



Policy Brief

Vanilla & Biotechnology: Traceability through DNA

Addressing Systemic Vanilla Theft in Madagascar

In recent years there has been increasing consumer demand for natural flavorings, especially in developed countries. To attract consumers many large food manufacturers are switching from synthetic to natural vanilla flavorings. The most common and popular natural vanilla flavoring comes from the vanilla bean. These recent changes have placed huge demand on the vanilla market, contributing to skyrocketing vanilla prices.

Madagascar produces 80% of the worlds vanilla beans and this boom in the vanilla market has contributed an upswing in vanilla theft and violence throughout the

nation. Dozens of people have died in vanilla related murders in Madagascar. High vanilla prices (over \$600/kg in 2018) in a country with an average annual income of \$1,500 creates a strong incentive for theft. Furthermore, some farmers resort to theft when they cannot fill advance payment orders.

Farmers are forced to watch their vanilla 24 hour a day, fearing that thieves will steal their livelihoods. Many farmers resort to harvesting vanilla pods before they are fully matured, dramatically reducing their quality. Lower supplies of quality vanilla further drive up prices, while simultaneously reducing demand as

Key Points

- **Rising vanilla prices contribute to increased theft and violence in Madagascar**
- **Current solutions to theft and other vanilla boom issues are inadequate**
- **Genetic identification codes unique to each farm will increase traceability and decrease theft and violence**
- **These codes will contribute to a more economically and socially sustainable vanilla industry.**

Sarah Ditton Analysis

Food systems scholarship, analysis and stewardship

Statements in this brief are Sarah Ditton's analysis and opinions alone, not associated with MENV Program or University of Colorado Boulder

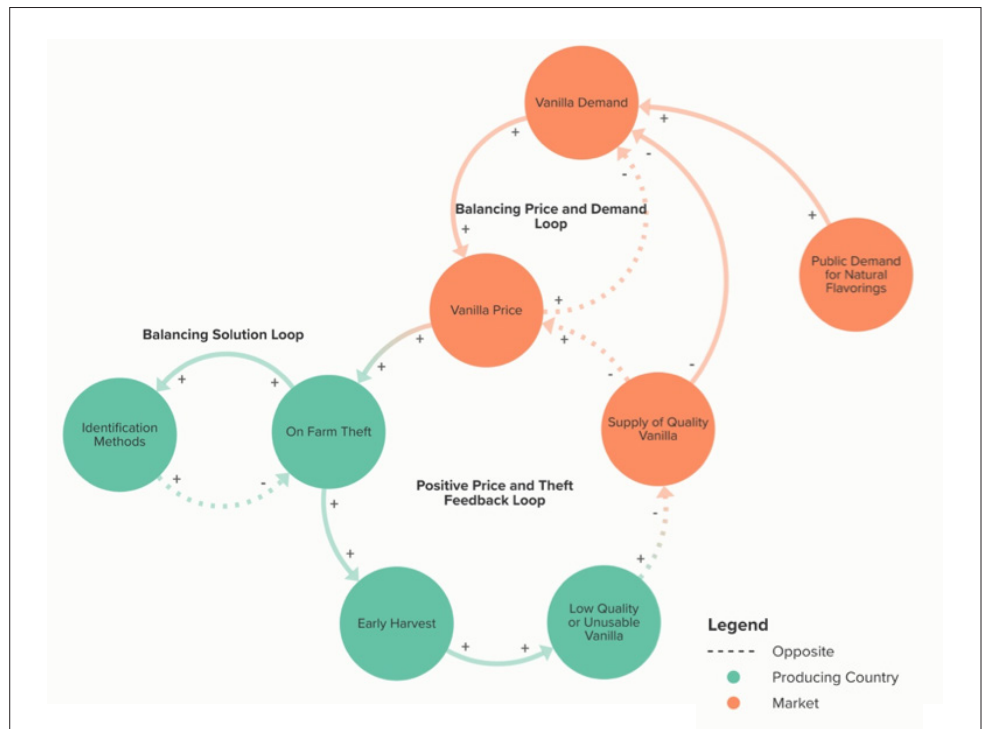


Fig. 1: System map relating demand, price, theft and quality in vanilla market

Source: Map created using kumu.io

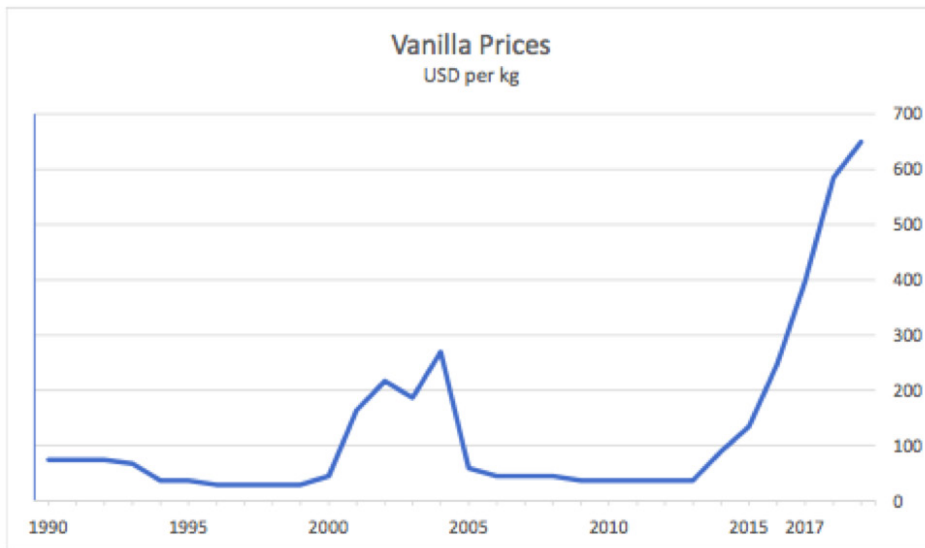


Fig. 2: Vanilla prices are reaching record highs due to weather related vanilla shortages, consumer demand for natural flavorings, and improper farming methods impacted by theft and financial necessity.

Source: The Vanilla Bean Crisis and ANPC's Commitment to Quality. (2017, November 16).

producers resist paying more for lower quality vanillas (see figure 1). Already low-quality beans are more expensive than extremely high-quality beans were only a few years ago.

If a vanilla thief is caught and convicted, they face 3-4 years prison time. As vanilla prices continue growing, this punishment is not proving strong enough to disincentivize vanilla theft.

and traders implementing projects to increase sustainability and quality and price stabilization. Many companies support the Livelihoods Fund for Family Farming which in turn partners with Fanamby, a Malagasy NGO. Fanamby and the Livelihoods Fund work to reduce theft by organizing neighborhood watch programs, supplying coded stamps for the vanilla bean pods to simplify marking vanilla beans, and notifying authorities of theft so farmer don't have to leave their vulnerable farms to do so.

Another organization, the Sustainable Vanilla Initiative (SVI), with members representing over 70% of global vanilla purchases, works to address:

- Vanilla supply chain sustainability and transparency
- Sustainable incomes for vanilla growers
- Stabilizing vanilla quality and prices

Current Solutions

The Malagasy government, farmers, and the vanilla industry players are implementing solutions to vanilla theft and subsequent immature harvesting practices.

The Government and Farmers

To create transparency and prove ownership, the Malagasy government provides registration documents to farmers. These documents have corresponding numbers that farmers stamp onto their growing vanilla beans. Each bean has to be stamped for this method to provide protection, requiring many hours of labor. However, even stamped beans are stolen and presumable sold to unscrupulous middle men and vanilla curers. Even if the buyers are looking out, the stamps can be marred and altered.

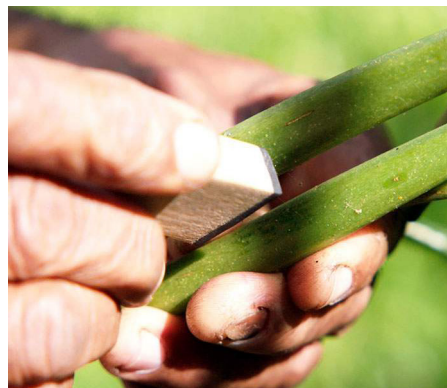


Fig. 3: Stamping each bean by hand is time intensive and often ineffective.

Source: Kacungira, N. (2018, August 16)

Vanilla Industry

It is in the vanilla industry's best interest to support sustainable and stable vanilla production and prices. The highly volatile vanilla market both makes it difficult to create stable prices for vanilla-containing products and creates an incentive to source vanilla flavoring away from farmed vanilla beans. There are many individual vanilla processors

Even though the SVI launched in 2015, it has already succeeded in creating a Code of Conduct that prohibits child labor and increases transparency. In 2016 it also received funding from the US department of Labor to improve the governance and traceability of vanilla among other initiatives.

Members of the SVI and other vanilla industry members have individual initiatives to support livelihoods in Madagascar, cultivate stewardship of the land, and teach farmers effective vanilla growing techniques. Effective initiatives working to support livelihoods through improving Malagasy education and opportunities will decrease theft and violence as people become less dependant on vanilla markets and production swings. However, if theft and violence continue, initiatives teaching farmers to avoid

harvesting vanilla prematurely, will not effectively improve quality or decrease theft. Many farmers prematurely harvest vanilla out of fear of theft, not because they are unaware of the immature vanilla's lower quality and price.

Ambrosus, a blockchain technology and supply chain tracking company, has created a blockchain based solution to vanilla traceability. Unfortunately, this solution, so far, only begins at the regional level and cannot trace vanilla to each farmer, and thus does not prevent theft.

The Future is in Genetic Identification

Stamping is currently not perfectly effective because stamps can be marred, altered, or ignored. Farmers live in fear that even their stamped beans will be stolen. However, there is a method to individually identify every vanilla bean to a farm, without the effort and alterability of stamping.

A genetic engineering technique called Crispr/CAS9 can reliably and accurately insert short DNA sequences into the vanilla

genome. The technique can target specific locations in the vanilla genome that will not alter any of the function of the plant and the short DNA sequence will have none of the mechanisms needed to produce outputs, thus causing no change other than creating a reliable genetic identifier.

There are around 80,000

smallholder vanilla farms in Madagascar. Due to the nature of DNA, it would take sequences only 9 DNA units in length to create the diversity of sequences needed to uniquely identify vanilla from every smallholder farm. Most sequencing services can sequence up to 800 DNA units accurately per sample, and they do not charge more for

Box 1: Process Behind the Insertion of the DNA Identification Codes

- 1. Create Custom DNA Sequences** - DNA synthesizing organizations will ship orders of custom DNA sequences as cheap as \$5.00 per sequence. Ensure the sequences all share the same end sequences on both sides, known as primers.
- 2. Identify non-impactful location in vanilla genome** - Locations in the genome in non-encoding regions.
- 3. Create a guide sequence for the Crispr/Cas9 mechanism** - Make a sequence that will have the gene editing only occur at the chosen location in the vanilla genome.
- 4. Use Crispr/Cas9 in combination with the custom DNA Sequence** This process will create an incision in the specified location and an insertion of the custom DNA sequence.
- 5. Test to ensure insertion** - Ensure that the sequence is inserted and is the expected code. To make testing more streamlined, the team creating these vanilla seeds might need to include a signalling gene that gives a physical signal that the insertion succeeded.

Source: Bortesi, L. & Fischer, R. (2015), Fister, K. et al. (2016).

Box 2: DNA labeling and Information Storage

In 2012 scientists encoded a 53,000 word book, eleven jpeg images, and a JavaScript program into DNA as a proof of concept that DNA could store digital data. Further studies have shown DNA data storage could be done with 99-100% accuracy with large amounts of data and DNA.

Since its invention, the price of DNA sequencing has dropped dramatically and continues to do so. DNA synthesis prices are also steadily dropping.

A few plant scientists recognized the use of DNA storage as a label and researched its plausibility. By using common genetic and biochemical techniques they inserted short, unique, non-coding DNA segments into plants and which were capable of remaining over generations. There is little information on the current extent or use of this labeling technique, but it is not common.

Source: Church, G. M. et al. a (2012), Fister, K. et al. (2016), Sawyer, E. (2011, July 20).

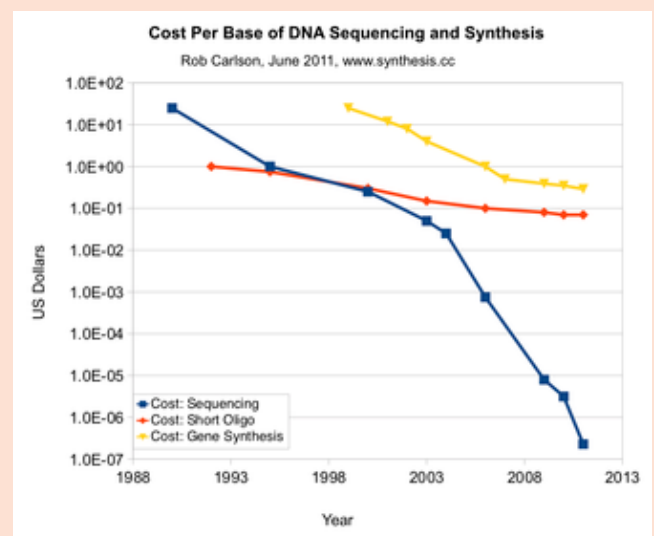


Fig. 4: Dropping prices of DNA sequencing and synthesis

Box 3: Vanilla Market Boom and Bust Cycles

Many factors contribute to vanilla markets booms and busts including changing consumer demand, weather catastrophes, drops in quality and price increases incentivizing food manufacturers to look elsewhere for flavorings. The first major drop in vanilla market prices occurred in the early 1990s, then another major boom occurred right before a bust in 2003 and now vanilla prices are again reaching record numbers

The current boom is a result of a 2017 typhoon that wiped out much of Madagascar's vanilla crop combined with increased consumer demand for natural products. In 2015, Nestle eliminated artificial flavorings from its products. Soon after other large actors, including General Mills, Hershey's, and Kellogg's, followed suit. High demand for natural vanilla preceded the typhoon in which many Malagasy farmers lost their crops and needed to replant, waiting three years before they could harvest their first beans. Low supply and high demand in recent years had led to skyrocketing prices.

However, as prices reach record highs, these companies are looking towards other sources of natural vanilla flavoring. Prices and quality must stabilize or the vanilla market will fall into another bust round as companies must look for cheaper flavoring options.

Source: *The Vanilla Bean Crisis and ANPC's Commitment to Quality*. (2017, November 16), Cadot, A. et al. (2006, August)

longer sequences.

If farmers received or bought vanilla seeds with a genetic sequence that uniquely identified them, every cell in the vanilla beans would be able to identify the original farmer. There is no room for subterfuge or alteration.

The SVI is already investing in more transparent and traceable supply chain. This method would allow for guaranteed traceability all the way to the original farmer.

Implementation

The addition of these unique identifying DNA sequences to genomes is much more accessible and cost effective now than ever before due to the Crispr/Cas9 genetic engineering system. However, it will take years for genetic engineers to craft 80,000 unique codes and insert them into seeds. As seeds are produced, farmers will buy or receive the seeds and a registration document connecting them with their unique code. Nothing about the growth or quality of the seed will change due

to the insertion of the identification sequence and farmers can produce the vanilla as they always have.

Vanilla plants take three years to mature and create vanilla beans. These three years will give the supply chain time to implement methods to read the identification sequences in the vanilla beans of the first adopters. The most cost effective and immediate method to read these sequences would require setting up DNA sequencing machines in Madagascar if they are not already present.

The majority of vanilla farmers sell their beans to middle-men and vanilla curing operations. This is often the step in which stolen vanilla can become untraceable to its original farmers. Government policies and contracts between vanilla industry members and these middle-men and curing operations will need to be created to require DNA testing to verify the seller of the vanilla is the original grower. If DNA testing operations are nearby, the turnaround time for single samples would be less than 24 hours and the cost per sample would be

less than \$10. If samples are pooled the price per sample can go down to less than \$5 per sample.

In 2016 the average farm produced about 30kg¹ of vanilla. With vanilla's final price over \$600/kg, \$10 per farm testing is less than .1% the final price of vanilla.

Once the infrastructure of coded vanilla seeds and DNA sequencing machinery is in place, the overall continuation costs of this identification and theft prevention method would be sustainably affordable.

The Benefits

If this DNA identification method is implemented, thieves can no longer sell their stolen vanilla beans. Farmers will no longer have to spend countless hours stamping every bean and sleepless nights patrolling their plantations. With the help of other technologies, such as Ambrosus mentioned earlier, vanilla beans can be thoroughly traceable from consumer to farm. This traceability will allow for a stronger boutique vanilla market as consumers demand to know their food's origins (as seen in the trends towards boutique coffee).

As theft decreases, early harvesting practices will correspondingly decrease as farmers no longer worry about losing their livelihoods. When farmers allow their beans to fully mature on the vine the quality dramatically increases. Simultaneous quality decreases and price increases have driven many companies away from vine-grown vanilla, but if quality sustainably increases those companies might return and fewer will seek alternatives. The Malagasy government fears that Madagascar vanilla will lose its association with quality and this DNA identification

¹ 30kg vanilla per farm calculated from 2016 Madagascar vanilla production of 2.6K tons divided by approximately 80,000 Malagasy vanilla farms.

process will allow for vanilla and quality to be one and the same.

Stabilizing the quality of vanilla will help stabilize price and demand. One of the main reasons for vanilla's boom and bust cycle is high prices leading to theft and lower quality beans resulting in lower demand and prices. If theft can be taken out of the equation, this part of the boom and bust cycle will be much less influential.

Vanilla industry actors and those in the SVI will be key players in making this initiative possible. This DNA identification method will help fulfill every one of the SVI's stated goals and needs their support and power to fund the seed improvements and create incentives for DNA testing compliance.

Drawbacks

The manufacturing of seeds with unique DNA codes will be potentially time consuming and expensive. Those that want to

see sustainable, traceable vanilla production will need to assist in funding this initiative. Since vanilla requires three years to produce beans, the investments in this transition will take many years to come to fruition. However, once they do, the upkeep costs will be much lower.

Vanilla beans with these identification codes will still be "natural," however, under the Non-GMO Project's standards the beans will not be non-GMO since they will be products of synthetic biology. With rising consumer demand for non-GMO foods, the lack of this label could be prohibitive to many manufacturers with goods containing vanilla.

This solution does not address many other issues associated with vanilla production including child labor, unfair production contracts, and payment inequity. However, increased traceability could meld well with solutions to these other issues and increase their viability.

Next Steps

The SVI and other vanilla industry actors, the Malagasy government, and vanilla farmers must collaborate on the next steps. The current vanilla boom and bust cycles are not socially or economically sustainable. Many suffer, especially farmers, during both the boom and bust sides of the cycle. Steps must be taken to create safeguards so fewer suffer due to theft and subsequent lower quality vanilla harvests during the booms in the vanilla market.

Vanilla stakeholders should consider investing in a new DNA-label based infrastructure that will vastly increase transparency and allow vanilla to be traced to their origin. Investments in seeds and sequencing machinery in Madagascar will create vast returns in social equity, community peace of mind, price and quality stabilization and less intense boom and bust cycles.

Written by Masters of the Environment Candidate
Sarah Ditton (sarah.ditton@colorado.edu)

References

- Baker, A. (2018, June 13). The Bittersweet Cost of Madagascar's Vanilla Boom. Retrieved from <http://time.com/5308143/vanilla-price-climate-change-madagascar/>
- Bortesi, L., Fischer, R. (2015). The CRISPR/Cas9 system for plant genome editing and beyond. *Biotechnology Advances*, 33(1), 41-52. <https://doi.org/10.1016/j.biotechadv.2014.12.006>
- Cadot, O., Dutoit, L., de Melo, J. (2006, August). The Elimination of Madagascar's Vanilla Marketing Board, Ten Years On. Retrieved from <http://documents.worldbank.org/curated/en/244911468271511638/pdf/wps3979.pdf>
- Church, G. M., Gao, Y., Kosuri, S. (2012). Next-Generation Digital Information Storage in DNA. *Science* 337(6102), 1628. [OI: 10.1126/science.1226355](https://doi.org/10.1126/science.1226355)
- DNA Sequencing Pricing (n.d.). Retrieved from <https://functionalbio.com/web/pricing.php>
- Fister, K., Fister, I., Murovec, J., Bohanec, B. (2016). DNA labelling of varieties covered by patent protection: a new solution for managing intellectual property rights in the seed industry. *Transgenic Research*, 26(1), 87-95. <https://doi.org/10.1007/s11248-016-9981-1>
- Kacungira, N. (2018, August 16). Fighting the vanilla thieves of Madagascar. Retrieved from https://www.bbc.co.uk/news/resources/idt-sh/madagascar_vanilla
- Sawyer, E. (2011, July 20). DNA Synthesis. Retrieved from https://www.nature.com/scitable/blog/bio2.0/dna_synthesis
- Sustainable Vanilla Initiative (n.d.). Retrieved from <https://sustainablefoodlab.org/initiatives/sustainable-vanilla-initiative/>
- SVI: Driving Sustainability in the Vanilla Supply Chain. (2016, December 2). Retrieved from <https://www.foodingredientsfirst.com/news/SVI-Driving-Sustainability-in-the-Vanilla-Supply-Chain?type=article>
- The Vanilla Bean Crisis and ANPC's Commitment to Quality. (2017, November 16). Retrieved from <https://www.anpc.com.au/blogs/anpc/the-vanilla-bean-crisis-and-anpcs-commitment-to-quality>