



Comparing The Tear Resistance Of PVC Sheets With Dioctyl Phthalate (DOP) And Epoxydized Soybean Oil (ESBO) Plasticizers

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Abstract:

Background. One of the PVC (Polyvinyl Chloride) products is a raincoat whose manufacture has been mixed with a DOP (Dioctyl Phthalate) plasticizer. The use of DOP in PVC since 1982 has been indicated as a chemical harmful to human health, especially causing gene mutations in the chromosomes of female eggs and infertility in men, as well as interfering with health. In addition, DOP is quite expensive.

Aims. The purpose of the study is to replace DOP with the Epoxidized Soybean Oil (ESBO) plasticizer, which is non-carcinogenic, non-toxic, recyclable, and biodegradable.

Methods. The PVC sheet products are tear-resistant and tested using the Elmendorf method. The mixing observed was analyzed using Fourier Transform Infrared (FTIR) spectroscopy.

Result. The results using 100% ESBO meet the standard, even though the tear strength is still lower than with 100% DOP.

Conclusion. FTIR analysis shows that a mixture of DOP and ESBO with a 50:50 ratio shows that other ingredients appear that do not interfere with the mixing process as a whole.

Keywords: PVC sheet, DOP, ESBO, tear resistance test, Fourier Transform Infrared



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INTRODUCTION

During the rainy season, one important piece of equipment is a raincoat (Figure 1.1a,b). Raincoats are waterproof clothing that protect the body from rain, help prevent disease, and support safety while driving, and can be worn by people from young children to adults [1]. Choosing the right raincoat based on size, material, and features such as

reflective safety features is essential to ensure comfort and durability. Proper care, such as avoiding excessive sun exposure and non-harsh use, will extend the life of the suit [2].

Raincoat materials are generally made of polymers. The manufacture of raincoats using Polypropylene/Polypropylene (PP) material is indeed not very common in the market because PP has poor water resistance, is brittle, and tears easily (Figure 1.1c) [3]. The raincoat is also made from *Low-Density Polyethylene* (LDPE) and High-Density Polyethylene (HDPE). The advantages and disadvantages of LDPE and HDPE are as follows: LDPE is more durable, more flexible, softer, more pliable, and more comfortable for repeated use [4]. While HDPE is stiffer, stronger, and generally cheaper, it is very affordable for temporary or emergency use [5]. However, HDPE has the disadvantage of being more easily damaged or torn if used repeatedly in the long term. The advantages of HDPE are that they are stiffer, stronger, and generally



Figure 1.1 (a), (b) Raincoat made of polymer material
(c) Torn raincoat (red circle)

cheaper, very affordable for temporary or emergency use [5]. However, HDPE has the disadvantage of being more easily damaged or torn if used repeatedly in the long term.

The polymer materials used for making raincoats, namely PP, HDPE, and LDPE, which have weaknesses, are replaced with Polyvinyl Chloride (PVC) in sheet form (Figure 1.2a,b). PVC is a synthetic polymer made from *Vinyl Chloride Monomer* (VCM), whose chemical structure is shown in Figure 1.3. PVC sheets are widely used for making raincoats, coats, and jackets because this material is economical, lightweight, strong, and highly water-resistant, so it is not easily penetrated or seeped through. Its non-water-absorbing properties also make it easy to clean and durable [6]. However, the manufacture of raincoats using PVC sheets always involves a PVC plasticizer, which means that PVC is added as a plasticizer to make the product soft and elastic [7]. The *plasticizer* commonly used is di-(2-ethylhexyl) phthalate (DEHP), also known as ***DiOctyl Phthalate (DOP)***. The use of DOP in PVC

(*compounded* PVC) products improves insulating properties, as it can be applied to cables, and the resulting compounds exhibit greater elasticity with a less significant reduction in strength [8].



However, DOP *plasticizers* in PVC have been identified since 1982 as harmful chemicals affecting human health, especially the phthalate component, which is harmful to humans, causing gene mutations in female egg chromosomes and possible infertility in men. In addition, *phthalates* are carcinogenic to children [9]. *DOP is still used because it is economical.* DOP PVC per kg, 2 inches in size, costs around Rp. 2,600 – Rp. 7,659 [10].

As is known, phthalate-based plasticizers can harm the environment and human health. In this study, *a superior bio-based plasticizer that is environmentally friendly with lower migration, namely a phosphorized formal glycerol monoester based on soybean oil, is synthetically modified through carbonation with a catalyst to increase the polarity of the plasticizer.* This modified and pure plasticizer is incorporated into *acrylonitrile–butadiene* rubber, and its migration analysis during 60-hour sample heating is performed using Fourier transform infrared spectroscopy (FTIR-ATR) with total muted reflectance. Observation of the characteristic carbonyl stretch vibration peak absorbance (1736 cm^{-3}) of *the plasticizer* relative to the C^{-3} butadiene stretch vibration (968 cm^{-3}). The results of migration kinetics and mechanical testing showed a decrease in diffusion coefficient due to modification, while hardness and tensile strength were almost unaffected. In addition to soybean oil being a natural resource and more sustainable, additional synthesis steps to bind CO_2 are advantageous for green chemistry approaches [11].

Efforts have been made to develop multilayered synthetic leather made of PVC with a paraffinic PCM for use in car seats. The thermal behavior of materials was analyzed using

the Alambeta tool, thermal cameras, and thermal mannequins. The results showed that synthetic leather with integrated Phase Change Materials (PCM) provides a cooler feeling and responds more quickly to environmental temperature variations than materials without PCM. Globally, the new design material improves thermal comfort for car occupants. In addition, the quality of the material is evaluated according to customer standards BMW 9.210.275; Edition/Version 4, 2010-10-01, which indicates that the material meets all tested requirements, except for flexibility [12].

Bio-based plasticizers for polymers are a must to replace conventional phthalate-based *plasticizers*. In this study, *Citrullus lanatus* (ECLO) seed oil was deep-oxidized in a magnetic-stirring reactor. Polyvinyl chloride films are synthesized using various concentrations of ECLO. At an ECLO concentration of 40%, the film exhibits better surface morphology and shows maximum break strength and elongation. Plasticized PVC film shows a tensile strength of 18.6 MPa and a break elongation of 136.18%. No migration was observed in the water, which shows the hydrophobic characteristics of the film. In gasoline, acid (acetic acid), and alkali (Sodium hydroxide), plasticized samples show low resistance to migration. X-ray diffraction analysis confirmed no change in PVC crystallinity after the addition of ECLO. Thermogravimetric analysis shows that the plasticized PVC film is thermally stable. Differential scanning calorimetry shows the plasticization effect of ECLO, as the glass transition temperature (T_g) of the plasticized film shifts to a lower temperature. Furthermore, Fourier transform infrared spectroscopy revealed the interaction of ECLO with PVC by detecting C–Cl bond peaks (833 cm^{-2}) and C—O strain (1739 cm^{-2}). Thus, this study led to improved phthalate substitution by supporting the use of ECLO in PVC mixtures as a *plasticizer* [13].

The purpose of this study is to use an Epoxidized Soybean Oil (ESBO) plasticizer in place of DOP in the PCV sheet mixture. ESBO is a derivative of a *benzoate-based* plasticizer used as an alternative *plasticizer*. ESBO is a *non-phthalate-based plasticizer* that is non-carcinogenic and non-toxic. The use of less ESBO *plasticizers* increases production efficiency, improves recyclability, and enhances biodegradability [14]. The price of ESBO for PVC sheets per kilogram in 2024 varies widely depending on the supplier and quality, but is estimated to range from IDR 16,767 to IDR 26,156, making it more expensive than DOP for PVC sheets.

Another material added to the PVC *plasticizer* is a *stabilizer*. *Stabilizers* are additives that are added to a product to maintain its physical and chemical properties, such

as texture, consistency, and stability so that they do not change easily over time or due to environmental influences such as temperature and pH. The *stabilizer* material added to the PVC plasticizer is in the form of mixed metal powder, such as barium (Ba)/Zinc (Zn), Calcium (Ca)/zinc (Zn), calcium (Ca)/aluminum (Al)/magnesium (Mg)/zinc (Zn). This material functions to retain heat so that in the manufacturing and production process of PVC sheets, it is not easy to burn [15]. A common additive to PVC sheets is calcium carbonate powder (CaCO₃), which improves both impact strength and stiffness [16]. So the focus of this research is to optimize the variations of DOP and ESBO plasticizers in producing PVC sheets for raincoat applications.

LITERATURE REVIEW

A recent, state-of-the-art finding for PVC sheets is a study of raincoats whose outer layers are usually stiff and flake around creases and tears. *The plasticizer*, identified by matrix-assisted laser desorption-ionization mass spectrometry (MALDI-MS) and ¹H and ¹³C nuclear magnetic resonance (NMR) spectroscopy, was identified as poly(1,3-butylene) adipate. *This plasticizer* is known to have originated in 1986, when the Swiss company Ciba-Geigy introduced poly(1,3-butylene) adipate as a PVC *plasticizer* under the trademark Reoplex® 346 [17].

Other studies show that the mechanical properties of PVC can be adjusted to meet needs; for example, the use of plasticized PVC (PVC-P) accounts for 60% of the world's PVC consumption, but it has limited thermal stability during melt mixing (*hot melt mixing*). Modulus of elasticity and tensile strength (*Tensile Strength*) can be improved in high PVC-P by adding ESBO as a secondary plasticizer and, at the same time, as a Co-Heat Stabilizer, which helps overcome the limitations of PVC-P thermal stability during mixing in rheomix tools (*Twin Screw Extruder*).

The composition of ESBO varies from 0 to 6 phr. While DOP, as a primary plasticizer, is added in the same composition (28 phr in PVC resin). The results showed that ESBO at 4 phr reduced the modulus of stiffness (acting like PVC-P). Meanwhile, at 6 phr, the stiffness modulus increases. Observations using FTIR showed the interaction of ESBO molecules with PVC molecules in the form of cross-ties, indicating tight cross-connections, suggesting that ESBO functions as an elasticity controller for PVC products. The results indicate that ESBO has the potential to serve as a primary plasticizer, reducing the use of DOP, which is known to be toxic [18].

Another line of research indicates that processing PVC at high temperatures requires the use of thermal stabilizers. Thermal stabilizers widely used for PVC contain toxic heavy metals and organotin compounds that have been widely criticized for environmental concerns. To address this problem, several organic and inorganic compounds compatible with polymers have been researched. When added in relatively low amounts, these compounds serve as excellent thermal stabilizers for PVC. These compounds serve as primary, secondary, and co-stabilizers. This class of chemical compounds yields an ideal PVC thermal stabilizer, which can be termed a "green thermal stabilizer" [19].

Still related to research on thermoplastic polymer materials, if they are torn, cracked, broken, broken, they are usually thrown away, or recycled, which requires a long process. The purpose of this study is to connect broken thermoplastic polymers using hot gas hand welding with various variations of welding wires/electrodes. The thermoplastic polymer materials used are LDPE, PP, and PVC, with welding wire for all three. The method is carried out using hot-gas hand welding; the results show that two materials cannot be spliced: PE with PVC welding wire and PP with PVC welding wire. The test *permeable liquid penetrant* is PP with PE welding wire, and PVC with PE welding wire. The best welding result is PE, with PE welding wire at 15.96%, and the best bending result is PVC, with PVC welded wire at 181.2 kgf/mm². All microstructures were described using *Scanning Electron Microscopy* (SEM) observations [20].

The main problem with polymer-based composite materials arises when subjected to dynamic loads, resulting in initial cracks that continue to propagate. Cracks in metal can be welded. Cracks in concrete can also be reconnected by *grouting*. As for cracks in polymer-based composite materials, there is no single solution. The purpose of this study is to reconnect cracked polymer-based composite materials and perform impact tests (ASTM D6110-04 standard) to determine impact strength and breaking energy magnitude, test tensile strength, and observe the structure using Scanning Electron Microscopy (SEM). The highest impact strength, breaking energy, and tensile strength in sample A were 50% resin + 1% catalyst + 19% calcium carbonate + 25% fine fiber + 5% roving fiber, with an impact strength value of 23.89 Joules/mm², a large breaking energy of 130.67 Joules, and a tensile strength value of 7.22 kgf/mm². SEM observations of microstructures showed that the cracks were brittle [21].

METHOD

The implementation of the research is described in detail in the flowchart Figure 2.1. The stages of implementation are as follows:

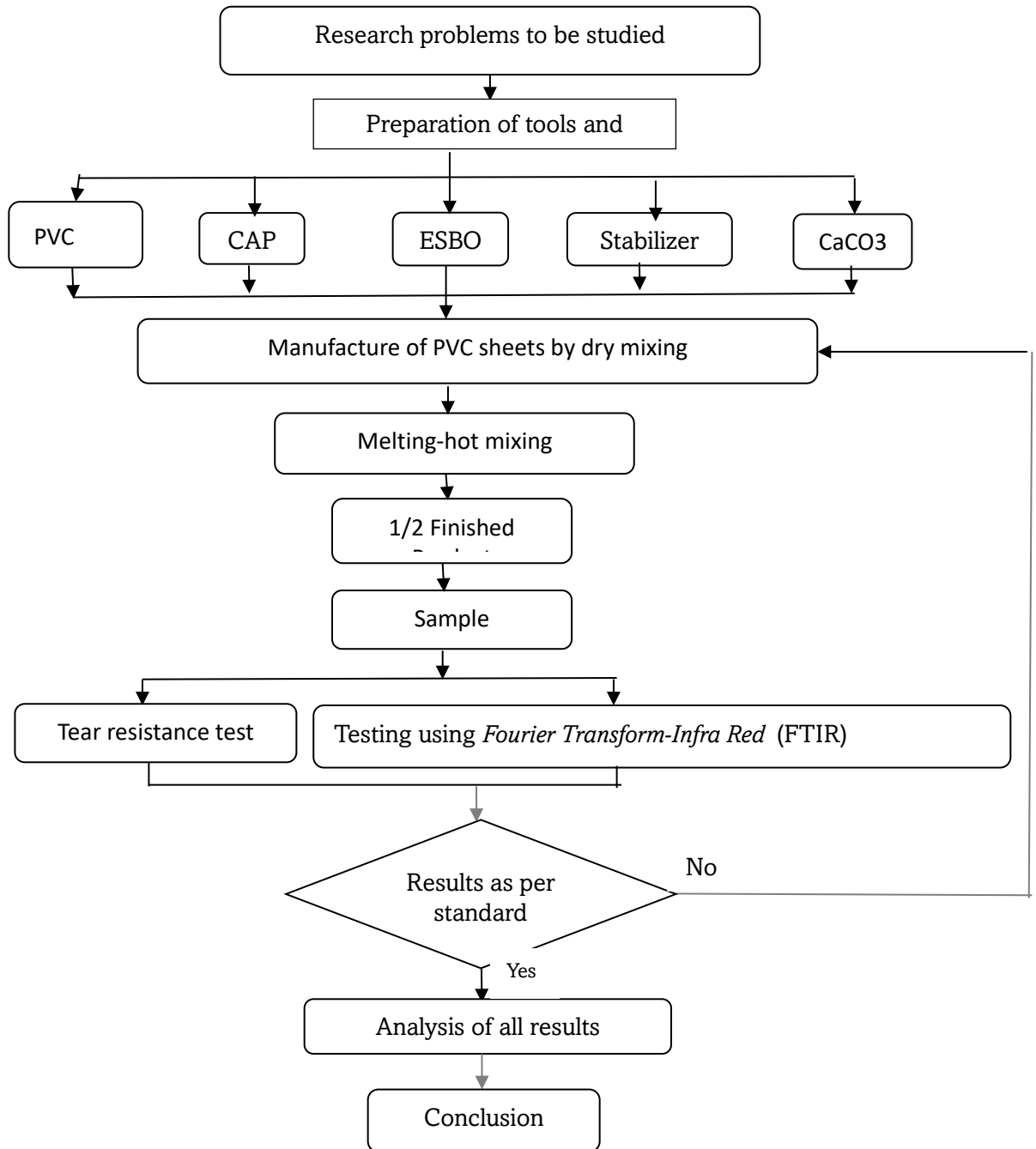


Figure 2.1 Research flowchart

2.1 Ingredients

The research problem that has been determined, the materials have begun to be prepared,

namely, PVC resin powder, DOP, ESBO from Sigma catalog no. ESP-801, *stabilizer powder* 120 with a Ba-Zn base, CaCO₃ type TSV 1, and J-TOP Black D-003 as pigment.

2.1.1 Equipment Worn

The equipment used in this research process includes:

a. Sample Formulation Tool

Tools used to calculate and measure the composition of samples:

- Digital scales
- 100 ml and 200 ml beakers
- Plastic spoon
- Personal safety equipment in the form of masks and gloves

b. Dry Mixing Equipment

Tools used to perform the dry mixing process on samples:

- 100ml and 200ml measuring cups
- Stirring spoon, usually made of wood

c. Melting-Hot Mixing Equipment

Tools used to perform the process of hot mixing on samples:

- *Stopwatch*
 - *Mixing roll* with a power of 2000 W, motor rotation 100-110 rpm, temperature variation used for experiments 120-175 °C depending on phr. The optimal capacity of the *mixing roll* in the experiment was 40-60 gr. (

d. Sample Preparation Tool

Tools used to take samples from *mixing rolls*:

- Pangot knife
- *Cutter*
- Calipers
- Personal safety equipment in the form of masks and heat-resistant gloves
- *Peacock thickness gauge* is a thickness gauge for plastics with an accuracy of up to 0.01mm. (Figure 2.2).



Figure 2.2 Peacock thickness gauge

e. Testing

e.1 Tearing Strength Test

Tear resistance testing is used to determine the tear strength of PVC sheets by the falling pendulum method (Elmendorf Manual method YG033A-II/YG033B-II) (Figure 2.3). *Tearing Strength Tester* according to BSN standard : ISO 1974:1990(E)

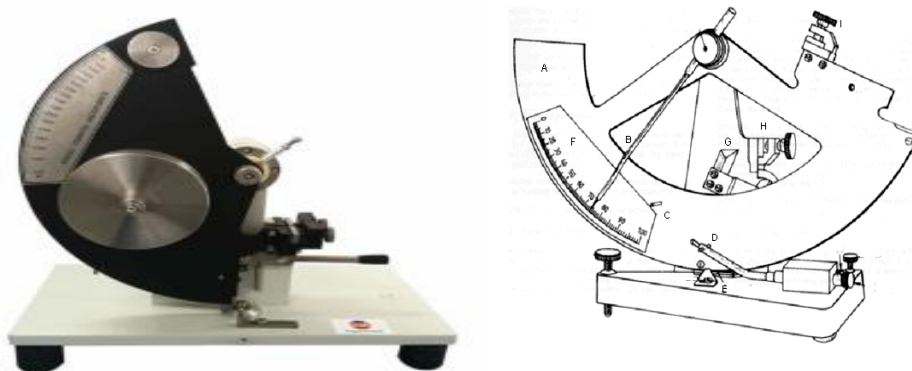


Figure 2.3 Falling pendulum tear testing tool

e.2 Determining the Grammatical Value of PVC Sheets

Grammatical is the mass of PVC sheets per unit area, shown in equation (2.1).

$$\dots\dots\dots (2.1)G = \frac{m}{A}$$

With:

- = Grammatical (grams/cm²) *G*
- = mass of PVC sheet(gram) *m*
- = PVC sheet area (cm²) *A*

e.3 Determining the Density of PVC Sheets

Determining the density of PVC sheets, calculated using equation (2.2).

$$\dots\dots\dots (2.2)\rho = \frac{m}{V}$$

With:

- = PVC sheet density (grams/cm³) *ρ*

= mass of PVC sheet(gram) m
 = volume of PVC sheet (3 grams) V

e.4 Determining the Tear Index of PVC Sheets

The tear index is a measure of the tear strength of a paper that is normalized to its thickness. The Tear Index equation is shown in equation (2.3)

$$\dots\dots\dots (2.3) IS = \frac{F_s}{G}$$

With:

- IS = PVC sheet tear index ($10^{-1} \text{cm}^3 \text{N/gram}$)
- = Tear resistance force of PVC sheet ($\text{mN} = F_s^{10^{-1} \text{cmN}}$)
- G = Grammatical (grams/cm²)

f. *Fourier Transform Infra Red* (FTIR) Spectrophotometer

PVC sheet testing by identifying chemical compounds, analyzing functional groups, and characterizing solid, liquid, or gaseous samples by measuring the infrared spectrum absorbed or emitted by the sample using *the Fourier Transform Infrared Red* (FTIR) Spectrophotometer (Figure 2.4) at the Metallurgical and Materials laboratory of the Sepuluh Nopember Institute of Technology (ITS) Surabaya. FTIR is used to observe molecular interactions using electromagnetic radiation that is at a wavelength of 0.75-1000µm or at a wavelength of 13,000-10 cm⁻¹.



Figure 2.4 FTIR Spectrophotometer

2.3 Composition Created

The composition of PVC sheet is shown in Table 2.1, using DOP 100%+0%ESBO, DOP75%+25%ESBO, DOP50%+50%ESBO, DOP25%+75%ESBO, and DOP0%+100%ESBO. The treatment of making PVC sheets is:

- Stabilizer Powder: 0.525 phr
- CaCO₃: 10 phr
- PVC : 30 phr
- J-Top Black : 0,125
- Time *Hot Mixing*: 240 seconds
- Rotor rotation: 100 rpm
- Oven time: 160 seconds
- Oven temperature: 220oC

Table 2.1 Variations in the composition of PVC samples for tear tests

Yes	Composition PVC Sheet(%)	CAP	ESBO	Temperature (°C)
1	CAP 100/0 ESBO	21	0	155
2	CAP 75/25 ESBO	15	6	155
3	CAP 50/50 ESBO	10,5	10,5	155
4	CAP 25/75 ESBO	6	15	155
5	CAP 0/100 ESBO	0	21	155

2.3.1 PVC Sheet Results

PVC sheet making machine (machine *Mixing roll*) shown in Figure 2.5. The scheme of the PVC sheet made is 60 mm long, 50 mm wide, and 0.1 mm thick (Figure 2.6), while the finished result is shown in Figure 2.7.



Figure 2.5 PVC sheet making roll mixing machine

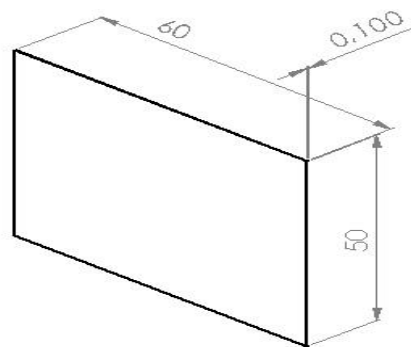


Figure 2.6 Sample size for testing

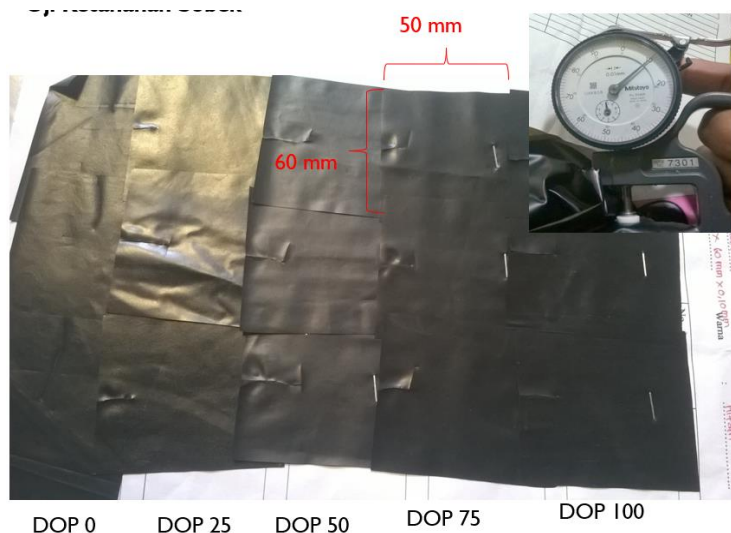


Figure 2.7 Finished PVC sheet

In the composition variation, the dry mixing process takes 130 seconds. Hot-melt mixing is carried out at 155°C, rotor speed 100 rpm, and mixing time 240 seconds. After mixing the hot melt in the *mixing roll*, the material is lifted and measured with a peacock thickness gauge to ensure a thickness of exactly 0.10 mm. After the thickness is appropriate, the sample is placed on the table to cool at room temperature. Then the material is formed with a sample measuring device consisting of a cutter and a caliper, to the size listed for the tear test: 50mm x 60mm. This test aims to determine the PVC sheet product's resistance to tearing when used as a raincoat. (BSN: ISO 1974:1990(E)).

DISCUSSION

Tear Resistance Test Results

The results of the calculation of PVC sheet mass, density, and grammage are shown in Table 3.1. The area of the PVC sheet ($A = 6 \times 5 = 30 \text{ cm}^2$), and the volume of the PVC sheet ($V = 30 \times 0.1 = 3 \text{ cm}^3$). Meanwhile, the value of Tear Resistance and Tear Index is shown in Table 3.2.

Table 3.1 Results of Grammatical and PVC sheet values

No.	Composition (%)	Mass (gram)			Average mass (grams)	Weighting (gr/m ²)	Density (gr/m ³)
		1	2	3			
1	CAP 100/0 ESBO	55	53	51	53	286,3	28.63 x 10 ⁵

2	CAP 75/25 ESBO	50	53	53	51,7	287	28.7 x 10 ⁵
3	CAP 50/50 ESBO	48	52	50	50	291,67	29.16 x 10 ⁵
4	CAP 25/75 ESBO	53	49	51	51	297	29.7 x 10 ⁵
5	CAP 0/100 ESBO	51	54	49	51,4	285	28.5 x 10 ⁵

Table 3.2 Results of Tear Resistance and Tear Index

Yes	Faction (%)	Tear Resistance (mN)	Tear Index (mN ² /gr)
1	CAP 100/0 ESBO	1130,67	0,3949
2	CAP 75/25 ESBO	1102,94	0,3842
3	CAP 50/50 ESBO	1066,67	0,3657
4	CAP 25/75 ESBO	1088	0,3738
5	CAP 0/100 ESBO	1096,53	0,3874

Tear resistance testing using *the Tearing Streght Tester*; the Elmendorf *method* refers to SNI 0436:2009 with a pendulum sector force of 64,000 mN. Tests were performed on 3 samples in each experiment. The purpose of repeating up to 3 samples per experiment is to determine the average tear resistance to the pendulum factor. A graph of the results of the Tear Resistance test is shown in Figure 3.1.

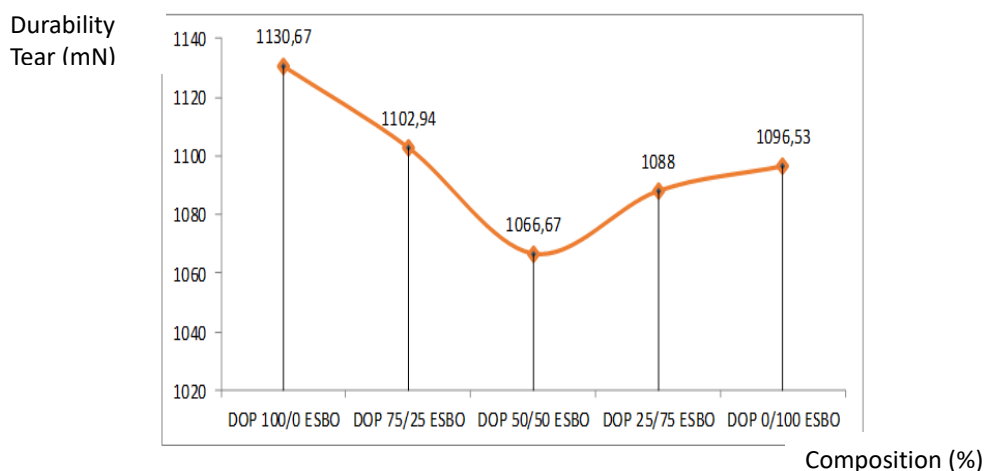


Figure 3.1 Tear resistance test results

In Graph 3.1, it appears that PVC product samples with compositions of 100% DOP and 0% ESBO have the highest tear resistance values. Meanwhile, in the composition of

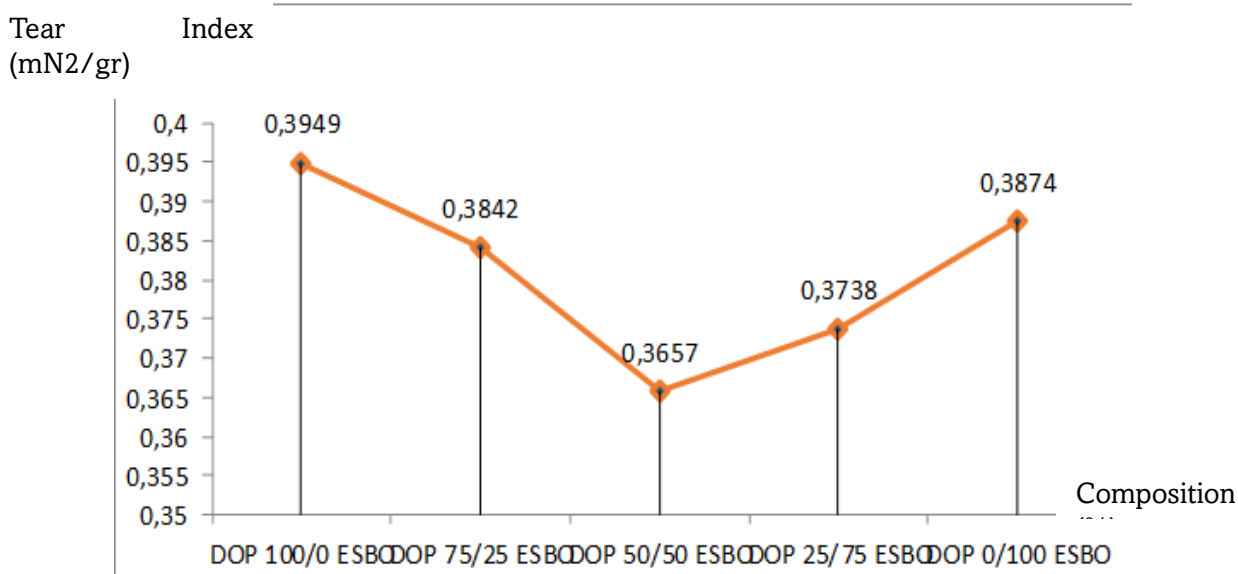
50% DOP and 50% ESBO, PVC products have the lowest tear resistance value but all sample results in the test are in accordance with the test standard, namely referring to SNI 0436:2009 (Table 3.3).

Table 3.3 Tear resistance standards referring to SNI 0436:2009

Remarks No.	Grammage (g/m ²)	Tear Resistance (mN)	Thickness (μm)
No. C	63.20	1114.04	123
No. B	61.44	993.74	129
No. F	66.27	794.99	77.3
No. E & A	42.60	402.72	57.7
No. D high)	77.48	1406.93	108
No. D	>70	990-1115	>100

Source : (BSN: ISO 1974:1990(E))

Table 3.3 and Figure 3.2 show the tear index obtained from the division of the tear resistance force of PVC sheets by grammage, which appears to have a downward tendency until the composition of PVC products with 50% DOP plasticizer and 50% ESBO plasticizer, starting to increase with variations of 25% DOP plasticizer and 75% ESBO. The value of the pendulum factor for PVC sheet is either very strong in tensile or a value of "D".



Graph 3.2 Results of the Tear Index calculation

Chemical Identification Results on PVC Sheets Using *Fourier Transform Infrared (FTIR)*

Fourier Transform Infrared (FTIR) is useful for identifying organic and inorganic chemicals. It can be used to estimate the amounts of several components in an unknown mixture. It can be applied to the analysis of solids, liquids, and gases. The FTIR analysis used was the composition of 50% DOP + 50% ESBO (Table 3.4), because the results of the tear resistance test for 100% DOP were so large that the results of the DOP composition were used

Table 3.4 Observed PVC products

Experiments	CAP	ESBO	Stabilizer	CaCO3	PVC	Temperature
50:50	10,5	10,5	0,525	10	30	155

50% + ESBO 50%. This composition was chosen to evaluate the formation of cross-linking bonds (cross-bond modification) between PVC molecular chains with ESBO and DOP, with the help of the PerkinElmer FTIR *Analysis device* in the chemistry laboratory of the Department of Metallurgy and Materials ITS, where the vibration frequency of the functional group was observed, so that an observation value in the form of *wavenumber* was obtained(emitted wavelength) functional groups contained in samples of PVC products. The observed chemical bonds of FTIR are shown in Figure 3.3

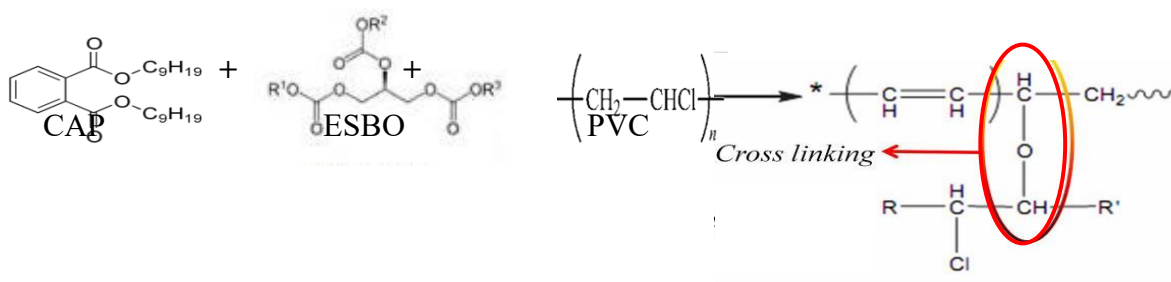


Figure 3.3 Reaction between PVC molecules and ESBO than DOP

Based on Figure 3.3, to evaluate the performance of ESBO in stabilizing unstable chlorine atoms (Cl), the C-O-C group vibration can be measured using FTIR. Meanwhile, based on the position of the C-O-C (simple ether) group in terms of frequency and intensity, the C-O-C group is observed at 1578.24 cm⁻¹, which is attributed to the anti-strain vibration.

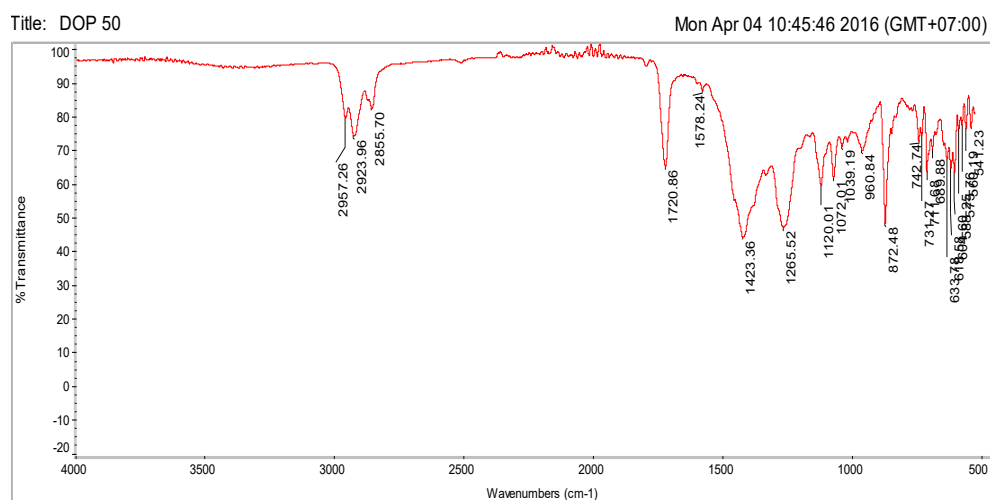


Figure 3.3 50% DOP *wavenumber transmission-wavenumber* curve based on FTIR test results

The symmetrical C-O-C group (COC) has a wide range of frequencies, while the symmetric strain vibration of the C-O-C group is very weak. The ratio is called *transmittance*, and it is usually expressed as a percentage (% T).

The results of the FTIR test in Figure 3.3 show that the transmission peak with the highest vibration frequency, 1423.36 cm⁻¹, is observed in PVC product samples with 50% DOP plasticizer and 50% ESBO. The *infrared* spectrum for the DOP 50 sample has 23 peaks, namely:

- At frequencies 2957.26 cm⁻¹, 2923.96 cm⁻¹, and 2855.70 cm⁻¹ are caused by vibration from CH Stretch (Alkane) ALKYD RESIN.
- At frequencies of 1720.86 cm⁻¹ and 1578.24 cm⁻¹ due to C=O Stretch (Alheid) Tygon Polymer B-44-4X which is Chemical Structure stable and good Flexibility.
- At frequencies 1423.86 cm⁻¹ and 1265.52 cm⁻¹ are caused by vibrations from C-H Stretch (Alkanes) Calcium Carbonate with a composition of 99.995+%.
- At a frequency of 1120.01 cm⁻¹ due to C-O Stretch (Alcohol) Tygon polymer S-50-HL, which is odorless, tasteless, and non-toxic.
- At a frequency of 1072.01 cm⁻¹ caused by C-O Stretch (Alcohol), Polyester Terephthalate (PET) is a thermoplastic polymer resin of the polyester group. PET is widely produced in the chemical industry and used in synthetic fibers, beverage

bottles, and food containers, thermoforming applications, and combined with glass fiber in engineering resins, and its molecular formula is (-CO-C₆H₅-CO-O-CH₂-CH₂-O-).

- At frequencies of 1039.19 cm^{-1} and 960.84 cm^{-1} are caused by C-H Stretch (Alkene), Fluorinated hydrocarbons, which are useful as coolants and solvents.
- At frequencies 872.48 cm^{-1} and 742.74 cm^{-1} are caused by C-H Stretch (Alkene) *Diocetyl phthalate* with a composition of 99%.
- At frequencies 731.27 cm^{-1} , 711.68 cm^{-1} , and 689.88 cm^{-1} are caused by C-H Stretch (aromatic ring) in *Diocetyl phthalate*.

CONCLUSION

The implications of the publication of this research for the academic world, society, nations and countries, as well as the international community is that the results of this research are expected to have input for the industrial world, especially in considering the use of *Diocetyl Phthalate* (DOP) and *Epoxydized Soybean Oil* (ESBO) for the manufacture of raincoats, so that the results are obtained according to the standards for the tearing strength.

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BIBLIOGRAPHY

- [1]. Eka Fitriana, 2020, *Alternative Design Variations of Various Raincoats*, Assignment End of Product Design Study Program , Faculty of Design and Creative Arts University Jakarta's Buana Lighthouse.
- [2]. Juliansyah Eka Putra Nakrowi, 2024, *The Influence of Brand Image, Product Quality, and Price Perception on the Decision to Buy Plevia Brand Raincoats at Toko Dian Denpasar*, Journal of Bakti Saraswati Vol. 13 No. 01, p.36-47, March 2024 ISSN : 2088-2149, e-ISSN : 2685-3302.
- [3]. Charles A, Harper & Edward M. Petrie, 2003. *Plastics Materials and Processes: A Concise Encyclopedia*. USA: John Wiley & Sons, Inc.
- [4]. O'Connel, Paula. And all. 2005 *Encyclopedia of Polymer Science and Technologies*. USA: John Wiley & Sons, Inc.
- [5]. Imam Mukhamad Asyrofi, Wawan Trisnadi Putra, Yoyok Winardi, 2023, *Effect of Mixture of LDPE Waste Plastic and Polyester Resin Matrix PET on Tensile Strength and Microstructure*, TEKNOSCIENCE: Journal of Science, Technology

- and Informatics Volume 10, Number 1, January 2023, pp. 51-58, ISSN 2087-3336 (Print) 2721-4729 (Online), <http://jurnal.sttmcileungsi.ac.id/index.php/tekno>, DOI: 10.37373.
- [6]. Burgos, Nuria, 2009, *Degradation of poly(vinyl chloride) plasticized with non-phthalate plasticizers under sterilization conditions*. University of Alicante, Analytical Chemical Department. Alicante, Spain.
- [7]. Roya Jamarani, Hanno C. Erythropel, James A. Nicell, Richard L. Leask and Milan Mari, 2018, How Green is Your Plasticizer?, *Polymers* 2018, 10, 834; Page: 1-17, doi:10.3390/polym10080834 www.mdpi.com/journal/polymers,
- [8]. Mesua ferrea, L. 2001. *Epoxydized Plasticizer for Flexible PVC Injection Moulded Toy Applications. Plastic and Compounding*.
- [9]. Yufei Wang and Haifeng Qian, 2021, Review Phthalates and Their Impacts on Human Health, *Healthcare* 2021, 9, 603. <https://doi.org/10.3390/healthcare9050603>
<https://www.mdpi.com/journal/healthcare>
- [10]. Schütze, André, Claudia Pälmeke, et al. 2001. *ESBO Robust Summary*. Velsicol Chemical Cooperation. Rosemont, Illinois.
- [11]. F. Gerull, J. Borchert, 2011, *Epoxidized soybean oil (ESBO) analyzed by PiCA Method*, PiCA GmbH, Rudower Chaussee 29, 12489 Berlin Germany.
- [12]. Jie Yu, Lushi Sun, Chuan Ma, Yu Qiao, Hong Yao, 2020, *Thermal degradation of PVC: A review*, *Waste Management* (2015), <http://dx.doi.org/10.1016/j.wasman.2015.11.041>, Volume 48, February 2016, Pages 300-314 <https://doi.org/10.1016/j.wasman.2015.11.041>, <https://www.sciencedirect.com/science/article/abs/pii/S0956053X15302233?via%3Dihub>
- [13]. BSN: ISO 1974:1990(E), *Pulp, Paper, Leather and Sheet – Determination of tearing resistance (Elmendorf method)*. SNI 14-0436-2009.
- [14]. F. Gerull, J. Borchert, 2011, *Epoxidized soybean oil (ESBO) analyzed by PiCA Method*, PiCA GmbH, Rudower Chaussee 29, 12489 Berlin Germany.
- [15]. Jie Yu, Lushi Sun, Chuan Ma, Yu Qiao, Hong Yao, 2020, *Thermal degradation of PVC: A review*, *Waste Management* (2015), <http://dx.doi.org/10.1016/j.wasman.2015.11.041>, Volume 48, February 2016, Pages 300-314 <https://doi.org/10.1016/j.wasman.2015.11.041>, <https://www.sciencedirect.com/science/article/abs/pii/S0956053X15302233?via%3Dihub>
- [16]. BSN: ISO 1974:1990(E), *Pulp, Paper, Leather and Sheet – Determination of tearing resistance (Elmendorf method)*. SNI 14-0436-2009.
- [17]. Clara Bratt Lauridsen, Theis Brock-Nannesta and Kim Pilckjar Simonsen, 2021, *Analyses And Findings Of Unusual Substitute Materials In A Raincoat From WWII*, *Herit Sci* (2021) 9:98 Page 3 of 10 <https://doi.org/10.1186/S40494-021-00572-7>
- [18]. Mochamad Chalid, RudiYansah, 2012, *Study of the Effect of Epoxidized Soybean Oil as a Polyvinyl Chloride Elasticity Controller*, <https://www.researchgate.net/publication/291206574>.
- [19]. O. M. Folarin and E. R. Sadiku, 2011, *Thermal Stabilizers For Poly(Vinyl Chloride): A review*, *International Journal of the Physical Sciences* Vol. 6(18), pp. 4323-4330, September 9, 2011, Available online at <http://www.academicjournals.org/IJPS>, DOI: 10.5897/IJPS11.654, ISSN 1992 -1950 ©2011 Academic Journals

- [20]. **Prattasi Harmi Tjahjanti**, Iswanto, Edi Widodo, Sholeh Pamuji, 2023, *Examination of Thermoplastic Polymers for Splicing and Bending*, Nano Hybrids and Composites, Research Impact Score: 0.6, Q=Quartil 3, (Volume 38) Pages: 87-97, ISSN: 2297-3400, DOI: <https://doi.org/10.4028/p-8myjhn>, Online since: February 2023, <https://www.scientific.net/NHC.38.87.pdf>
- [21]. **Tjahjanti P H**, Firdaus R, Iswanto, Ahnan M F, 2020, *Study of Crack Connections in Composite Materials Based on Polymer*, Journal IOP Conference Series: Materials Science and Engineering, 874 (2020) 012026, Published 01 July 2020 Published under licence by IOP Publishing Ltd, 1st International Conference Earth Science And Energy, CitizenM Hotel, Bukit Tinggi, Kuala Lumpur, Malaysia, November 7-8, 2019, doi:10.1088/1757-899X/874/1/012026, <https://iopscience.iop.org/issue/1757-899X/874/1>