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Modified Genes of Coffee Beans

A complicated story of crop yield, globalization, and third-world exploitation

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1. Why I chose this topic (Preface)

When I was first told I was to write a paper on genetic modification, I was rather clueless on what to write about. I knew the basic principles of genetic modification but had no idea where it was put into practice and to what extent. I started my research by scrolling through a list of genetic modification in agriculture and was surprised by the vast variety of its uses: bananas without seeds, fast growing fish, lawns that don't need frequent mowing, cows that produce human milk, bunnies that glow in the dark, the list was endless. They all seemed like interesting topics to write a paper on, but when "genetically modified coffee beans" caught my eye, I knew it was my calling. Being an avid coffee drinker, I was very excited to start working on my paper, but I didn't expect it to involve much more than the method of modifying the genes of coffee beans. I wasn't prepared, for instance, to be faced with ethical questions such as: Should I feel guilty about having my Starbucks Latte Macchiato, now that I know I am contributing to the impoverishment of small coffee growers? Or: Are advances in gene technology even a good thing in terms of everyone's welfare? First off, I should mention that there are three types of genetically modified (GM) coffee in question:

- decaffeinated coffee – a genetically engineered coffee plant that is already decaffeinated when it grows,
- insect-resistant coffee plants,
- and the controlled ripening of coffee beans

As soon as I googled "GM coffee", I was overwhelmed by an affluence of information, so I decided to narrow my topic down to the controlled ripening of coffee beans. From there on writing my paper went fairly smoothly and I finished it about three weeks before due date. After a slightly delayed reply from the researcher I had contacted for my interview, I finally had everything I needed. The only catch was that my interviewee had informed me (see *Appendix*) that the company ICTI (Integrated Coffee Technologies Inc.), which had been developing GM coffee, had recently gone out of business and that its GM coffee would probably never reach the market. In retrospect, it *was* a little odd that most of the information I had obtained for my paper was from the year 2001 – yet one would expect some sort of notification somewhere informing people that the technique was not being developed anymore.

I suppose this is all part of researching a topic and learning that not everything works out the way you planned. I decided to leave my paper as it was, since all the information I give about the technique and the concerns surrounding it were relevant when GM coffee was still thought to be a viable product. Because the company ICTI went out of business, I unfortunately wasn't able to obtain any lab photos, but I trust my paper will be just as interesting – despite the "outdatedness" of the subject matter.

2. Where there's a will, there's a way (Introduction & Procedure of Genetic Modification)

The coffee plant is an evergreen bush of the genus *Coffea* – the two main commercially cultivated species are *Coffea canephora* and *Coffee arabica.* It is usually grown in high elevations and is intolerant of subfreezing temperatures; hence its primary cultivation is in Latin America, Southeast Asia and Africa. When left unpruned, a coffee plant can grow to a height of about 5m. It has dark green leaves with clusters of white flowers and oval berries of about 1.5 cm in diameter. These berries usually each contain two seeds, the coffee beans (though – despite their name – they are not technically beans), which are picked, then skinned, dried, hulled, roasted, and ground. These ground beans are then packed into a coffee maker, which sends highly pressurized water through them to produce the hot dark brew that winds up in our coffee cup.

When the berries ripen, they turn from green to red, which is when they should be harvested. But there is a minor problem: they do not all ripen at the same time. Depending on the plant and climate, harvesting can occur from as little as once a year to all year round, and consequently the picking (called "selective picking") has to be done by hand in conditions similar to sweatshops. In some countries, such as Brazil where the landscape is relatively flat and the coffee fields immense, harvesting can also be done mechanically (called "strip picking").

The problem with mechanical harvesting, however, is that, although it is faster and more productive, it can only be done by simultaneously stripping or shaking the berries off the trees regardless of their ripeness. Not only does this damage the trees by ripping off smaller branches and leaves, but also requires the ripe berries to be sorted from the unripe ones. Selective picking is therefore the more environmentally-friendly method, though it is also more costly and labor-intensive.

But what if, say, all the berries could ripen at once? Wouldn't that make harvesting a whole lot easier and cheaper? Wouldn't that solve the whole problem? And this is where genetic modification comes in.

In 1999, the first US patent involving the genetic make-up of coffee was granted to the University of Hawaii. The patent describes how biotechnologists have "switched off" the natural ripening processes of coffee berries:

> […]The invention further provides techniques to isolate substantially pure RNA from coffee fruit even though the fruit contains high levels of phenolic compounds and carbohydrate which would otherwise interfere with obtaining clean RNA preparations from this tissue. The invention provides purified proteins, nucleic acid sequences that code on expression therefore and recombinant DNA molecules, including hosts transformed therewith, and methods for transforming coffee plants to suppress the expression of coffee fruit-expressed ACC synthase and/or coffee fruit-expressed ACC oxidase necessary for ethylene biosynthesis and the ripening of coffee fruit. Coffee plants are transformed with vectors containing coffee fruit-expressed ACC synthase and/or with ACC oxidase DNA sequences that code on expression for the respective RNA that is antisense or sense to the mRNA for the respective ACC synthase and/or ACC oxidase. The result is that the expression of the respective enzyme is eliminated and the transformed plants are incapable of synthesizing ethylene during coffee fruit ripening, although other aspects of their metabolism is [sic] not affected. The invention further provides methods for controlling the ripening of coffee fruit from the transformed coffee plants by applying exogenous ethylene.[1] (for more information on the procedure, see *Appendix*)

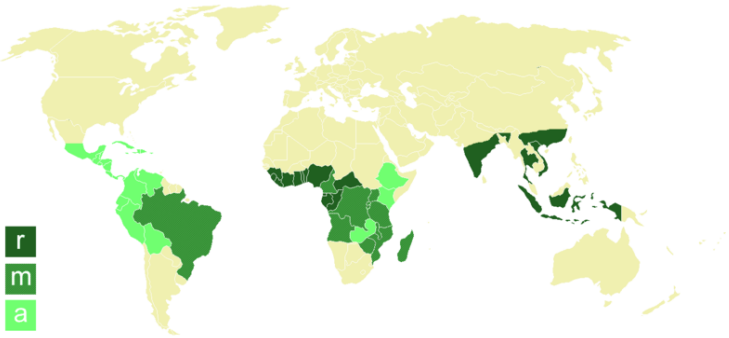
To translate this biological jargon: Basically, the coffee bean contains a hormone, called *ethylene*, which stimulates and regulates its ripening. For other fruit, such as tomatoes, bananas and apples, producers use ethylene to accelerate the ripening process, but in the case of the coffee bean the synthesis of ethylene is inhibited. That way all the coffee berries will only develop to become green and hard without ripening any further. After all the berries have reached this stage, they can be sprayed with ethylene in order to synchronize their ripening, and can then simultaneously be picked. ICTI is still developing this method and expects to begin selling plants with ethylene-controlled ripening traits in 2012.[2]

Now as attractive as this method may sound, there is a down side…

[1] Purified proteins, recombinant DNA sequences and processes for controlling the ripening of coffee plants (August 2002)

[2] Genetically modified coffee confrontation brewing in Hawaii (June 2009)

3. Coffee and Globalization (Discussion I)



Because coffee bean harvesting is based on such a labor-intensive system, small coffee growers in developing countries (*see picture*) are responsible for about 70% of coffee production. Within these countries, coffee exports can account for up to 75% of their earnings. Unfortunately, while the prices of beans have sunk to 30-50 US cents a pound on the world market, the price of a cup of coffee at a trendy coffee shop like **Starbucks** remains high. The smallholder farmers have absolutely no control over the price of their crops. According to the charity **Oxfam**, the price of raw coffee exported from producer countries makes up less than 7% of the eventual price Western consumers pay for coffee. The rest is pocketed by the big corporate traders and speculators. **Nestlé**'s coffee profits, for example, rose to $1 billion last year – something it calls "favorable commodity prices" which, in other words, can also be described as exploiting the ex-colonial third world.

GM coffee would simply push the small coffee growers into even deeper poverty. "We already have a terrible crisis in the coffee market," says Bruno Riesen, Swissaid's executive secretary and president of the **May Havelaar Foundation**. "The price has collapsed and most small farmers can't meet their costs any more. The aim of this GM coffee is to cut the costs, increase production and reduce the price even more. Many producers may have no choice but to leave their farms and migrate to the slums in the big cities."[3]

Even ITCI acknowledges these concerns: "It has been suggested that controlled ripening coffee favors large landholders over small or so-called 'subsistence' farmers in underdeveloped countries. Controlled ripening coffee plants could face political resistance in those countries." [4]

This shows that while it may facilitate the harvesting process, GM coffee is aimed at helping big plantations and to contributing to the globalization of agricultural products.

Others have argued that if the production were cut back, the problem would be partially resolved. If a shortage of coffee reached the market, coffee roasters would inevitably have to pay more. Some coffee producers from Columbia, Mexico and Central America have recently made an attempt to prove this theory by destroying over one million bags of low-grade

[3] Swiss Info (May 2002)
[4] Genetically modified coffee confrontation brewing in Hawaii (June 2009)

coffee, but to no avail. Even if they were able to raise the price of coffee, coffee giants would simply pass the increase on to the working-class consumers in the West. Destroying agricultural products because of "overproduction" just shows the crazy effects that capitalism can produce.

4. Politically Correct Coffee (Discussion II)

In the late 1980s a new product appeared, called "Fair Trade Coffee". Fair Trade standards require that farmers receive fair wholesale prices for their crops. This ensures that farmers will receive a minimum of $1.29 per pound of coffee beans – which goes directly to them, not to the middlemen who pay farmers usually no more than 35 cents a pound. As it turned out, American coffee lovers enjoy satisfying their conscience as much their taste buds, and the demand for Fair Trade Coffee (or "politically correct coffee", as **Time magazine** dubbed it) has skyrocketed in the last couple of years. Many US coffee vendors now advertise Fair Trade certified coffee, including **Dunkin' Donuts**, **McDonald's**, **Starbucks**, and almost all independent coffee shops. But is that enough? Or is it just another opportunity for big corporations to win over more customers – in this case, the ethical consumer?

As the Starbuck's website pretentiously informs readers:

> "We know our long-term success is linked to the success of the thousands of farmers who grow our coffee. That's why we work on-the-ground with farmers to help improve coffee quality and invest in loan programs for coffee-growing communities. It's not just the right thing to do, it's the right thing to do for our business. By helping to sustain coffee farmers and strengthen their communities, we ensure a healthy supply of high-quality coffee for the future."[5]

Then they list a modest number of vague goals of how they want to go about improving the welfare of the farmers and the quality of their coffee.

Jim Stewart, chairmen of the $100 million **Seattle's Best**, also likes to claim he is helping coffee producers. "Globalization has been great for me," he says. "We're doing our part. We've helped them build two schools and a road [in a community in Guatemala] but we're not a church." [6] In other words, he's still in the business to make a profit.

Certainly, Fair Trade Coffee is a good way of helping out the small farm owners and bringing the issue of fair trade prices to more people's attention. It probably does not offer a long-term solution, however. One youth in Seattle summed up the situation

[5] starbucks.com/responsibility/sourcing/farmer-support
[6] The Socialist issue 213, 6 July 2001: Capitalism's Bitter Coffee

very well. When asked what he thought of sweatshop coffee, he replied: “Everything we buy comes from a sweatshop. This country’s economy is based on sweatshops.”[7]

And that is exactly the heart of the matter. No matter how much money is given to the developing countries, it will only reach the owners of the farms, and not the workers themselves.

5. All’s well that ends well… right? (Recent Progress)

To end this paper on a happier note, I’d like to mention that already three campaigns against GM coffee are being organized, one each by **Action Aid**, **Genetic Food Alert** and **the Organic Consumers Association**. Many major coffee outlets have also issued statements saying that they will not stock GM coffee when it is available on the market. To list some of these statements:

- **WHITTARD OF CHELSEA** (from Letter to ActionAid)

"Whittard of Chelsea does not currently buy any GM crops and we have no intention of doing so in the future. Specifically we would have no difficulty in pledging not to stock or sell ripening-controlled GM coffee. We are already talking to our suppliers in order to agree this. We agree with ActionAid that the introduction of this technology would be potentially very damaging to a large number of the world's coffee producers."[8]

- **CAFE NERRO** (from Letter to ActionAid)

"Thank you for having drawn my attention to GM ripening-controlled coffee. I was not aware of this potential threat to the traditional method of collecting coffee beans. All of our coffee beans are hand picked to ensure that the Caffe Nero coffee is the best and we are proud of that fact. We asked all of our suppliers last year to confirm that they were not supplying us with genetically modified ingredients or products containing genetically modified ingredients. […] That is still our position today and we have no intention of changing that position."[9]

Even Switzerland partook in the boycott of GM coffee. **Swissaid** and the **Bern Declaration** stated that some of Switzerland's biggest coffee importers - **Coop**, **Migros, Mövenpick** and **Merkur** – shared their concerns about GM coffee and would not stock it. Coop spokesman, Jörg Birnstiel, said he did not believe there was any public demand for GM coffee, and that, in any case, the chain had strict guidelines about not stocking GM products if they had social, environmental or ethical implications.[10]

Apparently, all this work paid off. ICTI went out of business not only because the technique posed some difficulties for them but because of the resistance to GM coffee. The coffee market is still not in any

[7] The Socialist issue 213, 6 July 2001: Capitalism’s Bitter Coffee
[8] Richard Knight, Managing Director 16/5/01
[9] Paul Ettinger, Commercial Director 26/6/01
[10] Swiss Info (May 2002)

ideal condition, but as I have shown in my paper, its problems are more due to globalization and trade practices than to coffee production itself.

6. Summary

In this paper I have described the technique of genetically modified coffee, and discussed its potential impact on smallholder farmers if it were put into practice. I have also briefly outlined the problems presented by the huge agricultural business of coffee harvesting as a result of globalization and have examined different measures taken to help coffee producers.

In nature coffee beans do not all ripen at the same time and therefore have to be individually picked by hand. This is usually done by smallholder farmers in developing countries. GM coffee provides a technique which ensures that all coffee beans ripen at the same time and can then be simultaneously picked. With the controlled ripening of the coffee bean, harvesting can be done mechanically which would improve the crop yield on big plantations, but also would result in the unemployment of many smallholder farmers.

Many articles that I read on the subject matter expressed concerns about the consequences of GM coffee and requested readers to help. I have therefore also added a section on “Fair Trade”, an organization which promotes healthier working conditions and greater economic incentive for producers in developing countries.

At the end of my paper, I listed a number of boycotts against GM coffee, which seemed to be successful, as my interviewee, Chifumi Nagai, informed me, the company which had been developing the gene-modification technique has gone out of business. GM coffee, for the time being, will not be a threat to small third-world farmers.

Appendix

a) Interview with Chifumi Nagai, scientist at Hawaii Agriculture Research Center (HARC):

1. **I've been reading a lot of articles on the internet about genetically modified coffee, but it's hard to find information that is up to date. Can you tell me what the current state of the controlled ripening of the coffee bean is?**

   In Hawaii no research and development is going on as long as I know. The reasons (1) the scientist and the company (Company: Integrated Coffee) is out of business (2) controlling ripening by ethylene needs many steps beyond the plants with ripening gene. For example ethylene effects (timing and amount) on coffee ripening, registration of ethylene to be used for coffee (to US government such as EPA)

   Is it still being tested?

   I don't think it never went out of green house stage.

2. **Can you explain the exact procedure used for the genetic modification of a coffee bean?**

   It's a lengthy and complicated procedure. If you need details I must send you a copy of the paper.

   Summary:
   1. Start tissue culture of coffee from young leaves. Put sterilized cut leaf pieces on tissue culture agar media to induce callus (undifferentiated cells- clusters). After 2-4 months somatic embryos are produced.
   2. Prepare target DNA/ genes in a construct (form of functional orders) and precipitate on gold particle to be bombarded into coffee cells of somatic embryos
   3. Using Biolistic instrument insert DNA into the somatic embryos.
   4. Select somatic embryos on the selection media (with antibiotics). Since DNA for antibiotic resistance is inserted too, somatic embryos with inserted genes can survive on the culture medium with antibiotics.
   5. Obtain plants (regenerate) from surviving somatic embryos.
   6. Induce roots of plants.
   7. Test if the target DNA was inserted by extracting DNA from leaves of these new plants.

3. I have read a number of controversial articles on what the controlled ripening of the coffee bean, should it be put into wide practice, would mean to small coffee growers. Some experts maintain that it would put them out of business, especially farmers who rely on a labor-intensive system. Others say they would hardly be affected since only the plantations that already mechanically strip-pick their fields would use this new technology. Do you think there is a risk of small coffee growers going out of business if this new technology were introduced?

The issue is not for science and technology. I can answer only as a scientist not as a grower or a policy maker.
After genetically modified plants are produced many many steps must be worked out it the plants can work properly at commercial scale. Coffee bean quality using this plants must be tested and coffee's ripening uniformity must be studied. After these studied, finally some farmers will use and others don't. These issues are economical issues and not scientific issues.
You must interview growers or other people about.

b) References:

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- GM coffee threat to farmers in the developing world (date unknown) www.greenpeace.org.uk/gm/gm-coffee-threat-to-farmers-in-the-developing-world
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- Coffee Research (date unknown) http://harc-hspa.com/HARCCOF8.HTM
- Chifumi Nagai, scientist at Hawaii Agriculture Research Center

Pictures:

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