Proposed role of biofabricated horn in addressing illegal wildlife trade

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Winston Churchill wrote in 1932, "We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium" (p. 397). He made that statement as part of an essay examining the speed of human progress and projecting it forward 50 years. Nonetheless, 1982 came and went without the commercialization of *in vitro* meat or any other so-called cultured food product. That year did, however, mark the first time the product of a genetically modified organism was approved for use by the U.S. Food and Drug Administration (FDA) (Altman, 1982). Shortly thereafter, the product in question, a biosynthetic insulin, entered the market. Less than a decade later, the FDA approved the first genetically engineered food product, a biosynthetic rennin for use in cheese making (Gladwell, 1990).

It was not until the early 21st century that Churchill's vision started to become a reality. Catts and Zurr (2004) were the first to grow frog skeletal muscle over biopolymers. They then consumed the resultant three-dimensional steak. Around the same time, New Harvest, a non-profit research organization dedicated to advancing the field of cellular agriculture, was established ("About us," n.d.). In 2008, People for the Ethical Treatment of Animals announced a $1 million prize for the commercialization of lab-grown chicken (Travis, 2014). The deadline to claim the prize passed on 4 March 2014 without anyone presenting a solution. Still, the field made tremendous progress during the intervening years. In fact, a little more than a year prior to the expiration date of the contest, Dr Mark Post, of Maastricht University, created a proof-of-concept *in vitro* hamburger (Kupferschmidt, 2013). It was composed of small strips of muscle cells arising from stem cells extracted from cow muscle tissue. The hamburger cost $375,000 to develop and was financed via a donation from Sergey Brin, the co-founder of Google. By 2016, several startups were working on animal-free animal products, including Modern Meadow with its biofabricated leather and Clara Foods with its hen-free egg whites (Pedruelo, 2015).

The coming post-animal bioeconomy subsumes more than just conventional farmed animals. Methods of biofabrication can easily be extended to wildlife products. For instance, a startup called Sothic Bioscience is biosynthesizing the components of Limulus Amebocyte Lysate (LAL), which is normally obtained from the blood of the "Near Threatened" Atlantic horseshoe crab (Leibowitz, 2016). LAL clots in the presence of bacterial endotoxins. Thus, it is used extensively in modern medicine to ensure that pharmaceuticals and medical devices are uncontaminated. Other "Near Threatened" or threatened species may benefit from the emergence of cellular agriculture, particularly the two species of African rhinoceros. These species are being poached to extinction because their horns are prized as a carving material in East Asia (Ammann, 2015). This is happening despite an international trade ban on rhinoceros horn. Perhaps, to put a spin on Churchill's quote, society can escape the absurdity of having a whole rhinoceros poached for its horns by turning to biotechnology.

Rhinoceros horn mainly consists of calcium and melanin embedded in a keratin matrix. It is produced by epidermal cells that undergo keratinization in a manner similar to the growth of human hair and nails (Nowell, 2012, p. 6). There are two basic ways to biofabricate rhinoceros horn. The first way involves 3D printing a biodegradable scaffold in the shape of a horn. Next, stem cells taken from a rhinoceros are cultured, differentiated into keratinocytes, and seeded onto the scaffold. Over time, the keratinocytes become filled with keratin protein filaments and die leaving behind a solid object. The second way starts with the production of rhino-specific keratins in genetically engineered microorganisms. Once purified, these keratins are then amalgamated with rhinoceros DNA and other biomolecules into a solid using a proprietary 3D printer. Whatever the process, the intent is the same, namely to produce an artefact that is physically and forensically identical to rhinoceros horn.

Given biofabricated horn of good enough quality, the work of Akerlof (1970) suggests that the illicit market in rhinoceros horn can become a "market for lemons." Such a market is characterized by two properties: asymmetric information and adverse selection. Asymmetric information is present when a buyer and seller have unequal information about the quality or authenticity of an item being offered for sale. Its presence leads to a situation in which the buyer is unwilling to pay more than the expected value (payoff multiplied by probability of legitimacy) of the item. That situation is known as adverse selection. Akerlof puts forth an unregulated used-car market as an example of a "market for lemons"; the intuition behind his example being that a lack of information makes it difficult to ascertain if one is about to purchase a plum automobile or a lemon.

Applying Akerlof's insights, suppose a seller can either obtain rhinoceros horn from the wild at $12,000 per kilogram or from a biofab at $8,000 per kilogram. Further suppose the seller can sell the acquired horn at $35,000 per kilogram. In this case, the markup for the wild-sourced horn is 192% versus 338% for the biofab-sourced horn. So, all things being equal, it is in the seller's interest to sell biofabricated horn. On the other hand, assume a buyer knows there are biofabricated horns on the market. Further assume the buyer estimates that about 75% of the horns being sold are biofabricated. In this case, the expected value of any given horn is $8,750 per kilogram. Thus, it is in the buyer's interest to either push for a price reduction or not transact at all.

The end result is a positive feedback loop:

1. The markup on the cost of biofabricated horn entices sellers to sell it;
2. The probability of buying a biofabricated horn increases;
3. The expected value of any given horn decreases;
4. Market equilibrium rests;
5. Technology advances and the cost of biofabricating horn decreases;
6. Repeat steps 1 through 5 until the price of rhinoceros horn approaches a level that disincentivizes poaching even if aggregate demand rises.

The initial price for biofabricated horn in the above exercise (i.e., $8,000 per kilogram) is roughly the inflation-adjusted price of rhinoceros horn in 1993 (i.e., $4,700 per kilogram) (Biggs et al., 2013, p. 1038), a time when only 14 rhinoceroses were poached in South Africa (Milliken & Shaw, 2012, p. 69).

There are several counterstrategies that market actors may attempt to use to blunt the impact of biofabricated horn on the illicit market. The first of these is the establishment of a certificate authority. Such an authority issues certificates attesting to the authenticity of sellers' horns. Buyers, in turn, rely on the certificates when making purchasing decisions. Any horn lacking a certificate is suspect and would trade at a steep discount to a certified horn. The problem is that, in order to be trusted, the certificate authority must be a well-known and well-respected organization. This would necessitate a legalized trade in rhinoceros horn, something unpalatable to the international community. Furthermore, certificate authorities are vulnerable to corruption. The diamond industry's ongoing struggle to keep undisclosed synthetic diamonds out of its supply chain illustrates the threat (Biesheuvel, 2015).

Another counterstrategy of interest is the presentation of additional biological evidence during the sale of a putative rhinoceros horn. Save the Rhino International (2016) has postulated that a seller might want to show a patch of rhinoceros skin or a toenail to a potential buyer as a way of allaying their fears of being cheated. Of course, the more evidence required to consummate a transaction, the more costly and risky it is to do business. New burdens include the prolonged harvesting times needed to gather the additional evidence and the enhanced techniques needed to preserve it. Evidence also facilitates convictions, so having to transport more of it around in a synchronized manner is quite daunting. Finally, there are no guarantees that the additional evidence shown to a buyer is not itself biofabricated.

The deployment of cheap, portable testing equipment capable of detecting biofabricated horn is yet another counterstrategy to consider. A handheld near-infrared spectrometer capable of determining if a Viagra pill is real or not already exists (McGoogan, 2015). Fortunately, only crude rhinoceros horn fakes are detectable using this technology. The immediate worry is that biofabricated horn is not going to be available in time to replace the exposed fakes, since fake horn currently buffers the true demand for rhinoceros horn (Ammann, 2015, p. 39). Over time, as biofabrication techniques improve, the cost of testing becomes unbounded and the utility of testing diminishes.

A final counterstrategy to consider is brand building. When biofabricated horn infiltrates the illicit market, sellers must find ways to bolster their perceived trustworthiness. Efforts to do so may attract the attention of law enforcement. Worse, a trusted brand can easily be appropriated by other sellers, as often happens in illicit drug markets (Clifton, 2012). Alternatively, a trusted brand may be susceptible to rumours that the products it is selling are biofabricated.

None of the aforementioned counterstrategies invalidates the role of biofabricated horn in addressing the illegal wildlife trade. Rather, it is increasingly clear that if biofabricated horn is passable as rhinoceros horn, then rhinoceros horn will become a normal good that cannot be economically supplied by poaching.

References

About us. (n.d.). Retrieved from http://www.new-harvest.org/about

Akerlof, G. (1970). The market for lemons: Quality uncertainty and the market mechanism. *The Quarterly Journal of Economics*, 84(3), 488-500.

Altman, L. K. (1982, October 30). A new insulin given approval for use in U.S. *The New York Times*. Retrieved from http://www.nytimes.com

Ammann, K. (2015). Wishful thinking and rhino conservation. *Swara*, 2015(2), 39-43.

Biesheuvel, T. (2015, October 7). Why this De Beers lab makes diamonds it will never sell. *Bloomberg*. Retrieved from http://www.bloomberg.com

Biggs, D., Courchamp, F., Martin, R., & Possingham, H. P. (2013, March). Legal trade of Africa's rhino horns. *Science*, 339(6123), 1038-1039.

Catts, O., & Zurr, I. (2004, Winter). Ingestion / disembodied cuisine. *Cabinet Magazine*, 16. Retrieved from http://cabinetmagazine.org

Churchill, W. (1932, March). Fifty years hence. *Popular Mechanics*, 57(3), 390-397.

Clifton, J. (2012, March 28). The art of heroin bags. *Vice*. Retrieved from http://www.vice.com

Gladwell, M. (1990, March 24). FDA approves bioengineered cheese enzyme. *The Washington Post*. Retrieved from http://www.washingtonpost.com

Kupferschmidt, K. (2013, August 5). First artificial burger gets tepid reviews, billionaire financier unmasked. *ScienceInsider*. Retrieved from http://www.sciencemag.org

Leibowitz, D. (2016, January 18). Sothic bioscience. Retrieved from http://www.new-harvest.org/sothic-bioscience

McGoogan, C. (2015, October 15). This tiny molecular sensor can identify a Viagra pill. *Wired UK*. Retrieved from http://www.wired.co.uk

Milliken, T., & Shaw, J. (2012). *The South Africa – Viet Nam rhino horn trade nexus: A deadly combination of institutional lapses, corrupt wildlife industry professionals and Asian crime syndicates*. TRAFFIC.

Nowell, K. CITES. (2012). *Species trade and conservation – rhinoceroses: Assessment of rhino horn as a traditional medicine* (SC62 Doc. 47.2 Annex (Rev. 2)). TRAFFIC.

Pedruelo, I. (2015, December 14). From lab to table. *Policy Innovations*. Retrieved from http://www.policyinnovations.org

Save the Rhino International [@savetherhino]. (2016, January 13). Poachers killed adult rhino cow in Kaziranga NP in Assam; take horn, toenails & a patch of skin. To prove it's real? http://bit.ly/1JKcoOy [Tweet]. Retrieved from https://twitter.com/savetherhino/status/687238324944302081

Travis, J. (2014, March 3). PETA abandons $1 million prize for artificial chicken. *ScienceInsider*. Retrieved from http://www.sciencemag.org