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THE POTENTIAL OF DIFFERENT PULPING PROCESSES IN PRODUCTION OF PULP-PLASTIC COMPOSITES (PPC) FROM BAGASSE AND RICE STRAW

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Abstract

Natural fibres are renewable, biodegradable, low-cost, low-density raw materials with high stiffness and strength compared to the other conventional products such as glass, aramid and carbon. There are a large variety of natural fibers such as rice straw, rice husk, wheat straw, corn stalks, palm, bagasse, hemp, flax and other agricultural residues. Natural fibers contain various organic materials (mainly celluloses as well as hemicelluloses and lignin) and there are several chemical treatments such as bleaching, esterification, silane treatment, use of compatibilizer, acetylation, alkali treatment and treatment with other chemicals in order to enhance the fiber matrix adhesion, which improve the physical and mechanical properties of composites.

This study investigates different pulping processes as a novel chemical treatment on bagasse and rice straw fibers and consequently, properties of biocomposites. By pulping processes, the treated natural fibers as a biofiller could be used to produce the new classes of bio composites defined as pulp- plastic composites (PPCs). Different pulping processes which are categorized in mechanical, semi-chemical and chemical methods led to natural fibers with different anatomical and chemical properties such as surface modification and delignification in comparison with untreated fibers. Furthermore, the comparison of natural fibers treated by chemical and mechanical pulping processes and effects of these treatments on physical and mechanical properties of natural fibers are worth considering.

Therefore in this paper, High-density polyethylene (HDPE), bagasse and rice straw fibers treated by four pulping processes (AS-AQ (alkaline sulphite anthraquinone), SODA-AQ (soda anthraquinone), MEA (monoethanolamine) and chemical mechanical pulping (CMP)) and maleic anhydride polyethylene as coupling agent were used to produce pulp plastic composites (PPCs) by injection molding. The physical and mechanical properties of corresponding composites were evaluated according to ASTM standards. The results showed that compared to untreated bagasse and rice straw/HDPE composite, the addition of bagasse and rice straw pulp fibers increased significantly the mechanical properties such as tensile strength and modulus, flexural strength and modulus, and hardness. The chemical pulps-reinforced composites showed better mechanical strengths than that of CMP-reinforced composites, but in some properties, CMP pulp composites have comparable results to the chemical pulp-reinforced composites. Natural fibers (untreated and treated) increased water absorption and thickness swelling of composites compared to pure HDPE. The comparison of PPCs from bagasse and rice straw untreated and treated fibers will be also presented and discussed.

Keywords: Biocomposite, Pulp, Natural fibre, Bagasse, Rice straw

1. Introduction

Wood plastic composites (WPCs) are a relatively new class of materials and one of the fastest growing sectors in the wood composites industry. WPCs have experienced significant market expansion in recent years as a replacement for solid wood, mainly in outdoor applications such as railings, decking, landscaping timbers, fencing, playground equipment, windows and door frames, etc. (Hosseini 2013). With increased wood costs and competition of wood resources from traditional wood sectors, developing

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alternative, cheap, and environmentally friendly natural fiber sources for plastic composite is highly needed (Hosseini et al.

2014). The utilization of lignocellulosic material, such as wood or nonwood as a reinforcing component in polymer composites (thermoplastic or thermoset), has received considerable attention particularly for price-driven/high-volume application (Felix and Gatenholm 1991, Joseph et al. 1996, Bledzki et al. 1996, Gassan and Bledzki 1997, Rozman et al. 1999, Rozman et al. 2001). This development has been brought about by several advantages offered by lignocellulosic materials, such as: (1) low density, (2) low cost, (3) non-abrasive nature, (4) safe fiber handling, (5) high possible filling levels, (6) low energy consumption, (7) high specific properties, (8) biodegradability, (9) a wide variety of fiber types, (10) recyclability, and (11) generation of a rural/agricultural based economy (Mapleston 1997, Scheller 1996). As can be seen by the recent trends, lignocellulosic materials have been the subject of intensive studies in producing fiber-reinforced plastic (Felix and Gatenholm 1991, Joseph et al. 1996, Bledzki et al. 1996, Gassan and Bledzki 1997, Rozman et al. 1999, Rozman et al. 2001, Rozman et al. 1998, Valadez-Gonzalez 1999, Marcovich et al. 1998, Gassan 2002, Marcovich 2001a,b)

Blending of different polymers to achieve superior properties is a widely used process (Park 2008). Solution blending is one of the processes that are used for blending varieties of polymers and making polymer composite (Deka and Maji 2010, Deka et al. 2011). But the major problems to make composite are the immiscibility among different polymers and decrease in interfacial adhesion between polymers and wood. This results in the formation of inferior composites. In order to improve the miscibility among the polymers as well as with wood, a third component called compatibilizer is used (Ashori 2008). Compatibilizer is such a compound which can interact with the hydrophobic polymer through their non polar group and with the hydrophilic wood flour (WF) through their polar group. This leads to an improvement in interfacial adhesion that enhances the properties (Chiu et al. 2010). Different types of compatibilizer like glycidyl methacrylate (GMA), polyethylene grafted glycidyl methacrylate (PE-g-GMA), maleic anhydride grafted polypropylene (MAPP), maleic anhydride grafted polyethylene (MAPE), etc. are widely used to enhance the compatibility among different polymers and WF (Devi and Maji 2007, Dikobe and Luyt 2007, Kim et al. 2007).

In general, the low compatibility of natural fibers with the hydrophobic polymeric matrices persists as their major disadvantage. In spite of a small cost increase, fiber surface treatments may be able to partially overcome these limitations. Simple treatments such as mercerization (Vazquez et al. 1999), heat treatment (Sapieha et al. 1989), sizing (Mutjé et al. 2006) or refining (Nakagaito and Yano 2004) have been attempted with discreet positive effects. More recently, newer treatments have been reported to improve the fiber/matrix compatibility in natural fiber composites. Corona discharges (Belgacem et al. 1994), treatment with high-frequency ultrasounds (Gadhe et al. 2006), vacuum ultraviolet- induced surface oxidation (Hollander et al. 1994, Kato et al. 1999), graft copolymerization (Mondal et al. 2002), treatment with silanes (Gironès et al. 2007) and other chemicals have been positively applied. One of the most popular treatments is alkaline treatment (Rozman et al. 1998, Valadez-Gonzalez et al. 1999, Marcovich et al. 1998, Gassan 2002, Marcovich 2001a,b, Gassan and Bledzki 1999). According to Bledzki and Gassan (Bledzki and, Gassan 1999), alkaline treatment of natural fiber would make the fibrils more capable to rearrange themselves along the tensile deformation.

Soda anthraquinone (SODA-AQ), alkaline sulfite anthraquinone (AS-AQ) and Monoethanolamine (MEA) are the most important chemical pulping methods to treat lignocellulosic non-wood natural fibers. SODA-AQ pulping is a promising and environmentally friendly method compared to sulphur based processes: Kraft and Sulphate (Khristova et al. 2002). SODA-AQ pulping is categorized as alkaline pulping processes with using mainly NaOH and partial anthraquinone (AQ) in cooking liquor. Alkaline sulphite anthraquinone (ASAQ) pulping is another alkaline pulping process with cooking liquor consisting of a mixture of Na2SO3 and NaOH which is able to delignify lignocellulosic materials, particularly in present of anthraquinone (AQ). The extent of delignification depends on the lignin structure as well as on the adjusted Na2SO3 to NaOH ratio. Monoethanolamine (MEA) pulping process is an organosolv pulping process which has appropriate performance on lignocellulosic non-wood natural fibers (Hedjazi et al. 2009). The most important advantage of MEA pulping of annual plants is the direct MEA recovery by distillation. After distillation of MEA, the residual organic matter could be used either as chemical feedstock or as nitrogen containing organic fertilizer, which, contrary to nitrogen in minerals, has slow-release long-term effects because nitrogen is gradually released by microbial degradation of the carrier material. The most prominent feature of MEA pulping is the exceptionally good preservation of hemicelluloses resulting in unusually high pulp yield. Green and Sanyer (1982) presumed that carbohydrates in the presence of MEA are stabilized against peeling reactions by reduction of reducing end groups. Compared to the SODA pulping, MEA pulping gives 12% higher yield (Hedjazi et al. 2009). The chemical-mechanical pulping (CMP) process has the advantages of a mild chemical treatment with cooking liquor consisting of a mixture of

Na2SO3 and NaOH and of high pulping yield compared with the chemical pulping process. Additionally, a lower refining energy is required in the CMP process than in mechanical pulping and this is because of chemical treatment in chemical-mechanical pulping (CMP) process.

The objective of present study is to investigate the influence of different pulping processes as treatments of bagasse and rice straw fibers on the physical and mechanical properties of pulp plastic composites (PPCs) and presentation a comparative study on performance of bagasse against rice straw as natural fiber reinforcement factor in biocomposites.

2. Materials and Methods

2.1. Materials

Injection molding grade high-density polyethylene (HDPE) was supplied by Jam Petrochemical Co. (Iran), with melt flow index of 18 g/10min and density of 952 kg/m^3. Maleic anhydride polyethylene (MAPE), as a coupling agent was obtained from Kimiajavid chemical products (Iran), with trade name PE-G 101, melt flow index of 50-80 g/10min, and maleic anhydride content of 0.8-1.2 %. The bagasse fibers were provided by Pars Paper Co., Khuzestan province, south west of Iran. Bagasse fibers were ground into flour with particle size of 40 mesh by screening. Rice straw was obtained from rice farms of north of Iran. The rice straw was cut into shorter length of 5-7 cm to incorporate in pulping processes. Bagasse and Rice straw pulp fibers which are treated by pulping processes (AS-AQ, SODA-AQ, MEA, and CMP) were investigated in this study and both of them were ground into flour subsequently.

2.2. Sample Preparation

Bagasse and Rice straw fibers turned to pulps by four pulping processes under different pulping conditions including various cooking time and chemical ratio. However, the optimum pulping conditions which used to produce pulp plastic composites are given in tables 1 and 2. Pulps were dried in an oven at 103±2 ºC for 24 hours. Polymer to fibers ratio for all reinforced composites were 60:40 wt.%. MAPE amount was reduced from polymer amount. Formulation of the composites and abbreviations used for the corresponding composites are given in Table 3.

Table 1. Pulping conditions and the properties of produced bagasse pulps

Process	Abbreviation	Features			
		Time (Min)	Yield (%)	Kappa	Details
Alkaline sulphite anthraquinone	AS-AQ	90	62.16	12.3	16% alkalinity, NaOH to Na_2S ratio 50:50, AQ:0.1%, 160°C
Sodium hydroxide anthraquinone	SODA-AQ	90	61.44	11.45	20 % alkalinity, AQ:0.1 %, 160°C
Monoethanolamine	MEA	90	76.8	12.5	MEA to H_2O ratio 75:25, 160°C
Chemi- mechanical pulping	CMP	30	86.4	-	NaOH to Na_2SO_3 ratio 4:10 on the basis of OD bagasse and NaOH, 160°C

Table 2. Pulping conditions and the properties of produced rice straw pulps

Process	Abbreviation	Features			
		Time (Min)	Yield (%)	Kappa	Details
Alkaline sulphite anthraquinone	AS-AQ	90	50	20	16% alkalinity, NaOH to Na_2S ratio 20:80, AQ:0.1%, 160°C
Sodium hydroxide anthraquinone	SODA-AQ	45	49.8	19	16 % alkalinity, AQ:0.1 %, 160°C
Monoethanolamine	MEA	30	55.25	18	MEA to H_2O ratio 50:50, 160°C
Chemi- mechanical pulping	CMP	30	85	-	NaOH to Na_2SO_3 ratio 8:18 on the basis of OD bagasse and NaOH, 160°C

Table 3. Composition of the studied formulation

Composites *	Bagasse (wt.%)	Bagasse pulp (wt.%)	Rice straw (wt.%)	Rice straw pulp (wt.%)	MAPE (wt.%)	HDPE (wt.%)
PE	-	-	-	-	-	100
PE/B	40	-	-	-	5	55
PE/AS-AQ	-	40	-	-	5	55
PE/SODA-AQ	-	40	-	-	5	55
PE/MEA	-	40	-	-	5	55
PE/CMP	-	40	-	-	5	55
PE/R	-	-	40	-	5	55
PE/AS-AQ	-	-	-	40	5	55
PE/SODA-AQ	-	-	-	40	5	55
PE/MEA	-	-	-	40	5	55
PE/CMP	-	-	-	40	5	55

* PE:HDPE, B:Bagasse, AS-AQ:Alkaline sulfite anthraquinone, SODA-AQ:Soda anthraquinone, MEA:Monoethanolamine, CMP:Chemical mechanical pulping, R:Rice straw

Composites were prepared by following processes:

The compositions were extruded by Collin twin screw extruder (screw speed of 60 rpm, L/D 16, Germany, 1990), then they were grounded to prepare the granules using a pilot scale grinder (WIESER, WGLS 200/200 model). Experimental specimens were prepared by injection molding (Injection pressure 100 kg/m^2, temperature 180 C°, Imen Machine, Iran) according to ASTM standard. Dimension of specimens for tensile and flexural properties were 165×19×3.2 and 100×12×5 mm, respectively.

2.3. Mechanical Testing

Injection-molded specimens were tested following ASTM standards, D 638 for tensile properties, D 790 for flexural properties, and D 256 for notched Izod impact strength. The flexural properties were measured in three-point bending tests. Flexural and tensile tests were conducted using an Instron Universal Testing Machine (model 4486) at crosshead speed of 8 mm/min at room temperature. Impact test was performed by a digital impact test machine (SANTAM, SIT-20 D model) using conventional V notched specimens. Three replicates were tested for each property and each formulation.

2.4. Physical Testing

Physical properties, namely, water absorption (WA) and thickness swelling (TS) were tested in according to ASTM D 570. Before testing, the weight and thickness of each specimen were measured. Conditioned specimens of each type of composite were soaked in distilled water at room temperature for 24 hours. For each measurement, specimens were removed from water, patted dry and then measured again. Each value obtained represented the average of three specimens. WA and TS were calculated according to Eqs. (1) and (2).

$$WA\ (\%)\ =\ \frac{W_{f-}W_i}{W_i}\times 100 \quad \textbf{(1)}$$

$$TS\ (\%)\ =\ \frac{T_{f-}T_i}{T_i}\times 100 \quad \textbf{(2)}$$

Where W_f (gr) and T_f (mm) are the weight and thickness at given time, respectively and W_i (gr) and T_i (mm) are the initial weight and thickness, respectively.

One-way variance of analysis was conducted using SAS statistical software (9.1 version). The Duncan test, at the 99% confidence level, was used for comparing and grouping of the mean values.

3. Results and Discussion

3.1. Tensile Properties

The effect of bagasse and rice straw pulps content on the tensile strength and modulus of composites are presented in Fig. 1. Natural fibers have higher modulus compared to the HDPE and it is expected to have higher modulus values when the amounts of them are increased in the matrix (Dönmez Çavdar et al. 2015). Bagasse and rice straw fibers (in both form of treated and untreated) led to significant increase of tensile strength and modulus of natural composites compared to pure HDPE sample (Fig. 1). The addition of natural fibers resulted in a reinforcement of the HDPE matrix in terms of stiffness and strength (Migneault et al. 2015).

Alkali treatment leads to an increase in tensile strength and modulus of composites. These changes in mechanical properties are affected by modifying the fiber structure, basically via the crystallinity ratio, degree of polymerization, and orientation (Gassan and Bledzki 1999). It is also noteworthy that the AS-AQ, SODA-AQ, MEA, and CMP bagasse fibers showed similar performance in both tensile strength & modulus and there is no clear difference concerning tensile strength and modulus between chemical and mechanical pulps. Untreated rice straw and CMP rice straw composites showed similar results of tensile modulus and also minimum value among rice straw reinforced composites. By contrast, AS-AQ and SODA-AQ rice straw composites reached to maximum performance.

According to Fig. 1a, the maximum values of tensile modulus (4076.2 MPa) belong to PE/CMP bagasse composite. As it was expected, the minimum value of tensile modulus (1235.4 MPa) belongs to pure HDPE. Addition of AS-AQ rice straw pulp to composites demonstrated the maximum values of tensile modulus (3648.6 MPa). Generally, composites which are reinforced by both treated bagasse and rice straw fibers with AS-AQ and SODA-AQ pulping processes shown effective results between others. This is due to role of anthraquinone (AQ) in pulping processes by improving pulping factors.

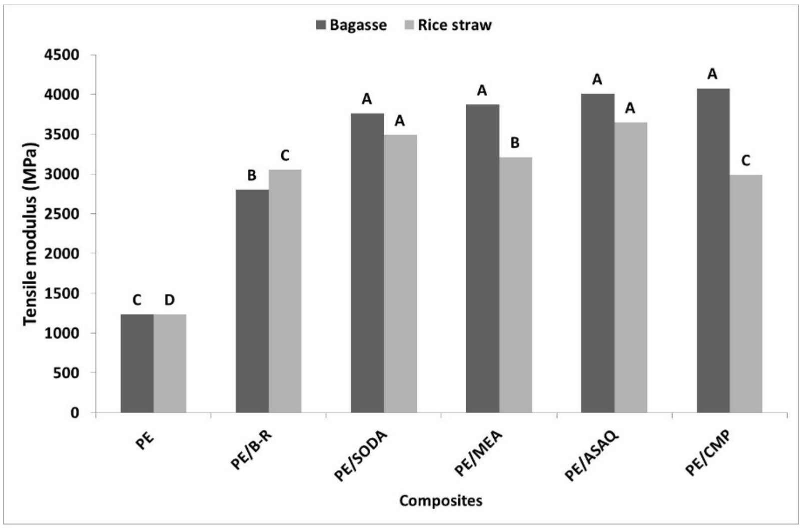

Figure 1a. Tensile modulus as function of bagasse and rice straw pulps

According to Fig. 1b, addition of natural fibers led to significant and positive effect on tensile strength of pulp plastic composites compared to pure HDPE with minimum value of tensile strength (22.71 MPa). From Fig. 1b, MEA fibers filled composite containing bagasse fibers reached to maximum tensile strength (44.87 MPa) among all biocomposites (both bagasse and rice straw reinforced composites). Fig. 1b also shows that AS-AQ fiber filled composite containing treated rice straw exhibited the highest tensile strength (32.74 MPa) compared to other rice straw reinforced composites. The tensile strength of oil palm empty fruit bunch (EFB) pulp polypropylene composites showed improvement as the NaOH content in the treatment was increased (Tay et al. 2010). However, the results of tensile strength demonstrated higher performance of bagasse filled composites compared to rice straw reinforced composites. Compared to that of chemical pulp reinforced HDPE composites, the better strength of CMP reinforced HDPE composites are rather surprising, because it is well known that chemical pulps are preferred reinforcing fiber source for paper products prepared from CMP in paper industry. By contrast, mechanical pulping processes such as chemical-mechanical pulping (CMP) and thermal-mechanical pulp (TMP) show higher reinforcement in polymer composite; this improvement is result of more remained lignin is mechanical pulping processes in comparison to chemical pulping processes. Other researchers reported similar results that TMP-reinforced PP composites have the highest tensile strength compared to bleached Kraft pulp (BKP) PP composites (Li and Sain 2003).

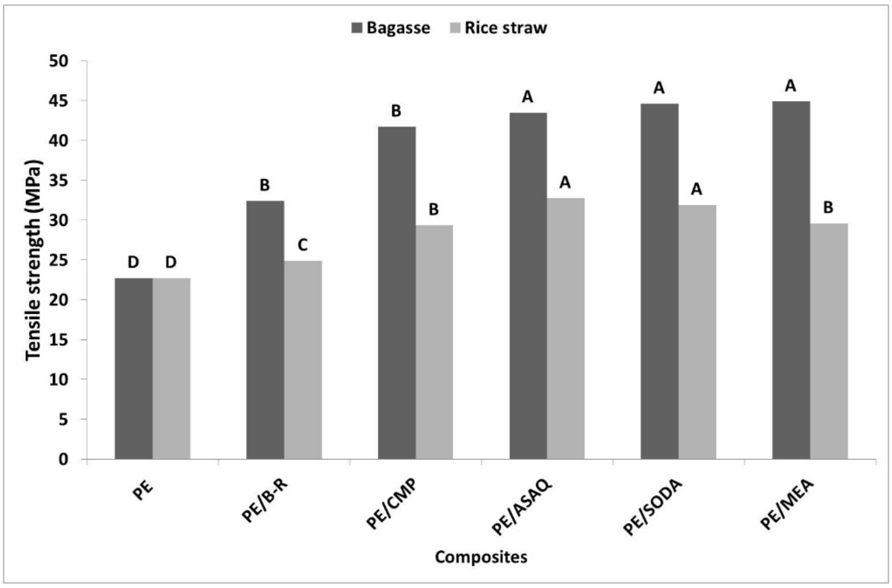

Figure 1b. Tensile strength as function of bagasse and rice straw pulps

3.2. Flexural Properties

Flexural strength and modulus of pulp plastic composites compared to untreated fiber composites which could be considered as common wood-plastic composites and pure HDPE are shown in Fig. 2. The addition of untreated fibers and both bagasse and rice straw fibers which were treated by different pulping processes led to noticeable increase in flexural strength and modulus results. This is due to the fact that the natural fibers have higher modulus than polymer matrix (Mengeloğlu and Karakus 2008, Bouafif et al. 2009, Dönmez Çavdar et al. 2011). The results of flexural modulus showed two different trends for bagasse and rice straw reinforced composites (Fig. 2a). On the one hand, the minimum flexural modulus of pulp plastic composites containing bagasse fibers belongs to untreated bagasse-HDPE composite (2158.11 MPa) and the addition of treated bagasse fibers by pulping processes led to significant increase in flexural modulus of composites with maximum value of 2803.89 MPa for CMP bagasse composite (Fig. 2a). On the other hand, untreated rice straw composite with maximum flexural modulus of 2953 MPa showed the best performance of flexural modulus among all bio-composites. As it is obvious from figure 2a, all of pulping processes as rice straw treatments demonstrated noticeable decrease and negative effect on flexural modulus of rice straw composites. In term of rice straw treated composites, chemical pulping processes including SODA-AQ, AS-AQ, and MEA pulping processes showed higher flexural modulus compared to CMP-rice straw composite. Chemical pulping processes led to more delignification and solubilization of lignin and subsequently, higher fiber strength. Cellulose was reported to be positively related with stress transfer and benefit the mechanical strength of the polymer composites (Shebani et al. 2009, Liu et al. 2014, Migneault et al. 2014).

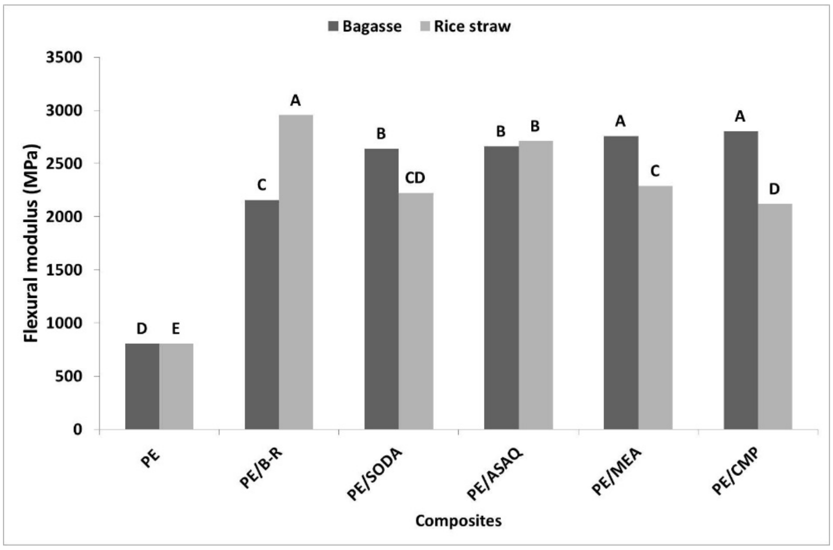

Figure 2a. Flexural modulus as function of bagasse and rice straw pulps

As shown in Fig. 2b, the minimum values of flexural strength belong to pure HDPE (26.55 MPa) and untreated bagasse and rice straw composites which are 45.79 and 40.49 MPa, respectively. Flexural strength results of composites demonstrated that bio-composites with treated fibers by pulping processes shown better performance compared to untreated natural fiber composite and pure HDPE in both cases of bagasse and rice straw filled composites (Fig 2b). The chemical treatment of fiber improved the adhesion between fiber surface and polymer matrix by modifying fiber surface and also increasing fiber strength and their mechanical properties (Li et al. 2007). MEA and AS-AQ bagasse composites depicted maximum (61.6 MPa) and minimum (57.88 MPa) flexural strength values among other pulping processes. By contrast, AS-AQ rice straw composite showed the highest flexural strength (44.87 MPa) and other treatment methods had not significant difference in flexural strength (Fig 2b). An alkali treatment applied on different tropical wood polymer composites improved the strength of up to 16% and the modulus of 13% maximum (Islam et al. 2012). The alkaline impregnation may cause fiber fibrillation and increase adhesion between fiber and polymer matrix (Bisanda and Ansell 1991, Mohanty et al. 2000, Habibi et al. 2008). This is also supported by some researchers who studied on the effects of alkaline treatment on properties of reinforced low density polyethylene composites (Ikhlef et al. 2012).

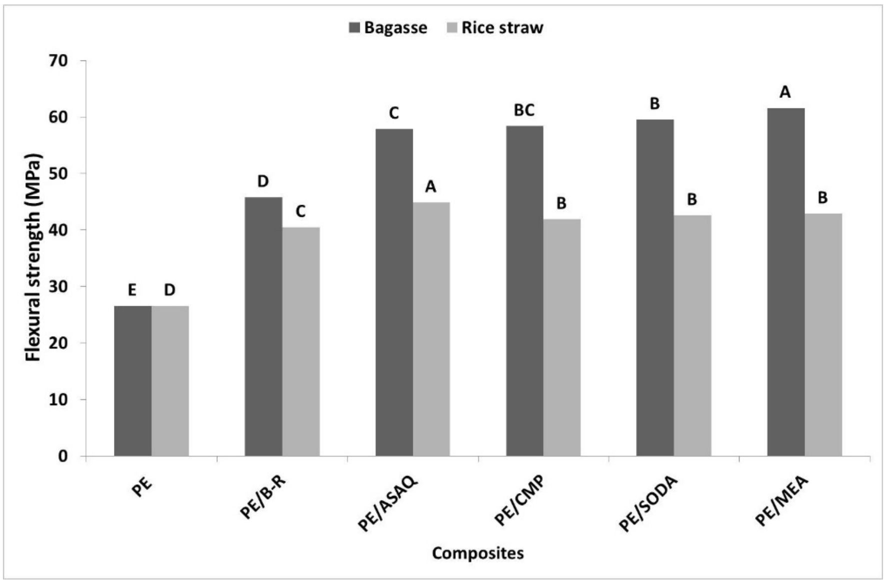

Figure 2b. Flexural strength as function of bagasse and rice straw pulps

3.3. Impact Strength

Impact strength values of the four types of HDPE/pulps fibers composites for both bagasse and rice straw/HDPE composite are shown in Fig. 3. As it can be seen in Fig. 3, the addition of all types of fibers (treated and untreated) decreased the impact strength of HDPE matrix, but untreated bagasse composite (B/PE) showed so close impact strength value (60 J) to pure HDPE (60.88 J). This negative effect may be ascribed to the reduction of polymer matrix content and poor compatibility between the fibers and polymer matrix. Decreasing of impact strength values by addition of natural fibers are observed in many studies (Klyosov 2007, Mengeloğlu and Karakus 2008, Basiji et al. 2010, Hosseini et al. 2014). Different types of pulps showed no significant influence on impact strength of rice straw composites compared to untreated rice straw reinforced composite (Fig 3). However, all types of bio-composites counting treated and untreated rice straw fibers showed significant and higher values of impact strength compared to pure HDPE and also other bagasse filled composites. The maximum impact strength value was related to SO-AQ, AS-AQ, MEA, and untreated rice straw with 74 J. the Izod impact strength of CMP rice straw composite and pure HDPE were 73 and 60.88 J, respectively.

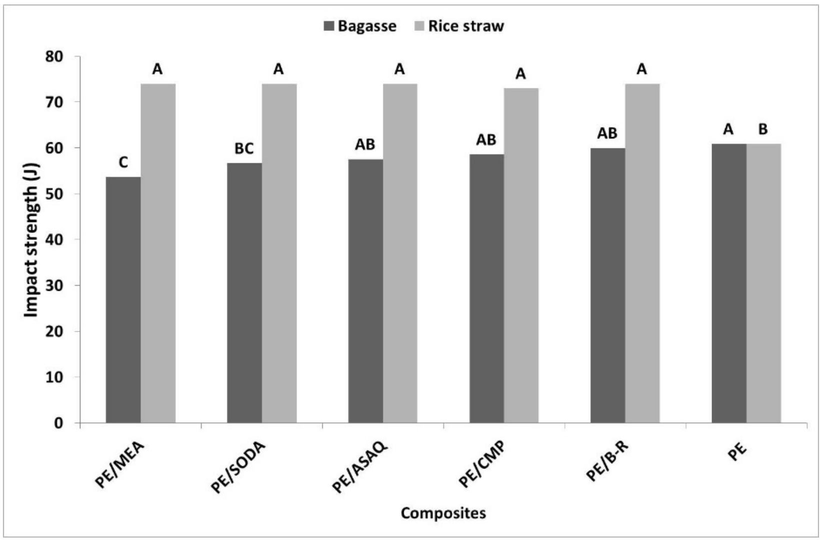

Figure 3. Comparison of impact strength of the composites as function of bagasse and rice straw pulps

3.4. Water Absorption

The water absorption results of pure HDPE and fiber reinforced composites containing bagasse and rice straw are shown in Fig 4. Mechanical properties of composites are known to be greatly affected by the presence and distribution of water, and this distribution should be taken into consideration during testing (Gnatowski et al. 2015). The value of water absorption capacity of pure HDPE (0.12 %) was significantly increased after the addition of pulps and untreated fibers into the pure HDPE for both bagasse and rice straw composites. The hydrophilic nature of natural fibers (free hydroxyl groups) caused an increased in the water absorption. These hydroxyl groups strongly interact with water molecules by hydrogen bonding and then favor water absorption by fibers (Pouzet et al. 2015). AS-AQ, SODA, and CMP bagasse composites exhibited almost same values of water absorption, whereas MEA bagasse composite showed the highest WA (0.46 %) compared to other pulp plastic composites due to high hemicelluloses content of this type of pulp. The addition of treated and untreated rice straw fibers into HDPE matrix led to no significant change of WA among all types of natural fiber reinforced composites. However, untreated rice straw composite showed maximum WA (1.5 %), whereas AS-AQ rice straw composite demonstrated the minimum value of water absorption (1.19 %), (Fig 4). The different trend in mentioned composites is due to fiber properties, agglomeration of their fibers and consequently, formation of composites. It is noteworthy from Figure 4 that all water absorption values of bagasse composites were less than 0.5 %, whereas WA values of rice straw reinforced composites were in range of 1.19-1.5 %.

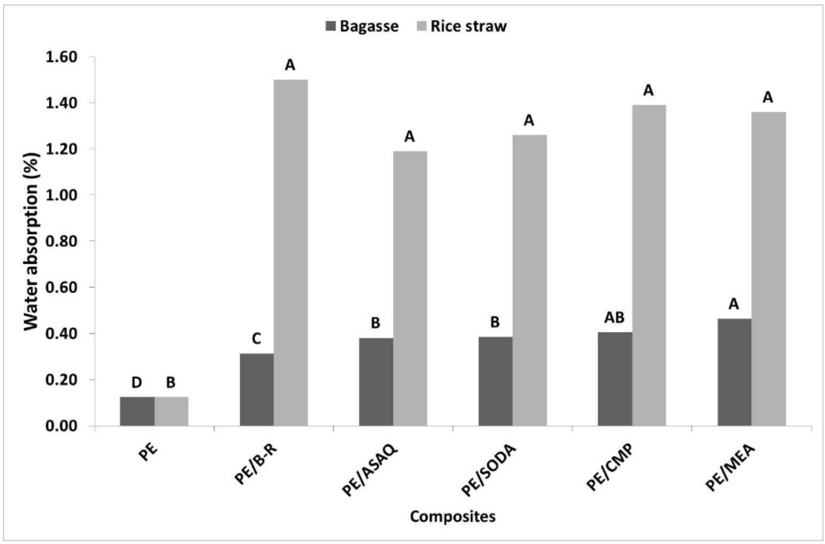

Figure 4. Comparison of water absorption (WA) of the composites as function of bagasse and rice straw pulps

3.5. Thickness Swelling

Fig. 5 depicted the thickness swelling (TS) values of natural fibers/HDPE composite and pure HDPE. As shown in Fig. 5, by addition of both bagasse and rice straw fibers and pulps into HDPE; the thickness swelling values are increased. The increasing of thickness swelling could be expected due to the inherent features of lignocellulosic materials (the water uptake capacity). Once again, reinforced composites by bagasse pulp fibers (specially, SODA-AQ pulp composite) shown better performance (lower TS of 0.46 %) in comparison with untreated bagasse composite (0.1 %). All pulping processes as rice straw treatments showed significant and positive effect on thickness swelling by decreasing maximum TS of untreated rice straw composite (1.95 %) to minimum TS (0.71 %) for AS-AQ rice straw filled composite. It is obvious from Fig. 5 that chemical pulping treatments on both fibers led to lower TS in comparison with CMP-pulp and untreated natural composites.

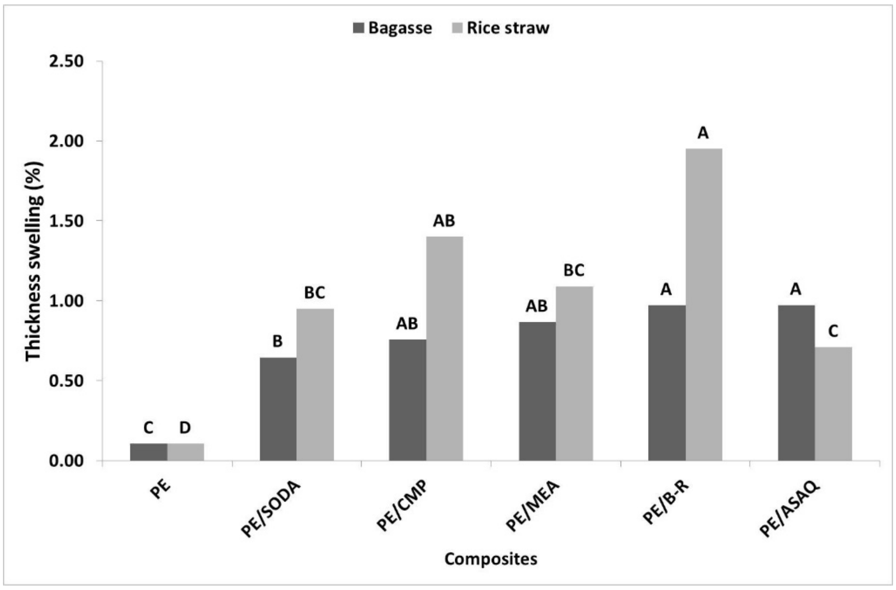

Figure 5. Comparison of thickness swelling (TS) of the composites as function of bagasse and rice straw

4. Conclusion

The present study investigated effect of four pulping processes (ASAQ, SODA, MEA, and CMP) as chemical treatment of bagasse and rice straw fibers on physical and mechanical properties of pulp plastic composites (PPCs). Treated bagasse fibers by pulping processes increased tensile, flexural, and water absorption properties of composites. By contrast, treated bagasse fibers decreased impact strength and thickness swelling of pulp plastic composites. The addition of rice straw treated fibers by chemical and mechanical pulping processes led to increase of tensile strength and modulus and flexural strength properties of composites. The addition of treated rice straw also caused negative effects on some properties by decreasing flexural modulus and thickness swelling of rice straw treated composites. In term of Izod impact strength and water absorption, treated rice straw fibers led to no significant change compared to untreated rice straw composite. This study demonstrated that chemical treatments are more effective on bagasse fibers compared to rice straw, but untreated rice straw in comparison to untreated bagasse fibers showed better performance in many properties. The addition of rice straw and bagasse fibers (both treated and untreated) illustrated positive and negative effect on Izod impact strength of biocomposites compared to Pure HDPE, respectively. According to results of water absorption, the minimum WA among all types of fiber reinforced composites belongs to untreated bagasse composite, whereas rice straw filled composites (both treated and untreated) showed noticeable increase in water absorption. Thickness swelling of untreated bagasse and rice straw composites remarkably decreased by addition of treated fibers via four pulping processes. TS results also demonstrated better performance of chemical pulping processes for decreasing TS of composites compared to chemical mechanical pulping (CMP) process. According to this research, the pulp-plastic composites (PPCs) are superior to untreated fiber reinforced composites (both bagasse and rice straw composites) and PPCs could be introduced as serious alternatives of natural fiber reinforced composites.

5. Acknowledgments

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