Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2018, 5(4): 236-243

Research Article ISSN: 2394 - 658X

Comparison of Some Mechanical Properties of Injection and Extrusion Moulded Pineapple Leaf Powder Filled High Density Polyethylene

I O Eze and I O Igwe

Department of Polymer and Textile Engineering,
Federal University of Technology, Owerri, P. M. B. 1526, Owerri, Nigeria
innocento4u@yahoo.com

ABSTRACT

Comparison of some mechanical properties of injection and extrusion moulded pineapple leaf powder (PALP) filled high density polyethylene (HDPE) was studied. PALP and HDPE composites were prepared using injection and extrusion moulding techniques respectively. The weight percentages (wt.%) of filler contents investigated were varied as 0, 2, 4, 6, 8, 10 wt.%. It was observed from the results of the mechanical properties carried out on the composites that the tensile strength, tensile modulus, abrasion resistance, and hardness of the composites increased with increases in filler content for all the filler contents investigated both for the injection, and extrusion moulded composites while the elongation at break (EB) for HDPE/PALP composites was found to decrease with increases in filler content for all the filler contents investigated both for the injection, and extrusion moulded composites. The results also showed that the extrusion moulded HDPE/PALP composites exhibited better tensile strength, tensile modulus, hardness, abrasion resistance and flexural strength than the injection moulded HDPE/PALP composites for all the filler contents investigated while the elongation at break (EB) of the extrusion moulded HDPE/PALP composites exhibited lower elongation at break (EB) values than the injection moulded composites for all the filler contents investigated. From the present study, it has been proved that PALP can be used as reinforcing filler in polymer composites and that the use of extrusion moulding technique produced HDPE/PALP composites of slightly better mechanical properties than those produced using injection moulding technique. This has shown that the quality of moulded products depends on the selection of correct processing techniques. Therefore, in processing biocomposites, suitable processing techniques must be carefully selected in order to obtain optimum composite properties.

Keywords: Injection moulding technique, extrusion moulding technique, mechanical properties, pineapple leaf powder, high density polyethylene, composites.

INTRODUCTION

Thermoplastic composites are composites that have a thermoplastic polymer as a matrix. The moulding of thermoplastics can be carried out non-isothermally, i.e., they can be heated rapidly and cooled without any damaging effects to their microstructure. The melt viscosities of polymer thermoplastics are 500 to 1000 times that of the thermosets [1-2]. The natural fibres that can be used to reinforce thermoplastics include wood, cotton, flax, hemp, jute, sisal, banana, pineapple, rice straw, and sugarcane fibres [3]. The greatest advantage of using polymer composites is the improvement on their light-weight, strength and stiffness [4]. If appropriate choices of reinforcement and matrix materials are selected, an improved property that will fit into the desired structure will be obtained. Unlike metals, polymer composites do not break up easily under stress. A small crack in a piece of metal can spread rapidly to cause great problem especially when used in aircraft but polymer composite material will block the crack, share in the stress due to the effect of fibrous materials used for reinforcement. Polymer composites are resistant to heat and corrosion. This is why polymer composites are ideal products for use in boats, spacecraft etc. that are liable to be used in extreme environmental conditions. Composites are durable especially when plastics are used as the matrix material. They provide design flexibility and could be moulded into different shapes as desired [5-6].

The manufacturing processes for the fibre-thermoplastic composites include extrusion moulding, injection moulding, calendaring, thermoforming and compression moulding [7]. The quality of moulded products depends on the selection of correct processing techniques and parameters. The process temperature is of utmost importance, since at temperatures above 200°C, natural fibres start to degrade [7]. Li *et al* [8] determined the appropriate values of injection temperature and pressure for flax fibre reinforced high density polyethylene bio-composites. The results showed that higher fibre content in composites led to higher mechanical strength. An Injection temperature of lower than 192ºC was recommended for better composite quality because at higher temperature, fibre degradation (fibre degradation temperature ≈ 200ºC) might have occurred, thereby leading to inferior tensile properties. In comparison with the injection temperature, the influence of injection pressure was not obvious in this study. However, higher injection pressure was preferred to obtain better composite tensile properties.

The extrusion process for composite production is by far the most common processing method for the production of fibre-thermoplastic composites. The injection or compression moulding technique is used when the processing of a continuous piece is not desired, or a more complicated shape is needed. However, the total weight of product is much less than that obtained with the extrusion moulding [7]. When fillers are added during the extrusion or injection moulding process, changes occur which alter the processing parameters, fibre orientation, and mechanical properties of the product [9].

Many factors influence the performance of natural fibre reinforced composites and these include the nature of fibre, fibre/filler size and content, the presence or absence of coupling agents, processing technique among others. The effect of fibre content on the properties of natural fibre reinforced composites is particularly of importance. It is often observed that increase in fibre content leads to an increase in the tensile properties of composites. Ma *et al* [10] investigated the effects of fibre contents on the tensile properties of micro winceyette fibre reinforced corn starch composites and found that the tensile strength of the composites was approximately trebled when the fibre content increased from 0 to 20 % wt. However, the elongation at break decreased with increase in fibre content. Similarly, Lee *et al* [11] studied kenaf and jute fibre reinforced polypropylene, and found that the tensile strength and Young's modulus increased with increase in fibre content, reached a maximum, and thereafter, decreased with further increase in fibre content. Another important factor that significantly influences the properties and interfacial characteristics of polymer composites is the processing techniques used. Therefore, suitable processing techniques must be carefully selected in order to obtain optimum composite properties [12]. Tungjitpornkull and Sombatsompop [12] studied the tensile properties of E-glass fibre (GF) reinforced wood/PVC (WPVC) composites produced by twin screw extrusion and compression moulding processes and reported that the GF/WPVC composites produced from compression moulding had better tensile modulus than those from other production techniques. The shear stress in compression moulding was lower than that in twin screw extrusion; as a result, there was less thermal degradation of polyvinylchloride (PVC) molecules and less breakage of glass fibre, resulting in longer fibre length in the composites produced by compression moulding. The composite manufactured by compression moulding had higher specific density which resulted in fewer voids in the composites.

The aim of this study is to compare some mechanical properties of injection and extrusion moulded PALP/HDPE composites.

EXPERIMENTAL PROCEDURES

Materials

The materials used in this study include high density polyethylene (HDPE) and pineapple leaf powder (PALP). The HDPE with a density of 0.97g/cm^3, and melt flow index of 9.0 g/10 min. at 170 ^{0}C was sourced from Ceeplast Industris, Aba, Abia State. The pineapple leaves from where the powder that was used as filler in this study was prepared were collected from a pineapple orchard near Umuagwo Polytechnic, Owerri, Imo State, Nigeria. The particle size of the PALP is 0.3mm. Mesh sieve (0.3 mm), cutlass, injection moulding machine (Negri Bossi, Italy), extrusion moulding machine (Qingdao Yifeng Zhongrun, China), instron machine (Instron ltd., United Kingdom), electronic weighing balance (Contech, India), shredding machine, grinding machine, personal protective equipments (PPEs) were some of the processing equipments used in this study.

Preparation of PALP

The pineapple leaves were cut into smaller sizes and sun-dried for fourteen days. The dried leaves were later oven-dried for 24 hrs at 80ºC prior to grinding. A manual grinder was used to grind the chopped dry pineapple leaves into powder. The pineapple leaf powder (PALP) obtained was sieved with a sieve grid of 0.3mm (75 microns).

HDPE/PALP Composites Preparation

Samples of HDPE/PALP composites were prepared by thoroughly mixing 200 g, 198 g, 196 g, 194 g, 192 g and 190 g of high density polyethylene with 0, 2, 4, 6, 8 and 10 wt % filler contents respectively. The formulated blend compositions were each processed at the same temperature (165ºC) using an injection moulding machine. The whole process was repeated using an extruder to process the composites.

Determination of Mechanical Properties

Tensile strength, tensile modulus, and elongation at break of the HDPE/PALP composites were determined using Instron testing machine (Lloyds) according to standard method (ASTM D638). Other properties of the composites determined include abrasion resistance (ASTM D1044) hardness (ASTM D2240) and flexural strength (ASTM D790).

RESULTS AND DISCUSSION

Tensile Properties of High Density Polyethylene Composites

The tensile properties of high density polyethylene containing different amounts of pineapple leaf powder (PALP) as filler were determined in this study. The composites were produced using two processing techniques: injection and extrusion moulding techniques.

Tensile Strength of HDPE/PALP Composites

From Fig. 1, it can be observed that the tensile strength of the composites increased with increase in PALP (filler) content for both injection and extrusion moulded composites for all the filler contents investigated. The observed trend of increase in tensile strength of the composites with increase in filler content may be attributed to two main factors: the better dispersion of filler in the polymer, and filler-matrix interaction [13]. It is evident also from the figure that the HDPE/PALP composites processed through extrusion moulding technique gave slightly higher tensile strength than those processed through injection moulding technique for all the filler contents investigated. This result is similar to the findings of Vineta [14]. Vineta [14] prepared eco-composites using compression, and injection moulded techniques and reported that the flexural, impact, compression and tensile strengths of the injection moulded composites decreased by about 25 % when compared to the strengths of samples prepared by compression moulded technique. The processing technique of polymers has profound effect on the properties of the polymer product. It was observed that the extrusion moulded HDPE/PALP composite exhibited 2.20%, and 3.15% increase in tensile strength at 2 wt%, and 10 wt% filler content respectively when compared with the samples processed through injection moulding technique. This increase in the tensile strength obtainable with extrusion moulded composites may be attributed to one or both of the following reasons: (i) better mixing of the filler and matrix by the screws of the extruder than that of the injection moulding machine and (ii) cold-drawing (observed in extrusion, and not in injection moulding technique) which is a physical treatment that improves the strength and other properties of polymer [15]. At temperatures above Tg (glass transition temperature), a thicker than desired polymer film can be forcibly stretched to many times its length and in so doing the polymer chains become entangled and tend to align in a parallel fashion. This cold-drawing procedure organizes randomly oriented crystalline domains of polymer, and also aligns amorphous domains so that they become more crystalline. In this case, the physically oriented morphology is stabilized and retained in the final product [16].

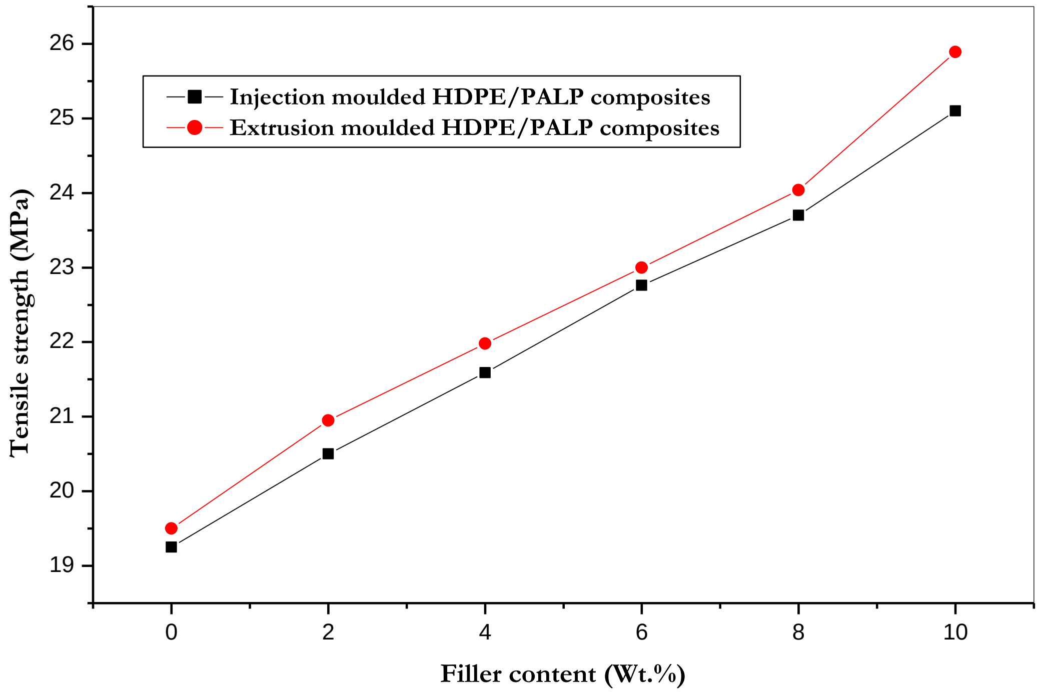

Fig.1 Tensile Strength of Injection and Extrusion Moulded HDPE/PALP Composites

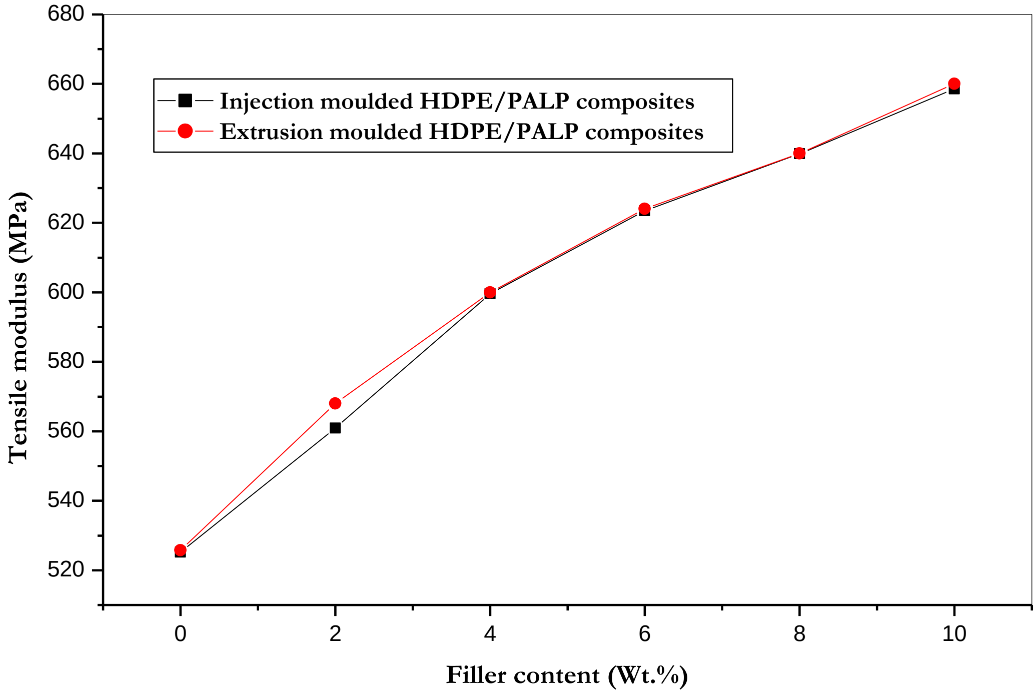

Fig. 2 Tensile Modulus of Injection and Extrusion Moulded HDPE/PALP Composites

Tensile modulus of HDPE/PALP composites

Fig. 2 shows the effect of filler content on the tensile modulus of injection and extrusion moulded HDPE/PALP composites. Like was observed on the effect of filler content on the tensile strength of HDPE/PALP composites, the tensile modulus of the composites was observed to increase with increase in PALP content for both the injection, and extrusion moulded composites for all the investigated filler contents. This increase in tensile modulus is to be expected when rigid fillers are incorporated into softer polymer matrices since at high filler content, the composites will be able to withstand greater load [17]. It can also be observed from Fig. 2 that the extrusion moulded HDPE/PALP composites produced very slight increase in tensile modulus for all the filler contents investigated when compared to the samples processed through injection moulding technique. Vineta [14] reported that the techniques used for producing eco-composites under certain processing conditions induced slight changes on the composites mechanical properties. This result is similar to the ones reported by Avella *et al* [18], and Siaotong *et al* [19]. This very slight increase in tensile modulus may be attributed to either or both of the following reasons, as stated previously in the case of tensile strength of the composites, better mixing of the filler and matrix by the screws of the extruder, or cold-drawing (observed in extrusion, and not in injection moulding technique).

Elongation at break of HDPE/PALP composites

The effect of filler content on the elongation at break of HDPE/PALP composites processed through injection and extrusion moulding techniques respectively can be seen from Fig. 3. The figure also showed that the elongation at break for all the HDPE/PALP composites decreases with increase in filler content for all the filler contents investigated both for injection and extrusion moulded composites. Increasing filler content in HDPE matrix resulted in the stiffening and hardening of the composites. This reduced the matrix resilience and toughness, and led to the lowering of elongation at break [17]. The injection moulded HDPE/PALP composites were observed to have higher elongation at break values for all the filler contents investigated when compared to the extrusion moulded composites. It has been reported that the stiffer the natural fibre (filler), the higher the tensile modulus of composites [19-20]. It was also observed, from the results of this study that as the tensile modulus of HDPE/PALP composites increased, the elongation at break decreased for all the filler contents investigated. Therefore, the reason for the observed trend of the elongation at break values for the injection moulded composites being higher than the elongation at break values for extrusion moulded composites for all filler contents investigated can be inferred from the results of the effect of processing techniques on the tensile strength and tensile modulus of HDPE/PALP composites earlier discussed in study.

Abrasion Resistance of HDPE/PALP Composites

Fig. 4 shows that the abrasion resistance for HDPE/PALP composites increases with increase in filler content for both the injection and extrusion moulded composites for all the filler contents investigated. This study shows that the abrasion resistance of HDPE/PALP composites increases with increase in the tensile modulus of composites. Lee and Wang [21] in their studies on polymer composites had reported increases in the abrasion resistance of composites with increases in the tensile modulus. It can also be observed from Fig. 4 that at 2 wt% filler content, the abrasion resistance of injection, and extrusion moulded HDPE/PALP composites was increased by 12.40%, and 13.63% respectively; while at 10 wt% filler content, the abrasion resistance of injection, and extrusion moulded composites was increased by 17.92%, and 21.20% respectively. The observed slight increase in abrasion resistance of the extrusion moulded composites when compared to the injection moulded ones may be attributed to the fact that composites manufactured by compression or extrusion moulding has higher specific density which resulted in fewer voids in the composites [12]. It may also be attributed to either or both of the following reasons, as previously advanced for other parameters of extrusion moulded samples, better mixing of the filler and matrix by the screws of the extruder or cold-drawing (observed in extrusion and not in injection moulding technique).

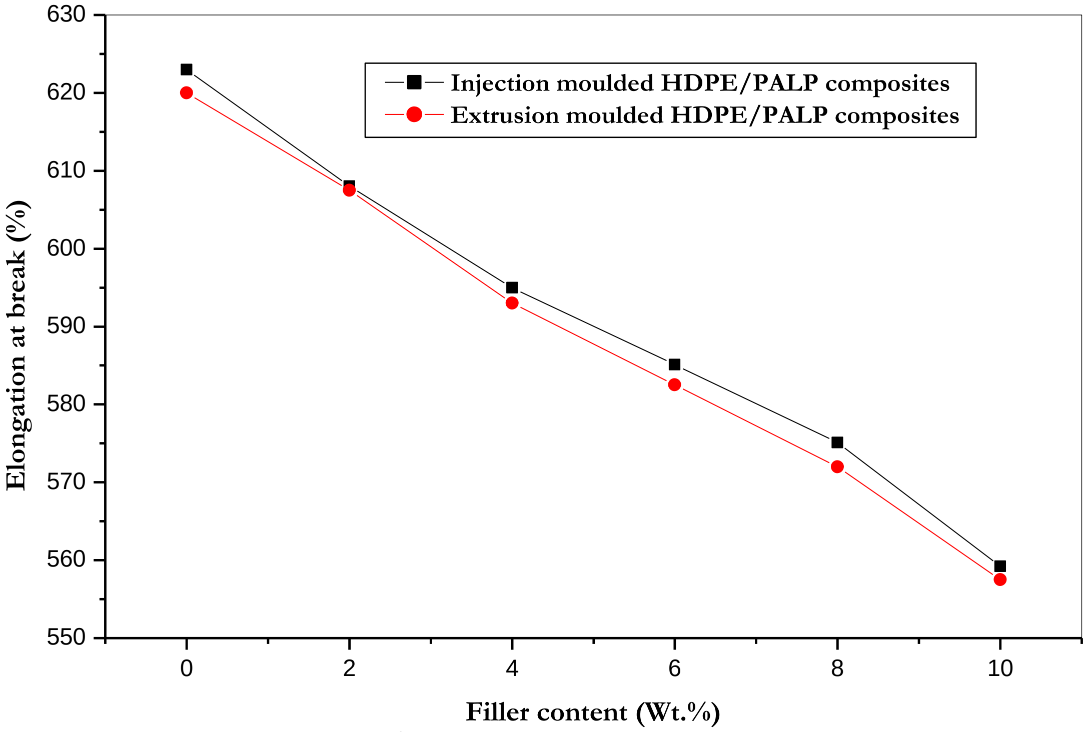

Fig. 3 Elongation at break of Injection and Extrusion Moulded HDPE/PALP Composites

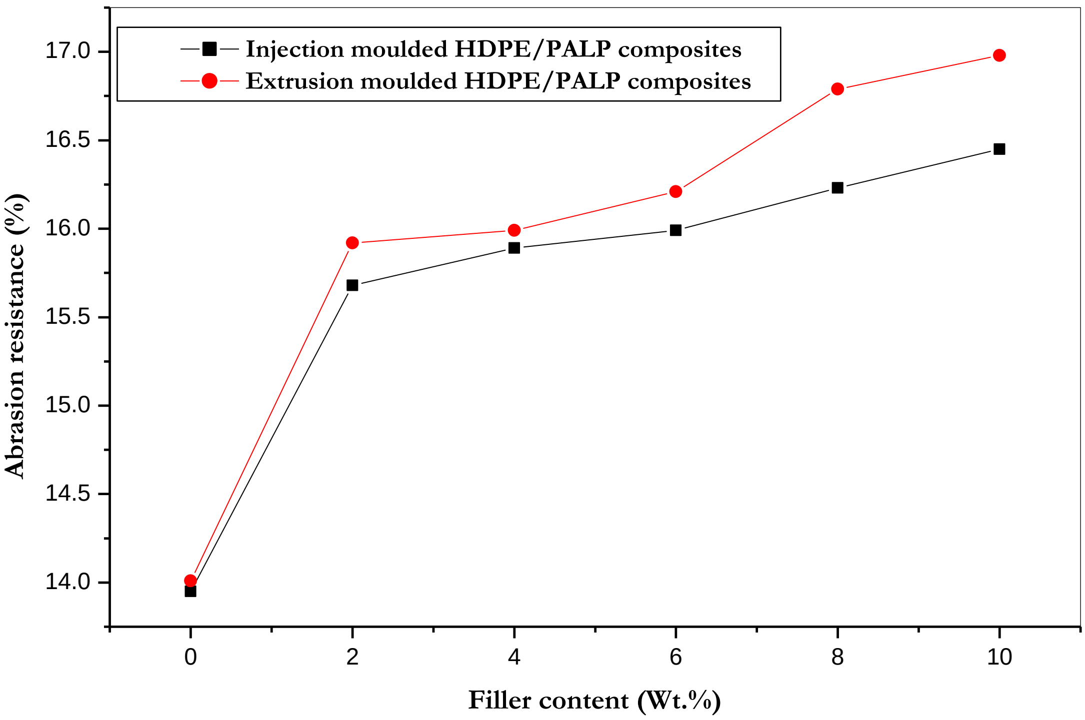

Fig. 4 Abrasion Resistance of Injection and Extrusion Moulded HDPE/PALP Composites

Hardness of HDPE/PALP composites

The hardness (Shore D) of injection and extrusion moulded HDPE/PALP composites are illustrated in Fig. 5. It is evident that the hardness of HDPE/PALP composites increased with increase in filler content for all the filler contents investigated both for the injection and extrusion moulded composites. This observation is in agreement with the findings of Onuegbu and Igwe [22] who reported that at a given filler particle size, the hardness of polypropylene composites increased with increase in the amount of filler incorporated into polypropylene. This was attributed to the stiffer filler increasing the hardness of HDPE. Therefore, the more the incorporation of filler (PALP), the greater will be the hardness of HDPE. From Fig. 5, it can also be seen that extrusion moulded HDPE/PALP composites have higher hardness values than the injection moulded HDPE/PALP composites for all filler contents investigated. The hardness of the extrusion moulded composites at 2 wt% filler content was increased by 14.94%, while that of the injection moulded composites was increased by 14.03%. Similarly, at 10 wt% filler content, the hardness of the extrusion moulded composites was increased by 24.60% while that of the injection moulded composites increased by 23.47%. As advanced earlier on the effects of filler content on tensile modulus of HDPE/PALP composites, the incorporation of fillers into polymers makes the latter harder and stiffer [17]. Therefore, the only plausible reason that can be adduced that is responsible for the variation in hardness of the extrusion and injection moulded HDPE/PALP composites can either be that there was better mixing of the filler and matrix by the screws of the extruder than those of the injection moulding machine, or cold-drawing [15]. It has also been reported that composites manufactured by compression or extrusion moulding had higher specific density which resulted in fewer voids in the composites [12].

Flexural strength of HDPE/PALP composites

The effect of filler content on the flexural strength of injection and extrusion moulded PALP/HDPE composites is shown in Fig. 6. It can be observed that the flexural strength of PALP/HDPE composites increased with increase in filler content for all the filler contents investigated both for injection and extrusion moulded composites [23]. The observed increases in flexural strength with increase in filler content is attributable to the better increased surface area of filler in the matrix and the fact that the filler which is known to have high crystalline content, is strong and stiffer than the matrix and is, therefore expected to share the load applied in the matrix effectively with the crystalline fibrils in it [24]. It was also observed that the flexural strength of the extrusion moulded composites were higher than those of injection moulded composites for all filler contents investigated. As was advanced earlier, the observed increases in flexural strength may be attributed to either one or both of the following: (i) better mixing of the filler and matrix by the screws of the extruder, (ii) cold-drawing (observed in extrusion and not in injection moulding technique) which is a physical treatment (carried out by the use of different rollers with varying speeds) that improves the strength and other properties of polymer [15].

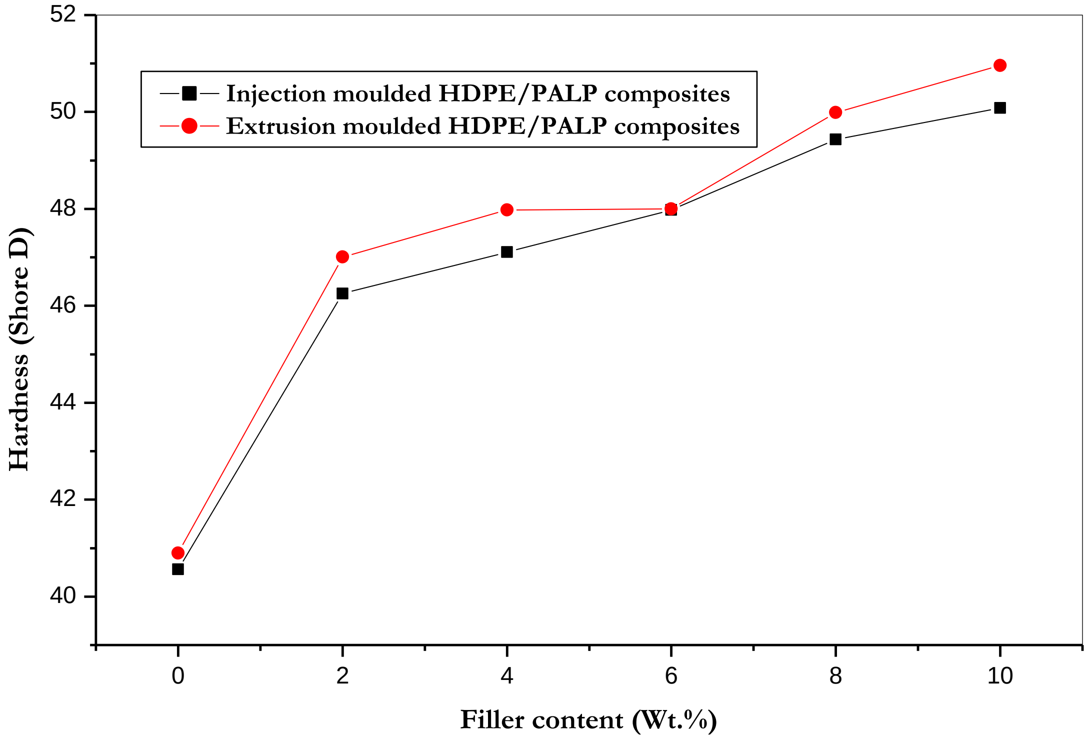

Fig. 5 Hardness of Injection and Extrusion Moulded HDPE/PALP Composites

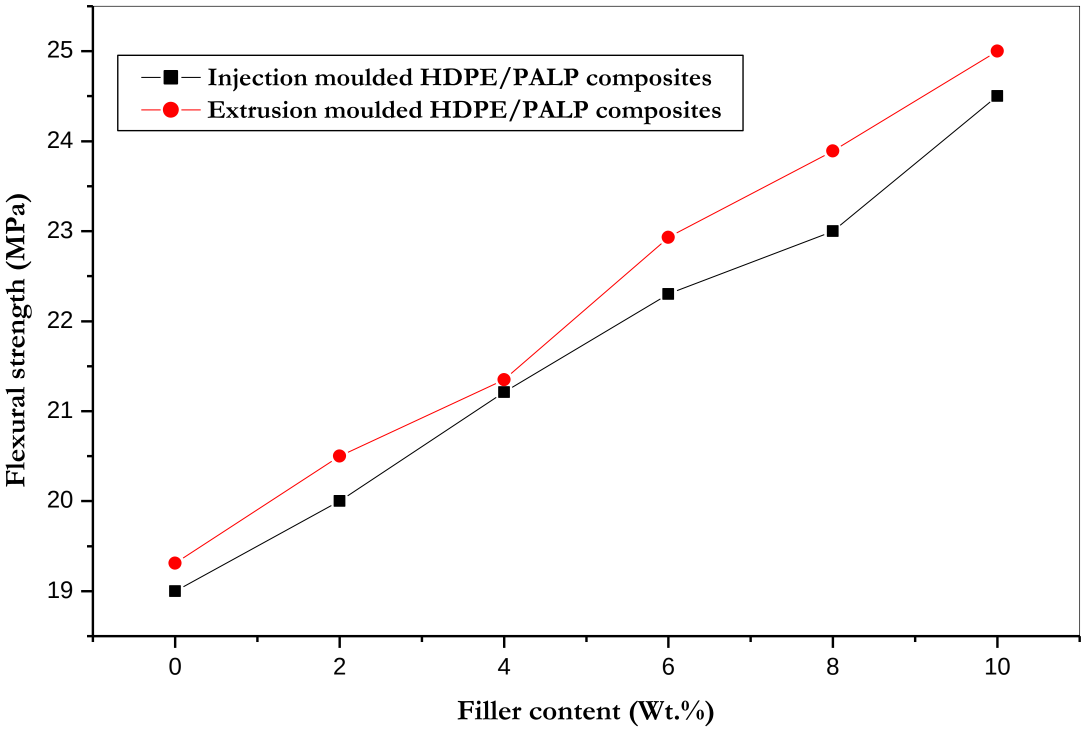

Fig. 6 Flexural Strength of Injection and Extrusion Moulded HDPE/PALP Composites

CONCLUSIONS

From the study, PALP has proved to be a veritable alternative to the use of synthetic fillers in reinforcing plastics. This can be justified from the results of this study which showed that the tensile strength, tensile modulus, abrasion resistance, hardness and flexural strength of HDPE/PALP composites increased with increase in filler content for both injection and extrusion moulded composites. Although, both injection and extrusion moulding techniques are widely used in polymer processing, the present study has also proved that the extrusion moulding technique produced HDPE/PALP composites of slightly better mechanical properties than samples produced using injection moulding technique. This is justifiable from the results of the mechanical tests carried out on the HDPE/PALP composites processed using extrusion and injection moulding techniques which showed that the extrusion moulded composites had higher tensile strength, tensile modulus, flexural strength, abrasion resistance and hardness than composites processed using injection moulding technique for all the filler contents investigated while the injection moulded composites exhibited higher elongation at break (EB) than the extrusion moulded composites for all the filler contents investigated. Therefore, it is recommended that suitable processing techniques must be carefully selected when processing polymers in order to obtain optimum composite properties.

REFERENCES

[1] M Abdelmouleh, S Boufi, MN Belgacem and A Dufresne, Short Natural Fibre Reinforced Polyethylene and Natural Rubber Composites, *Composites Science Technology*, **2007**, 67, 1627-1639.
[2] AK Mohanty, M Misra and LT Drzal, Natural Fibres, Biopolymers and Bio composites, *LLC, Boca Raton, FL, USA: Taylor and Francis Group*, **2005**, 231-245.
[3] D Shuvescha, R Parvin and MD Rafiquzzaman, Fibre Orientation Effect on Mechanical Properties of Coconut Leaf Midrib Reinforced Polymer Composite, *European Journal of Advances in Engineering and Technology*, **2017**, 4 (12), 914-919.
[4] L Mohammed, MNM Ansari, G Pua, M Jawaid and MS Islam, A Review on Fiber Reinforced Polymer Composite and Its Applications, *International Journal of Polymer Science*, **2015**, 685, 104 -116.
[5] KSK Sasikumar, M Dhineshkumar, K Ponappa and MS Kumar, Study of Properties of Coconut Leaf Particle Reinforced Polymer Composite, *International Conference on Science Technology Engineering and Management*, **2016**, 104-127.
[6] MB Sandeep, D Choudhary, MDN Inamdar and MDQ Rahaman, Experimental Study of Effect of Fibre Orientation on the Flexural Strength of Glass/Epoxy Composite Material, *International Journal of Research in Engineering and Technology*, **2014**, 3 (9), 208-211.
[7] C Clemons, Interfacing Wood-Plastic Composites Industries in the U.S., *Journal of Material Science*, **2006**, 16 (6), 1548–1556.

[8] X Li, LG Tabil, S Panigrahi and LG Tabil, A Study on Flax Fibre-Reinforced Polyethylene Biocomposites by Injection Moulding, *Applied Engineering in Agriculture*, **2009**, 25, 525-531.
[9] Y Han-Seung, MP Wolcotta, K Hee-Soo, K Sumin and K Hyun-Joong, Properties of Lignocellulosic Material Filled Polypropylene Biocomposites Made with Different Manufacturing Processes, *Polymer Testing*, **2006**, 25, 668–676.
[10] X Ma, J Yu and JF Kennedy, Studies on the Properties of Natural Fibre- Reinforced Thermoplastic Starch Composites and Carbohydrate Polymers, *Journal of Science and Technology*, **2005**, 62, 119-124.
[11] BH Lee, HJ Kim and WR Yu, Fabrication of Long and Discontinuous Natural Fibre Reinforced Polypropylene-Biocomposites and their Mechanical Properties, Fibres and Polymers, *Polymer Science and Technology*, **2009**, 10, 283-298.
[12] S Tungjitpornkull and N Sombatsompop, Processing Technique and Fibre Orientation Angle Affecting the Mechanical Properties of E-glass Reinforced Wood/PVC Composites, *Journal of Materials Processing Technology*, **2009**, 209, 3079-3088.
[13] KB Sanjaya, Study on Mechanical Behaviour of Polymer Based Composites with and without Wood Dust Filler, *A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of Bachelor of Technology in Mechanical Engineering, Department of Mechanical Engineering National Institute of Technology Rourkela, India*, **2010**, 123-189.
[14] NY Vineta, Preparation and Recycling of Polymer Eco-Composites 1, Comparison of the Conventional Molding Techniques for Preparation of Polymer Eco-Composites, *Macedonian Journal of Chemistry and Chemical Engineering*, **2009**, 28 (1), 99–109.
[15] S Taj, MA Munawar and SU Khan, Review: Natural Fibre Reinforced Polymer Composites and Processing, *Pakistan Academy of Science*, **2007**, 44 (2), 129 –144.
[16] J Moran, V Alvarex, R Petrucci, J Kenny and A Vazquez, Mechanical Properties of Polypropylene Composites Based on Natural Fibres Subjected to Multiple Extrusion Cycles, *Journal of Applied Polymer Science*, **2007**, 103 (1), 227-237.
[17] M Jacob and S Thomas, KT Varughese, Mechanical Properties of Sisal Oil Palm Hybrid Fibre Reinforced Natural Rubber Composites, *Composite Science and Technology*, **2004**, 64, 955-965.
[18] M Avella, G Bogoeva-Gaceva, A Buzarovska, ME Errico, G Gentile and A Grozdanov, Poly (lactic acid)-Based Biocomposites Reinforced with Kenaf Fibres, *Journal of Applied Polymer Science*, **2008**, 108, 3542–3551.
[19] BAC Siaotong, LG Tabil, SA Panigrahi and WJ Crerar, Determination of Optimum Extrusion Parameters in Compounding Flax Fibre Reinforced Polyethylene Composites, *American Society of Agricultural and Biological Engineers*, **2006**, 1238-1431.
[20] L Medina, R Schledjewski and AK Schlarb, Process Related Mechanical Properties of Press Moulded Natural Fibre Reinforced Polymers, *Composites Science and Technology*, **2009**, 69, 1404-1411.
[21] SH Lee and S Wang, Properties of Natural Fibre Reinforced Polypropylene Composites, *Journal of Material Science*, **2006**, 37, 180–191.
[22] GC Onuegbu and IO Igwe, The Effects of Filler Contents and Particle Sizes on the Mechanical and End-Use Properties of Snail Shell Powder Filled Polypropylene. *Materials Sciences and Application*, **2011**, 2, 811-817.
[23] R Yahaya, SM Sapuan, M Jawaid, Z Leman and ES Zainudin, Effects of Fibre Orientation on Mechanical Properties of Kenaf-Aramid Hybrid Composite for Spall-Line Application, *Elsevier, Defense Technology*, **2016**, 12, 52-58.
[24] RM Rowell, JS Han and JS Rowell, Characterization and Factors Effecting Fibre Properties, *Natural Polymers and Agrofibres Composites*, **2000**, 115-129.