Hya Bioplastics

Solution summary

Hya-bioplastics is looking at replacing existing petroleum-derived disposable packaging with bio-degradable ones using the invasive water hyacinth as a major raw material.

Context

Water Hyacinth characteristics:

High growth rate 17.5 metric tons per hectare per day.

Causes: Its spread is largely linked to eutrophication emanating from increased water pollution, poor land use management practices and other environmental and climatic factors. The wastewater discharged from households and industries and contains these nutrients which when increased in concentrations result into eutrophication, which is growth of plant and algae. With increased urban population (25% growth rate) and industrial growth (6.5% growth rate) this nutrient loading of waterbodies is bound to grow and increase the yield of water hyacinth.

Location: Freshwater lakes in Southeast Asia, the South-eastern United States, central and western Africa, Central America and Iberian Peninsula in southwestern Europe and this poses a threat to the already scarce freshwater sources

Coverage: In Uganda, water hyacinth attained peak coverage of up to 2000 ha on the bays of Lake Victoria with most infestation focusing on the shores with ample nutrients and shelter which are suitable conditions for the growth of these weeds.

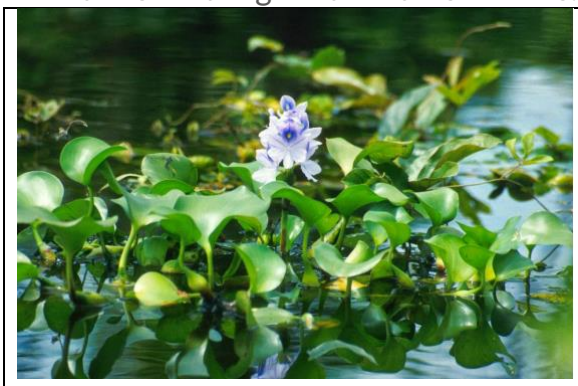


Figure 1 Water hyacinth

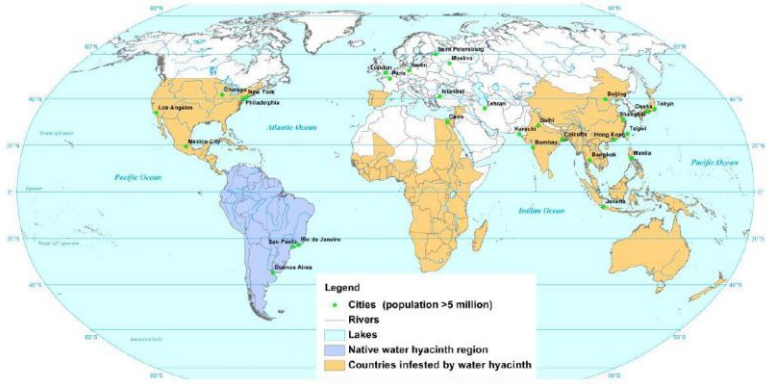


Figure 2 Global distribution of water hyacinth in water bodies

Contextual Problems associated with hyacinth:

PROBLEM	Instances of complete blockage of waterways by water hyacinth making fishing and recreation very difficult.	The fact that its mat-like nature results in the concentration of micro-organisms around the plant roots and shoots.	Its control measures yield no economic value: Mechanical, biological techniques are quite expensive and its explosive growth rate makes the measures seem unnecessary.

EFFECT	• Normally transporters of goods and fishermen consume two to three times more fuel when water hyacinth infestation is high and the fish catch is reduced by 50-75%. • Damage to fishing gear and losses due to inaccessible landing sites.	• It can enhance an increase in pests and diseases, such as schistosomiasis, filariasis, malaria and encephalitis which are a danger to public health. • Increased cost of pumping and treatment of water. These pose an economic burden to households and the government at large.**Invalid source specified.** • Its control measures yield no economic value: Mechanical, biological techniques are quite expensive and its explosive growth rate makes the measures seem unnecessary.	• Loss of revenue with no return on investment on the infrastructure for continuous removal of hyacinth.

The plastic problem;

Globally up to about 242 million tons of plastic waste have been generated in the municipal solid waste and increased to 300 million in more recent years. These have been observed to end up in landfills, litter on roadsides and a large proportion of about 300 million has ended up in the oceans. In Sub Saharan countries, consumed plastic packaging waste is rarely recycled due to technical and economic constraints and low profits for those involved.

The solid waste generated in Kampala city the capital of Uganda is about 350,000 tons annually and of this 37% generated is non-biodegradable causing blocked drainage channels, flooding hence posing a public health risk to the people. In this city the solid waste is handled by Kampala Capital City Authority which through private companies collects the waste and transports it to the landfill. The waste is sorted by locals to remove the recyclable plastic which is a source of livelihood for many of the slum dwellers. These then sell it off to recycling companies but despite this less than 30% of the waste is collected for recycling. With recycling and reuse rates still low there is need for more solutions that give both economic value and also reduce the impact on the environment by plastic pollution.

Cassava

Cassava is abundantly grown in sub-Saharan Africa with up to 50% of global cassava production (Limboonruang, 2018). The only value attached to it is consumption as food and with more than enough available for supply, lower prices are offered to the already poor farmers

Solution Overview

We want to replace existing petroleum-derived disposable packaging with bio degradable packaging created from water hyacinth and starch. We are using dried water hyacinth fibers as the filler material and boiled cassava starch as a binder to create a film that once heat compressed in various molds, can form disposable packaging to be used for carrying fast foods. We look to use beeswax layer as a protective coating to increase the hydrophobicity of the plate to make it more convenient for use.

We want to take advantage of the fast-growing nature of water hyacinth as this source is renewable. A resource is considered 'renewable' if it can be naturally regenerated on a human timescale. This means that the rate of regeneration has to keep up with harvesting and consumption (Keawmanee, 2015). With the fast-growing nature of water hyacinth coupled with the fact that it doesn't compete with land resources, it will be a much better alternative than other existing biomass sources.

We are testing our packaging for its ability to be compostable. This will help us in producing compost that can be supplied to Cassava farmer groups in Uganda at a lower cost. In addition to this, we will increase the demand for cassava, increasing its market value, and most importantly, earn the farmers more income.

By using dried water hyacinth fiber (reduction of the moisture content), the overall calorific value of the disposable packaging will be increased. This will fit its use for energy recovery as an additional source of fuel for the user, hence eliminating waste. With currently 96% of households in Uganda relying directly on firewood and charcoal as their main fuel for cooking (UBOS, 2016), we look to have our disposable packaging used as an additional source of fuel in homes.

Customer/user validation.

The government of Uganda has on several occasions enacted several laws on the ban of plastic used in packaging ranging from polythene bags to disposable packaging. These have all been reverted due to implementation issues arising from the poor mechanical properties of alternatives such as paper bags and lack of an affordable biodegradable alternative to this type of packaging.

With most disposable packaging being imported into the country benefiting only a few economically, a local alternative that involves the use of locally sourced materials and creation of employment opportunities along the product life cycle has to be introduced which also allows for elimination of the invasive water hyacinth.

Material Analysis.

The bio-plastic is to be developed as a composite material of hyacinth fiber, cassava starch as a binder and glycerol as the plasticizer for the product.

Water Hyacinth Fiber

The invasive water hyacinth being readily available is the raw material for the fiber for the composite bio-plastic being developed. The fiber is main source of strength for the bio-plastic however requires reinforcing binder to achieve strength properties.

Water hyacinth compared to alternative sources of fiber for composite bioplastics like wheat bran requires less input for its growth like fertilizers and labor. We look to harvest the existing water hyacinth on the water bodies present in Uganda through forming partnerships with agencies formed to fight the invasive plant including the National Environment Management Authority.

Water hyacinth being grown in a controlled environment in applications like vertical gardening and in some instances like open channels for wastewater guarantees constant supply of raw material for production. This protects the open environment from the invasive plant since areas where it is grown can be closely monitored to avoid disruption of other activities on water bodies. Water hyacinth farmers can gain value from this plant and improve livelihoods.

The plant can also offer treatment of this wastewater that flows through drains since it has been observed to achieve treatment through nutrient uptake with up to 70% removal efficiency of nutrients like phosphorous.

Binder Matrix:

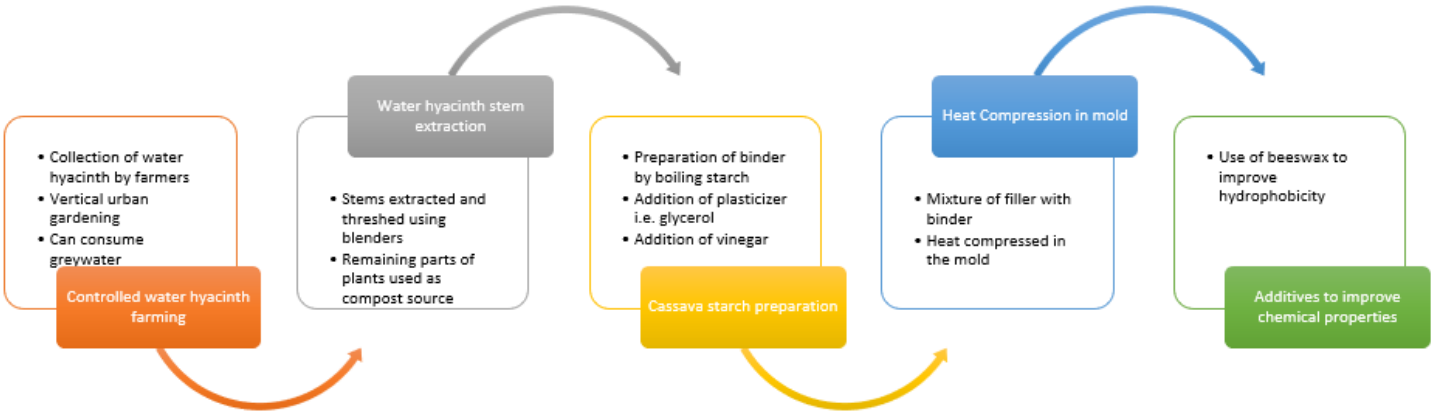
Cassava starch: This is used as binder for the mixture but however is a brittle substance with low strength and therefore requires enhancement of its properties through the use of glycerol and vinegar to modify its chemical composition. The glycerol enhances the ductility of the starch and the vinegar down the molecules of amylopectin in starch. The tensile properties of starch are suitable for production of packaging materials. (Limboonruang, 2018)

Vinegar as a component of bioplastics is also observed to offer protection to fungus and the optimum composition for the bioplastic which achieves performance for hardness and density is 70% water, 20% starch, 5% glycerol, 5% vinegar. This mixture forms the ideal matrix for a binder and combined with natural fibers from the water hyacinth generates a bioplastic with the required strength and flexural requirements.

Cassava is abundantly grown in sub-Saharan Africa with up to 50% of global cassava production ((Limboonruang, 2018))and the only value attached to it is consumption as food with more than enough available for supply hence lower prices are offered to the already poor farmers. There is need to have it gain more utility value such that the farmers can gain more value through expanded markets like as a source of starch.

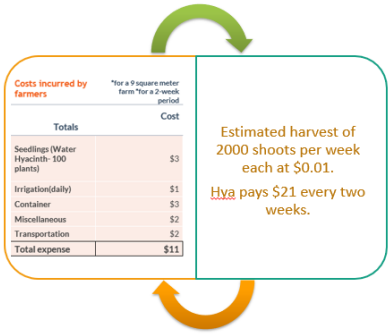
Economic Analysis.

Pipeline for production of Hya bioplastic plates.



Hya Bioplastics is looking to start by extracting existing water hyacinth on the water bodies in Uganda. With this model, we will be paying **$60** cents for a bundle of **50** shoots collected.

Proposed model for water hyacinth farmers



Production cost breakdown for 1 plate.

Production cost breakdown *per 10 plates

Material	Quantity	Cost	
Water	0.875 litres	$0.00	
Glycerol	0.04 litres	$0.09	
Cassava Starch	0.25 kg	$0.05	
Water hyacinth stems	100 shoots	$1.10	Cost per plate
Totals		**$1.24**	**$0.124**

*based on estimates achieved in our 1st and 2nd prototyping trials

Competitor analysis

Aluminium foil

Aluminium foils are the most commonly used packaging material for takeaway food purchased from roadside vendors. The buying price per piece is **$0.08** to the roadside vendor.
The single use nature and short lifetime of this aluminium foil packaging makes our biodegradable packaging a perfect alternative.

Machine cost breakdown

Machine Parts	Projected Amount	Quantity	Total (USD
Cylinder	$ 250.00	1	$ 250.00
Top Plate Moulds	$ 100.00	4	$ 400.00
Bottom Plate Moulds	$ 100.00	4	$ 400.00
Main frame	$ 400.00	1	$ 400.00
Plunger	$ 150.00	1	$ 150.00
Pneumatic system installation	$ 500.00	1	$ 500.00
Fabrication	$ 500.00	1	$ 500.00
PLC	$ 500.00	1	$ 500.00
Total			$ 3,100.00

SWOT Analysis

Strengths: Patent the product to monopolize the production and team with knowledge on materials and product development.
Weaknesses: High cost of research and development and product development.
Opportunities: High consumer demand due to need for more green packaging (eco-friendly product). Reliable raw materials in form of water hyacinth.
Threats: Large firms can easily set up their own bioplastics products to cut off supply from outsider.

Profit-Loss Assessment Statement.

Hya Bioplastics
Profit and Loss (P&L) Statement
[USD $]

	2021	2022	2023	Key Assumptions
Revenue stream 1(Sell of disposable plates)	168,480.0	202,176.0	252,720.0	* Unit cost per plate- $0.27, 50% of plates sold
Total Net Revenue	**168,480.0**	**202,176.0**	**252,720.0**	
Cost of Goods Sold	-	-	-	
Gross Profit	**168,480.0**	**202,176.0**	**252,720.0**	
Expenses				
Production costs	154,752.0	154,752.0	154,752.0	
Machine cost	3,100.0	3,100.0	3,100.0	*Production rate of 1000 plates per day
Rent	3,600.0	3,600.0	3,600.0	
Salaries, Benefits & Wages	10,800.0	10,800.0	10,800.0	*3 full-time employers
Marketing	12,000.0	12,000.0	12,000.0	
Transport	2,400.0	2,400.0	2,400.0	
Utilities	1,800.0	1,800.0	1,800.0	
	-	-	-	
	-	-	-	
Total Expenses	188,452.0	188,452.0	188,452.0	
Earnings Before Interest & Taxes	**(19,972.0)**	**13,724.0**	**64,268.0**	
Interest Expense	1.8	1.8	1.8	
Earnings Before Taxes	**(19,973.8)**	**13,722.3**	**64,266.3**	
Income Taxes		-	-	*Locally fabricated machine will reduce taxes charged.
Net Earnings	**(19,973.8)**	**13,722.3**	**64,266.3**	

IMPACT ASSESSMENT

Impact of removal of hyacinth and application as a bioplastic feedstock:

Water hyacinth has been used for various applications including arts and crafts in making baskets and mats. and wastewater treatment due to its superior treatment performance and invasive nature. Its potential use for energy recovery has been investigated but due to its low calorific value, the energy recovered per metric ton is very low making it not economically feasible. (Keawmanee, 2015). Below are the different types of impact we hope to achieve;

Economic Impacts

- Reduced investment in herbicide for removal of water hyacinth. $115 million between 1975 and 2013
- Reduced losses incurred due to damage of fishing gear $83000 per fishing season.
- Boost trade and transportation of goods across waterways save up to $1.8 million.
- Save on costs of treatment and pumping of water.
- Income generation for water hyacinth harvesters since it is a raw material for a valuable product.
- Reduced investment in treatment of diseases like malaria $24.8 per capita both direct and indirect due to productivity losses

Social Impacts

- Improved lifestyles for communities dependent on landing sites formerly affected.

- Reduced public health and less danger to people due to pests and disease that flourish in hyacinth presence.
- Increased jobs for those in harvesting of hyacinth, accessible landing sites and unblocked waterways.

Environmental:

- Reduced pollution by plastic in environment through reduced disposal in landfill, open drains since the bioplastic waste is utilised in composting.

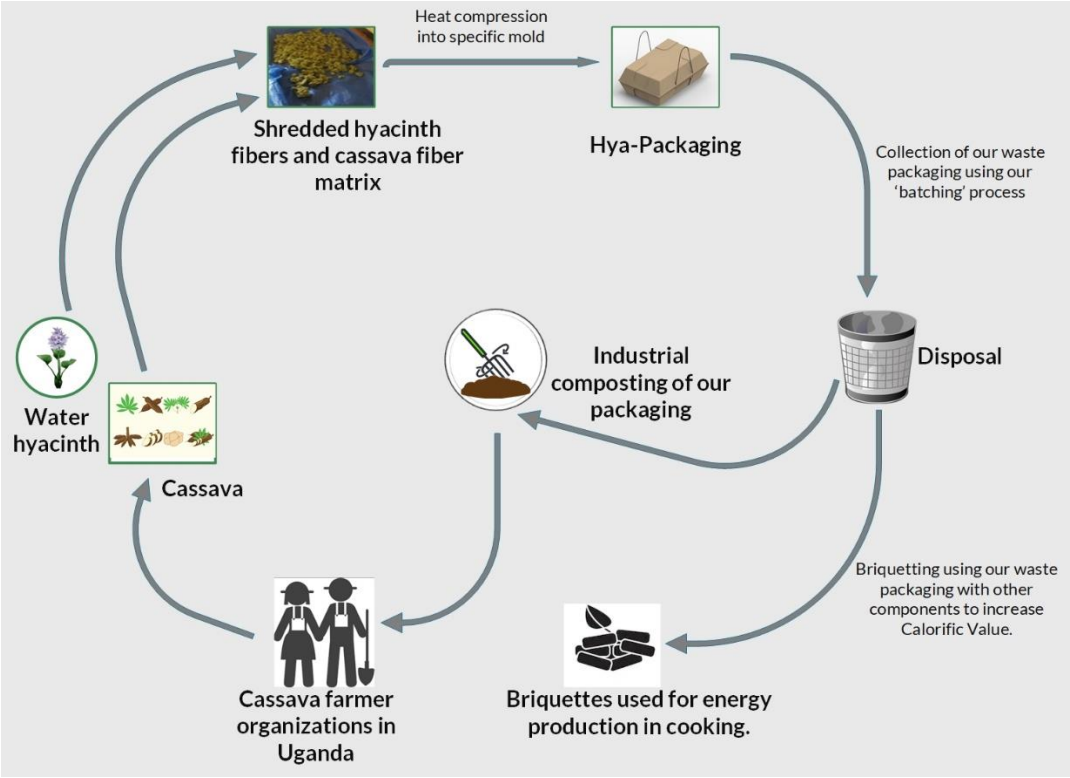
Circular economy

Batching;

Weak legislation, lack of law enforcement and low public awareness are among the reasons for poor waste management. Lack of infrastructure and low public awareness leads to systems that are ineffective due to lack of existing infrastructure including separate waste collection bins.

This will help create a more effective waste collection system that will help in closing the loop.

Hya Bioplastics Circular Economy Model



Prototyping

Literature Review

A state-of-the-art review of the viable facts that can back up the production of packaging from water hyacinth has been carried out with supervision from Professor Olupot, a material science professor at the College of Design, Art and Technology (CEDAT), Makerere University. Water hyacinth was studied and this particular venture aims to exploit its constituent fibers that will act as reinforcements for the packaging. As a way to bind the particular fiber of the water hyacinth, a binder, Cassava starch, was deduced from the various locally available cassava due to the rigidity that it possesses when dried it. This enhances the strength of the final product hence can be relied upon as a packaging material keeping

The specific material properties like flexural strength, tensile strength, density and water absorption, all together vary according to the composition ration between the water hyacinth fiber and binder.

Test for compostability.

Composting transforms wastes into stabilized organic form through decomposition of the organic materials by micro-organisms in a controlled environment. Compostable bioplastics are those that can be recycled through organic recovery(composting), the key distinguishing factor from the generally biodegradable plastics is that the compostable bioplastics undergo biodegradation in a controlled time frame and in controlled environment determined by the composting technique.

Hya bioplastics has initiated three different types of composting tests namely; rectangular windrow(uncovered), in vessel composting and vermi-composting due to feedback from judges.

Below is a link to write up showing details about the compostability tests we have commenced.

https://drive.google.com/open?id=1FnM0Dyluf3Phtq7KtzZGmVLC111ahc-m

Briquetting procedure.

Hya Bioplastics is looking to obtain the calorific value of our bioplastic material and find ways to increase it through addition of substances such as chicken droppings. These tests will be carried out upon re-opening of the university. We have carried out a literature review on existing energy sources and charcoal is the main source of energy with about 25.4% of families relying on it in Uganda as per a World Bank report in 2016. Most rural families obtain this firewood through tree cutting and collection which is usually carried out by the women and children. In peri-urban communities, charcoal is purchased in 100kg sacks that cost between $15-$22 depending on the season. Our prior analysis shows that we can produce a fuel source that is cheaper than this by using our packaging combined with other substances.

Mentors

Dr. Olupot Peter- Makerere University, Material Science Researcher

Eng. Musiimenta Julius- Margherita Millers, Managing Director, Plastics manufacturer

Partnerships created.

United Social Ventures- Business Model development and advice.

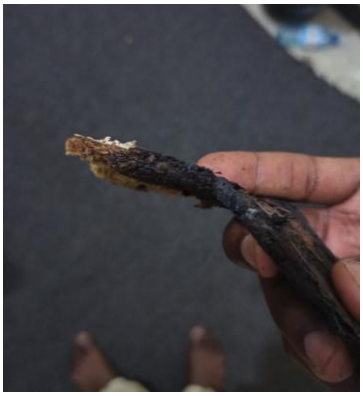
Makerere University- Research guidance and prototyping equipment provided.

Production Process.

The main materials used for testing consist of water hyacinth fiber, cassava starch modified with vinegar and glycerol, plain water, fine blender, filter cloth, digital weighing machine, and a compression machine. Water hyacinth fibers are prepared starting from cutting roots and leaves of fresh water hyacinth to have stalk remained only, washing with clean water, and then slicing fresh water hyacinth into small pieces in approximate size for 5 mm. After that, water hyacinth is blended to be fine with a blender and when blending is completed, they are dried with sun exposure. The cassava starch is mixed with water, vinegar

and glycerol as plasticizers to form a pasty solution that binds the sun-dried fibers. The mixture is made up of a **40:60**, fiber: starch ratio, which takes up the shape of the various molds over which it is spread.
The first mold that has been develop yields a plate who material properties shall later be enhanced to fit other various packaging applications like paper bags, wraps etc.
The compression machine that has been developed is made from dumped electrical equipment like an oven, and low-cost steel angle bars. From these rudimentary methods, 1 plate comes off the miniature production line, meaning only 36 plates can be processed.
This prototype was made using a heated plate surface and the other main raw materials.





Designs.
Developed CAD model for both the machine and render.
Please follow this link to a simulation of our developed CAD model for the machine and plate.
https://www.youtube.com/watch?v=FqFh2amFlnY&feature=youtu.be

Future prospects

- Fabrication of an operational machine to create viable market ready products.
- Launching of our business model and product at our beachhead market i.e. Makerere University.
- Awaiting results from compostability tests that we have commenced.
- Continued formation of partnerships locally with farmer groups and garbage collectors.

Barrier acknowledgment

Composting at a large scale	Identify partners in solids waste management through collectors in urban centers to ensure products are delivered to areas within the 9 municipalities with compost plants just like other organic wastes.
Behavioral change	Limited knowledge on the potential of bio plastics. There is need to create awareness about them as an alternative to conventional plastics and how this will reduce the plastic pollution problem.
Legislation	In Uganda alone, there is no supporting policy for the speedy adoption of bioplastics as an alternative to single-use oil derived plastics.

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