Biotech and Apples: Why They Fit

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Okanagan Specialty Fruits is a company of seven people, not much different from many labs in the publicly funded sector. Our lab is in Saskatoon, and, amongst the seven motivated, highly trained staff, we have a research team, we have a marketing director and a communications person, and myself running around like a chicken with its head cut off.

The Arctic apple is our platform project. We wanted to get involved in increasing apple consumption and one way to achieve this was to get them used more broadly, particularly when freshly cut. The Arctic apple has no polyphenol oxidase, the enzyme that drives the browning reaction; it is truly non-browning. Other apples that don't turn brown within six hours are referred to as low-browning, a consequence of substrate deficiency, not lack of the enzyme.

We are often asked, "Is Arctic a new variety?" No. We can do this with any variety. We did it first with Goldens and Grannies (Figure 1), which are now in the hands of the regulatory people. We have done it also with Gala, Fuji, McIntosh, Honeycrisp and Jonagold. The trees behave in the orchard exactly like their conventional counterparts, until the fruit is bruised, bitten or cut. They are equally healthy and productive. The apples in Figure 1 were cut several days before. The flesh of Arctic apples dries out before it goes brown.

Figure 1. First non-browning varieties.
Left: Arctic® Golden vs. conventional Golden Delicious
Right: Arctic® Granny vs. conventional Granny Smith

Initially we worked on various projects with peaches, cherries and apples, but soon realized the need to focus. We concentrate on apples, and particularly on the Arctic technology with the objective of making it available to the apple industry as a whole. If Okanagan Specialty Fruits survives commercially, we hope to diversify in due course.

Figure 2 shows that the overall trend in fruit and vegetable consumption has been upwards, with apple a notable exception. The *per capita* consumption of apples has been trending downwards for the past 25 years, which is bad news for growers. The industry maintains current production levels because of increasing population, not because we're exporting more. China, the biggest apple grower in the world, now dominates Asian export markets that have, historically, bought US apples.

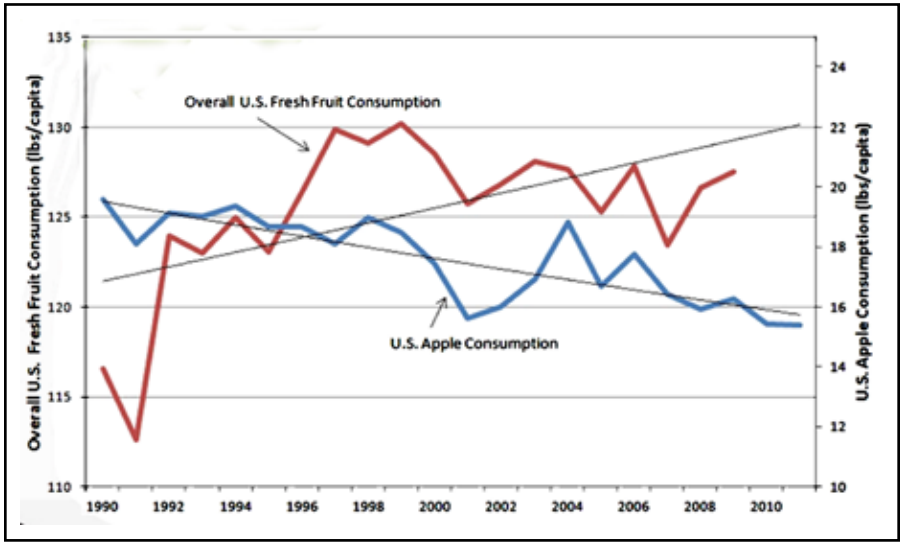

Figure 2. Trends in fruit consumption (USDA Economic Research Service).

What could we do to increase apple consumption? We looked for a consumption trigger, and found one in the fresh-cut carrot model that was introduced in 1988 (Figure 3). Carrots were cut up, tumbled it and bagged, and, by 1997, consumption had doubled. It essentially saved the carrot industry. Before then, they were used as ingredients for soups and stews and rarely eaten raw. The trend has been down since 1997 because of competition from other products, mostly other vegetables. If we could do this with apples, and increase consumption even by 1 lb per person per year, it would be great news for the industry.

Silencing PPO

RNAi is used to silence the four genes that encode polyphenol oxidase. This is like rerouting ten pieces of track on a railway from Los Angeles to New York (Figure 4). Our vector has approximately 1,800 base pairs and there are 750 million base pairs in apples; it's an exact process.

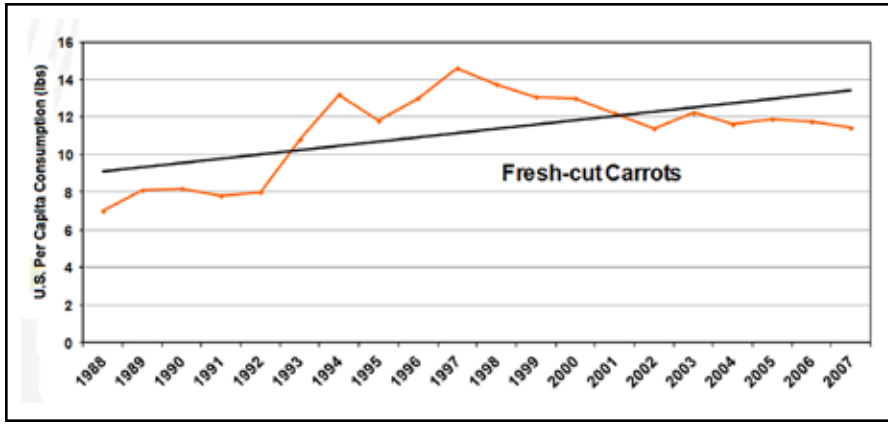

Figure 3. Trend in carrot consumption (USDA Economic Research Service).

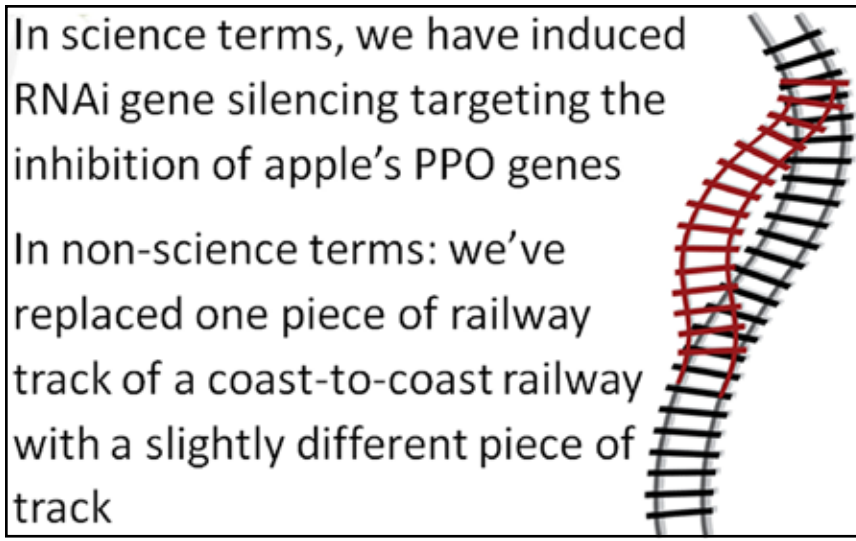

Figure 4. The science is relatively simple.

People ask if browning is an important issue. In fact, browning precludes apples from many potential markets. The need to be treated with an antioxidant to stop browning means that a lot of commercial kitchens won't handle it. It's just too much work.

The control of enzymatic browning in Arctic apples benefits everyone in the value chain. Scuffing that occurs during harvesting and post-harvest handling doesn't show on Arctic apples, thus reducing cullage. Similarly, in the packing shed, handling losses are mitigated. The fact that the juice doesn't turn brown provides opportunities for new products. Because the pulp doesn't go brown, fruit leathers look more appealing. From the grower to the processor (Figure 5) to the consumer, we can identify quantifiable benefits and creative people will find many new uses for these apples.

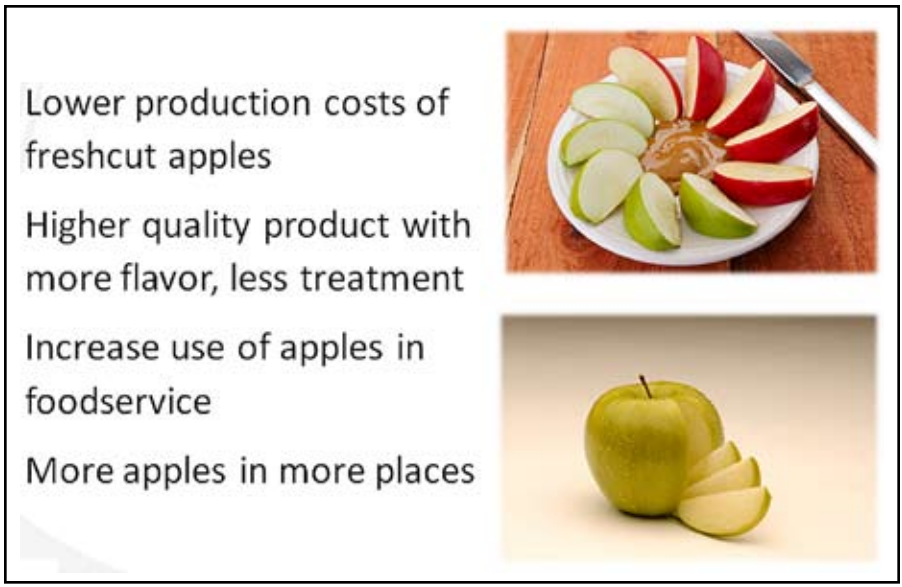

Figure 5. Fresh-cut apple processors' benefits.

Consumer Preference

What does the consumer think? Every single person in our many focus groups has wanted to try an Arctic apple. Even with those who react initially with, "Oh, no, I only eat organic," or "Oh, I'd never eat any GM," 90 minutes exposure to the air without browning results in "Wow, I must try one of these things."

We surveyed 1,000 self-professed apple eaters, asking, "What's the likelihood of your buying a non-browning apple?" About 51% said "somewhat likely" or "extremely likely." So then, against the advice of our consumer-survey company, we said, "A non-browning apple exists and it was developed through genetic engineering." Positive responses fell from 51% to 49%; we lost 2% when we used the term "genetic engineering." So then we said, "A non-browning apple exists. It was developed through genetic engineering by using the apple's own genes to turn off the gene that makes it go brown." With that half sentence added, it went to 59%—above what it was initially. When asked, "Would you rather eat an apple that is genetically engineered to prevent browning or one that had an antioxidant chemical applied?" two-thirds professed preference for the untreated, genetically engineered slice. Clearly, a little information can go a long way.

Our target is fresh-cut apples in bags, similar to baby carrots. Surprisingly, the whole apple is becoming too big a commitment in the world of texting and smart phones; how do you eat an apple and text? If apples were offered during our coffee break, few would avail themselves:

- What if someone engages you in conversation when you have a mouthful of apple?
- What do you do with the core when you're finished?

Figure 6. All Arctic apples will be voluntarily labeled.

In contrast, if apple slices were offered, it is likely that they would all disappear.

The fresh-cut opportunity in apples is huge, but the problem is that the antioxidant used to control enzymatic browning is worth as much as the fruit. If we can dispense with the antioxidant, we'll get rid of the citrus-like "buzz" and 40% of the cost. The price break will make apples more accessible for packed lunches and for food-service and many other uses.

Labeling Policy

Part of our commitment to transparency includes telling people about what they buy. Growers interested in planting Arctic apples will have to agree to apply the sticker shown in Figure 6. It doesn't say "genetically engineered," but it does say "Arctic," and media attention dictates that by the time Arctic apples hit the marketplace, many if not most people will know that they have been genetically engineered. Also, our website details the underpinning science.

From Then to Now

In 1996, we formed Okanagan Specialty Fruits to use genetically engineering tools in apple. We licensed a technology from CSIRO in Australia, who had proven the non-browning concept in potato. However, we found that the potato method doesn't work in apple; we had to silence four genes. By 2002, we had it working in the greenhouse (Figure 7) and in 2003 and 2005 we planted field trials in Washington and New York States. We started to build a package of data for regulatory purposes. In the apple business, particularly with plants from tissue culture, there is a juvenile tendency. It is essential to ensure that everything is stable, so, every year, we took buds, and propagated more and more new trees—with larger and larger field trials—and then we started to get fruit from the early trees. We felt that we were getting a properly representative data set.

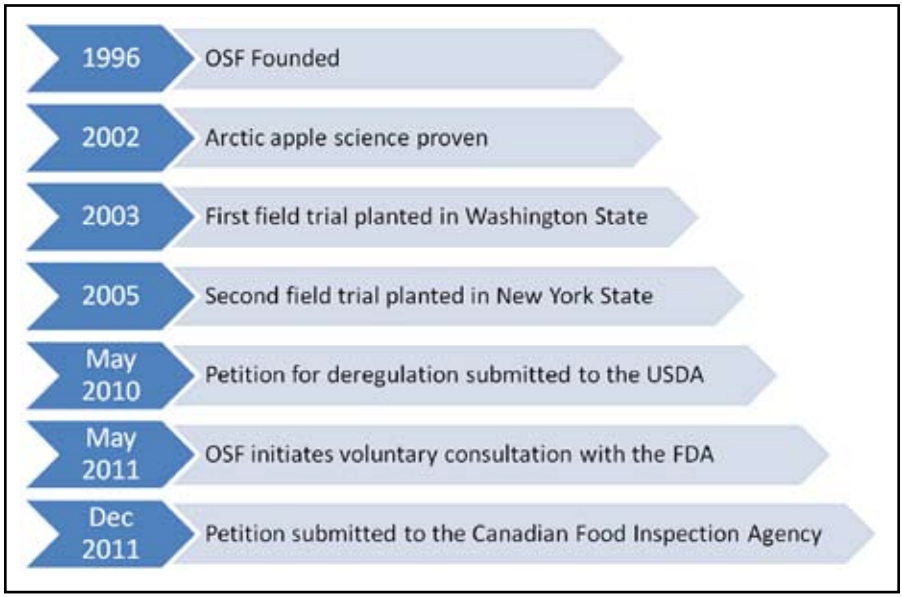

Figure 7. The path to market.

When we had the data we needed, we embarked on the regulatory process in 2010 (Figure 7), which takes us to where we are today. Hopefully, we are close to obtaining deregulation.

Obtaining Deregulation

I can't provide a firm number for the cost of the deregulation process. A major item is staff time. We spent $10,000 to $15,000 on the services of regulatory consultant who made things overly complicated, so we did it ourselves. I don't know whether advice received from the federal agencies in the end helped us or not. The advice from APHIS was "Keep it simple. Don't bring a trailer in here and dump all sorts of data. We want it synthesized and analyzed with good statistics." In the end, we went a little light and

they came back with questions and we had to add more data and more statistics. It was our first time through and we had no benchmarks. We examined other submissions, entailing different crops and different traits, and it was hard to correlate ours with theirs. However, my major comment is that this is doable and it's not exceedingly expensive. It takes time and a lot of frustration, but if you're stubborn and bull-headed, you'll get there. People shouldn't be thinking in terms of millions of dollars. The out-of-pocket component isn't that much.

In Canada we regulate the product, not the process, whereas in the United States, you regulate the process, but the submission materials were essentially the same. In Canada a significant challenge lies in having to submit all three documents at once, related to food, feed and environmental issues. For the United States, we tackled the USDA-APHIS petition first, which raised many questions that got us bogged down. Eventually we submitted the FDA application and the questions coming from APHIS helped us put the environmental document in better shape for submission in Canada (Figure 7).

By now, we had hoped to be in the midst of the second public comment period with APHIS, but we're not. The delay results from our petition being one of eleven. I don't know why they can't be done one at a time, but we hope to be deregulated by the end of the year. In Canada, we are working our way through molecular and agronomic questions with the authorities; we had a constructive meeting with them in April 2013. We expect to provide the necessary information by the end of July 2013, and we have been told that we should be finished in Canada by the end of 2013.

Figure 8. Preparation for commercialization.

Commercial Status

We are talking to growers, industry representatives, retailers, wholesalers, brokers, *etc.*, on an almost daily basis to build industry buy-in. Test blocks have been planted by growers in Canada and United States. Figure 8 shows Arctic trees planted in the spring of 2012 and now 7–8 ft tall (June 2013). They were defoliated in the spring of 2013 to prevent flowering, pending deregulation; they are grown under permit. We are putting trees in the hands of growers so that they can "kick the tires," and make sure that Arctic trees perform to expectation. We have a fair amount of uptake, but there's also a lot of pushback. Some growers don't want to have to go through the unfamiliar permitting process to put in a test block. And then some are concerned about market reaction, and many don't want to plant until after deregulation. If they plant a 10-acre block and then it's not deregulated, what will they do with it? On the other hand, if approval occurs according to expected timelines, we will have fruit for test-marketing in 2015.

We are heavily in the educational mode, particularly *vis-à-vis* growers. I have spoken around twice per month for the last two years at conventions, conferences and trade events, trying to educate. For a company of seven people with two involved full-time in education, that's a huge commitment, but this is what it takes. It's not about the science anymore and the product is worth the effort, but now it's about educating. As already stated, a strong focus is on transparency. Only 25% of people have heard of biotech crops, and many people who don't have a clue are likely to give weight to anti-biotech activists.

Our message is short and sweet: it's just like any apple; it looks like an apple; it grows like an apple; and it tastes like an apple. It just doesn't go brown. And, associated consumer benefits can drive consumption, by putting apples in more places and reducing waste in the home.

Immediate Future

Right now, our lab workers are answering regulatory questions and generating more Arctic varieties. But we are also involved in proof-of-concept work in scab resistance, fire-blight resistance, and storage scald. We have made a commitment that by the third quarter, we will ramp up our research work in those three traits and investigate stacking technologies.

NEAL CARTER is president and founder of Okanagan Specialty Fruits™ (OSF), a biotechnology company specializing in the creation of novel tree-fruit varieties. Outside of OSF, he and his wife, Louisa, grow and pack apples and cherries from their orchard in British Columbia's Okanagan Valley. For nearly 30 years, Neal has worked with numerous crops as a bioresource engineer around the globe, ranging from maize to mango, from growing to harvesting, packing, storage, processing and packaging. It was through this firsthand experience that he was persuaded that biotechnology can help agriculture meet the ever-expanding global demand for food.

The Carters founded OSF in 1996 in order to explore opportunities to utilize biotechnology to boost fruit consumption and sustainability. OSF's flagship project is the development of non-browning Arctic® apples, which have been engineered to resist browning by silencing genes that produce polyphenol oxidase. Arctic apples are currently progressing through the deregulation processes in Canada and the United States; availability in grocery stores is expected within a few years.

With apple consumption flat-to-declining for the past couple of decades, Mr. Carter believes that Arctic apples will provide a consumption trigger for the industry by providing numerous benefits throughout the supply chain.