IOP Conf. Series: Materials Science and Engineering **429** (2018) 012045 doi:10.1088/1757-899X/429/1/012045

Dyeing Polyurethane Foam by Plant Based Pigment

F Zainuddin[1*], N S Ahmad Fauzi[1], S N F Syed Adam[1]

[1]School of Materials Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis Malaysia

*E-mail: firuz@unimap.edu.my

Abstract. Polyurethane rigid foam composites were produced by addition of plant-based filler as colour pigment. The filler used were turmeric powder, Kumkum powder, Telang's flower powder and dragon fruit peel's powder. These plant-based fillers were chosen due to their strong colour pigment that can enhanced the aesthetic value of the foam. In this study, these fillers were prepared by drying, blending and sieving, in order to obtain fine powder that can be added as particulate filler in polyurethane foams composite. The properties of the composite foam were compared with control PU foam with two variation of filler percentages (10wt% and 12wt%). The Fourier Transform Infrared (FTIR) spectra analysis show that the addition of filler in PU foam did not producing any new functional group, which proven that only physical mixing exists. On the other hand, compressive strength of 12wt% of filler is higher as compared to 10wt% and control PU foam. Morphology analysis by using Optical Microscope reveals that the addition of plant-based filler in PU foam has greatly enhanced the colour of the foam to strong yellow, red and blue respectively.

1. Introduction

Nowadays, it hard to live without coming across with some sort of polymer foams. This cellular material has been used in a wide variety of application such as disposable packaging of fast- food, cushioning of furniture and also in insulation application. Polymer foam started on 1940s when polystyrene was first invented as foam. Several years later, polyurethane (PU) foam was produced on Second World War by Dr. Otto Bayer [1]. PU foam has low thermal conductivity as compared to another polymer foamed that has been used in commercial world. Rigid PU foam were used in wide variety of application such as for sole insulation, coating, construction and many more, due to the unique and excellent combination between thermal insulation and mechanical properties.

Natural dyes have been used since ancient times for dyeing of body, food, walls of caves, textiles, leather and objects of daily use. Early of 16th century was the time when France, Holland and Germany began the cultivation of dye plants as an industry [2]. Natural dyes were used for coloring of textiles till 19th century when synthetic dyes pushed them out [3]. It is only since few decades ago that textile industries have turned to synthetic dyes, but they were so successful that natural dyes currently account only for about one percent of the total amount of dyes used worldwide. Although synthetic dyes are widely used, there are drawbacks that fears the consumers, especially on health effects to human body if exposes to high doses of dyes. Therefore, study on the use of natural dyes as an alternative for filler in polymer foam is needed.

2. Methodology

2.1. Materials
The primary materials to produce PU foam composite are isocyanate, palm oil-based polyol and natural dyes which are dragon fruit's peel, turmeric, Telang's flower and Kumkum powder. It is expected that these fillers will enhance the colour of the foam, from light yellow (control PU) to purple, bright yellow, blue and red, respectively.

2.1.1. Chemical
Methylene diphenyl diisocyanate (MDI) is a dark brown, fused solid. It is soluble in acetone, benzene, and kerosene. For this study, MDI was supplied by Maskimi Polyol Sdn. Bhd. The polyol with the series of R3110 Polygreen's bio-based was supplied by PolyGreen Chemicals. The bio content inside the polyol is 89%.

2.1.2. Plant Based Filler
The natural fillers that have been used are dragon fruit's peels, turmeric, Kumkum and Telang's flower. Generally, these fillers were purchased and taken from local sources. Turmeric and Kumkum powder were used as received, while dragon fruit's peels and Telang's flower were further processed to fine powder form.

2.2. Preparation of Natural Dyes
Natural dyes purchased were in different sized and shape. Therefore, the plant must be processed into powder foam with appropriate particle size. The plant in its original form, especially dragon fruit's peel and Telang's flower cannot be used as filler due to its size and need to be processed to required size. These plants must be cut into thin slices, dried under the sun for 24 hr and further dried in universal oven at 80°C for another 24 hr. Dried plants were then crushed by using blender, and sieved by using 63 microns siever.

2.3. Preparation of PU Foam Composite
The method for PU foam composite preparation was according to [4]. The polyol was first stirred by using overhead stirrer at 2000 rpm for 4 minutes. It must be stirred until its color changes into milky and creamy. Later, isocyanate was added, and the mixture were mixed at 2000 rpm for another 15 minutes. Then specific weight of plant-based powder was added and continues mixed at same speed for 4 minutes. Finally, water was added as blowing agent (5wt%) and continuously stirred for another 4 minutes until the mixture releasing heat that leads to initiation of chemical reaction.
The mixture was then poured into open mold with the dimension of 180 mm x 180 mm x 100 mm. The mold was placed in room temperature for 24 hours. After curing, the samples were taken out from mold for further characterizations.

2.4. Characterizations
There were several characterizations performed in order to analyze the effect of plant-based filler to the properties of the foam composites.

2.4.1. Fourier Transform Infrared Spectroscopy (FTIR)
Natural dyes were analyzed in the powdered form, with the amount of weight was approximately 10 mg. Nevertheless, PU foam composite was tested in bulk foam form, to ensure accurate data provided. The sample was scanned in the scan range of 4000 cm^{-1} to 250 cm^{-1}.

IOP Conf. Series: Materials Science and Engineering **429** (2018) 012045 doi:10.1088/1757-899X/429/1/012045

2.4.2. Compression Test

The compression test was conducted according to ASTM D1621-10 by using the Universal Testing Machine (UTM) Instron 5560 machine. The crosshead speed for compression test was 10 mm/min at 25°C with tolerance 3°C, and the load was applied until the foam was compressed to approximately 80% of its original thickness (height). The sample needed to be cut by using a band saw machine with dimension of 50 mm x 50 mm x 50 mm. The samples were compressed in the direction parallel to foam rise. Five sample of each composite composition were tested, and average value of compression strength were recorded.

2.4.3. Optical Microscope Analysis

Optical microscope analysis was conducted to observe the morphology, relative to the used of fillers in PU foams. It was also performed in order to determine the size of cells and their size distribution. The sample were cut into small size which was 10 mm x 10 mm x 10 mm.

3. Results and Discussions

The FTIR spectrum of PU foam composites shown in Figure 1 to Figure 5. The spectra exhibit the characteristic peaks of urethane bond and some functional group from dyes. As shown in Figure. 1, control PU foam exhibit the wavenumbers ranging from 2100 cm^{-1} to 2260 cm^{-1} attribute to-NCO groups (black box), 1709 cm^{-1} to 1712 cm^{-1} (-CO stretch, in red), 1517 cm^{-1} to1519 cm^{-1} (-NH bend, in green) and 1393 cm^{-1} to1395 cm^{-1} (-OCONH asymmetry stretching, in orange). All compound shows well defined hydroxyl band at range 3570 - 3200 cm^{-1}. According to Nur Azni et al, hydroxyl band is important in miscibility of filler and matrix since polyol and hydroxyl exhibit polar behavior to ease the formation.

Figure 2 shows PU foam composite with turmeric powder as filler. Turmeric is known producing curcumin radical, where the functional group is (-OCH_3) and was detected at 1050 cm^{-1} to 1150 cm^{-1}. As in Figure 3, PU/Telang's flower composite shows peak at 3010 cm^{-1} to 3100 cm^{-1} (=C-H), and for dragon fruit's peels (Figure4), the functional group is (-CO_2H), from ester 1000 cm^{-1} to 1300 cm^{-1} (-C-O). Moreover, Kumkum powder is producing crocin radical, and was detected at 2980 cm^{-1} - 3000 cm^{-1} (-CH stretch), and 1670 cm^{-1} - 1820 cm^{-1} (-C=O).

In general, there are no much differences in peaks from the results obtained due to the same aggregate of chemical and materials. It also can be concluded that the addition of plant filler did not affecting the chemical constituent of polyurethane foam.

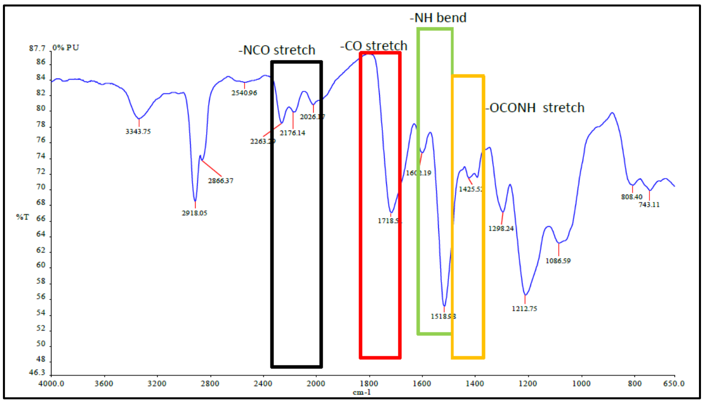

Figure 1: FTIR spectra of control PU foam

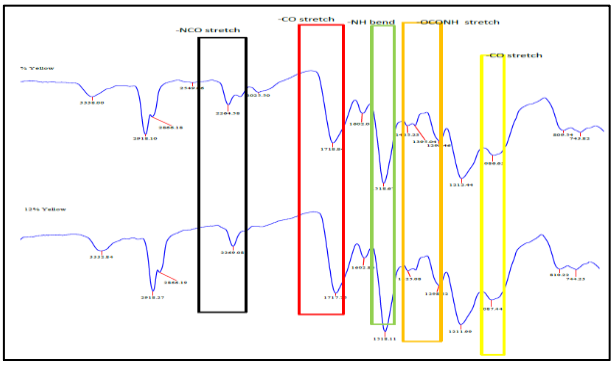

Figure 2: FTIR spectra of PU/turmeric foam composite

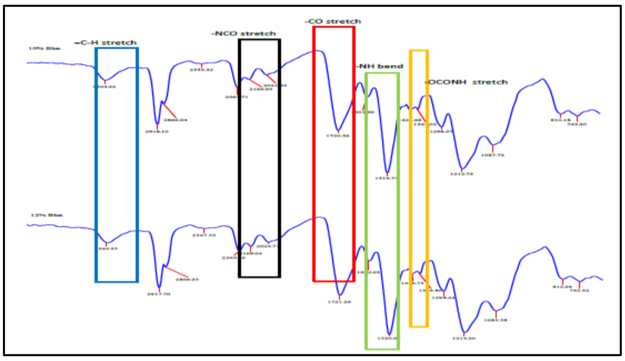

Figure 3: FTIR spectra of PU/Telang's flower composite

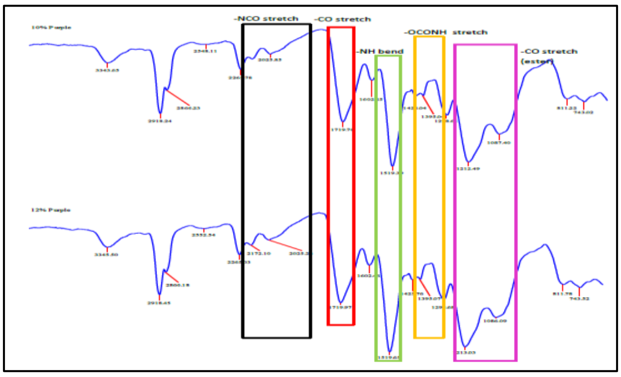

Figure 4: FTIR spectra of PU/dragon fruit's peel composite.

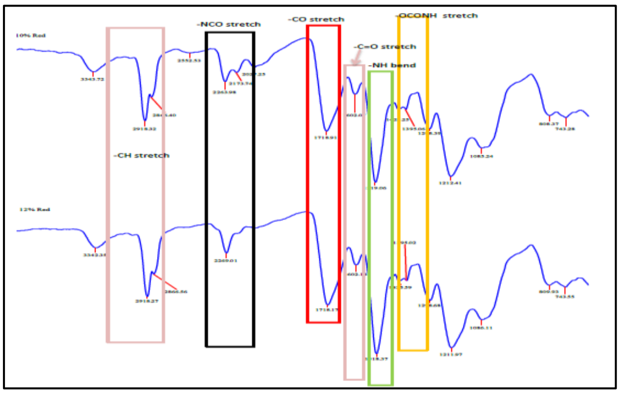

Figure 5: FTIR spectra of PU/Kumkum composite.

Figure 6 shows the compressive strength value of the composite with different percentages of natural dyes. It can be concluded that control PU has the lowest value which is 0.282MPa. As the percentages of natural dyes increases, the compressive strength was also increase. It is believed that plant-based filler was incorporated homogenously in PU foam, attributing to excellent load transfer, thus leads to good improvement of its compression strength property.

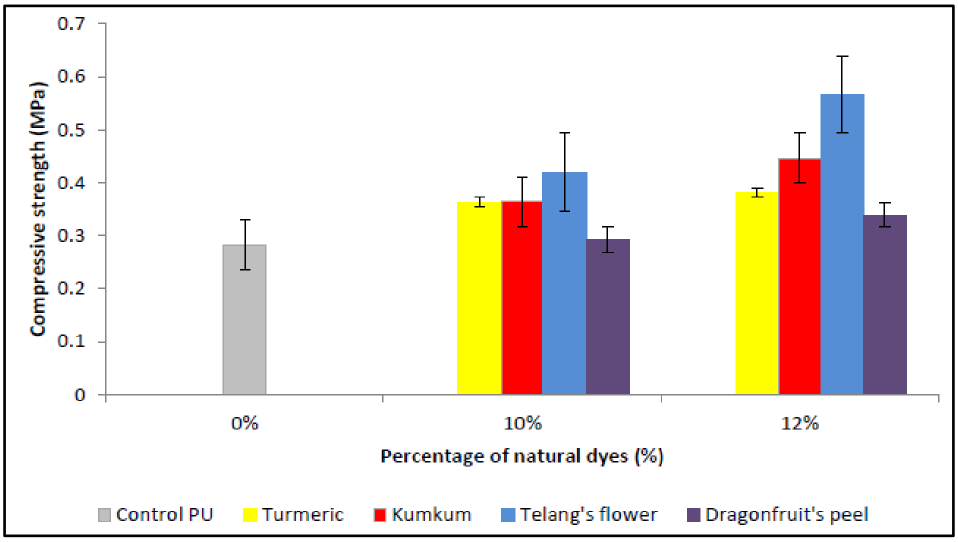

Figure 6: Compressive strength of PU foam composites.

PU foam composite with Telang's flower as filler has the highest compression strength value as compared to the other type of dyes. It is believed that the distribution of the filler inside the composite was at it best in PU/Telang's flower foam. As compared to PU/dragon fruit's peel foam, the compressive strength was the lowest. Dragon fruit's peel have a fiber like structure. Therefore, it might not be able to mixed homogenously with the PU foam.

Optical microscope (OM) result are shown in the Figure 7. It is noticed that almost all cells structure is in spherical shape with many cell wall, which proven that they are closed cells. It was found that the filler was dispersed homogenously inside the foam, with no discovery of agglomerate powder inside cell wall.

IOP Conf. Series: Materials Science and Engineering **429** (2018) 012045 doi:10.1088/1757-899X/429/1/012045

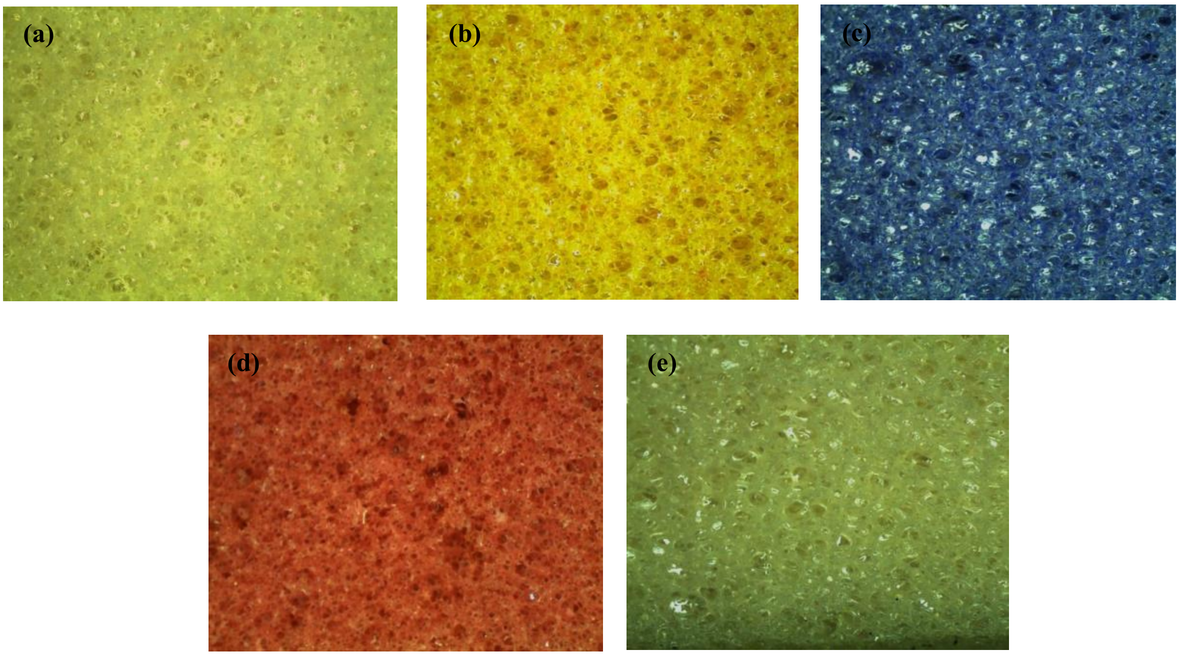

Figure 7: Optical micrograph of PU foam composites; (a) PU foam control, (b) PU/turmeric foam, (c) PU/Telang's flower foam, (d) PU/Kumkum foam, (e) PU/dragon fruit's peel foam

It was clearly shown that the addition of plant-based filler has enhancing the color of the foam. Other that dragon fruit's peel, these plant-based fillers was successfully highlighting the color of the foam, as compared to control PU foam (Figure 7(a)).

4. Conclusion

PU foam composite with variation of colour was successfully produced by incorporating natural dyes from plant-based filler. Compressive strength results show that by increasing the percentages of natural dyes, the strength of PU foam composites increases. The addition of this natural dyes was also found to enhance the colour of PU foam composite, making it suitable to be used in household and children appliances.

References

[1] D Klempner and K C Frisch 1991 *Handbook of Polymeric Foams and Foam Technology* Oxford University Press
[2] G Oertel 1993 *Polyurethane Handbook* Hanser Publisher
[3] M Desroches, M Escouvois, R Auvergne, S Caillol, B Boutevin 2012 *From Vegetable Oils to Polyurethanes: Synthetic Routes to Polyols and Main Industrial Products* Polymer Reviews **52** (1): 38–79.
[4] F Zainuddin, H M Akil, S Ahmad, R Rasid, & S N F S Adam 2014 *Drop weight impact analysis of laminated polyurethane foam/cloisite 30B clay*
[5] M A Nur Azni, A A Sinar, Z Firuz, & A G Supri 2014 *Deformation and energy absorption characteristics of biomass foam composites*