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Once Upon a Time – Is it possible to turn straw into gold?

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Abstract
In Once Upon a Time (OUAT), a series based on fairytale characters and their real stories from another realm, one of the characters, Rumplestiltskin (The Dark One), possesses the magical ability to spin straw into gold. While this is clearly fiction, the concept raises an intriguing scientific question: is it possible to extract gold from straw in the real world? Advances in genetic engineering have made it possible to modify plants for phytoextraction. This paper will explore the process by which plants take up gold from the soil, through phytomining.

Keywords: *TV Programme; Biology; Genetic Modification; Phytoextraction; Once Upon a Time; Rumplestiltskin*

Introduction

Once Upon A Time (OUAT) [1] is a series based in the fictional town of Storybrooke, Maine, where the fairytale characters' tales are real. The characters were ripped from their world and transported to the "real world" by the Evil Queen, Regina [2]. Mr Gold, aka Rumplestiltskin (fig 1), has the magical ability to spin straw into gold. In our world, magic does not exist, as such it is not possible to spin straw into gold. This paper will discuss the possibility of extracting gold from straw, using genetically modified plants to take up gold from the soil through phytoextraction.

Figure 1 – Rumplestiltskin/Mr Gold [3].

Genetic Modification

Humans have been genetically modifying various plants for millennia through selective breeding, with teosinte being one of the first plants to be selectively bred to produce maize ~10,000 years ago in South America [5]. Selective breeding is limited in what it can achieve, but it allowed humans to breed bigger, better, juicier, sweeter fruits and vegetables, and enabled diversification of edible plant foods. With the onset of genetic engineering using genome editing, plants can be modified to produce vitamins (e.g. vitamin C in golden rice), become drought tolerant, and to carry out certain tasks, such as phytoextraction.

Figure 2 – Phytoextraction of Gold. The biomass is dried and burnt, then the ash is collected for smelting and refinement [9].

Phytoextraction

Phytoextraction takes up and incorporates heavy metals into the plant via phytoremediation [6], or precious metals via phytomining [7, 8, 9] (fig 2 above). It is almost always a human-engineered process using plants to carry out tasks, such as cleaning up environmental pollution or converting the pollutants into less or non-toxic compounds through phytoremediation. Phytoremediation in plants causes the accumulation of heavy metals in various parts, such as the stalks, leaves, and fruits. To phytomine, the plant can be engineered to accumulate only gold and induced to hyperaccumulate, resulting in more than 1 mg per kilogram of biomass, 10-100 times that naturally found in plants [7].

Before any accumulation can occur, the gold needs to be bioavailable. In some geological areas this occurs naturally through environmental soil-chemicals. Where it does not occur naturally, chemicals such as ammonium thiocyanate, thiourea, and sodium cyanide can be used to make the gold soluble for phytoextraction. This process is known as phytomining [9]. Adding chemicals forces the plant to take up gold and is described as chelate-enhanced phytoextraction [7]. An example of a soluble bioavailable form of gold is Gold(III) – Thiocyanate complexes $(\mathrm{Au(SCN)}_4^-)$, which is formed when thiocyanate is added to the soil.

Phytoextraction at the Genetic Level

At the genetic level, Heavy Metal ATPase (HMA) genes are crucial for the transportation of heavy metals from roots to shoots [10]. HMAs are part of the P-type ATPase family and facilitate the absorption and translocation of metal ions across membranes, by combining the metal ions with ATP hydrolysis. Beyond heavy metal transport, HMAs play a vital role in plant growth and development, helping plants resist metal-induced stress and preventing toxic metal accumulation.

A 1999 study using dead biomass of alfalfa *(Medicago sativa L.*) showed alfalfa tissues have the ability to bind to gold(III) ions in aqueous solutions, reducing them to gold(0) [11, 12, 13]. It was suggested that gold(III) reduction likely involves oxidation of biomass functional groups like cysteine or methionine [12]. The findings, along with subsequent studies, highlight the potential of bioaccumulation for gold extraction, with a focus on targeting HMA genes for bioengineering applications. Leveraging these genes should further enhance gold accumulation in plants to be used for phytoextraction and phytomining.

Phytoextraction: Gold Phytomining

Various plant species possess the unique ability to hyperaccumulate heavy metals, translocating the metals from the roots to the shoots, with some of the metal remaining in the roots. Hyperaccumulator plants do not all accumulate metals in the same quantities, thus the best hyperaccumulator plants tend to be used [9]. Crop plants such as wheat, barley, oats, rice, maize, and tobacco are capable of phytoextracting gold for phytomining [14, 15] and can be utilised for straw production. However, these straw-producing crops are generally not hyperaccumulators of gold, in contrast to certain species like *Brassica spp.* and *Alyssum spp.*, which exhibit significantly higher capacities for gold accumulation [7]. While the yields of gold may be far smaller than Rumplestiltskin's, scientific methods offer us innovative ways to turn straw into gold.

Among straw-producing crops, tobacco has been shown to be one of the most viable for phytoextraction. In a field experiment, 39g of gold was extracted from 100 kg of tobacco plants, yielding 1.2 mg of gold per kilogram of dry biomass [14]. This yield places tobacco plants just within the hyperaccumulator range. However, it is likely that phytomining with tobacco would serve as a secondary purpose, with the primary focus remaining on harvesting tobacco for its conventional uses.

To extract the gold from the plants, the straw is not spun on a Saxony wheel as it is by Rumplestiltskin, but by harvesting the plants, drying them, and burning them to an ash (i.e. bio-ore). The ash is collected for extraction of the gold by either smelting or by using chemicals (fig 2 and 3). The burning process can also be used to generate energy [9] (fig 2).

Fig 3 – Processing and extraction of gold [14].

Conclusion

Using a Saxony wheel to spin straw into gold, as Rumplestiltskin does, is impossible in our world. Scientific methods have been shown to offer an alternative. By bioengineering plants to phytoextract gold from soil, gold can accumulate in plant biomass when made bioavailable, either naturally or with chemical treatments. The bioaccumulated gold can then be extracted and purified from the bio-ore, yielding pure gold.

References

[1] Horowitz, A., Kitsis, E., Hales, B., Fong, L., Goodman, D. H., Espenson, J., Chambliss, A., Horgan, D., Wolkoff, B., Karp, A.J., Schwartz, J., Chun, T., Vazquez, K., Goldberg, I., Hull, R., Thomson, D. T., Boylan, C. Nimerfro, S., Hollier, C., Tigelaar, L., Ridings, B., Karp, P., Cvetko, V., Soler, N., & Raya, M.I. (2011-2018) *Once Upon a Time.* [TV Series] Directed by Hemecker, R., at al. USA: Kitsis/Horowitz and ABC Signature. First released 23 October 2011.

[2] Fandom (2025) *Once Upon a Time.* Fandom. Available from https://disney.fandom.com/wiki/Once_Upon_a_Time [Accessed: 20 January 2025]

[3] Bennett, M. (2016) *Once Upon a Custom – Rumplestiltskin/Mr Gold.* Available from: http://www.onceuponafandom.com/news/once-upon-a-costume-rumplestiltskinmr-gold [Accessed :20 January 2025]

[4] Martin, T. (2012) *Spinning Gold*. Once Upon a Fandom. Available from http://www.onceuponafandom.com/origins/spinning-gold [Accessed: 20 January 2025]

[5] Ha, M. & Schleiger, R. (2020) *Selective Breeding and Genetic Engineering*. Libre Texts. Available from https://bio.libretexts.org/Bookshelves/Ecology/Environmental_Science_(Ha_and_Schleiger)/04%3A_Humans_and_the_Environment/4.03%3A_Agriculture/4.3.03%3A_Selective_Breeding_and_Genetic_Engineering [Accessed: 21 January 2025]

[6] Symth, S.J. (2020) *The human health benefits from GM crops*. Plant Biotechnology Journal. Vol 18(4), pp 887-888. DOI: 10.1111/pbi.13261

[7] Wilson-Corral, V., Anderson, C.W.N. &Rodriguez-Lopez, M. (2012) *Gold phytomining. A review of the relevance of this technology to mineral extraction in the 21st century*. Journal of Environmental Management. Vol 111, pp 249-257. DOI: 10.1016/j.jenvman.2012.07.037

[8] Sheoran, V., Sheoran, A.S. & Poonia, P. (2013) *Phytomining of gold: A review.* Journal of Geochemical Exploration. Vol 128, pp 42-50. DOI: 10.1016/j.gexplo.2013.01.008

[9] Sharma, S., Parihar, N., Dabhi, J., & Saraf, M. (2021) *Phytomining of Heavy Metals: A Green Technology to Sustainable Agriculture*. *International Journal of Innovative Research in Science, Engineering and Technology.* Vol 10(6), pp 7527-7538. DOI: 10.15680/IJIRSET.2021.1006278

[10] Taylor, A.F., Rylott, E.L., Anderson, C.W.N. & Bruce, N.C. (2014) *Investigating the Toxicity, Uptake, Nanoparticle Formation and Genetic Response of Plants to Gold*. *National Library of Medicine.* Vol 9(4), e93793. DOI: 10.1371/journal.pone.0093793

[11] Marchiol, L. (2012) *Synthesis of Metal Nanoparticles in Living Plants*. Italian Journal of Agronomy. Vol 7(3), e37. DOI: 10.4081/ija.2012.e37

[12] Gardea-Torresdey, J.L., Tiemann, K.J., Gamez, G., Dokken, K., Cano-Aguilera, I., Furenlid, L.R. & Renner, M. (2000) *Reduction and Accumulation of Gold(III) by Medicago sativa Alfalfa Biomass: X-ray Absorption Spectroscopy, pH, and Temperature Dependence*. Environmental Science and Technology. Vol 34(20), pp 4392-4396, es991325m. 10.1021/es991325m

[13] Gardea-Torresdey, J.L., Parsons, J.G., Gomez, E., Peralta-Videa, J., Troiani, H.E., Santiago, P. & Yacaman, M.J. (2002) *Formation and Growth of Au Nanoparticles inside Live Alfalfa Plants*. Nano Letters. Vol 2(4), pp 397-401, nl015673. DOI: 10.1021/nl015673

[14] Krisnayanti, B.D., Anderson, C.W.N., Sukartono, S., Afandi, Y., Suheri, H. & Ekawanti, A. (2016) *Phytomining for Artisanal Gold Mine Tailings Management.* Multidisciplinary Digital Publishing Institute. Vol 6(3). DOI: 10.3390/min6030084

[15] Kurniawan, R., Hamim, Henny, C., & Satya, A. (2022) *Identification of Potential Phytoaccumulator Plants from Tailings area as a Gold Phytomining Agent*. Journal of Ecological Engineering. Vol 23(1), pp 169-181. DOI: 10.12911/22998993/143978