The Pipeline of Future Foods

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Working in agriculture, we have been at the center of some of the most significant and hottest debates in society. In 6 out of the last 10 years, grain consumption has exceeded grain production. We have seen energy costs quadruple, and concern over global warming has escalated greatly, with the last 10 years representing the warmest on modern record. These issues are central to agriculture, and we all face the question of how to overcome these obstacles and continue to provide the food supply the world needs. At Monsanto, we believe that innovation will be key, and we believe that we have a role to play, as an input producer in agriculture, in helping to meet these challenges.

Food Quantity

Global population is increasing dramatically, and is expected to be over 9 billion by the middle of this century. Many experts agree that the food supply will need to double to meet the demands of that increased population. We have made an evaluation of how this is likely to affect our business. We have observed that corn consumption has increased by 34% in the last 10 years, while soybean consumption has increased by 52%. As incomes increased in developing nations consumption of grain-fed beef has increased by 21%. At the same time 55% of the habitable land is now used for agriculture and two thirds of annual fresh-water withdrawals are used in irrigation. These forces are creating critical challenges, and we need to focus on how to improve agricultural sustainability.

A few years ago, we began conversations with stakeholders to try to determine how we could best contribute to solutions to these challenges, and 2 years ago we launched a commitment comprising three primary factors and that we called our *Commitment to Sustainable Yield*. It includes the component of how to meet the need for an increased food supply and we committed to working with farmers to double yields of major food

and fiber crops by the year 2030, relative to year 2000. It included an evaluation of how to reduce environmental and resource impacts while achieving this increased food production. And we committed to reducing agricultural inputs to a third lower than they are today per unit of output. We believe that there are many ways to increase crop output per unit of input, and we want to improve the economic viability of farming, to improve the lives of farmers, their families and their communities.

Food Quality

Although much of our effort is focused on the capability of producing enough food with the minimum impact to the environment, many of our initiatives are focused on improving food quality.

Soybean comprises almost two thirds of the US diet of edible oils, more than half of which is used in processes in which they are partially hydrogenated for stability. This partial hydrogenation leads to formation of *trans* fats, which are now widely recognized as undesirable in the human diet. So, we have opportunities to modify the composition of soybean oil to help address some issues concordant with it being a major source of fats in the human diet.

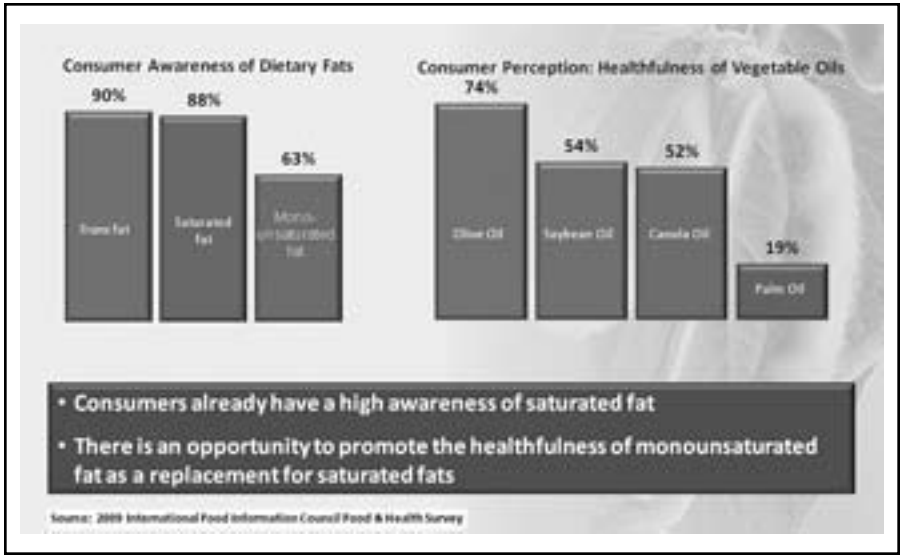

Figure 1. Consumer awareness of dietary fat.

Consumers are aware of the various oil compositions and have clear perceptions of their desirability; nearly 90% of consumers understand the significance of *trans* fats (Fig. 1). They are aware of saturated fat and they also have perceptions about the relative health merits of various vegetable sources of edible oils. We believe that we have an opportunity to promote the healthfulness of mono-unsaturated fats as an alternative to saturated fats, which are now abundantly present in the human diet. The American Heart Association

has recommended that saturated fats comprise only 7% of dietary energy, and recently, the Dietary Guidelines Advisory Committee proposed that saturated fats be reduced from the current guideline of 10% of dietary energy intake to 7%. In reality, the current saturated fat composition in the diet is about 12% and a 5% reduction to the recommended 7% would significantly reduce the risk of cardiovascular and other diseases. A majority of consumers read the nutritional labels on products they consider for purchase. They are aware of the significance of the information on dietary fats, and, in a 2009 survey by the International Food Information Council, 63% claimed to be trying to reduce their intake of saturated fats.

We have worked with a number of food-company representatives to design specifications for what we thought would be an improved composition of soybean oil. We defined significant reductions in the saturated fatty acids palmitic and stearic, a significant increase in the mono-unsaturated oleic and a reduction in linoleic acid to improve stability, and less linolenic to reduce *trans* fat (Fig. 2). We are at the pre-launch phase, and, within 2 or 3 years, we will release Vistive® Gold seeds, which will produce oil with this composition.

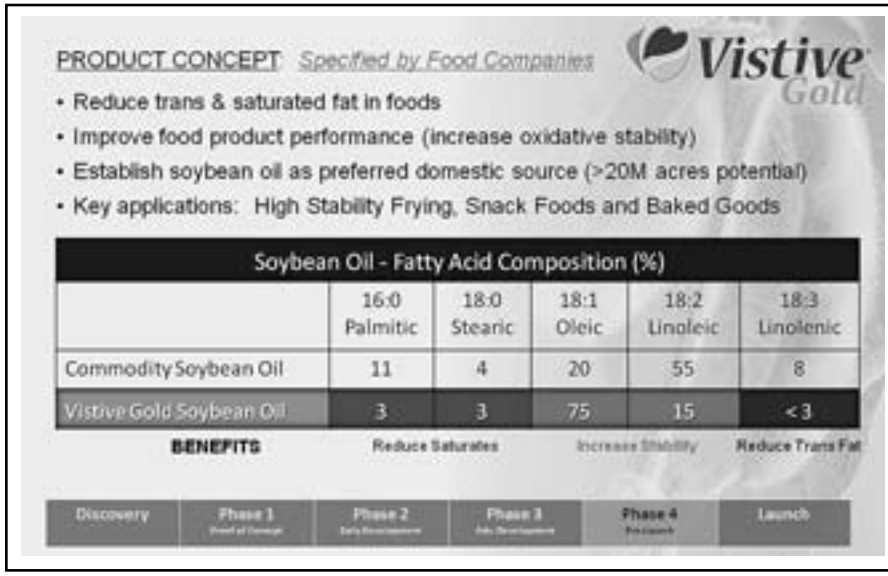

Figure 2. Vistive® Gold soybean will provide low-saturate, high-stability and zero-*trans*-fat oil.

To achieve this, we reduced the activity of three enzymes that are involved in the biosynthesis of oil in soybean. The first is FATB thioesterase; by reducing its activity, we allow more of the fatty acids to be shunted toward oleic acid. Reduction in FAD2 desaturase results in an elevation in oleic acid. Both of these changes are delivered by RNA inactivation of genes that naturally exist in soybean. And the third change is a FAD3-desaturase reduction through conventional breeding, using a mutant in soybean that reduces the level of linolenic acid, which again promotes stability.

With these three changes, soybean produces an oil that is almost identical in properties to high-oleic canola oil, an expensive specialty oil that is available in much less abundance than is soybean oil. This will be a major contribution to the abundance of oil with improved properties for food applications. French fries cooked in Vistive® Gold soybean oil versus conventional partially hydrogenated soybean oil show a reduction of 23% in saturated-fat content and a 98% reduction of *trans* fats. Importantly, this allows food companies to provide labels that indicate zero *trans* fats, no partially hydrogenated oil and lower saturated-fat content.

This oil, importantly, could go into a range of food products, including those designated with the Vistive® Gold emblem in Figure 3, and reduce the saturated-fat levels in those processed food products. We can still get our fix of saturated fats through steak, ice cream, cheese and cheesecake and various other sources that we like to eat. The bigger picture is that 40% of the saturated fats in our diet come from prepared foods such as potato chips, French fries, margarines, and salad dressings, in all of which Vistive® soybean oil could be substituted for currently used oils. Therefore, without making any changes in consumer habits, dietary preferences, if current oil sources are replaced by Vistive® Gold in these processed foods, it could result in a 9% decrease in dietary intake of saturated fat for the average individual. And, for those in the top 10% of the population for intake of saturated fats, it would result in a 13% decrease in saturated fat. This is a significant opportunity for us to help food companies help consumers improve their diets.

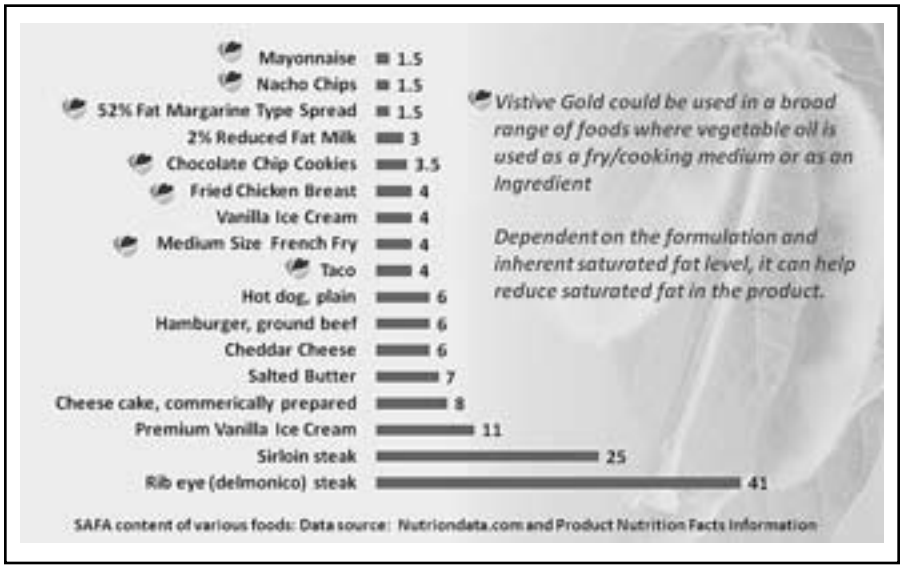

Figure 3. Vistive® Gold could be incorporated into many foods with varied levels of saturated fat (SAFA=saturated fatty acid, g/serving) (Commercialization is dependent on many factors, including successful completion of the regulatory process.)

In addition to reductions in consumption of saturated and *trans* fats, it is also recognized by health experts that cardiovascular health would be improved by increasing the level of omega-3-fatty acids in our diet (Fig. 4). Currently, these omega-3 fatty acids come predominantly from fish and a recent analysis showed that, of the risks leading to death in the American population, the sixth largest is an excessively low dietary intake of omega-3 fatty acids. In this analysis, that single risk was associated with 100,000 deaths per year in the US population. Of course, consumers are addressing this risk in increasing numbers by taking fish-oil supplements, and we are looking at what we may do by changing the composition again of soybean oil, the major oil that is used in processed food manufacturing in the United States. We have defined a way by which the composition of soybean oil may be modified to contain 20% stearidonic acid (SDA), an omega-3 fatty acid that currently comes from consumption of fish fat. The fish obtain it by eating algae, which possess the biosynthetic pathway to produce the SDA.

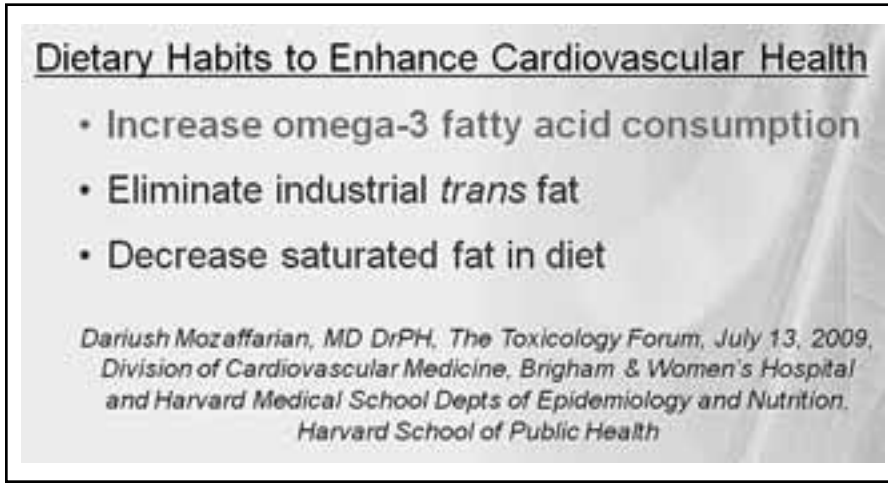

Figure 4. Dietary changes endorsed by experts in health and nutrition.

We want to reproduce in soybean the biosynthetic pathway that exists in algae, by adding two enzyme steps, achieved by borrowing a gene from a plant and one from a microbe, that allow the conversion of fats normally produced in soybean oil to the 18:4 fatty acid, SDA (Fig. 5). This, we believe, is the preferable point at which to stop in the biosynthesis of omega-3 in soybeans, due to improved stability. It doesn't have the off flavor or undesirable aroma that are associated with fish oil and eicosapentaenoic acid (EPA); in fact, the human body is able to convert SDA to EPA. With a 20% composition of SDA in soybean oil, just one acre of soybeans would provide as much potential EPA as is present in 10,000 3-ounce servings of salmon.

Obviously, fish-oil sources are not a sustainable solution for the entire world. They are not available in the appropriate abundance in many parts of the world, and we would have a sustainability issue trying to get this much from fish. On the other hand to obtain

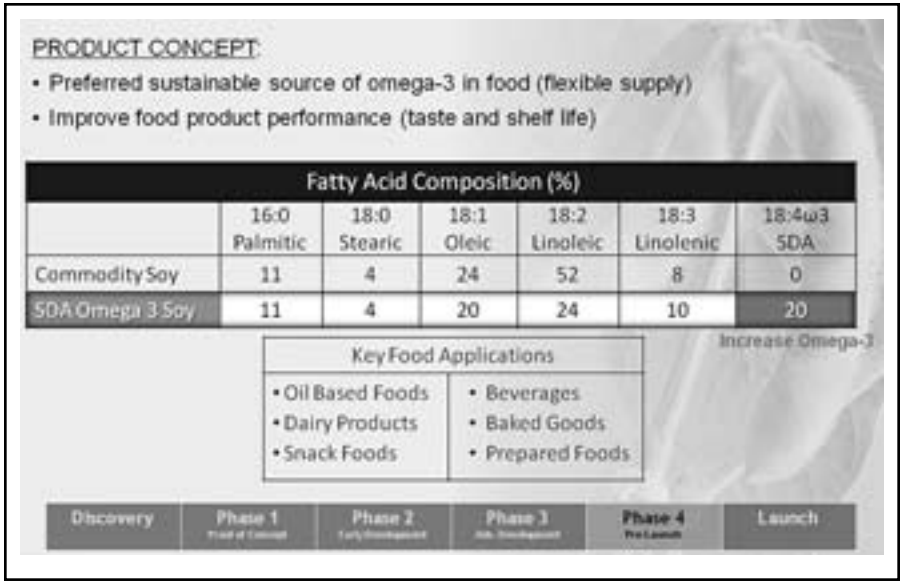

Figure 5. SDA soybean oil would provide a sustainable source of omega-3.

sufficient omega-3 fatty acids from soybean—with approximately 80 million acres grown in the United States alone—is very achievable. We have formulated this soybean omega-3 oil into various food products—yogurt, salad dressing, snack bars, smoothies, *etc*.—and the flavor properties are indistinguishable from currently used oils. This is an exciting opportunity for us to contribute to what is a major dietary limitation affecting human health.

Studies have demonstrated that SDA oil formulated into human diets results over the course of just 12 weeks in increased blood EPA, comparable to EPA formulated into the diet, which does not occur with commodity soy (Fig. 6).

Vegetable Innovation

Onion

About 5 years ago, Monsanto bought into the vegetable seed business by purchasing Seminis, with the primary objectives of increasing crop productivity, yield, reducing need for inputs, and breeding in natural disease resistance. At the same time we had the opportunity to provide vegetables improved in terms of the consumer sensory experience, realizing that helping consumers find it easy and desirable to eat more vegetables would be a positive contribution to their health.

We've launched a couple of products. The Evermild onion is a long-day storage variety that has the same mild properties of short-day onions that are available only seasonally, such as the Vidalia onion from the United States and the Peruvian sweet onion, which is available in the winter. The Evermild provides the same consumer benefit, but it is a

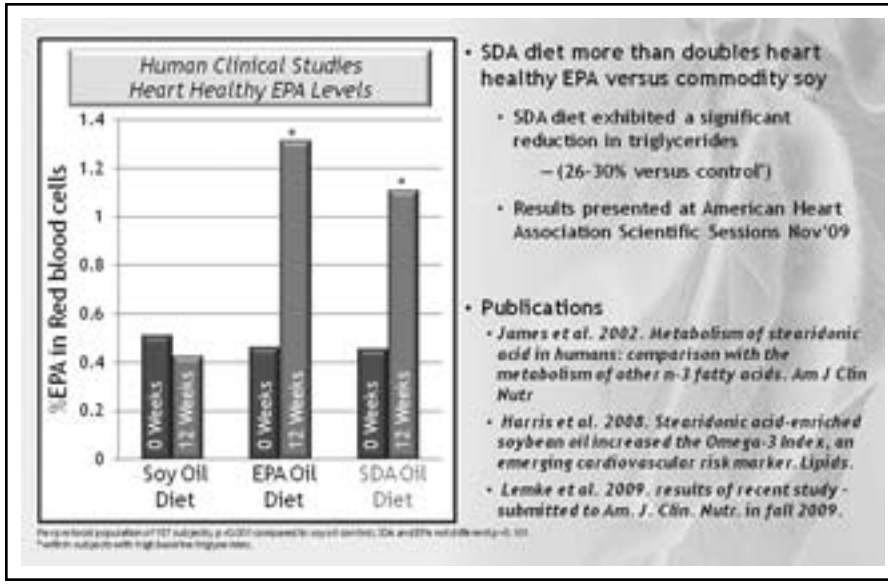

Figure 6. SDA omega-3 increases heart-healthy EPA in humans.

long-day storage onion available throughout the year. Bella Verde is an innovative new broccoli with an elongated stalk. Recently launched in Europe, it produces nutritious tender side-shoots with improved consumer appeal.

Tomato

By moving into this vegetable space, we acquired an array of elite diversity in crop species. Figure 7 illustrates diversity in tomatoes that are consumed around the world, representing all kinds of opportunities to use native genes to enhance quality, sensory properties and nutrition. Similar opportunities exist for our other major crops, peppers and onions; it's a tremendously useful toolbox for plant breeders developing improved products for growers and for consumers.

Figure 8 provides examples of innovations in our vegetable pipeline that are designed for consumer appeal. A seedless tomato in the upper left-hand panel combines cytoplasmic sterility with parthenocarpy, the ability of fruit to develop without pollination. We've developed a tomato that is completely seedless and delicious. Importantly, lacking seeds, it helps people with diverticulitis to avoid digestive distress. A great-tasting orange mini-tomato, a grape tomato, is shown in the upper right-hand panel; very high in natural sugars with a great acid balance, it is absolutely delightful to eat. People who generally don't like tomatoes do like this one, like the grower's son who is sneaking some from the greenhouse in Holland. In the lower left-hand panel is an all-flesh tomato. Slicing tomatoes that are used in sandwich shops, *etc.*, are often processed in central distribution centers, for safety reasons and shipped to sandwich vendors. In the process of being shipped and handled, they can lose 5% to 10% of the juice and, with it, much of the nutrition. Our

all-flesh tomato—2 to 3 years from launch—doesn't have juicy locules so that, after slicing, the moisture and nutrition are conserved during distribution. Some of our customers are excited about this prospect, which will help tomatoes be delivered more often to sand-

Figure 7. Tapping into diversity in elite germplasm.

Figure 8. Sensory appeal critical for driving consumption: flavor, texture, color (nutrition) and convenience.

wich and fast-food businesses. And we have improvements in color and other nutritional components of tomato. In the lower-right hand panel, increased lycopene deepens the red color, which consumers find desirable aesthetically and nutritionally.

Lettuce

We have an innovation in lettuce that has been launched in Europe and which we are working on for the United States. It's a cross between the iceberg and Romaine lettuces that has the crispiness and texture and processing capability of an iceberg with nutritional benefits more comparable to the Romaine. It is more attractive when shredded and processed. Our studies on nutritional composition show that our "CRC" lettuce, represented in Figure 9 by the variety Rugby in the top panel, is a good source of vitamins A and C, unlike iceberg; it's more like Romaine in vitamin content. When we take it to consumer taste panels, we find that those who like Romaine like it equally to Romaine and Romaine dislikers—a significant portion of the population—like it equally to iceberg, and much better than Romaine. We think we have hit the sweet spot of doing something that improves nutrition while improving consumer appeal.

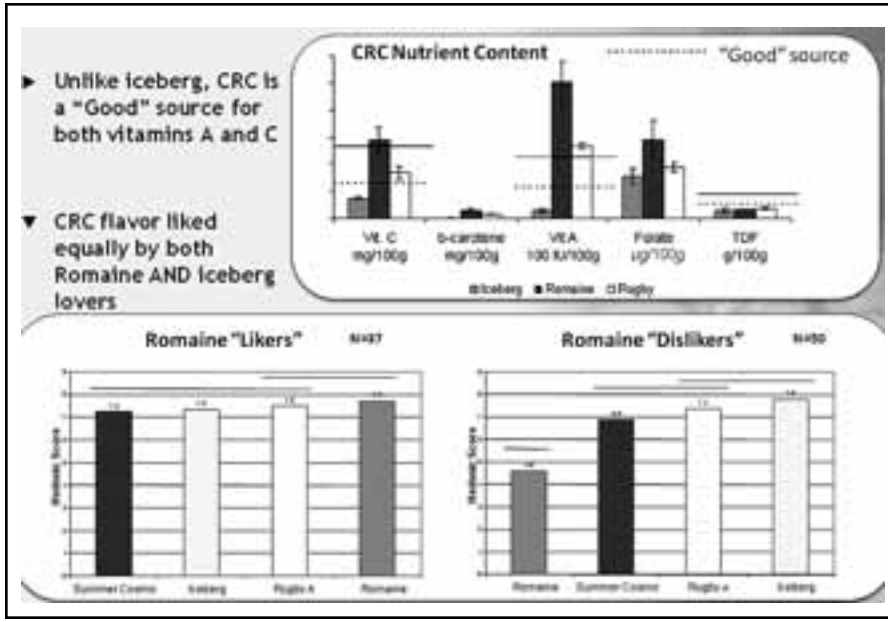

Figure 9. CRC lettuce provides nutrition and flavor.

Broccoli

For a number of years, we've been working in collaboration with scientists at the John Innes Institute and others in Europe to improve the nutritional content of broccoli through marker-assisted breeding. A relative of broccoli that grows in the hills of Sicily and is used locally in their salads, *etc.*, has a higher content of 4-methylsulfinybutyl glucosinolate

(MSB), which is obtained in the human diet only through intake of broccoli. In humans MSB is converted to sulforaphane, which enhances the body's own enzyme systems that preserve the activity of vitamins A, C and E, which are natural antioxidants that help to remove free radicals and environmental pollutants. We have introduced three genes to broccoli through marker-assisted breeding (Fig. 10). The panel on the left demonstrates that, over widely different environments, two- to three-fold increases in MSB have been achieved. The upper-right section shows that consumer panels indicated that this broccoli is just as desirable to eat, whether consumed raw or cooked. By increasing the levels, we have found that the MSB is rapidly converted into much higher levels of sulforaphane in human blood, which are conserved for many hours after consumption.

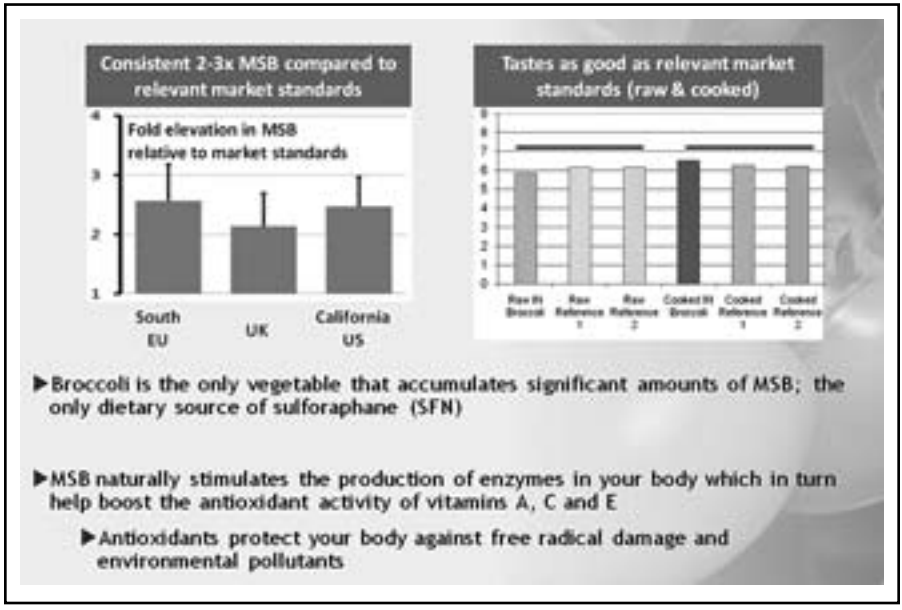

Figure 10. Broccoli with improved nutrition, developed through marker-assisted breeding.

As these examples illustrate, we are focusing on traits that we can deliver through seed and agricultural inputs that add benefits throughout the chain. Besides being beneficial for consumers, they have to be beneficial for growers, and for retailers, for produce and food companies. We have to share the benefits across the chain in order to get support in launching these products. We are working with regulators to validate the credibility of the nutritional improvements and we are working with consumers to make sure that the benefits are perceivable.

Biotechnology of Fruits and Vegetables

The wide perception is that biotech traits are not available in vegetables. In fact, some have been available for 15 years, virus-resistant squash for example. *Bt* sweet corn has been in the marketplace for nearly as long, and, of course, over 10 years ago, Cornell and the

USDA launched virus-resistant papaya, which saved the papaya industry of Hawaii. Other products are currently being worked on—whether by public or private institutions—in potato, tomato and fruit trees (Fig. 11).

A lot of the activity in biotechnology of foods is occurring in Asia. Figure 12 provides examples of a number of attributes that are being worked on by local and regional private interests as well as by government agencies, covering insect resistance, improved quality, virus resistance in eggplant, tomato and the brassicas.

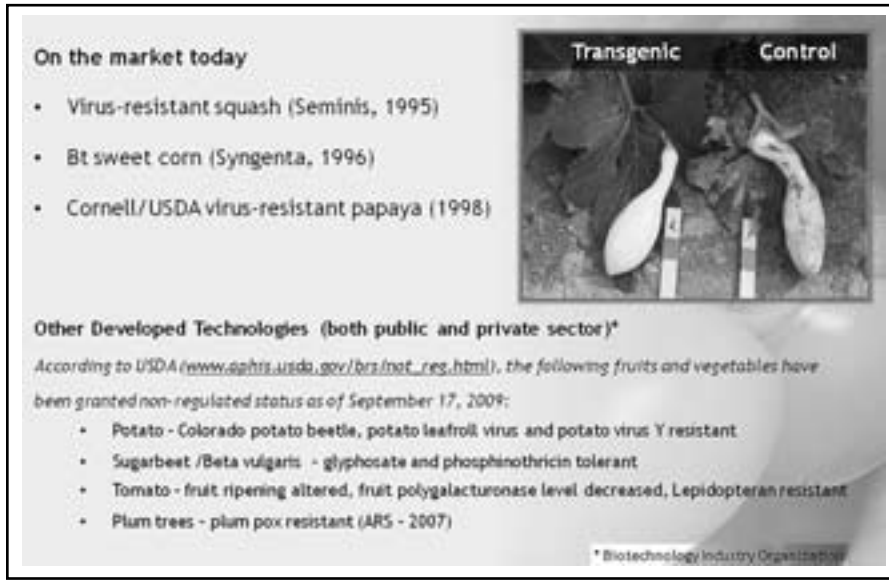

Figure 11. Biotechnology in the fruit and vegetable industries.

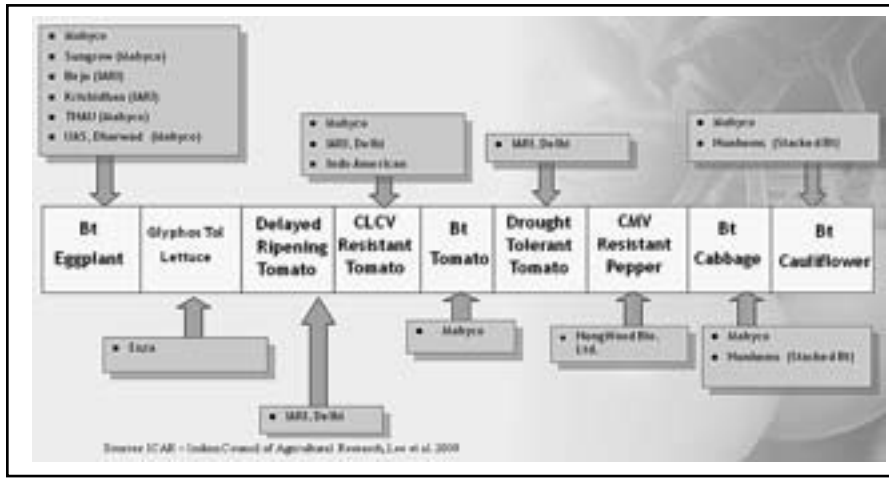

Figure 12. Biotechnology projects in Asia.

We are preparing to launch improved *Bt* sweet corn by 2012, initially targeted toward the fresh market, which is primarily where the competitive product from Syngenta has been used (Fig. 11). The market size in the United States is miniscule versus that of field corn—250,000 acres of sweet corn versus 90 million acres of field corn. It is designed to provide in-plant resistance to pests as well as herbicide tolerance, which is the same technology we launched in field corn some time ago. It's equivalent to our Genuity® VT Triple Pro™ which is widely established in field corn as providing great grower benefits. In sweet corn it will provide additional benefit because much sweet corn is produced in the southeast—in environments with intensive insect pressure—and shipped north to markets for much of the off season. Figure 13 shows results of a study that we conducted last fall in Florida, Georgia and Mississippi. The lower left-hand panel provides the numbers of marketable ears per plot from this *Bt* sweet corn, hybrid 'Passion,' as well as from the equivalent hybrid but without the biotech innovation; in the absence of any insecticide application, we completely failed to produce marketable ears. In the State of Florida, insecticide applications are recommended to begin before silking and continue at 2-day intervals all the way through product harvest, amounting to ten to twelve applications. In our trials, even with that level of insecticide application, we were producing only four to five marketable ears per plot. Therefore, this allows us to greatly reduce insecticide application in sweet-corn production and provide a better-quality, better-looking product to the consumer. There are other pests that this *Bt* doesn't control so, at this point, we are not advocating complete elimination of insecticide applications, but we are confident we can greatly reduce it, perhaps even more than the 50% that we now recommend.

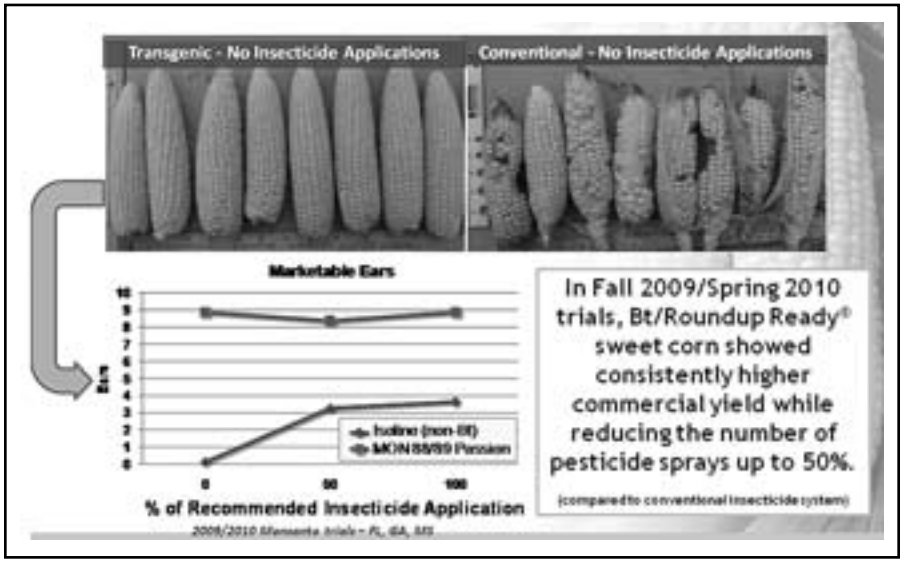

Figure 13. Sweet corn hybrid 'Passion' with the addition of Monsanto's Genuity® Triple Pro™ technology requires less pesticide to produce marketable ears.

There are many things that a company like ours can do in terms of providing agricultural inputs to help in human sustainability. Many issues are associated with today's diet. The majority of the US population has inadequate intake of a whole number of essential nutrients. Our calorie-rich diet is leading to problems with obesity, blood cholesterol, and type-2 diabetes. In fact 1% of the US GDP is spent in intensive care units. We have an opportunity—through increasing the attractiveness to consumers of our products and the internal composition of our products—to help address some of these issues.

Marlin Edwards joined Seminis, a subsidiary of Monsanto, in 2005 as the vice president of global research. Most recently he has led breeding technology at Monsanto where he developed the world's foremost high-throughput genotyping lab. This has allowed as much as 35% of Monsanto's plant breeding programs to be based on genetic marker-enabled selections.

Dr. Edwards has been involved in multiple aspects of plant breeding and agricultural biotechnology since he completed his post-doctoral research at North Carolina State University, where he conducted pioneering research into the application of molecular markers in plant breeding in the mid-1980s. He has experience in breeding field corn, sweet corn, peppers and cucumbers. He has a PhD in plant breeding and genetics, an MS in horticulture from the University of Wisconsin at Madison, and a BS in the Agriculture Honors Program from Kansas State University.