Ontario Engineering Competition 2023

Solving World Hunger and Homelessness Simultaneously

-Food Waste Extraction and Management System (FWEMS)-

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Abstract:

The need for food is ever increasing, with an expected demand of 2800 Mt/month of food needed in the near future. With all this food required it is imperative that food waste is limited by farmers and crop growers across the world. Unfortunately, in the current world climate, byproduct waste is extremely common and standard industry practice. In our specific case, contaminated wheat will usually be burned or discarded in one manner or another, which produces unwanted gases and requires immense amounts of energy. With both food demand and housing being ever increasing issues, we have come up with an innovative solution to tackle the issue at hand, using a simple system of chemical reactions and materials to transform rotting wheat stalks into a usable bio-control and plant growth promoting tool, and an easy, economic way to tackle the housing crisis in both developed and developing countries.

Problem:

Current agricultural practices result in large bales of good wheat stalk being left out in fields. Things like rain and hot summer days create ideal environments for wheat to mould and for bacteria to grow, specifically streptomyces, thereby creating contaminated wheat stalk. While this wheat stalk could be reused as livestock feed, the presence of streptomyces render it useless in that regard. In order to address this issue in a sustainable and equitable manner, the resultant product of the main bio-engineering process must be an upcycled product of this agricultural waste. To keep it a sustainable solution, any waste, or secondary resource, should be used in some other process that continues to not produce any waste by-products and that minimises the impact on the surrounding environment.

Proposal (high level design):

We are proposing a system that uses both chemicals and heat to separate the streptomyces from the wheat stalk. Streptomyces offers many possibilities with it being a proven tool in bio-control, and promoting plant growth. The leftover wheat stalk or agricultural waste will then be used as an ingredient for bio-bricks, which can be used in many different ways; such as providing a possible building material for low cost houses as well as heat or sound insulation for more expensive properties.

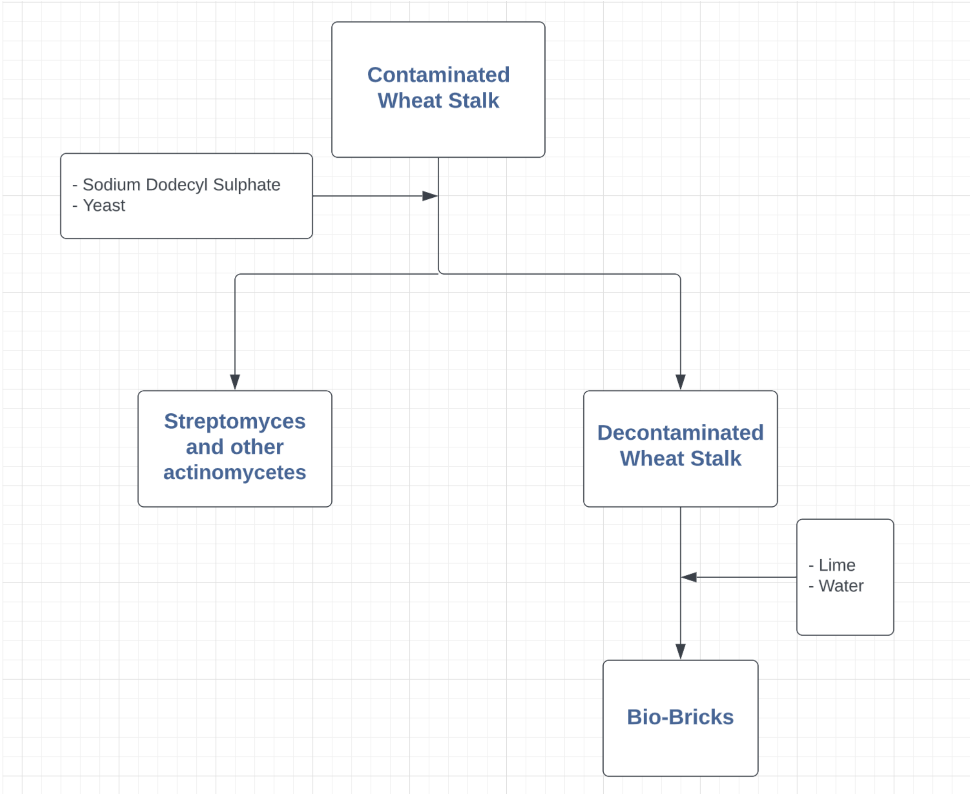

Figure 1: Visualisation of our design concept

Technical Details (detailed design):

The process begins by extracting the streptomyces from the contaminated wheat stalk. By extracting the streptomyces (valuable bacteria), a cleaner wheat stalk is left. To remove the streptomyces, 2.5% yeast and 0.1% sodium dodecyl sulphate are added, heated to 30°C, and then maintained at this temperature for 30 minutes. This process will cultivate the bulk of the actinomycetes (in which streptomyces are included) [1]. From here, there are a variety of uses for the actinomycetes. One of these options includes using these actinomycetes as fertiliser for soil enrichment. Actinomycetes increase the photosynthetic reactions, along with nitrogen content in the soil, which help to increase crop yield for legumes. [2] Along, with potentially beneficial pharmaceutical aspects, the cultivated actinomycetes have high economic value which is only growing in the market, which in 2013 was projected around $7 billion. [3] Furthermore, should it be needed, the produced actinomycetes can be reused to fertilise new crops being planted at the source of the original waste.

	PGPS	Elicited effects	References
Biocontrol activities	*Streptomyces griseus*	*Rhizoctonia solani*	Merriman et al. (1974)
	Streptomyces kasugaensis	*Fusarium* sp.	de Vasconcellos and Cardoso (2009)
	Streptomyces J-2		Errakhi et al. (2016)
	Streptomyces sp.	*Sclerotium rolfsii*	Gholami et al. (2014)
	Streptomyces sanglieri	*Ganoderma boninense*	Azura et al. (2016)
	Streptomyces griseorubens E44G	*Fusarium oxysporum* f. sp. *lycopersici*	Al-Askar et al. (2015)
	Streptomyces rochei ACTA1551		Kanini et al. (2013)
	Streptomyces felleus YJ1	*Sclerotinia sclerotiorum*	Cheng et al. (2014)
Plant growth-promoting activities	*Streptomyces anulatus* S37	Grapevine	Couillerot et al. (2013)
	Streptomyces sp.	Bean	Jarak et al. (2012)
		Chickpea	Gopalakrishnan et al. (2015)
	Streptomyces matansis BG5, *Streptomyces* sp. RSF17, *Streptomyces vinaceus* CRF2, *Streptomyces* sp. CRF14, *Streptomyces pulcher* CRF17, *Streptomyces griseoincarnatus* SCF18		Javaid and Sultan (2013)
	Streptomyces PRIO41	Pepper	Robles-Hernández et al. (2015)
	Streptomyces mutabilis	Wheat	Toumatia et al. (2016)
	Streptomyces fumanus gn-2	Soybean	Doolotkeldieva et al. (2015)

Figure 1: Potential plant growth promoting activities of streptomyces [2]

For the leftover wheat stalk, it is used to make what are known as bio-bricks, which have a variety of uses. For one, bio-bricks offer cheap solutions to housing issues in many developing countries, which also have high agricultural waste. It can also be used in more developed countries to produce cheap insulation and cheap housing for a growing housing crisis. [4]

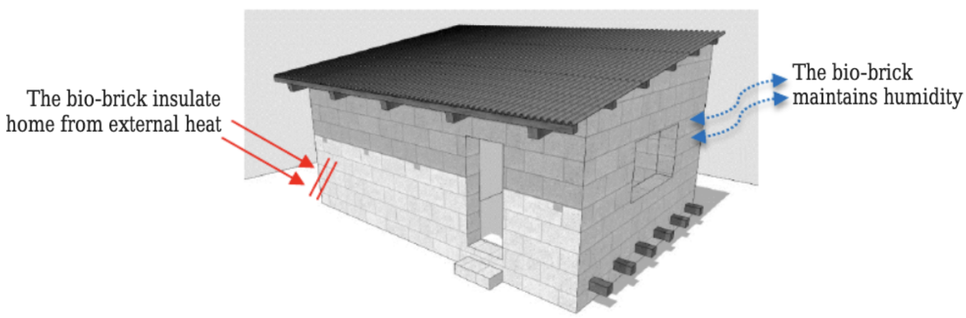

Figure 2: Potential Low Cost Load Bearing House [4]

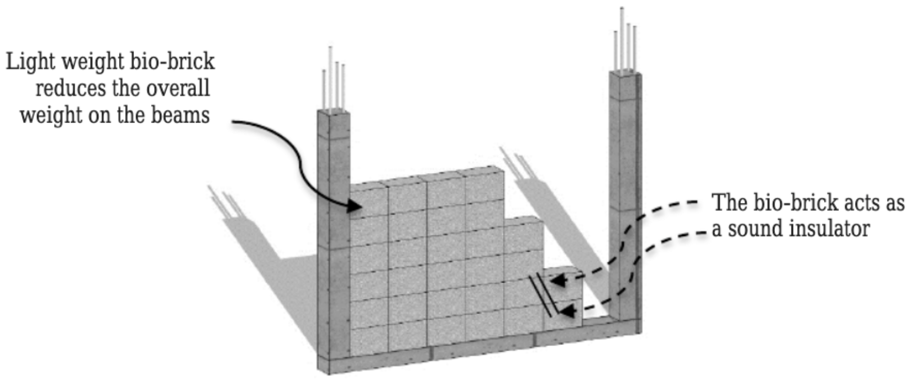

Figure 3: Potential Low Cost Filler Wall Material [4]

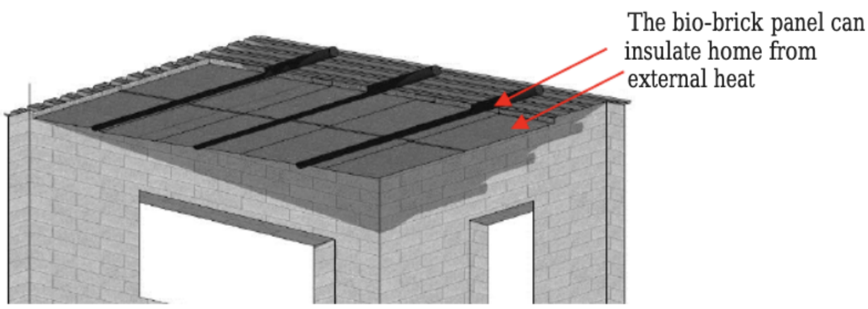

Figure 4: Potential Low Cost Insulated Roof [4]

Furthermore, bio-bricks have no significant bio-waste, as the composition of lime, water, a binder and agricultural waste uses all the resulting “sludge” produced in the first step of our process. [4] Also, the curing, and production of the bricks requires no heating and drying, the bricks can simply be left to dry for fifteen to twenty-five days, or the bricks could be heated to accelerate the process. [4] The storage of bricks presents a particular problem: where to store all the bricks? This would require a large scale factory, however through our cost analysis, money is still being saved as the food/agricultural waste issue accounts for massive money losses every year.

Other applications:

- Bio-bricks can also be produced potentially with food waste which tackles a further world issue.

Enzyme	Use	Industry of application
Protease	Detergents	Detergent
	Cheese making	Food
	Clarification- low calorie beer	Brewing
	Dehiding	Leather
	Treatment of blood clot	Medicine
Cellulase	Removal of stains	Detergent
	Denim finishing, softening of cotton	Textile
	Deinking, modification of fibers	Paper and pulp
Lipase	Removal of stains	Detergent
	Stability of dough and conditioning	Baking
	Cheese flavoring	Dairy
	Deinking, cleaning	Textile
Xylanase	Conditioning of dough	Baking
	Digestibility	Animal feed
	Bleach boosting	Paper and pulp
Pectinase	Clarification, mashing	Beverage
	Scouring	Textile
Amylase	Removal of stains	Detergent
	Softness of bread softness and volume	Baking
	Deinking, drainage improvement	Paper and pulp
	Production of glucose and fructose syrups	Starch industry
	Removal of starch from woven fabrics	Textile
Glucose oxidase	Strengthening of dough	Baking
Lipoxygenase	Bread whitening	Baking
Phytase	Phytate digestibility	Animal feed
Peroxidase	Removal of excess dye	Textile

Figure 5: Potential uses for various actinomycetes [5]

- Some of the extracted actinomycetes have pharmaceutical uses which provides a tertiary income to our process. Specifically, this is thanks to their ability to produce different classes of antibiotics. Furthermore, newer research suggests there is plenty of potential to find natural products due to their unique enzymatic set.

Limitations:

Bio-bricks are a relatively new piece of engineering and not much end of life research has been conducted on the product. However, based on the construction and composition of the bricks it is possible to assume that they could be reformed into new bio-bricks once they are not in usable condition. [4]

Another thing that was taken into consideration was the effect that both the streptomyces and sodium dodecyl sulphate have on the structure of the wheat stalk. Wheat stalk is composed of three main components: lignin, cellulose, and hemicellulose. The lignin acts like a cell wall, fully encasing the other two components. Cellulose and hemicellulose are both relatively easy structures to break down, however due to lignins dense chemical structure, it is very difficult to degrade it. While streptomyces has been shown to degrade lignin, it is not in high enough concentrations to make any significant impact on the amount of contaminated wheat stalk. [7] Sodium dodecyl sulphate is also technically capable of degrading lignin. This is because sodium dodecyl sulphate is an anionic detergent, which is known to degrade lignin. However, since the sodium dodecyl sulphate is used in such small concentrations (0.1%), there is not enough of it to make any significant impact. [8]

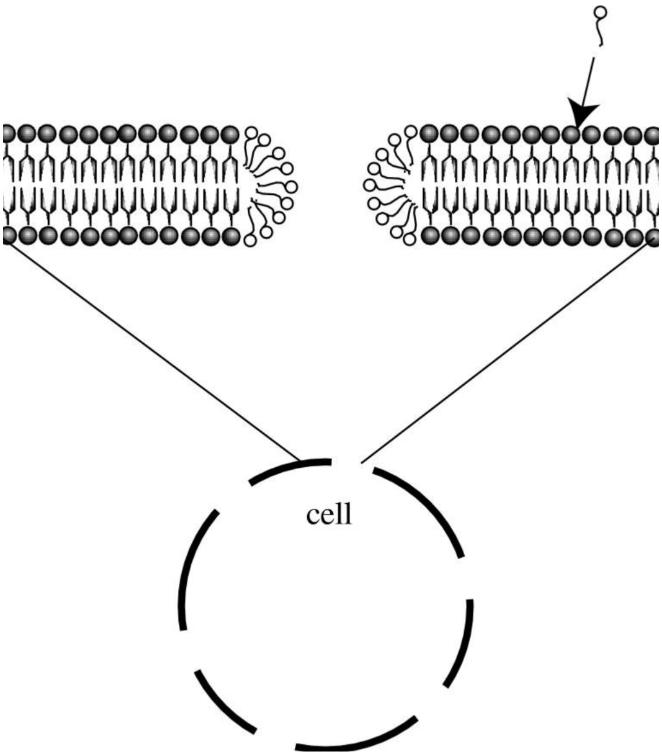

Figure 6: Potential effects of anionic detergent on a cell [6]

Some developing countries may not be able to afford such large factories, however, this can be addressed by either more developed countries implementing the plants and selling the bricks to developing countries. Another option, could be the repurposing of already present factories, this requires less money and infrastructure, and as our process above is simple and requires, minimal energy would be much more feasible in countries with developing economies while opening up jobs for people in those positions.

Some countries might not have the space for facilities like mentioned above, however these procedures, done together or separately can both be conducted on a small scale with relative ease and would still benefit farmers worldwide.

Cost Breakdown:

Factory, 1 Story with Concrete Block / Bearing Walls

Cost Estimate (Standard Union Labor)	% of Total	Cost Per SF	Cost
SubTotal		$96.23	$2,886,990.16
Contractor Fees (General Conditions,Overhead,Profit)	25%	$24.06	$721,747.54
Architectural Fees	7%	$8.42	$252,611.64
Total Building Cost		$128.71	$3,861,349.34
Cost Estimate (Open Shop)	**% of Total**	**Cost Per SF**	**Cost**
SubTotal		$86.56	$2,596,823.89
Contractor Fees (General Conditions,Overhead,Profit)	25%	$21.64	$649,205.97
Architectural Fees	7%	$7.57	$227,222.09
Total Building Cost		$115.78	$3,473,251.95

Figure 7: Cost breakdown for a basic one story factory [9]

Table 1: Rough cost estimate, including expenses and income streams

Expense	**Cost**
Sodium dodecyl sulphate	$3.00/ kg [10]
Lime	$0.188/kg [11]
Yeast	$34.7/kg [12]
Factory construction	3.5 million USD [9]
Income Source	**Income**
Sale of actinomycetes	Roughly $7 billion USD worldwide (2013) [3]

Table 1 is a rough cost estimate for this proposed solution. It accounts for all costs associated with both the operation, and construction of the factory required to manage the contagious waste and manufacture the bio-bricks. It is estimated that around USD2.6 trillion are lost every year to food waste, which is astronomically larger than the cost to build the factory.

Conclusion:

In conclusion, our design offers a cost effective, economically profitable, simple and clean way to dispose of agricultural waste, specifically by extracting valuable contaminants from streptomyces and creating useful products from the waste of the by-products.

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