Research Progress in Mechanical and Manufacturing Engineering Vol. 4 No. 1 (2023) 457-468
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RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773 - 4765

Evaluation of PVA Performance with Different Enzyme Concentration

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DOI: https://doi.org/10.30880/rpmme.2023.04.01.052
Received 01 Aug. 2022; Accepted 10 Nov. 2022; Available online 01 June 2023

Abstract: The utilisation of high-solubility PVA packing combined with the inclusion of protease enzyme has the potential to be an excellent option for the reduction of bacterial exposure. This study aims to prepare PVA films with varying enzyme concentrations and examine their effects. Mix PVA with 5 enzyme-containing detergent concentrations with ratio 1:0, 1:1, 1:0.5, 1:0.25 and 1:0.125. Fourier transform infrared spectroscopy (FTIR) was used to characterise the PVA film. Immersion tests at different temperatures measured the washing performance. Those PVA/enzyme films take too long to dissolve, so the speed and temperature of the washing test was increased to get the result. In FTIR analysis, the peak seen at wave number 1634 cm^{-1} represents the carbonyl group. The film able to removed the stain.

Keywords: PVA, Enzyme, Temperature, Soluble Film

1. Introduction

Dirty clothes can contain microorganisms that cause skin infections. Germ- and fungus-infested garments may create body odour. Regular laundry removes bacteria, filth, fleas, mites, and other irritants or diseases. Laundry reduces diarrhea, respiratory infections, scabies, and skin infections. Laundry detergent cleans dirty clothing (clothes). Powder and liquid detergent are available (laundry detergent). Enzymes help clean clothing and dishes effectively, environmentally, and efficiently. Proteases, lipases, and amylases are the three primary detergent enzymes, each with its own benefits [1].

In hospitals, PVA wash bags restrict staff exposure to infectious clothes and bedding. Dirty goods go in these bags, then into the washing machine. Polyvinyl alcohol is soluble in water, therefore the bags dissolve in dirty water. When the cycle ends, the clean clothing are collected. The contents of disposal bags are not exposed to the outside environment throughout transport, cleaning, disinfecting, and drying.

Guideline-outlined practices must be followed for contaminated textiles, towels, and bedsheets. Despite being put in safe packaging before washing, the worker must remove it for cleaning, exposing them to bacteria and viruses. High-solubility PVA packing with protease enzyme may decrease exposure by washing the contaminated clothes with the PVA.

Laundry detergent is available in two forms: powder (washing powder) and liquid (laundry detergent). Enzymes are used as functional components in detergents, assisting in the effective,

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ecologically friendly, and energy-saving cleaning of laundry and dishes. Proteases, lipases, and amylases are the three main types of detergent enzymes, each with its own set of advantages for use in laundry and automated dishwashing [1]. An enzyme is a substance that functions as a catalyst in living organisms, controlling the pace at which chemical reactions occur without being affected in the process. Many of these reactions would not occur at all if enzymes were not present. Enzymes are also used in the industrial sector. This study aims to prepare the PVA film with different enzyme concentrations and investigate the effect of enzyme concentration on the properties of the PVA film.

2. Materials and Methods

Making PVA/enzyme film involves numerous methods and equipment. Good samples should be tested to avoid problems. After preparation, the material undergoes a fabrication process followed by samples' testing.

2.1 Materials

The polyvinyl alcohol (PVA) was used as the raw materials combine with soap that contain enzyme with different ration.

Table 1: Name of the sample according to the distribution of enzyme

Name of ratio	Ratio	PVA (g)	Enzyme (g)	Total (g)
PE0	1:0	1	0	1
PE1	1:1	1	1	2
PE2	1:0.5	1	0.5	1.5
PE3	1:0.25	1	0.25	1.25
PE4	1:0.125	1	0.125	1.125

2.2 Preparation of PVA/enzyme films

Casting evaporation from aqueous polymer solutions produced PVA/enzyme films. After combining PVA and enzyme, the mixture was spread out to dry. In the following twenty-four hours, the liquid will harden into a plastic form after drying and become solid after drying. There will be five samples taken from the specimen. After films have been manufactured, their quality may be determined by analysing their thickness. To evaluate product quality, the PVA Optical Microscope (OM), Fourier's transform infrared spectroscopy (FTIR), moisture absorb test, and solubility tests will be administered.

In order to ensure that the PVA and enzyme are thoroughly combined, the solution was thoroughly mixed. The PVA and enzyme will be mixed with ratios 1:0, 1:2, 1:3, and 1:4 as given in Table 1.

2.3 Surface analysis

This method was used to examine the morphology of PVA films by optical microscope. On the other hand, an optical microscope may be utilised to examine the colour of the film at various concentrations. The 20x magnification was used. The presence of any bubbles during the addition of enzyme to the PVA concentration was observed.

2.4 Fourier's transform infrared spectroscopy (FTIR)

Using Fourier transform infrared spectroscopy (FTIR), it is easy to get the infrared spectrum of absorption, emission, and photoconductivity of solids, liquids, and gases. Using the Spectrum 100 FT-IR Spectrometer, all films' transmission infrared spectra was recorded at ambient temperature. During

32 scans, the range of wavenumber will be from 4000 to 400 cm^{-1}, with a resolution of 2 cm^{-1}. The film was put immediately in the sample holder after the backdrop has been scanned.

2.5 Moisture absorb test

By doing a moisture absorption test, the amount of water vapour absorption in the air can be evaluated. If the sample is dried at room temperature for at least 24 hours, the moisture absorption test can be achieved. After being extracted from the solvent, the samples was wiped clean and weighed. The weight gained is given as a proportion of the overall weight gain. The following formula is used to calculate the percentage moisture increase in weight after 24 hours of drying:

$$Percent\ moisture\ absoption = \left[\frac{(weight\ before\ -\ weight\ after)}{weight\ before}\right] \times 100\% \quad \text{Eq. 1}$$

2.6 Solubility test

Solubility tests determine how effectively a chemical dissolve in a liquid solvent. The solubility test also crucial for assessing the prospective uses of new compounds since it represents the chemical combination's stable concentration under test circumstances. Some polymers can only handle a little quantity of water at ambient temperature, but when heated, they can absorb large amounts. The 20 ml water was pour into a beaker. Place PVA/enzyme film sample in the beaker. Using a mechanical stirrer at a particular 500 rpm steady speed and 5 minutes time to test the solubility.

2.7 Washability test

Mixing dissolved stains like food and oil will test a cloth's performance. The stains are put in 150 ml of water. White cotton 2cm x 2cm fabric. The PVA film/Enzyme combination is then added to the container and stirred. The stirring speed was raised in 5 minutes to eliminate fabric stains. Then, the cleanliness of different stain types is examined. The washability was also conduct at different temperature which are 30 ° C, 50 ° C, and 60 ° C.

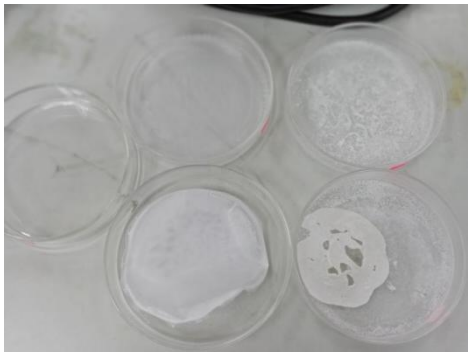
3. Results and Discussion

The findings were reported for surface analysis, FTIR analysis, solubility test, moisture absorption test, and washability test.

3.1 Prepared PVA film

The prepared films of PVA and enzyme at varying weight ratios are presented in Figure 1. Based on the figure, films were somewhat shrunken owing to capillary forces, and reveal PE1 sample did not appear like the other samples. The film gets overly shrunken, making the film smaller than other films, have many holes and thick, and the surface is not smooth, making the film unsuited for use in this experiment. This might happen because lumps are not easily dispersed by agitation and solubilization requires long mixing times [2]. The concentration must dry for 24 hours, but after 24 hours, the sample is still wet, therefore the drying duration is extended to 3 days, and the film may peel off from the petri dish.

PE0 PE4 PE3



PE2 PE1

Figure 1: PVA/enzyme films result with different weight ratio.

3.2 Optical microscope

Using this method, PVA morphology was studied. Figure following shows optical microscope weight ratios.

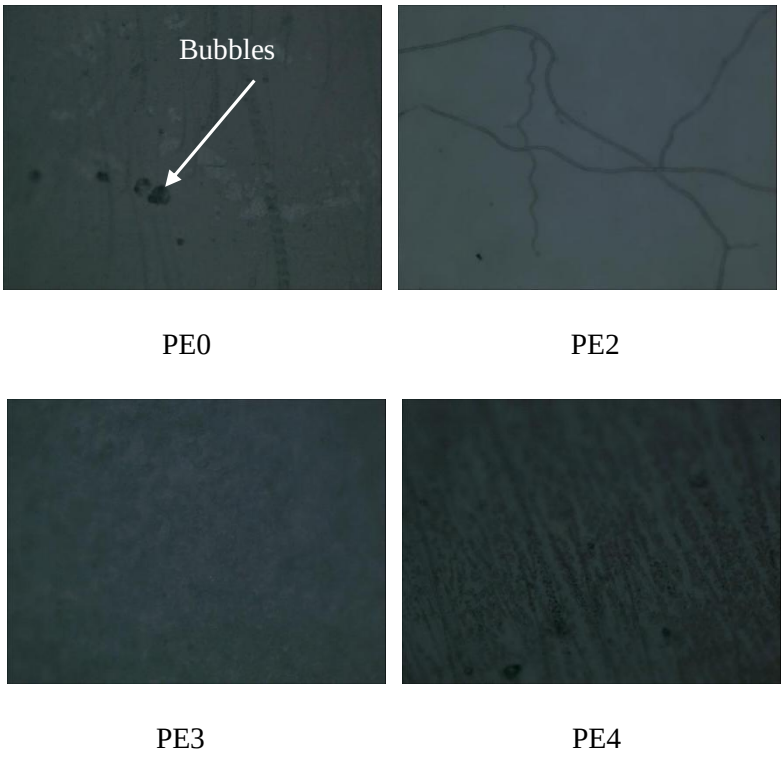


Figure 2: PVA/enzyme film sample with magnification of 20x

The figure above shows 20x optical microscope magnifications. The image revealed the microstructure and made analysis easier. The PE2 result shows more tiny bubbles in the microstructure, indicating that the PE2 film casts the PVA/enzyme film satisfactorily.

3.3 Fourier's transform infrared spectroscopy (FTIR) analysis

All films' functional groups were analysed using FTIR. Figures illustrate sample film FTIR spectra. The FTIR absorption peaks correlate to atom bond vibrations in nanoparticles [2]. Figure 3 shows

PVA/enzyme absorbance. Carbonyl group peak at 1634 cm^{-1}. All samples absorbed water. PVA film without enzymes transmits less light. The lowest transmittance revealed a high absorbance, and FTIR measurement confirmed water absorption [3]. Enzyme addition to PVA matrix increases transmittance, indicating less moisture absorption.

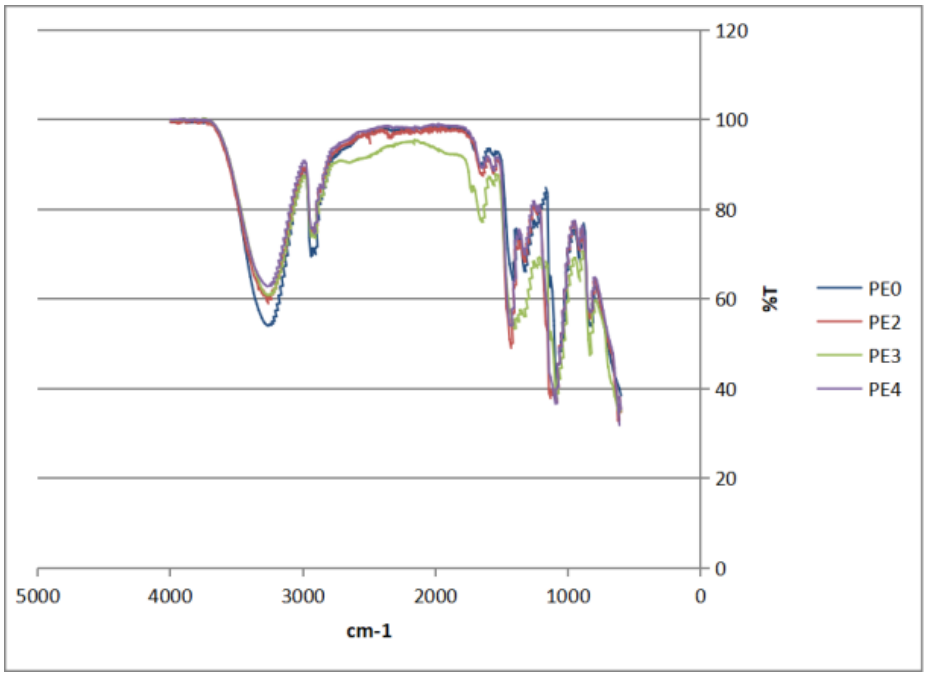


Figure 3: Absorbance for PVA/enzyme films

3.4 Moisture absorb test

By measuring air moisture absorption with a moisture absorption test. PVA film dried in a 60°C oven for 24 hours. Weight increase is given as a percentage. Following Table 2, the result of the calculation of percent moisture absorption.

Table 2: Result of percent moisture absorption

Name of sample	Ratio	Weight before (g)	Weight after (g)	Percent moisture absorption (%)
PE0	1:0	0.1017	0.0941	7.47
PE2	1:0.5	0.2089	0.1886	9.71
PE3	1:0.25	0.0856	0.0780	8.88
PE4	1:0.125	0.1019	0.0922	9.52

The table provides PVA film moisture absorption percentages. PE2 with a 1:2 PVA ratio absorbed the most moisture. 1:0.5 PVA film absorbs 9.71% moisture after 24 hours. Pure PVA film 1:0 contains 7.47%. Pure PVA film absorbs the most moisture, according to ASROFI et al [4]. This contradicts the tested outcome. Errors can occur. The oven is full of unconnected samples. It may impact the moisture absorption percentage of other PVA films.

3.5 Solubility test

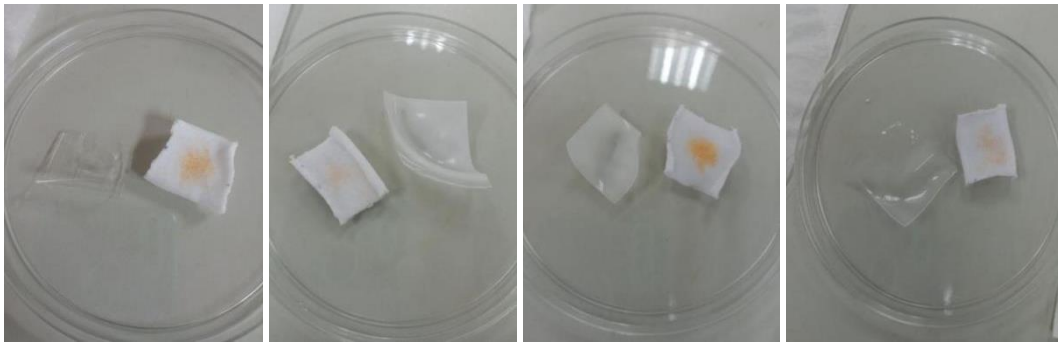
Figure 4 shows that none of the PVA films dissolve in water. This test uses a mechanical stirrer at 500 rpm for 5 minutes for each PVA film, and the films cannot dissolve in room-temperature water. Because of the slow mechanical stirrer, the PVA film didn't dissolve in water. Hassan et al. (2002) found that the degree of hydrolysis and molecular weight impact PVA solubility [5]. Solubility inversely increases with PVA hydrolysis. Due to H-bonds between PVA's hydroxyl groups, hydrolyzed PVA is less soluble in water. Increased mechanical stirrer speed dissolves PVA film in water. Catalyzing enzymes. They speed up a chemical reaction by decreasing its activation energy [6]. Since room temperature doesn't dissolve in water, time and temperature can be increased. PVA film dissolves better at 60^{o}C.

PE3 PE0 PE2 PE4

Figure 4: Result of solubility PVA film with different ration

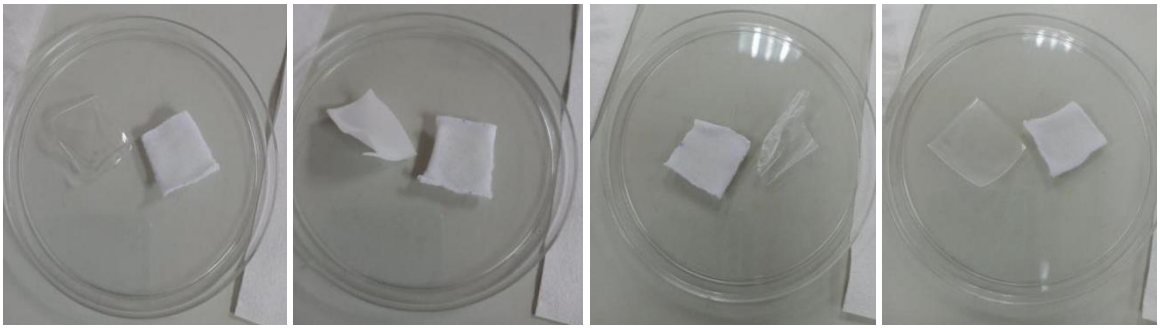
3.6 Washability test

This test utilised 0.2g/litre of leftover food and oil in room temperature. The Figure 5 shows leftover food and oil on a cotton cloth after the test run. Since the solubility test shows that PVA film doesn't dissolve in room-temperature water, the stained cloth can't be removed. To remove a stain from fabric, dissolve PVA film in water to release its enzyme and combine with the water. PVA film doesn't dissolve in water because of the magnetic stirrer's speed and duration. To dissolve PVA film, raise the magnetic stirrer speed and time, but this is inconvenient for industry. PVA dissolves in 12-18 hours at 90-100°C [7]. The thick, rigid PVA film is difficult to dissolve in water. It degrades slowly.



PE0 PE2 PE3 PE4

Figure 5: Leftover food result after test run



PE0 PE2 PE3 PE4

Figure 6: Oil result after test run

The same as washability but with temperature testing. The stain was evaluated at 30ºC, 50ºC, and 60ºC. The hot plate stirrer replaced the washing machine because its magnetic stirrer can spin and be heated. This shows the hotplate stirrer virtually has the same function as the washing machine, and it's more convenient because the test was done in the lab. Wet and dry test results on stained cotton fabric.

Table 3: PVA film (PE0) leftover food result.

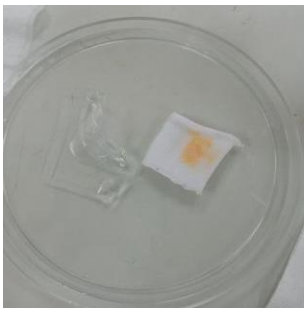
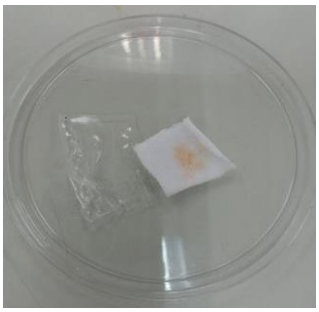
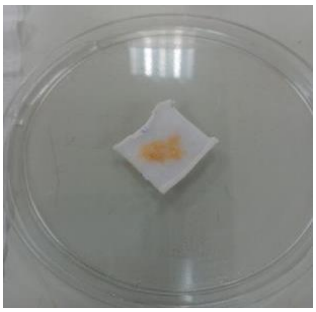
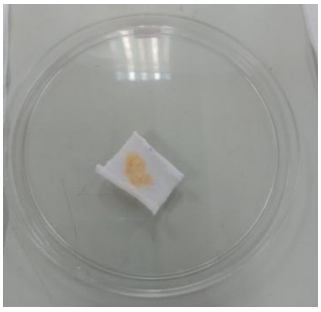
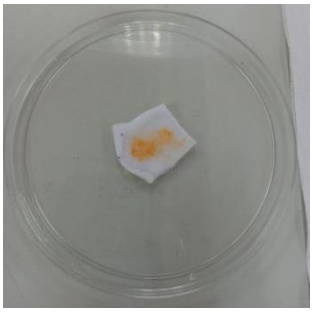
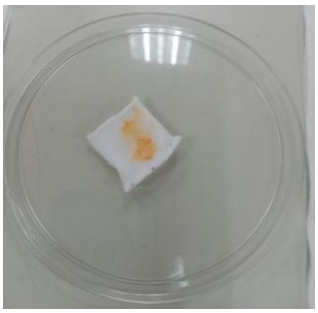
Temperature	Wetting	Drying
30		
50		
60		

Table 4: PVA film (PE2) leftover food result

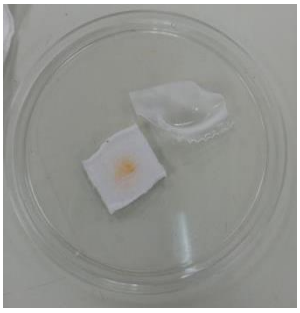
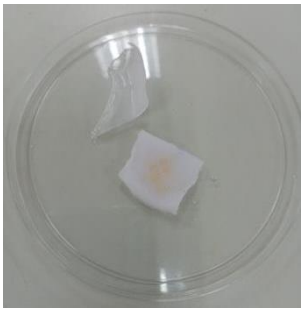
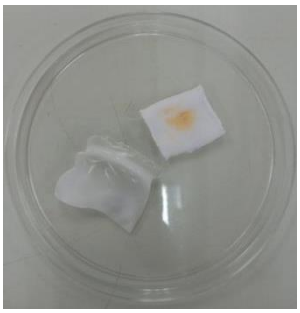
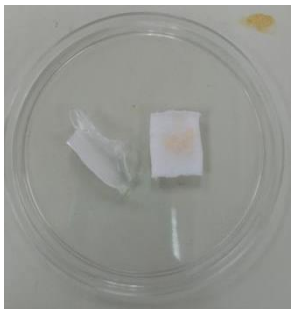
Temperature	30	50	60
Wetting			
Drying			

Table 5: PVA film (PE3) leftover food result

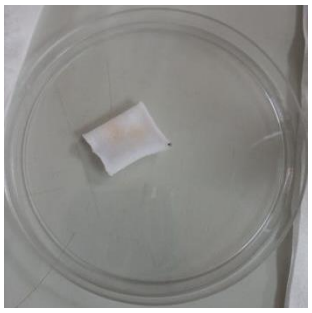
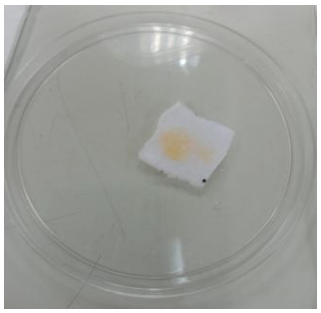
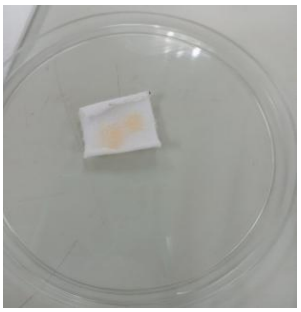
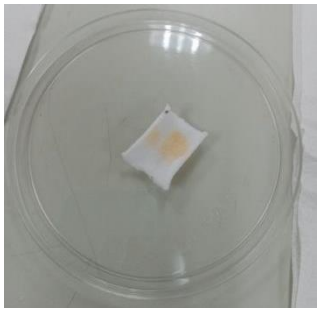
Temperature	30	50	60
Wetting			
Drying			

Table 6: PVA film (PE4) leftover food result

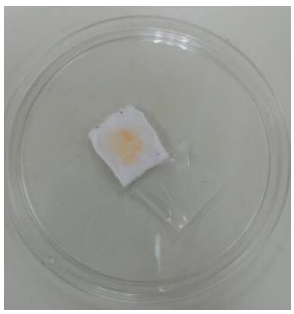
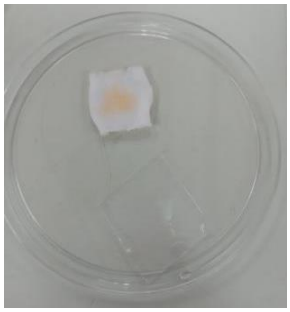
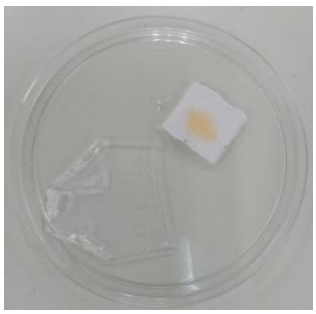
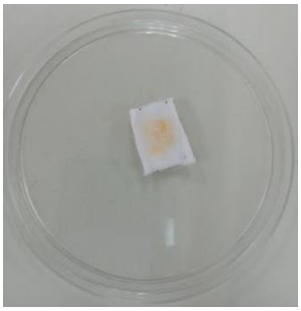
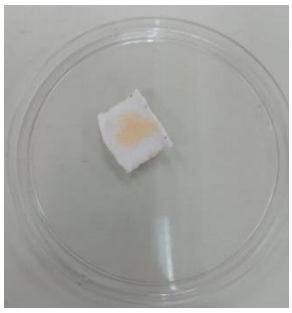
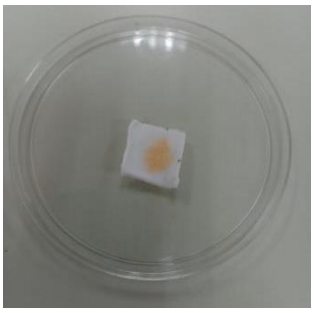
Temperature	30	50	60
Wetting			
Drying			

Table 3 – Table 6 shows the result of an analysis of a sample PVA/enzyme film washing cleaning test sample on cotton cloth with a leftover food stain. Even though the findings were acquired under two unique settings, the cotton fabric at 30 ^{o}C indicates that the stain was not removed throughout the washing test; the same holds true for 50 ^{o}C and 60 ^{o}C. The PVA/enzyme film did not dissolve in water at 30°C, but it partially dissolved at 50°C and totally dissolved at 60°C. However, at 50°C and 60°C, the stain could not be removed as the time given was insufficient for the PVA/enzyme to wash the stained cotton cloth. The temperature and length must be increased to remove a stain from the cotton material entirely. PE0 lacks an enzyme; hence its dissolution could not remove the stain.

Table 7: PVA film (PE0) oil result

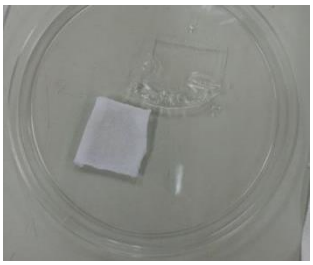
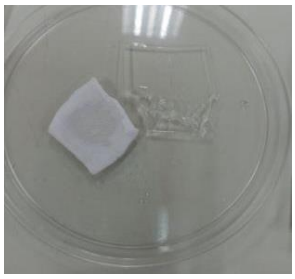
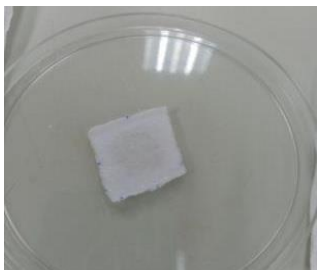
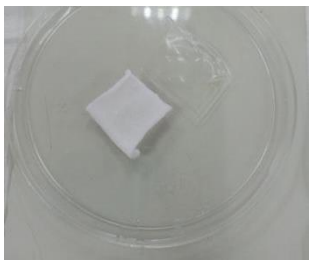
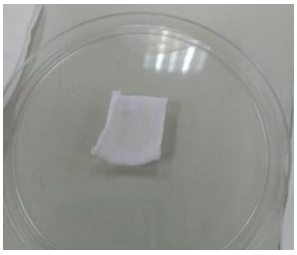
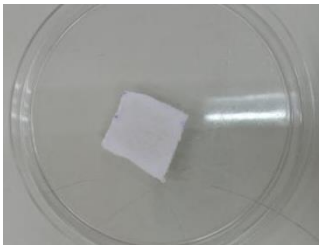
Temperature	30	50	60
Wetting			
Drying			

Table 8: PVA film (PE2) oil result

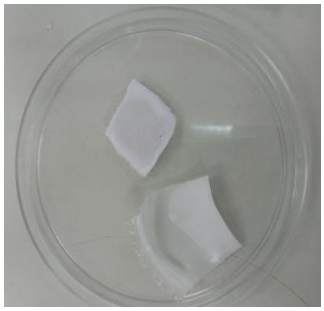
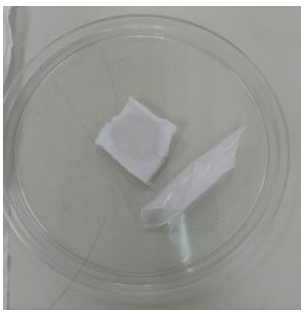
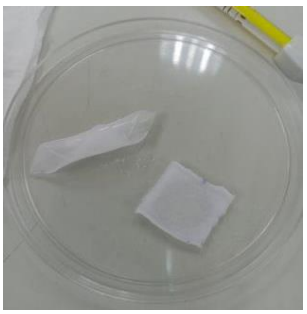
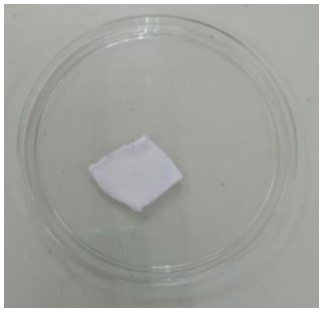
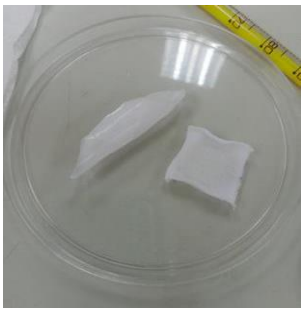
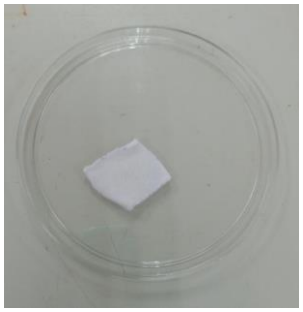
Temperature	30	50	60
Wetting			
Drying			

Table 9: PVA film (PE3) oil result

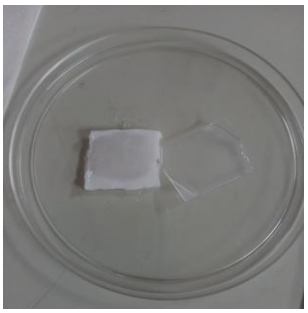
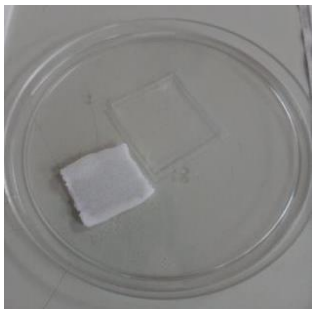
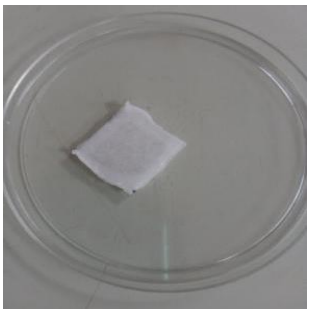
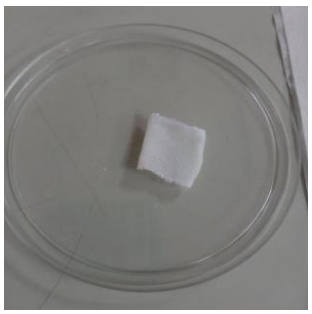
Temperature	30	50	60
Wetting			
Drying			

Table 10: PVA film (PE4) oil result

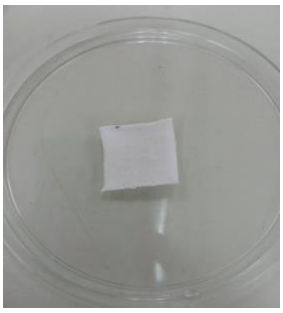
Temperature	30	50	60
Wetting			
Drying			

Table 7 – Table 10 shows the PVA/enzyme washing test result on oil-stained cotton. At 30 ºC, the cotton fabric indicates the stain didn't clear after washing; the same applies for 50 ºC and 60 ºC. The PVA/enzyme film didn't dissolve in water at 30 ºC, half dissolved at 50 ºC, and entirely dissolved at 60 ºC. The stained was able to be removed at higher washing temperature.

4. Conclusion

After the tests, PE2 is the best PVA/enzyme film which is the highest enzyme ratio. The optical microscope indicates that PE2 has fewer or no surface bubbles, improving film quality. The washability test reveals how well PVA/enzyme film cleans stained cotton fabric. Based on the results, it's clear that a stain on cotton cloth can't be removed in room temperature. However, at higher temperature (50 ºC and 60 ºC) the ability to remove the stain increases. The PVA/enzyme was fully soluble at 60ºC temperatures.

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for giving the opportunity to conduct this study.

References

[1] H.S., Olsen and P. Falholt, The role of enzymes in modern detergency. Journal of Surfactant Detergents 1, 555–567 (1998), https://link.springer.com/article/10.1007/s11743-998-0058-7

[2] “Preparation of Polyvinyl Alcohol (PVA) Solutions - US.” www.silverson.com, www.silverson.com/us/resource-library/application-reports/preparation-of-polyvinyl-alcohol-pva-solutions. Accessed 1 July 2022.

[3] Torres-Rivero, Karina, et al. “Metal and Metal Oxide Nanoparticles: An Integrated Perspective of the Green Synthesis Methods by Natural Products and Waste Valorization: Applications and Challenges.” Biosynthesized Nanomaterials, 2021, pp. 433–469, 10.1016/bs.coac.2020.12.001.

[4] M, Asrofi Dwilaksana D, Abral H, Fajrul R. Tensile, Thermal, And Moisture Absorption Properties of Polyvinyl Alcohol (PVA) / Bengkuang (Pachyrhizuserosus) Starch Blend Films. Mat. Sci. Res. India; 16 (1), DOI:10.13005/msri/160110

[5] C.M., Hassan, Trakampan, P., Peppas, N.A. (2002). Water Solubility Characteristics of Poly(vinyl alcohol) and Gels Prepared by Freezing/Thawing Processes. In: Amjad, Z. (eds) Water Soluble Polymers. Springer, Boston, MA. https://doi.org/10.1007/0-306-46915-4_3

[6] Bledsoe, Karen. Chapter 6, Section 4 Topic: Enzymes. 15 Sept. 2009

[7] Pischke, Colin. “Tips and Tricks for Succesful 3D Printing with PVA Filament.” Print Your Mind 3D, 12 Dec. 2018, www.printyourmind3d.ca/blogs/articles/tips-and-tricks-for-succesful-3d-printing-with-pva-filament. Accessed 30 June 2022.7.