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Evaluation of Virgin and Recycled LDPE Plastic Bags Manufactured using Film Blowing Machine

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Abstract: Plastic is a versatile material that can be shaped and molded, making it a popular choice for a wide range of items. As a result, the demand for and manufacturing plastic bags is gradually increasing. Every year, it is estimated that trillions of plastic bags are used as carrying bags all over the world. Film blowing extrusion is the most common method for producing plastic films, particularly in the packaging industry. The raw material used was Low Density Polyethylene (LDPE). Thus, in this study the mechanical properties of plastic bags are evaluated by using thickness measurement, density test, tensile test, tearing test and oxygen permeability test and and make comparison between Wahdah Plastics Industry Sdn. Bhd. and commercial plastic bags samples. The samples will undergo a few tests according to the American Standard Testing Method (ASTM) includes thickness measurement (ASTM D6988-13), tearing test (ASTM D689-03), tensile test (ASTM D882), oxygen permeability test (ASTM D1434-82) and density test. The results have shown that plastic sample A which is virgin LDPE from Wahdah Plastic Industries is best overall for the tensile and tearing test. In the tensile test, the most ductile sample is sample A at the cross direction. The tearing strength after divided by thickness of sample A is the highest which showed it needs more strength to tear the plastic film and withstand high tearing resistance. This sample tends to float on the water and is better for the environment since it is easy to be removed when it floats on the water. Overall, sample A which is virgin LDPE from Wahdah Plastic Industries showed the best performance in thickness, density, tensile, tearing strength and oxygen permeability test which achieved desired quality of plastic bag to sell on the market.

Keywords: Low Density Polyethylene (LDPE), Plastic, Recycled, Virgin

1. Introduction

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Plastic bags seem to have always been a part of our lives. Markets, grocery shops, and other retail establishments frequently utilize plastic bags. Plastic bags are used approximately 1 trillion times per year, owing to their durability and low cost. When shopping at markets or grocery stores, 96.00 % of shoppers use plastic bags, 2.00 % use paper-based bags, and only 2.00 % use reusable bags [1]. Plastic waste is easily dispersed, permanent, noticeable, and an essentially accumulated waste material due to the same characteristics that make it a flexible packaging material, durable, lightweight, and high strength. Plastic bag, on the other hand, is mostly non-biodegradable and if they are not properly handled, it will pollute the atmosphere and living organisms [1].

Plastic pollution has already established itself as a major problem. Plastic littering not only causes substantial discomfort to people of the impacted towns and suburbs, but it also harms bodies of water, forests, and the ecosystem in general. Various systems have previously been devised and used for the disposal of plastic utensils, windows, and other solid things. Plastic bags, on the other hand, have received insufficient attention [2]. This environmental problem has now caught the interest of governments all over the world, including Malaysia. The government has made numerous attempts to protect the environment from damage. Earth Hour, Go Green, and 3R (reuse, reduce and recycle). Each of these initiatives takes a different approach to raise public awareness. As a result, the Malaysian government has launched a "No Plastic Bag" initiative as part of its recycling campaign. Many businesses have contributed to the success of the "No Plastic Bag" movement by collaborating with the government.

In this project, the plastic film provided from Wahdah Plastics Industries Sdn. Bhd. will be undergone testing and be evaluated together with the plastic film bought from internet. Using recycled plastics can reduce natural gas and oil exploration, mining, and transportation, dramatically minimizing environmental consequences [3]. The machines used for testing are in Makmal Sistem Pengujian, UTHM Campus Pagoh and is specially designed for the testing for plastic. To improve the recycled plastic bag's quality, tests will be conducted to evaluate the mechanical properties of plastic films produced from the trial formulas according to the American Standard Testing Method (ASTM). ASTM includes thickness measurement (ASTM D6988-13), density test, tearing test (ASTM D1922), tensile test (ASTM D882) and oxygen permeability test (ASTM D1434).

Wahdah Plastics Industries Sdn. Bhd. is classified as Plastic Injection Moulding Manufacturers and Plastic Products. This industry's costumer is the majority from the furniture industry and fishery industry. The main focus of this project is the evaluation of virgin and recycled LDPE plastic bags produced from Wahdah Plastics Industries Sdn. Bhd. With testing the plastic films manufactured, Wahdah Plastics Industries will have better knowledge of the performance of their products in the market.

The study aims to evaluate the mechanical properties of plastic bags by using thickness measurement, density test, tensile test, tearing test and oxygen permeability test and and make comparison between Wahdah Plastics Industry Sdn. Bhd. and commercial plastic bags samples.

1.1 Plastic bag usage in Malaysia

Malaysia launched the No Plastic Bag Day campaign in 2011 to discourage people from using plastic bags. Plastic bags are widely used as shopping bags in the world. However, their widespread use generates a significant amount of plastic waste. Plastic waste takes a long time to decompose, leading to air, water, and soil pollution [4]. A study was carried out mentioned that out of 192 coastal nations, Malaysia is the seventh greatest supplier of mismanaged plastic trash. According to this report, Malaysia produced 0.94 million tonnes of poorly managed plastic trash, with 0.14 to 0.37 million tonnes potentially pouring into the oceans in 2010. Plastics account for 13.00 % of Malaysia's solid waste, with 55.00 % of that being mismanaged [5].

2. Materials and Methods

This section will discuss and focus on the framework used to complete this project. The methods start with the sample collection from Wahdah Plastics Industries Sdn. Bhd., followed by the purchasing of plastic from the market and ending with the data analysis of the plastics bags produced. The project will end with the reporting to Wahdah Plastics Industries Sdn. Bhd. Besides, this section also will explain about material and methods that were used in the five tests.

2.1 Material selection

In this project, virgin and recycled LDPE plastic samples were collected from Wahdah Plastics Industries Sdn. Bhd. Also, samples that were bought from the internet are selected and purchased to undergo several testings and to make a comparison.

2.1.1 Sample collection from Wahdah Plastics Industries Sdn.Bhd.

The plastic film provided from Wahdah Plastics Industries Sdn. Bhd. is virgin and recycled LDPE when collected the plastic sample from the factory. Therefore, the plastic film is decided to LDPE plastic type in this project, thus another virgin and recycled plastic film are bought from the market to make a comparison. Figure 1 and Figure 2 show the virgin and recycled LDPE plastic samples collected from Wahdah Plastic Industries.

Figure 1: Virgin LDPE plastic sample

Figure 2: Recycled LDPE plastic sample

2.1.2 Sample bought from internet

Other than sample collection from Wahdah Plastic Industries, another commercial virgin and recycled plastic films also purchased. Figure 3 shows the commercial virgin LDPE plastic sample while Figure 4 shows recycled LDPE plastic sample. These plastic films are then undergoing the same testing with the plastic films collected from Wahdah Plastic Industries.

Figure 3: Commercial virgin LDPE plastic sample

Figure 4: Commercial recycled LDPE plastic sample

2.2 Product testing

2.2.1 Thickness measurement

According to ASTM D6988-13, Standard Guide for Determination of Thickness of Plastic Film Test Specimens, this guide is intended to provide advice and best practices for determining precise dimensions when they are required for the calculation of physical unit attributes. This guide covers the determination of the thickness of plastic films where the thickness is used directly in determining the results of tests. According to ASTM D6988-03, a square shape film will be cut which is 10.00 cm ×

10.00 cm and a total of 20 pieces of specimen with 5 pieces each for the 4 different types of plastic film and every specimen will be marked for identification. Precision micrometer TMI 49-61 is used for thickness measurement.

2.2.2 Density test

The mass density of an object, also known as density, is the mass divided by the volume of the thing. The Greek letter rho (ρ) is used to denote density, which is determined using the density formula:

$$Density = \frac{mass}{volume} \qquad Eq.\ 1$$

The piece of the plastic specimen was cut into a given size that is the same as the thickness test, which is 10cm × 10cm and being weighed by using a weighing machine. A total of 20 specimens was needed for 4 different types of plastic film. 5 measurements on each specimen were required to be tested. The volume of the plastic film then is calculated from the thickness of the film multiplied by its area which is length multiplied by width, as shown in equation 2. To calculate the density of the plastic film, the measured mass was divided by the measured volume according to the equation shown above.

$$Volume = thickness\ x\ (length\ x\ width) \qquad Eq.\ 2$$

2.2.3 Tensile test

Tensile test was done according to the Standard Test Method for Tensile Properties of Thin Plastic Sheeting (ASTM D882), the method's properties are useful for identifying and characterization of materials for control and specification purposes. Tensile test was carried out using the hot tact tester. A trial test was performed to determine the elongation of the specimen. According to Thin Plastic Sheeting (ASTM D882), 10 specimens were to be tested from each sample, where 5 were used for machine direction and cross direction respectively. The sample preparation for the test was cut into each strip 15mm wide while the length of the specimen is 160 mm and it must be cut in one stroke condition. The area and reduced area after the tensile test of plastic are measured and calculated. Then, engineering stress and true stress are calculated and compared based on the results.

2.2.4 Tearing test

According to Standard Test Method for Propagation Tear Resistance of Plastic Film and Thin Sheeting by Pendulum Method (ASTM D1922), this test method is useful for comparing the tearing resistance of different plastic films and thin sheeting. The machine used to conduct the tearing test is Elmendorf Tearing Tester GT-7055-AD. In this tearing test, a total of 20 specimens from 4 different plastic films was cut to form a rectangle shape 76mm in length and 63 mm in width according to ASTM D1922. The gram force is a non-SI metric unit for force. Gram-force can be abbreviated as gf and Gram-force is a unit of force equal to the force needed to move one gram of mass at a rate of 9.80665 meters per second squared. The results were then recorded and be collected on the tearing tester. The tearing force is determined using the equation:

$$1\ gram\ force\ (gf) = 9.81\ millinewtons\ (mN) \qquad Eq.\ 3$$

2.2.5 Oxygen permeability test

Based on the Standard Test Method for Determining Gas Permeability Characteristics of Plastic Film and Sheeting (ASTM D1434-82), this test method covers the estimation of the steady-state rate of transmission of gas through plastics in the form of film, sheeting, laminates, and plastic-coated papers or fabrics. Oxygen Transmission Rate (OTR) is the measurement of the amount of oxygen gas that passes through a substance over a given time. The samples that are going to undergo the oxygen transmission test are placed in a room with controlled temperature and humidity for not less than 48 hours according to ASTM D1434-82. This can ensure the plastic film samples are at the steady state rate at which the oxygen gas permeates through a film at specified conditions like temperature and relative humidity. Figure 3 shows the oxygen permeability tester in Makmal Sistem Pengujian, UTHM. The size of the film sample was cut into 12.50 cm x 12.50 cm for the oxygen permeability test based on the template shown in Figure 6. Thickness for each sample is required before the oxygen permeability test started and the unit for thickness is in μm. Before the oxygen permeability test started, the machine will need 1 hour for conditioning. 4 cycles are required for the testing process and 3 times of the zeroing process.

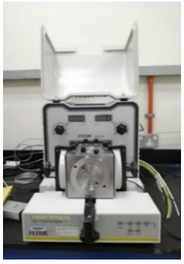


Figure 5: Oxygen permeability tester

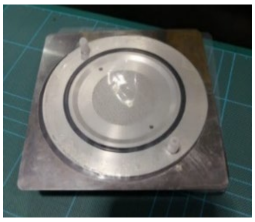


Figure 6: Size template

3. Results and Discussion

The results based on the data obtained from the varying test which are thickness measurement, density test, tensile test, tearing test and oxygen permeability test with the observation on the product has been discussed.

3.1 Relative observation between plastic samples

The samples used in this research include virgin and recycled LDPE. Here the observation of samples used was discussed including the colour, transparency, roughness compared to one another.

(a)

(b)

(c)

(d)

Figure 7: (a) Virgin LDPE from Wahdah, (b) Recycled LDPE from Wahdah, (c) Commercial virgin LDPE, (d) Commercial recycled LDPE

For the recycled LDPE sample from Wahdah Plastic Industry shown in Figure 7 (a), the colour is less white compared to the virgin material. The recycled LDPE is not so transparent as the virgin LDPE. The surface of the plastic is also less smooth and can feel it is grainy. Different from the recycled LDPE, the virgin LDPE in Figure 7 (b) has smoother surface. The transparency is also very good.

The virgin LDPE shown in Figure 7 (c) is the commercial plastic bag sample. The colour for this virgin LDPE plastic is blue therefore not transparent. The surface is smooth we can feel the thickness is thicker compared to the virgin LDPE plastic manufactured from Wahdah Plastic Industry. The commercial recycled LDPE is pink in colour in Figure 7 (d). It has some transparency. This plastic sample has a smooth surface and does not feel too grainy.

3.2 Tests on LDPE plastic films

The result of thickness measurement, density test, tearing test and tensile test are tabulated and discussed in the following sections.

3.2.1 Thickness measurement

A precision micrometer is used to conduct the thickness measurement. All specimens were cut into a square shape with a dimension of $10\ cm\ x\ 10\ cm$ according to ASTM D6988-08. Total 5 specimens were measured for each virgin and recycled LDPE plastic. The plastic sample A, B, C and D was represented by LDPE plastic bag as shown in Table 1.

Table 1: Description for plastic sample

Sample	Description
A	Virgin LDPE from Wahdah Plastic Industries
B	Recycled LDPE from Wahdah Plastic Industries
C	Commercial virgin LDPE
D	Commercial recycled LDPE

Table 2: Total average thickness for samples

Sample	Thickness of specimen (mm)
A	0.0496 ± 0.001
B	0.0577 ± 0.003
C	0.1165 ± 0.001
D	0.0398 ± 0.001

From the data tabulated from Table 2 which is the total average thickness for samples, the highest average thickness collected was sample C, that is commercial virgin LDPE plastic sample that is 0.1165 mm while the lowest average thickness is 0.0398 mm which is sample D, commercial recycled LDPE plastic sample recorded a value of 0.0398 mm.

The parameters used to manufacture virgin and recycled LDPE plastic from Wahdah Plastic Industry are maintained constant for both plastic films. In this condition, sample A which is recycled LDPE plastic film is thicker than sample B, which is virgin LDPE plastic. This can be explained based on the processing method of the material. Recycled plastics may contain a multitude of unintentionally added chemical additives or contaminants such as pesticide residues, pigments, flame retardants identification of which alone is challenging and establishing polymer-based toxicological signature more so [6].

3.2.2 Density test

Table 3 shows the density obtained that includes the data for thickness, area and volume of plastic film.

Table 3: Density of samples

Sample	Thickness (mm)	Area (cm^2)	Volume (cm^3)	Density ($\frac{g}{cm^3}$)
A	0.00496	100	0.496	1.028
B	0.00577	100	0.577	0.816
C	0.11650	100	1.165	0.953
D	0.03980	100	0.398	0.804

From Table 3, all the samples have a good density towards water since all the samples have a lower density than the seawater which is 1.03 g/cm^3. All four samples will float on the seawater and this will ease the plastic collection process if all the plastic waste is lighter than seawater's average density [7]. The lower the density of the plastic film sample, the higher the tendency of plastic film to be floating on the water. Thus, the sea life and quality of aquatic life will be improved by reducing the result of ingestion, starvation, suffocation, infection and drowning that caused by marine plastic pollution [8]. The low-density property of the four plastic samples is also better for the environment because the plastics are easy to remove when they float on water. To conclude, sample D has the highest tendency to be floating on the water as resulting it has the lowest density among the four samples.

3.2.3 Tensile test

Table 4 shows the description of plastic samples. The dimension of the specimen used in this test was 15.000 mm x 160.000 mm (width x length). At least 10 specimens, 5 specimens in machine and cross direction respectively were tested for each sample.

Table 4: Description for plastic sample

Sample	Description
A1	Virgin LDPE at machine direction from Wahdah Plastic Industry
A2	Virgin LDPE at cross direction from Wahdah Plastic Industry
B1	Recycled LDPE at machine direction from Wahdah Plastic Industry
B2	Recycled LDPE at cross direction from Wahdah Plastic Industry
C1	Commercial virgin LDPE at machine direction
C2	Commercial virgin LDPE at cross direction
D1	Commercial recycled LDPE at machine direction
D2	Commercial recycled LDPE at cross direction

Figure 8 (a) shows among the specimens for sample A1, four of the plastic films breaks, while only one does not break.

From Figure 8 (b), we can see that among the specimens A2, only one specimen failed. Four specimens did not fail after the end of the test. It as expected of the film because B are manufactured thicker. Two out of five specimens undergo three times necking, while the other three specimens undergo two times necking. It has better ductility due to long necking and has a strong bonding which is produced a better strength because it is hard to break. The plastic film with a better ductility exhibited greater susceptibility to plastic deformation and was easy to neck. This shows that the sample which experienced a higher number of necking has the higher plasticity. The higher degree of the strength for virgin LDPE at cross direction led to a higher degree of crystallinity and this will influence the mechanical properties of the plastic [9].

Figure 8 (c) shows specimens B1 after undergoing tensile test. It is clear to see the plastic specimen experience whitening after the tensile test. The plastic film needs more force to elongate it thus other parts of the film will now experience stretching. When force is applied to the plastic film, it can cause the amorphous sections of the chain to crystalize [10]. When that happens, the way the molecules scatter light changes causes molecular changes that lead to whitening. It is obvious to observe that all specimens B2 after undergoing tensile test are all broken down in a shorter time as they do not elongate more shown in Figure 8 (d). These specimens only experience a little whitening because they are only being strengthened in a small force which is only 6.60 N of average maximum force and 18.000 mm of elongation.

(a)

(b)

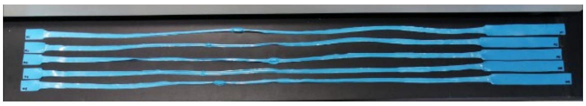
(c)

(d)

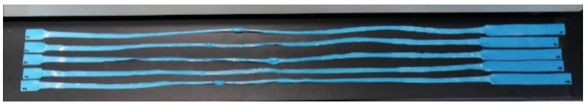
Figure 8: Specimen (a) A1, (b) A2, (c) B1 and (d) B2 undergo tensile test

All specimens C1 shown in Figure 9 (a) do not break as they are too thick, but they elongate and are strengthened until the end during the tensile test and were the longest elongation among the 8 samples which is 457.4 mm. Figure 9 (b) shows specimen C2 experiences three times of necking and they do not break until the end of the tensile test.

From Figure 9 (c), the 5 specimens for D1 all break into two with an average maximum force of 5.06 N. From Figure 9 (d), the specimens D2 all break into two with an average maximum force of 7.24 N. It required a higher force to break the plastic film in a cross direction compared to in machine direction.



(a)



(b)

(c)

(d)

Figure 9: Specimen (a) C1, (b) C2, (c) D1 and (d) D2 undergo tensile test

From Table 5, the most ductile sample in sample A2, which is the virgin LDPE plastic from Wahdah Plastic Industry at the cross direction, has the highest difference of average engineering and true stress. In conclusion for the tensile test, four specimens A2 did not fail after the end of the test. Two out of five specimens undergo three times necking, while the other three specimens undergo two times necking. It has better ductility due to long necking and has a strong bonding which is produced a better strength because it is hard to break. The plastic film of specimen A2 with a better ductility exhibited greater susceptibility to plastic deformation and was easy to neck. This shows that the sample which experienced a higher number of necking has the higher plasticity.

Table 5: Difference between engineering stress and true stress

Sample	Average engineering stress (N/mm^2)	Average true stress (N/mm^2)	Difference (%)
A1	14.7446	38.1152	164
A2	11.5753	49.7751	329
B1	11.6118	20.8166	79
B2	7.63030	22.8587	200
C1	11.9371	45.5646	282
C2	15.7173	56.6611	261
D1	8.48240	14.5438	71
D2	12.1340	19.6479	62

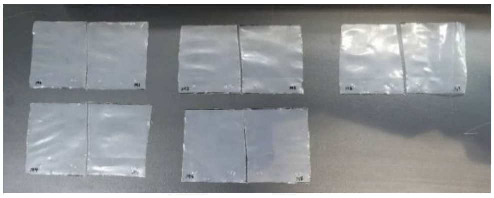
3.2.4 Tearing test

Table 6 is a result after the average tearing strength for each sample is divided by its thickness. This is to compare based on thickness for each sample as the sample is manufactured from a different factory.

After dividing the average tearing strength by thickness, the samples at machine direction which are samples A1, B1, C1 and D1 have a lower tearing strength than at cross direction which are A2, B2, C2 and D2 respectively. The tear strength in the machine direction is usually significantly lower than that in the cross direction. From Table 6, sample A shows that at the cross direction it is 20.00 % stronger compared to the machine direction, 33.00 % for sample B, 50.00 % for sample C and 24.00 % for sample D. The mechanical failure of the films is closely related to film orientation. Cracks are easier to be initiated in machine direction where crystals are aligned, and this shows that the plastic films are weaker and easier to be torn. In the cross direction, the crystals are bonded, so the strength to tear the films is higher.

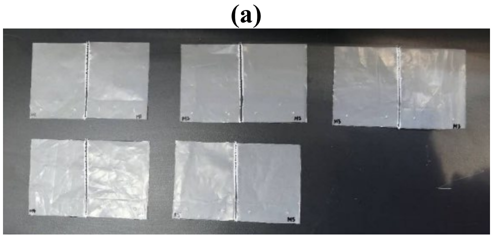
Table 6: Difference between machine direction and cross direction tearing strength

Sample	Thickness	Average tearing strength (mN)	Average tearing strength divided by thickness (mN)	Difference (%)
A1	0.0496	1640.84	33,081.45	
A2	0.0496	8290.76	167,152.42	20
B1	0.0577	2243.02	38,873.83	
B2	0.0577	6807.83	117,986.66	33
C1	0.1165	6848.28	58,783.52	
C2	0.1165	13564.09	116,429.96	50
D1	0.0398	1259.39	31,642.96	
D2	0.0398	5172.95	129,973.62	24



(a)

(b)



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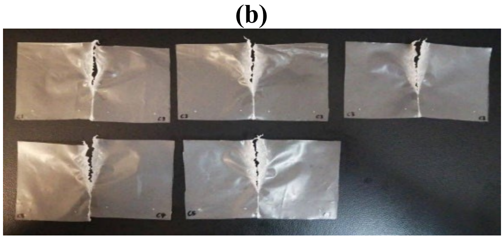

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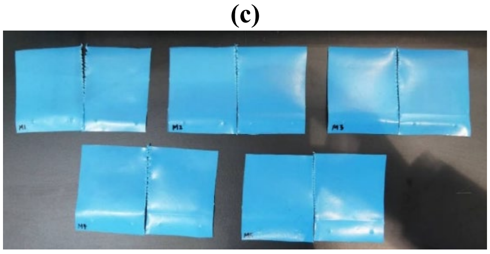

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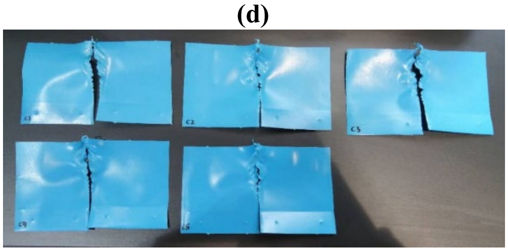

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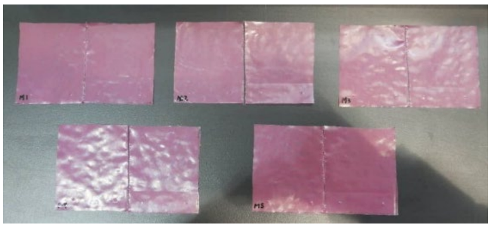
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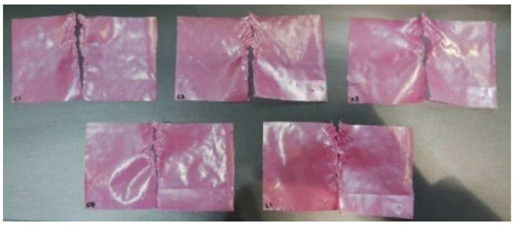
(h)

Figure 10: Specimen (a) A1, (b) A2, (c) B1, (d) B2, (e) C1, (f) C2, (g) D1 and (h) D2

The virgin LDPE plastic films at the machine direction show a smooth surface at the line of tear while at the cross direction, the line of tear is rigged. The effect for the machine and cross direction are the same from specimen A1 to specimen D2 and can be seen from Figure 10.

In conclusion for the tearing test, the virgin LDPE at cross direction collected from Wahdah Plastic Industries which is sample A2 performed better and stated the highest average tear strength at 167,152.42 mN after being divided by its thickness. A thicker sample will naturally yield better mechanical properties, but it is also less sustainable as more material is used. Thus, the sample is divided by its thickness to compare the performance of the samples. The samples at the cross direction show an obvious tear sign than the sample at the machine direction. This condition happened because the plastic at cross direction absorbs more energy therefore it needs more strength to let the plastic completely tear. While the plastic at the machine direction just affected little as the molecule aligns straight up at this direction, therefore it is more easily to be torn off. Also, the thickness of every specimen has different values which will affect the tearing strength value. Hence, the tendency to tear off the plastic film will be more difficult.

3.2.5 Oxygen permeability test

The thickness of each sample is inserted before the oxygen permeability test started therefore the machine will divide the thickness of the sample out. Table 7 shows the oxygen transmission rate for the plastic samples.

Table 7: Oxygen transmission rate for each sample

Sample	Oxygen transmission rate ($cm^3/m^2.24\ hours$)				
	First cycle	Second cycle	Third cycle	Forth cycle	Final
A	3853.159	3387.054	3047.281	2834.229	3280.431
B	0.027	1874.199	1239.927	2626.010	1913.379
C	514.540	614.522	864.165	912.238	912.238
D	3634.487	3631.917	3572.434	3614.976	3613.454

It is clear to see the lowest rate is sample C, which is the virgin LDPE from the internet at the rate of 912.238 $cm^3/m^2.24\ hours$. For virgin LDPE plastic, the OTR is between 7000 to 8500 $cm^3/m^2.24\ hours$ [10]. Sample A and sample C show a lower rate of OTR compared to the standard OTR.The graph shown in Figure 25 is acceptable and the final OTR taken for this sample is the average value from the 4 cycles which is 3280.431 $cm^3/m^2.24\ hours$. Based on Figure 11 (a), the graph shows that the result for this specimen is not stable, as there is an error during the first cycle. Furthermore, the graph of OTR shown at cycles 2, 3 and 4 are not stable. This is because the OTR is not stabilized yet and can be assumed that the graph will become stable after 6 cycles. From Figure 11 (b), the OTR taken is 912.238 $cm^3/m^2.24\ hours$ which is the last cycle for the oxygen permeability test for sample C. In this situation shown in Figure 11 (c), it can be assumed that after this cycle, the OTR will become more constant while the graph will be flat after a few more cycles like 6 cycles. However, this sample recorded the lowest OTR among the four samples and is the best barrier.

Generally, the lower the OTR, the oxygen barrier-providing layer and the better the barrier. Oxygen transmission rates through the barrier are critical to measuring and to is the longer a packaging system will maintain its desired gas composition. Figure 11 (d) shows the best graph after the oxygen permeability test among the four graphs. It is the most data reliability graph as the OTR from cycle 2 to cycle 4 are quite constant.

Sample C stated the lowest OTR which is 912.238 $cm^3/m^2.24\,hours$. The thickness of all samples was divided by the machine therefore the thickness factor is not considered in this situation. Another factor that causes this is the manufacturing process of the sample. The actual raw material production and processing will affect the barrier properties. Apart from this, the orientation of the material also affects and lowers the rate as it aligns the molecular chains and creates a less torturous path for vapor molecules to pass through.

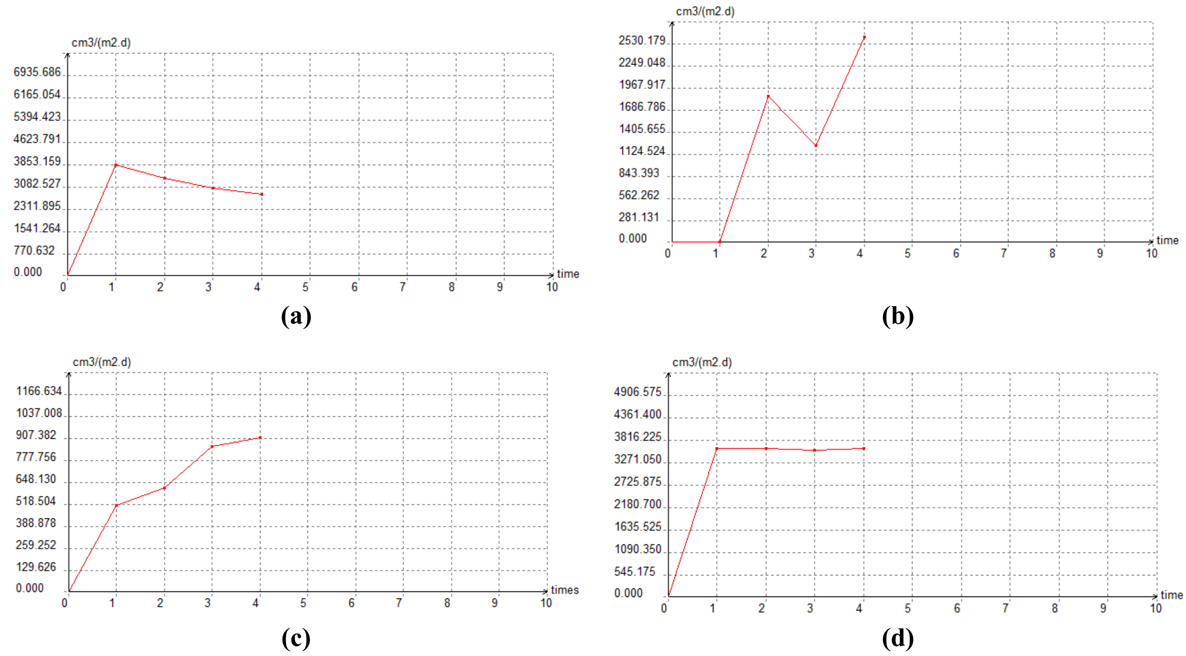

Figure 11: Graph for specimen (a) A, (b) B, (c) C and (d) D

4. Conclusion

In conclusion, based on the analysis of the result obtained from four tests conducted, sample A which is virgin LDPE from Wahdah Plastic Industries is best overall for tensile and tearing test, and C is the best in terms of thickness and oxygen permeability. Sample B and sample D which are the recycled LDPE from two companies are more sustainable in comparison to using virgin material. In tensile test, sample A at cross direction has better ductility due to long necking and has a strong bonding which is produced a better strength because it is hard to break. This sample with a better ductility exhibited greater susceptibility to plastic deformation and was easy to neck. Through the tearing test, sample A at the cross direction has the highest tear strength which means that the sample was not easy to be torn and it can withstand high tearing resistance to use as packaging. This shows that sample A absorbs more energy at cross direction therefore it needs more strength to let the plastic completely tear. Although the value of the density for sample A is not the lowest among the four samples, this sample tends to float on the water and is better for the environment since it is easy to be removed when it floats on the water. Thickness is a manufacture-controlled matter. Through the thickness measurement test, sample C has the highest value of thickness among all four samples. Based on the oxygen permeability test, sample C also has a lower oxygen transmission rate compared to other samples. The lower the OTR, the oxygen barrier-providing layer and the better the barrier. Based on the data analysis and all the results above, it showed that sample A which is the virgin LDPE plastic sample from Wahdah Plastic

Industries has the best mechanical properties with its thickness, tensile strength, tearing strength and oxygen permeability test.

As a recommendation, it is suggested that the four samples in this project can be undergone different chemical tests to evaluate the properties of plastic samples such as Chemical Compatibility (ASTM D543). This test covers the evaluation of plastic materials for resistance to chemical reagents, simulating performance in potential end-use environments. Chemical reagents can include lubricants, cleaning agents, inks, foods, or anything else that the test material may be expected to encounter. The test includes provisions for reporting changes in weight, dimensions, appearance and strength properties. With the addition of chemical tests, it can improve the data quality performed on the plastic. Moreover, it is recommended that the sample can be run for more cycles for the oxygen permeability test. Sample B and C are suggested to run longer to get a more reliable and accurate OTR result. The other recommendation is that the virgin LDPE resins can be manufactured by adding dehydrating agents to remove the moisture from recycled resin, to make sure there is no water vapour and bubbles during the process. The adding of dehydrating agent will increase the success probability of producing a more recyclable plastic film and reduce the cost. Last but not least, the project can be carried out by using Hyplas film blowing machine in Makmal Mesin Pembungkusan, UTHM Campus Pagoh.

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