glucosonite production in other plants. So the day may come when you won't have to eat broccoli to get your glucosonite.

Physoestrogens are very important especially the isoflavins genocine and diodzine and of course work is being done on increasing these concentrations of these products in soybeans.

My favorite are the phenolics. You've heard of the French wine paradox, the red wine paradox where French people can eat as much fat as they want and they stay healthy because they drink a lot of red wine. It's because of this phenolic reservatral but maybe you don't want that modified in other plants because there would go your excuse for drinking lots of red wine. But the potential is there.

And I know Dr. Pakash is going to focus on developing countries so I'll just mention briefly some of the incredibly exciting feats of molecular metabolic engineering that have been done to date on beta carotene production in rice.

Dr. Pakash will focus on more the implications I'm sure from a worldwide perspective on the deficiency in vitamin A and I won't talk about that. But just the incredible work that was done by Dr. Potrykus in recognizing a precursor of beta-carotene in rice.

It's called gernal-gernal dye phosphate there GGP and the man was so brilliant that he stitched on a bunch of the other genes and he overcame some of the shortcomings in the plant system. He introduced two genes from daffodil. You know the really bright orange yellow color of daffodil that's because of the carotenoids there.

But he put in a (inaudible) from bacteria which jumped three steps in what daffodil needed. And he also managed to target this so it was produced in the right area in the cell. It was an incredible piece of work.

Of course there's been controversy about it. Saying well you know that there's the amount that would be needed to eat for these individuals is enormous. But in fact when you think about it RDA, Recommended Daily Allowance is way higher than the level you need to be healthy. And for these countries Potrykus figures 10 to 15 percent of the RDA would be sufficient to make a huge difference in the number of diseases that occur from lack of vitamin A.

They're also working on a separate line where, you remember I talked about phytate a moment ago as being an anti nutrient. Well this, most of the phosphate in plants is bound up in phitac acid or phytate. And this especially for animal, well for farmers that have to feed animals, this is a real problem because it's not bio available.

In addition it (inaudible) and dines like iron and zinc and when you have animals you have to supplement their diets with phosphorus and the problem is they end up defecating a lot of this into the environment which leads to (inaudible). But by putting phytasin plants, it breaks down the phytate, it makes the phosphorus bio available and in addition it makes the (inaudible) bio available. So they're working on introducing this into rice as well.

So I need to finish and this is just a mark to finish with where a group and this is an individual from Davis, Ray Rodriguez who is using rice as a delivery system for the production of valuable proteins including lignin for high fiber content. But more importantly he's using this alpha-amalay system.

The promoter is turned on at high levels during plant germination so a false plant germination is malting, you know why? Again, being Irish, we're very familiar with malting barley to make whiskey but you can use the same malting system to turn on, for example he's introduced a bunch of mother's milk proteins into rice.

So you can imagine in countries like Africa where AIDS is a real problem and mothers can't breast feed, they could potentially use this as a substitute because with the mother's milk proteins in there, it has the same nutritional profile as mother's milk.

So I should finish with that. I'll leave the oils. You can see this on my Web site if you're interested on the type of work that's been done on high conjugated linoleic acids, high oleic acids so that you don't have spoiling of the oil.

You can use this for roasting peanuts for example and it won't go off. It's much healthier as well. High oleic oil is where you can get margarine at room temperature without chemical hydrogenation because this is a fatty acid that does not increase. It's as solid at room temperature but it does not increase blood cholesterol and the (inaudible) lyploxigenace is basically to get rid of off flavors so that your margarine doesn't taste fishy after it's made.

And really using canola or soybeans you can make an incredible number of different products by modifying the fatty acid composition of these, everything from as I said low saturated fats to cosmetics to long chain fatty acids where they use a gene from the joba-joba plant in the desert. It can be used in cosmetics and hydraulic fluid so the next time you're around an airplane you think you smell McDonalds it could be genetically engineered hydraulic fluids from canola.

And I'll finish with that. Thank you.