

An investigation into the use of Polyvinyl-Alcohol film as an alternative to internal plastic packaging

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Introduction

Every year around 300 million tonnes of plastics are produced and of that an estimated 8 million tonnes of plastic waste enters the world's oceans, with hundreds of thousands of tonnes of this being harmful microplastics (POI, 2018). This study has a key aim of reducing the amount of plastic produced, and therefore disposed of, by investigating further into the use of a cold water-soluble plastic alternative, polyvinyl alcohol (PVA for short) as a replacement for internal plastic packaging¹.

PVA is a polymer produced through a chemical reaction called 'alcoholysis' that renders it completely soluble in water, however insoluble in practically all other organic solvents (Britannica, 2009). It is also suggested to be safe for the environment when dissolved in natural water bodies and nontoxic to wildlife when consumed as it does not bioaccumulate in the system. Due to the way it is produced, PVA does not take charges and has the same antistatic properties as cellophane as well as having good tenacity, biaxial tension strength and anti-tearing strength making it more flexible at up to ten times as resistant as other films. It has also been commended for its natural gas barrier to oxygen, nitrogen, hydrogen, helium, argon, carbonic acid gas etc. but it permits moisture and NH_3 to penetrate. It additionally provides excellent fragrance preservation of produce and sufficiently retains moisture.

PVA has been historically used widely in industry for the production of paper, plywood and even in textiles. It also has many uses in medicine, as well as being used for recreational fishing as a bait capsule of sorts. It is most commonly known to be used in glue and more recently in washing up capsules that can be thrown straight into the basin with the promise of dissolving to release the detergent in a more efficient way than using powders.

The key players in this study include people like Lei Shi, Lilong Ao, Hu Kang and Haijia Su who wrote a paper on the effects of PVA when used to aid the growth of crops and their research has outlined potential successes and issues with this topic. As well as the work of Roberto Astete which unlocked new methods of making PVA more resistant to rain and other extreme conditions.

Investigations into the use of PVA as a plastic alternative have been researched before with an extensive amount of relevant papers available on the topic, however, additional data on effects of PVA to water and soil quality will always be relevant to help deepen our understanding of plastic alternatives. A study on the preservation qualities of PVA and a long-term analysis of PVA 'polluted' water's effect on the growth of plants in varying quantities will provide new information that has not publicly been researched yet and would prove to be greatly beneficial in

¹ Non-external packaging e.g using PVA to wrap individual sweets that are ultimately held in an overall plastic or card packaging.

advancing knowledge around polymers in general. It is very much a topic worth investigating as any outcome the study may have will provide a benefit, in the best case, a mass reduction in the amount of plastic waste and in the worst case, the negation of the possibility of PVA being used as a substitute for plastic. The data collected will be helpful to anyone who wishes to utilise PVA in any form, including industrial uses, as it will support previous research on environmental effects.

With millions of tonnes of plastics accumulating annually both on land and in the ocean's research such as the proposed, is becoming desperately more essential. Threats of there being more plastic in the sea than fish by 2050 are unsurprisingly causing concern and with the problem becoming increasingly worse daily viable solutions that are supported with extensive research are a requirement. If a study into PVA's efficiency at preservation and effects on the environment can potentially reduce the global plastic waste, then it is a study that must be completed and supported immediately.

As with every study, there are a few potential issues that could disrupt tests or hinder the use of PVA as an internal packaging. Mainly, cost being the biggest issue, as with many other plastic alternatives, PVA is more expensive to produce (making it less desirable as a substitute) as it requires ethylene gas which is produced by some plants as their fruit ripens, but due to the expense of this process the gas is more readily used in the production of oil. Unfortunately, another problem is that PVA can never reasonably replace plastic packaging entirely due to its water solubility, which would cause potential issues in wetter climates where heavy rains could cause damage to produce if the PVA was to melt partially or fully into the goods, especially in food produce where it could then additionally go on to have health affects in humans². It could become a viable solution in dry climates that sparsely have rain, but tests would have to be completed on the effects of prolonged exposure to extreme (30°C +) heats to ensure that the PVA continues to perform as expected under these conditions.

A number of lab tests will be conducted in this study including:

- PVA being diluted in varying concentrations into water
- PVA being deposited into soil in varying concentrations (via. water)
- PVA film being used to preserve various foods
- PVA water in varying concentrations being added to seeds in aid of the growth of plants³

The independent variable in each test will be the concentration of PVA as dissolved in the water whereas the dependant variable will be the effects on the water and soil quality as well as the success of the preservation and the health of the plant respectively.

Despite previous studies declaring that PVA has no effect on water quality, it can be hypothesised that there will be an acute effect on both water and soil quality potentially causing some shift in PH or changes to the enrichment. In large concentrations, it is difficult to believe that PVA will have absolutely zero effect on the surrounding environment, but the effects could be unharmed and as such is why the tests need to be done. If PVA is found to enrich soil and water with unintended additional nutrients, then this could cause issues in terms of

² There is research to suggest that PVA is non-toxic to humans but as with all things it is important to consider the amount of research done within this area.

³ More information about these tests can be found in the methodology

eutrophication and needs to be identified in preliminary stages of testing. It can also be predicted that PVA will be equally, if not more so effective at preserving food produce due to its afore mentioned properties.

The focus of this research will prevail around primary data collected from the proposed lab tests but additionally include reference to any other data found from previous studies and expert opinion on the matter. The reason for this lab based focal point is due to the desire to bring more relevant data to the table and provide a sufficient base for future studies to develop off of. In this particular case, just completing a review of previous research will not be relevant as rapid developments in plastic alternatives are already being made and new data is becoming increasingly more desirable. This study will not stray outside of the environmental effects of PVA despite suggestions to investigate further into the effects of extreme heat and the potential effects to human health as completion of these studies should be done by somebody within the respective fields with the resources to do so. However, these investigations would be necessary should PVA be considered for wide usage as a packaging alternative.

Some key definitions for this study include:

- Poly-Vinyl Alcohol - A colourless, water-soluble, thermoplastic resin, derived by the hydrolysis of polyvinyl acetate; used chiefly as an adhesive and as a sizing agent in the manufacture of textiles, paper, and plastics.
- Microplastics - Extremely small pieces of plastic debris in the environment resulting from the disposal and breakdown of consumer products and industrial waste.
- Tenacity - The quality of retaining something.

Literature Review

'Evaluation of Biodegradable Films Made of Waste Mycelium and Poly (Vinyl Alcohol) on the Yield of Pak-Choi' by Lei Shi, Lilong Ao, Hu Kang and Haijia Su. 2011.

This study completed in China saw the use of biodegradable films such as PVA and mycelium being used as alternative covers for pak-choi growth testing for their abilities to retain water and biodegrade successfully whilst having an impact on the yield and quality of the pak-choi. The experimental results showed that the use of the films could result in 50% higher water retention than a blank control film and the films were biodegraded within 14 weeks under natural conditions, leading to a significant mineralization, and proving to be beneficial for plant growth as fertilizer. The yield of pak-choi was additionally increased by 80% in weight when using these films.

This paper is beneficial to this study as it could support a hypothesis that PVA is not detrimental to the health of the environment in terms of plant growth but could in fact aid it and increase strength and yield through soil enrichment. However, this study also highlights potential issues with over mineralization of soil (and thus potentially water) which could lead to eutrophication in water bodies.

'Water-soluble 'plastic' may reduce ocean pollution' by China Daily. 2018.

Another study completed in China by Roberto Astete focused on creating a soluble plastic bag from PVA, faced with many challenges in both trying to make the bags resistant to

weathering but also soluble in cold water bodies, Astete finally managed to settle on a prototype that was produced in just two months. The cost of the bag is about 1.5 times of that of a normal plastic bag however he expects them to be as cheap as normal ones in their fifth generation (of prototype). He aims to use modified PVA to make glass lids, straws and diapers, and to replace products made from petrochemical plastics in the future using similar methods.

Though this is a news article source rather than an actual research paper it still benefits the study as Astete potentially discovered a way in which to create an external plastic packaging that is longer lasting and cheap.

Methodology

There will be a total of 4 differing lab tests that will take part in this study, these are the chosen tests as they best reflect the nature of the study and what it is trying to achieve whilst remaining plausible to be completed within a limited time frame with limited supplies and access.

The tests are as follows:

Test 1 – PVA's effect on water quality.

In a controlled environment, place 6 beakers of water of equal amounts in a line next to each other as to limit the differ in conditions. Leave one beaker as a sterile sample, meaning it will not have any PVA placed into it at all and then slowly increase the concentration of PVA for each of the respective beakers by a set amount making sure the amount is thoroughly documented. As PVA film will be used, measuring by weight is the best practice. Once the PVA is placed in each beaker, stir each mixture using a stirring stick an equal amount of times (this includes the sample without any PVA in it) making sure to clean the stick between each stir. Then taking a commercially available water testing kit, complete the test on each of the samples and document the data as compared to the kit's instructions. Ensure to take photographs of each of the samples using flash (to highlight potential fogginess) and document differentiations in the smell of each of the samples. This test should be repeated numerous times in order to assure accuracy. This test could additionally be recreated under different conditions such as being left for longer periods of time, in direct sunlight or in cooler areas.

Test 2 – PVA's effect on soil quality

Using the samples from the first experiment, pour each sample of water into a separate sample of soil totalling 6 samples in all. Allow the water a few hours to fully penetrate the soil making sure to document this number, then complete a soil test on each of the individual samples and record the data again including photographs. This test should also be repeated numerous times and potentially under varying conditions if necessary.

Test 3 – PVA's effect on plant growth

In this test, 6 pots of soil should be filled with seeds from the same package and left in an area with equal opportunities for light (preferably adjacent to each other) then each pot should be regularly watered with regulated samples from test one being cautious as to not mix up the designated watering jug for each plant. Continue to water the plants with the respective water samples for as many months as possible regularly documenting changes in growth speed, colour, strength etc. Though differentiations in the plants is to be expected, even slight variations should be documented in case they develop into something bigger later on in the experiment. As with the other tests, regular flashed photographs of each plant should be taken for reference. It is important to subject the plants to as similar conditions as possible, making sure they are watered the same amounts at the same times and remain undisturbed throughout the experiment for maximum reliability in results.

Test 4 – PVA's preservation effects

Taking an item of fresh fruit or veg and cutting it into thirds, cover one of the samples with an even layer of PVA film, one with an even layer of cling film and leave a final sample uncovered. Then, expose each sample to the same conditions and monitor them over a number of days noting changes in colour, texture, smell etc. Samples that have almost fully biodegraded may be removed from the experiment once the data has been recorded with relevant pictures attached. This test can be repeated numerous times with varying different food samples.

There will also be references to other papers and studies that have been done on PVA and relevant data will be used to support the hypothesis.

Results

The results that this methodology will provide will be mostly lab results consisting of numerical and visual data, as such, the data will be presented in relevant graphs, charts and tables that complement the results and make them easiest to comprehend, the pictures taken at each stage will also be presented and labelled appropriately to clearly visualise the development of each of the experiments over time. The well-presented data will then provide a clear support or debunk to the proposed hypothesis.

Evaluation

This is an extremely important research proposal because if it is found to be successful it could change the world in terms of plastic waste and marine litter which would benefit everyone and everything on this planet. Even if this experiment is not successful it will still be beneficial because it will provide a baseline of data for anybody wishing to continue delve into this topic area and develop a potentially successful idea from the research. The limitations with the project, include cost and extent of research possible. Ideally, the tests would be more extensive and take place in professionally controlled conditions, however due to limitations with funding the experiments must be reduced to just four standard ones. As for financial constraints, there is a list of items that will be required for this study to take place, although most of the items will be readily available in the lab a few of these items will need to be purchased by the researcher.

A compiled list of equipment includes:

- Beakers (or similar measuring container)
- Tap water
- PVA film
- Stirring stick
- A knife / Scissors
- Tongs
- A camera with a flash
- Kitchen roll
- Water testing kit
- Soil testing kit
- Plant pots
- Soil
- Seeds (Fast growing plant preferable)
- Fresh fruit / Veg
- Cling film

References

POI (2018). *Plastic Oceans Foundation*. [online] Plastic Oceans International. Available at: <https://plasticoceans.org/the-facts/>.

DeMerlis and Schoneker (2003). *Review of the oral toxicity of polyvinyl alcohol (PVA)*. - PubMed - NCBI. [online] Ncbi.nlm.nih.gov. Available at: <https://www.ncbi.nlm.nih.gov/pubmed/12504164>.

Britannica (2009). *Polyvinyl alcohol | chemical compound*. [online] Encyclopedia Britannica. Available at: <https://www.britannica.com/science/polyvinyl-alcohol>

Gaaz, T., Sulong, A., Akhtar, M., Kadhum, A., Mohamad, A. and Al-Amiery, A. (2015). *Properties and Applications of Polyvinyl Alcohol, Halloysite Nanotubes and Their Nanocomposites*. [online] Pdfs.semanticscholar.org. Available at: <https://pdfs.semanticscholar.org/8b18/030414dc9b6da321bb9b149eeda331a959a8.pdf>

PIR (2014). *PVA plastic – plasticisrubbish*. [online] Plasticisrubbish.com. Available at: <http://plasticisrubbish.com/2014/07/12/whitby-goths-and-cocoa/>.

