Performance comparison of plastic shopping bags in modern and traditional retail

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Abstract. Followed by implementation of paid plastic bag policy in Indonesia's modern and traditional retail, community question related to plastic shopping bag performance arise. But, there is limited information about it. Therefore, the assessment of the performance to compare between plastic shopping bags in modern retail and traditional retail should be interesting. The observation performance of plastic shopping bag were weight holding capacity, tear resistant and elongation. This performance were tested using Universal Testing Machine. Physical and physico-chemical properties also identified to determine factor affecting the performance of plastic shopping bag. The physical properties were analysed using visual and thickness gauge to see the colour and measure the thickness. The analysis of physico-chemical properties were carried out using DSC (Differential Scanning Calorimetry), TGA (Thermal Gravimetry Analysis), Furnace and FTIR (Fourier Transform Infra Red Spectroscopy) to identify the materials, also its melting and decomposition temperature. The result showed that the performance difference between modern retail plastic bag with traditional retail plastic bag appears only in the performance of elongation. The elongation of modern retail plastic bag is 121 - 413%, while traditional has 170 - 609%. According to physico-chemical test result, modern retail and traditional retail plastic bag contain polyethylene as main material and has melting temperature in the range of High Density Polyethylene (HDPE) melting temperature. However, modern retail plastic bag has 18.31 - 33.87% of inorganic filler percentage, whereas the traditional retail plastic bag has 0.35 - 9.85%. This inorganic filler percentage probably a contributing factor in the elongation performance difference between modern retail plastic bag with traditional retail plastic bag.

1. Introduction

Plastic bag are functional, lightweight and cheap [1]. Therefore, it used broadly over the retail sector, both in modern and traditional retail as single use plastic shopping bag [2,3]. Based on research done by Yustia (2011), 75% out of 100 responden often receive plastic bag from retailer when shopping [4]. In order to reduce the usage of plastic shopping bag, paid plastic shopping bag policy implemented in selected area of Indonesia's modern and traditional retail since February 2016. Then the question arise in community related to the performance of plastic shopping bag in modern and traditional retail.

Performance of plastic shopping bag is determined by its function, which is carrying and transporting goods such as food, merchandise or groceries out of the store. Some of the expected performance of a plastic shopping bag are [5] :

1) How much the maximum weight of goods which can be held by a plastic bag (Weight Holding Capacity)

2) How much the maximum load imposed on plastic bags that do not undergo a tear (Tear Resistant)

3) How much plastic shopping bag can be stretch before it breaks (Elongation).

Certain properties can affect the mechanical performance. Plastic bag contain biodegradable polymer , organic filler or inorganic filler will give change in mechanical performance compare to polyolefin bag [6-9]. At present, there is limited information regarding plastic shopping bag performance in Indonesia. The M. Cornelia, et al compare only tensile strength and elongation of several types of plastic shopping bags from domestic market [6]. Considering there is no availability of weight holding capacity and tear resistant data of plastic shopping bags in Indonesia's modern and traditional retail also the need to respond the community question about plastic bag performance, it is interesting to assess overall performance of modern retail and traditional retail plastic shopping bag.

In this research, mechanical performance of modern retail plastic shopping bag and traditional retail plastic shopping bag was assessed and compared. The physical and physico-chemcal properties of plastic bag was also identified to determine factor affecting the performance difference between modern retail plastic bag with traditional retail plastic bag.

2.   Methodology

2.1   Sampling Method

This study uses 10 samples of plastic shopping bags from Jakarta and Tangerang. Five samples of plastic shopping bags were taken from modern retail and the others five are from traditional retail. Modern retails that selected for sampling are members of Indonesia Retailers Association (APRINDO) which support the paid plastic shopping bag policy by charges Rp 200,- for a plastic bag. Plastic shopping bag samples from traditional retail are given free of charge to the costumer, also obtained from street vendors and traditional retail traders in Jakarta and Tangerang. Ten samples of plastic shopping bags are shown in Figure 1.

Figure 1. Ten Samples of Plastic Shopping Bags

2.2 Physical Properties Testing

The physical properties were analyzed using visual and thickness measurement. Visual analysis was used to see the colour. Thickness gauge Preisser Digi-Met was used to measure the thickness of the plastic bags.

2.3 Physico-chemical Properties Testing

2.3.1 FTIR (Fourier Transform Infra Red).

FTIR analysis was done to identify type of polymer on plastic shopping bags. FTIR spectra were collected on Bruker Tensor 27 FTIR using transmission FSF (Free Standing Film) method.

2.3.2 DSC (Differential Scanning Calorimetry).

DSC analysis was performed on Perkin Elmer DSC 8000 to identify melting point of plastic shopping bag. DSC result also used to support FTIR test result in polymer identification. Nitrogen gas was purged at a rate of 20 mL/min during testing. Scanning was carried out in a heated – cooled – heated program at temperature ranging from 30 - 150 °C at 10 °C/min.

2.3.3 TGA (Thermogravimetric Analysis).

Equipment used for measuring decomposition temperature of plastic shopping bag was Netzsch Tarsus TG 209. Temperature rate was 10 °C/min from range of temperature 30 up to 900 °C. Nitrogen rate flown during experiment was 20 mL/min while oxygen flown during temperature 600 - 900 °C with rate 20 mL/min.

2.3.4 Filler Content.

Determination of total filler content was done using ASTM D5630-13 method. This method involves placing 5 g plastic shopping bag samples in a crucible and heating it in an air atmosphere furnace to a temperature 800 °C for 30 min. Residue remaining in the crucible was considered filler unless the residue less than 1 % were typically the result of inorganic compound from additives burnt off.

2.4 Mechanical Performance Testing

The analysis of mechanical performance were done using Shimadzu AGS – 10kN Universal Testing Machine to measure the tensile strength (ASTM D882), elongation and tear resistant (ASTM D1004) at machine direction. The resulted force from tensile strength was used to calculate weight holding capacity of plastic shopping bags. Tensile strength force (Newton) was divided by specimen width (millimeter) then multiplied by total width of four handle in plastic shopping bags (millimeter). After that, the force was convert into mass (kilogram) to obtain weight holding capacity. Speed during tensile strength and elongation testing were 500 mm/min, while 50 mm/min for tear resistant testing. All experiment were conducted at room temperature.

3.   Results and Discussion

3.1 Physical Properties

Colour, thickness and dimension of plastic shopping bags from modern retail are shown in Table 1, while Table 2 present colour, thickness and dimension of plastic shopping bag from traditional retail. Plastic shopping bag sample used in this study was consists of small to medium sizes. Based on dimension data from Table 1 and 2, medium sizes of traditional retail plastic bag (plastic C1-E1) has slightly bigger dimension than all of modern retail plastic bag. A probability plot of the thickness of modern and traditional retail plastic bag in Figure 2 a - b showed that both of modern and traditional retail plastic bag have population being sampled are normally distributed. However, the bigger p-value of modern retail plastic bag thickness showed that modern retail plastic bag data is normally distributed better than traditional retail plastic bag [10].

Table 1. Physical Characteristic of Modern Retail Plastic Shopping Bags

Characteristic	A	B	C	D	E
Colour	Milky White	Milky White	Milky White	Milky White	Milky White
Thickness (mm)	0.015	0.011	0.012	0.019	0.009
Width (mm)	270	275	210	300	280
Length (mm)	386	355	265	405	400
Holding Length (mm)	115	130	70	125	130

Based on colour characteristic, plastic A1-B1 of traditional retail plastic bag more clearly or transparent than plastic C1-E1. This probably due to inorganic filler contained in plastic C1-E1, since inorganic filler tend to decrease transparency of polymer [11-12]. For modern retail plastic bag, all of samples tend to be more opaque than traditional retail plastic bag. The better opacity can also be contributed by less branches in chemical structure leading to more cristallinity [11,13]. This suggest

that modern retail plastic bag probably have more inorganic content or have less branches in chemical strucutre than traditional retail plastic bag.

Table 2. Physical Characteristic of Traditional Retail Plastic Shopping Bags

Characteristic	A1	B1	C1	D1	E1
Colour	Clearly Blue	Clearly White	Black	Red	Milky White
Thickness (mm)	0.006	0.009	0.033	0.013	0.012
Width (mm)	150	150	400	300	317
Length (mm)	213	234	430	405	425
Holding Length (mm)	80	90	145	125	130

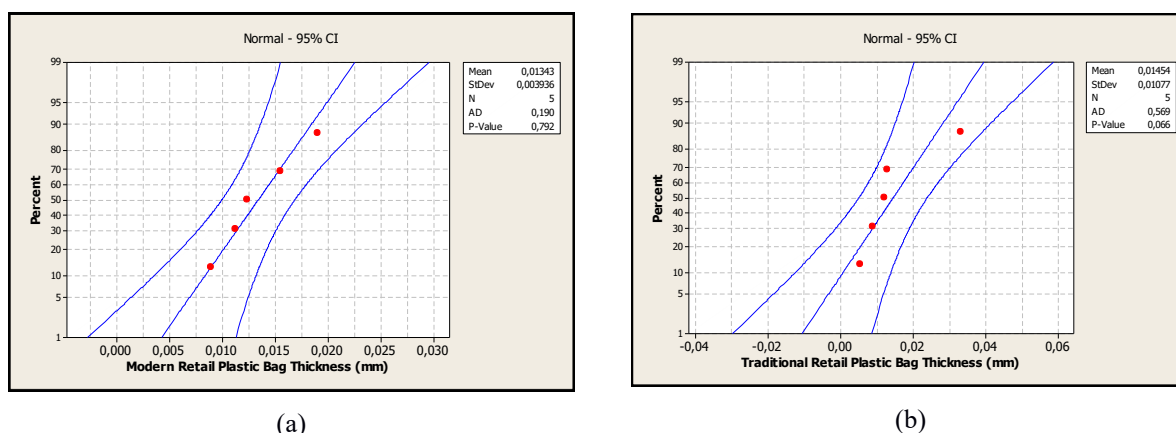(a)   (b)

Figure 2. Normal Probabillity Plot of The Thickness of (a) Modern Retail Plastic Bag ; (b) Traditional Retail Plastic Bag

3.2 Physico-chemical Properties

As seen in Figure 3 and 4, all plastic shopping bag samples have polyethylene characteristic peak. It shows antisymmetric and symmetric CH stretching vibration of CH_2 at 2919 – 2934 cm^{-1} and 2850 – 2851 cm^{-1}, CH_2 scissoring vibration at 1466 – 1467 cm^{-1} and 1472 cm^{-1}, CH_2 rocking vibration at 720 – 725 cm^{-1}. FTIR spectrum of traditional retail plastic shopping bags also show peak at around 1370 cm^{-1} which is CH_3 symmetric deformation, and its indicates the presence of methyl end groups and chain branches. Side chain will cause less crystalline, more amorphous structures to occur and lower density [11]. This can be seen that some traditional retail plastic shopping bags less opaque than others. FTIR spectrum of all modern and some traditional retail plastic shopping bag samples show broad peak at around 1466 – 1428 cm^{-1}. The broad peak indicated an inorganic filler [11]. The presence of inorganic filler in FTIR sepctrum of all modern and some traditional retail plastic shopping bag samples were seen by the additional FTIR peak at 876, 1430, 1796 and 2515 cm^{-1} . Also, peak around 720 cm^{-1} in modern retail plastic shopping bags (E, D and B) had shifted to around 710 cm^{-1}. The additional peak is estimated belonging to calcium carbonate peak characteristic, which is :

1) Carbonate peak in 1430 cm^{-1} for C=O stretch and 875 cm^{-1} for C=O bend [11].

2) Calcite (crystalline phase of calcium carbonate) peak in 2512, 1796, 1434 and 712 cm^{-1} [14].
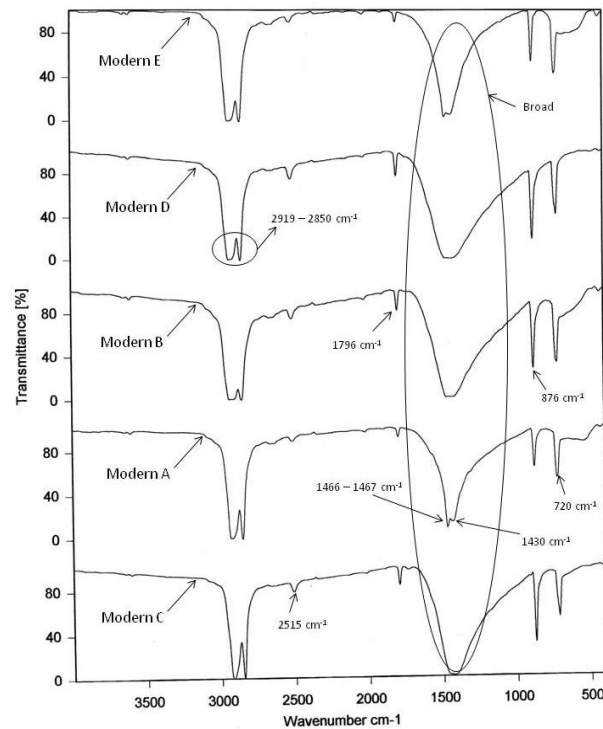

Figure 3. Overlay FTIR spectrum of modern retail plastic shopping bags
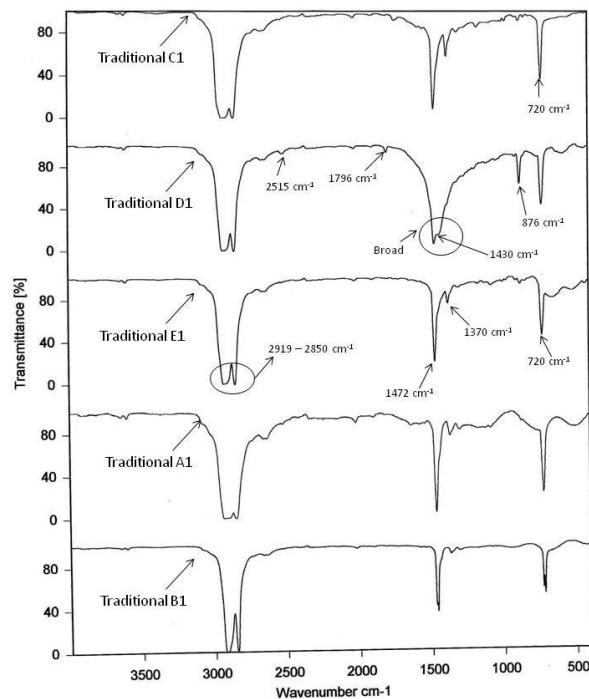

Figure 4. Overlay FTIR Spectrum of Traditional Retail Plastic Shopping Bags

However, this estimation of inorganic filler need to be confirmed by testing the filler using FTIR and SEM (Scanning Electron Microscope).

Table 3. DSC, TGA and Filler Content Analysis Results of Modern Retail Plastic Shopping Bag

Characteristic	A	B	C	D	E
Melting Temperature (°C)	126.06	126.37	127.91	126.38	126.43
Filler Content (%)	33.87	21.24	18.31	26.93	30.37
Decomposition Temperature (°C)	460.6	*	442.9	468.2	*

* Test is not done

Table 4. DSC, TGA and Filler Content Analysis Results of Traditional Retail Plastic Shopping Bag

Characteristic	A1	B1	C1	D1	E1
Melting Temperature (°C)	127.8	128.53	126.54	127.16	129.23
Filler Content (%)	0.35	0.07	3.28	9.85	2.87
Decomposition Temperature (°C)	*	*	474.4	494.4	448

* Test is not done

The presence of inorganic filler in all modern and some traditional retail plastic shopping bag samples were also indicated by the results of filler content analysis shown in Table 3 and 4. It showed that modern retail plastic shopping bags have more inorganic filler content than traditional retail plastic shopping bags. This is suitable with physical properties and FTIR result, where the modern retail plastic bag has more opacity and less side chain than traditional retail plastic bag.

Table 4 showed that the traditional retail C1, D1 and E1 plastic shopping bag containing inorganic filler. However, only FTIR spectrum of D1 plastic shopping bags that indicates the presence of inorganic filler because it has broad peak at around 1466 – 1428 cm^{-1} and calcium carbonate peak characacteristic (876, 1430, 1796 and 2515 cm^{-1}). This is probably caused by the fewer content of inorganic fillers in C1 and E1 plastic shopping bags.

Although FTIR spectrum of traditional retail plastic bag indicates some chain branching leading to less crystalline, DSC results analysis in Table 3 and 4 showed that melting temperature of all plastic shopping bag samples are in High Density Polyethylene (HDPE) melting temperature range, which is 125 – 137 °C [15]. However, melting temperature range of modern retail plastic bag is slightly lower than melting temperature range of traditional retail plastic bag. This probably due to inorganic filler content of modern retail plastic bag higher than traditional retail plastic bag. The increasing of inorganic filler loading might restrict the crystallization process so the heat required to melting is reduced [16].

Decomposition temperature analysis by TGA were carried out by sampling 6 samples from 10 plastic shopping bag samples. Table 3 showed the modern retail plastic shopping bags had decomposition temperature range 442.9 – 468.2 °C, while Table 4 showed that traditional plastic shopping bags had 448 – 494.4 °C.

3.3   Mechanical Properties

Figure 5 -7 showed the mechanical performace of modern retail and traditional retail plastic bag. According to Figure 5a - 6b, weight holding capacity and tear resistant of modern and traditional retail plastic bag have slightly different range. Weight holding capacity of modern plastic bag is 13 – 23 kg, while traditional retail plastic bag is 13 – 28 kg. Tear resistant of modern retail plastic bag in the range of 3 – 5 N, while traditional retail plastic bag is 2.5 – 7 N . The big difference of performance appears only in elongation. Figure 7a-b showed that elongation of modern retail plastic bag is 121 – 413%, while traditional retail plastic bag is 170 - 608%.
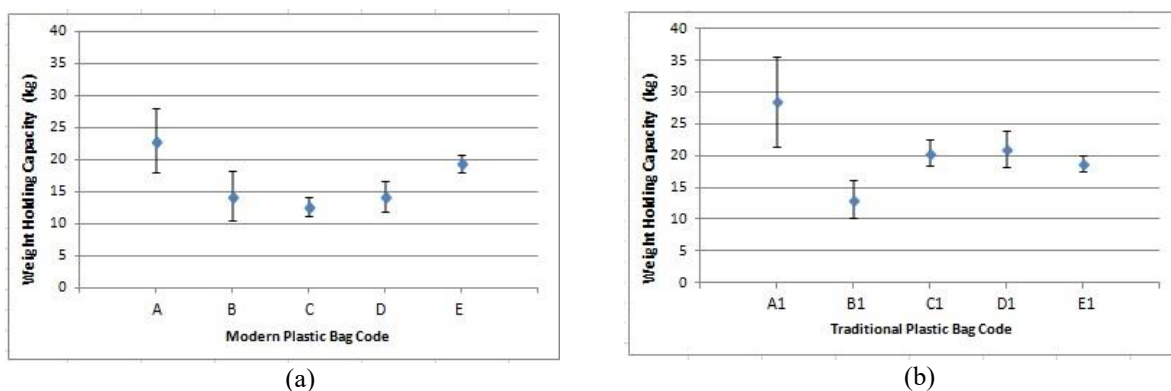

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Figure 5. Weight Holding Capacity of Modern (a) and Traditional (b) Plastic Shopping Bags
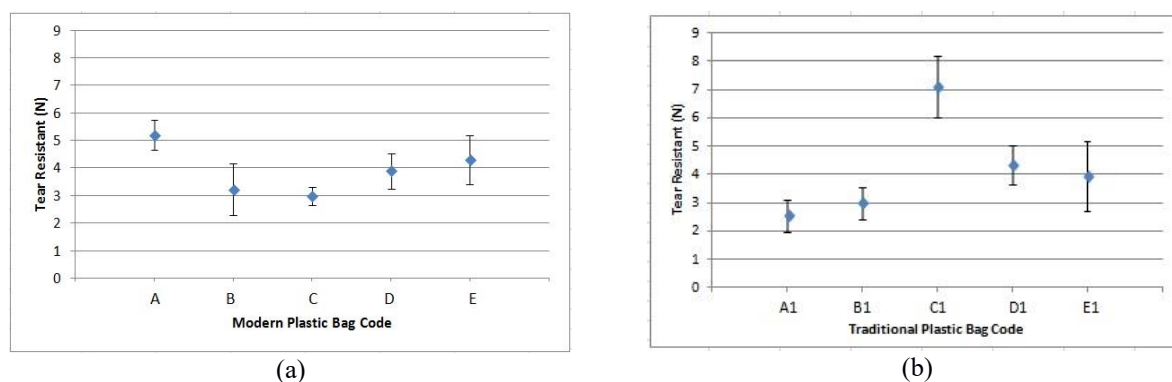

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Figure 6. Tear Resistant of Modern (a) and Traditional (b) Plastic Shopping Bags

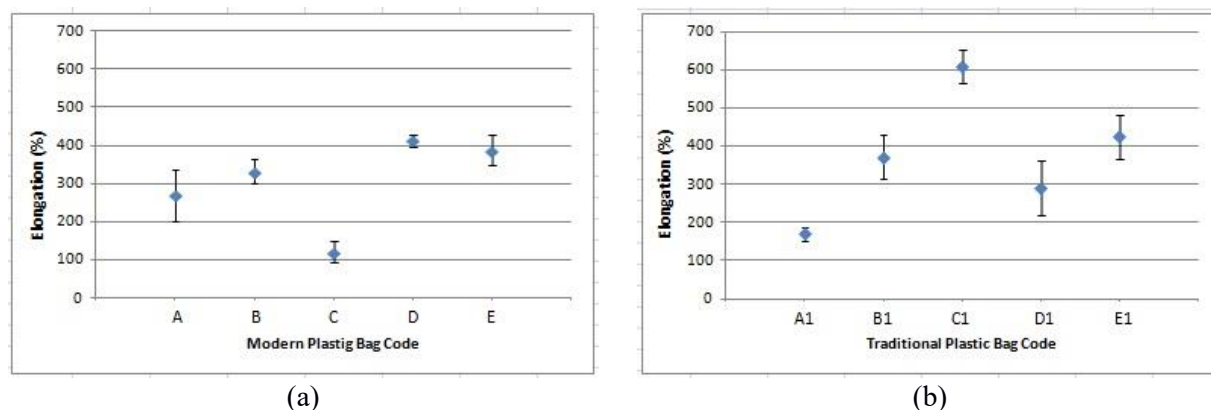(a)   (b)

Figure 7. Elongation of Modern (a) and Traditional (b) Plastic Shopping Bags

Based on the physical and physico-chemical explanation above, the important difference betwen modern retail plastic bag and traditional retail plastic bag relies on inorganic filler content. The inorganic filler content also affect the mechanical performance. Increasing inorganic filler load will improves stiffness of plastic bag hence elongation percentage of modern retail plastic bag lower than traditional retail plastic bag. The slightly difference in tensile strength and tear resistant is probably due to agglomeration of inorganic filler at higher concentration so that lowering the reinforcing ability of filler [7].

According to mechanical performance test result of plastic bag, increasing inorganic filler load in plastic bag will result decreasing mechanical performance. Increasing inorganic filler load more leads to lowering the cost of material by replacing expensive polymer [17].

4.   Conclusion

The assessment and comparison performance between ten plastic shopping bags from modern and traditional retail stores in Jakarta and Tangerang were already done. The performance difference clearly visible in elongation performance. Modern retail plastic bag has lower elongation than traditional retail plastic bag. This difference probably caused by higher inorganic filler load in modern plastic shopping bag.

Acknowledgement

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