International Journal of Advanced Engineering and Management Research

Vol. 6, No. 06; 2021

ISSN: 2456-3676

THE IMPACT OF ORGANIC SALTS ON THE TENSILE PROPERTIES OF POLYMER BIOCOMPOSITES

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Abstract

The tensile properties are the significant mechanical properties of composite materials. The properties consist of tensile stress, tensile modulus, and tensile extension data. The purpose of this short review is to discover the impact of different types of organic salts on the tensile properties of polymer biocomposites. First, organic salts such as surfactants and ionic liquids that are used in the preparation of polymer biocomposites were identified. Later, the percentages of increase and decrease of tensile properties of polymer biocomposites were calculated to observe the impact of organic salts. Finally, the change of tensile properties of polymer biocomposites was explained concisely. From the review, the use of organic salts can increase the tensile stress, tensile modulus, and tensile extension of polymer biocomposites by up to 136%, 758%, and 233%, respectively, compared to the polymer biocomposites without organic salts. Furthermore, organic salts can act as coupling agent, compatibilizing agent, and plasticizing agent for polymer biocomposites.

Keywords: organic salts, tensile properties, polymer biocomposites, ionic liquids, surfactants

1. Introduction

Polymer biocomposites are materials produced from the combination between synthetic polymers and natural fibers (Darus et al., 2020). On the other hand, the combination between biopolymers and organic or inorganic particles can also produce polymer biocomposites (Shamsuri & Daik, 2013; Shamsuri et al., 2020). Both synthetic polymer and biopolymer acted as matrices, whereas natural fibers, organic or inorganic particles acted as fillers for polymer biocomposites (Darus et al., 2020). Besides that, the production of polymer biocomposites is one of the ways for combining the outstanding properties of matrices and fillers. The approach is ordinarily low-cost and less time-consuming than the fabrication of new polymeric materials (Shamsuri & Syariff Tan, 2017). Polymer biocomposites may also probably be applied in the production of various products that have biodegradable and biocompatible properties (Shamsuri,

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2019). However, the mechanical properties of polymer biocomposites are moderate and non-expressive compared to their matrices (Shamsuri et al., 2016).

The mechanical properties of prepared polymer biocomposites can be improved via the treatment of fillers by means of alkaline (Shamsuri et al., 2015), acid, or steam explosion (Darus et al., 2020). Nowadays, the use of organic salts such as surfactants (Shamsuri & Jamil, 2021) and ionic liquids (Shamsuri et al., 2021) is a promising approach for improving the mechanical properties of polymer biocomposites. On the other hand, organic salts are environmentally friendly, and they can substitute hazardous chemicals for the treatment of fillers. Furthermore, organic salts are easy to handle and have good thermal stability. In this paper, different organic salts used in the preparation of polymer biocomposites were reviewed. The main objective of this short review is to demonstrate the capability of organic salts to alter the tensile properties of polymer biocomposites. In addition, the review has also calculated the percentages of change for tensile properties data of polymer biocomposites added with different types of organic salts.

2. Preparations of Polymer Biocomposites

Table 1 shows the polymer matrices, fillers, preparation methods, and organic salts used in polymer biocomposites. It can be observed that biopolymers, synthetic polymers, and synthetic biodegradable polymers can be used as polymer matrices for the preparation of polymer biocomposites. Figure 1 exhibits the chemical structures of agarose, polyethylene (PE), and polybutylene succinate (PBS). On the other hand, inorganic particles, organic particles, and natural fibers can be employed as fillers for polymer biocomposites. Figure 2 displays the chemical structures of talc, cellulose, and starch. Besides that, polymer biocomposites can be prepared via two methods, specifically solution blending and melt bending methods. Nevertheless, the most practical method to prepare polymer biocomposites on a large scale is the melt blending method (Sudari et al., 2017). This method is commonly carried out by using different conventional machines, for example, internal mixer (Shamsuri & Awing, 2020), extruder (Shamsuri & Md. Jamil, 2020), and compression molding machine (Sanmuham et al., 2021). In addition, organic salts such as ionic liquids and surfactants can be added into polymer biocomposites for changing their mechanical properties. Figure 3 indicates the chemical structures of 1-butyl-3-methylimidazolium chloride (BmimCl), hexadecyltrimethylammonium bromide (HTAB), 1-ethyl-3-methylimidazolium trifluoromethanesulfonate (EmimOTf), 1-ethyl-3-methylimidazolium bis (trifluoromethylsulfonyl)imide ($EmimNTf_2$), and 1-dodecyl-3-methylimidazolium bis (trifluoromethylsulfonyl) imide ($DmimNTf_2$).

Table 1. Polymer matrices, fillers, preparation methods, and organic salts used in polymer biocomposites

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Polymer Matrix	Filler	Preparation	Organic Salt	References
Agarose	Talc	Solution blending	BmimCl	(Shamsuri & Daik, 2013)
HDPE	Agar	Melt blending	HTAB	(Shamsuri et al., 2014)
LDPE	Cellulose	Melt blending	HTAB	(Shamsuri et al., 2014)
Gellan Gum	Kenaf	Solution blending	EmimOTf	(Shamsuri et al., 2021)
HDPE	Kenaf	Melt blending	$EmimNTf_2$	(Shamsuri et al., 2021)
PBS	Starch	Melt blending	$DmimNTf_2$	(Shamsuri & Md. Jamil, 2020)
PE	Cellulose	Melt blending	HTAB	(Sudari et al., 2017)
HDPE	Kenaf	Melt blending	EmimOTf	(Shamsuri & Darus, 2020)

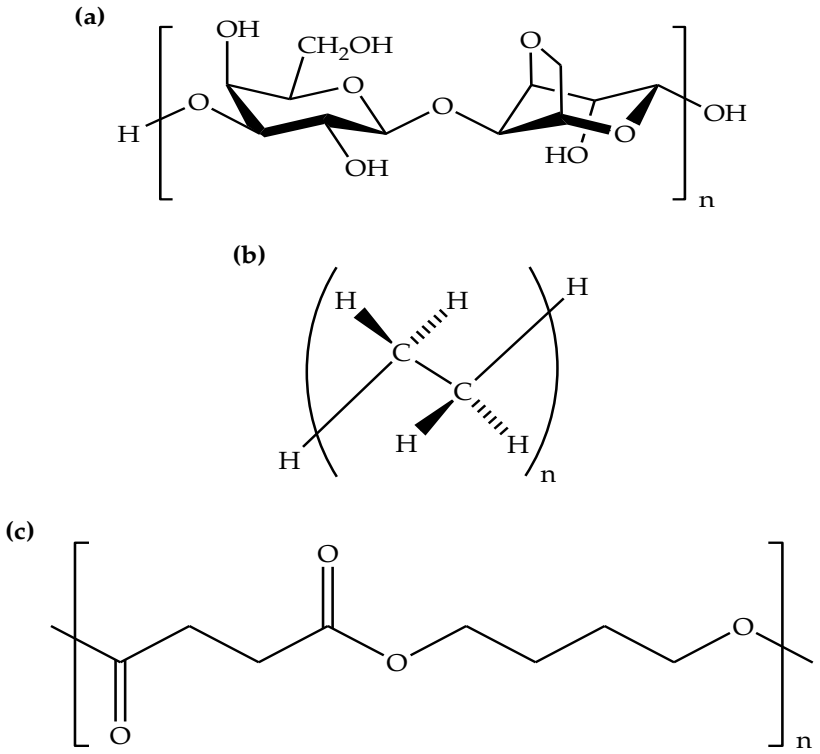

Figure 1. Chemical structures of polymer matrices (a) agarose, (b) PE, and (c) PBS

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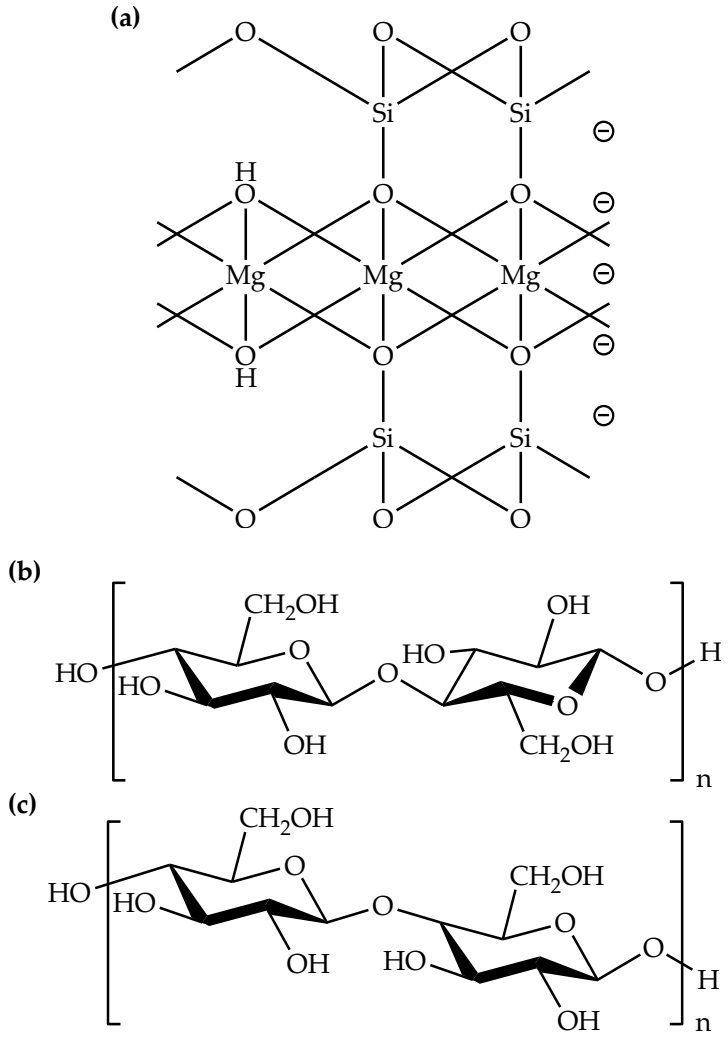
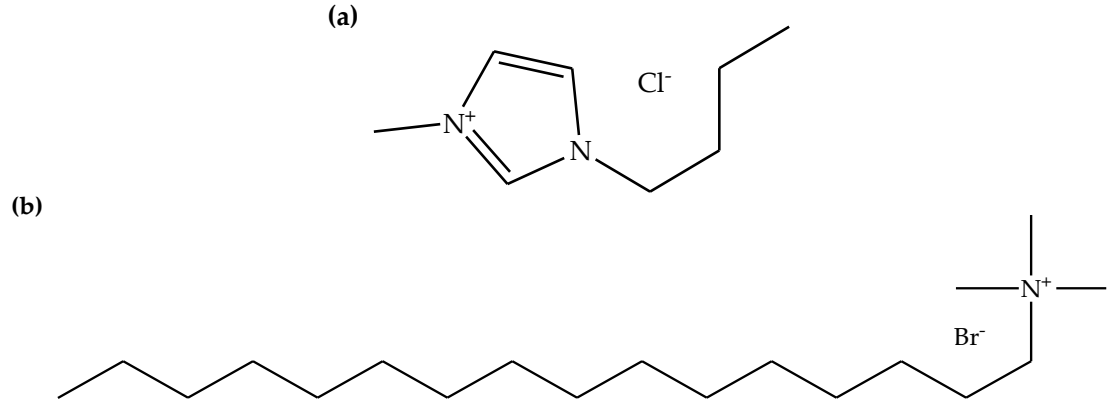


Figure 2. Chemical structures of fillers (a) talc, (b) cellulose, and (c) starch



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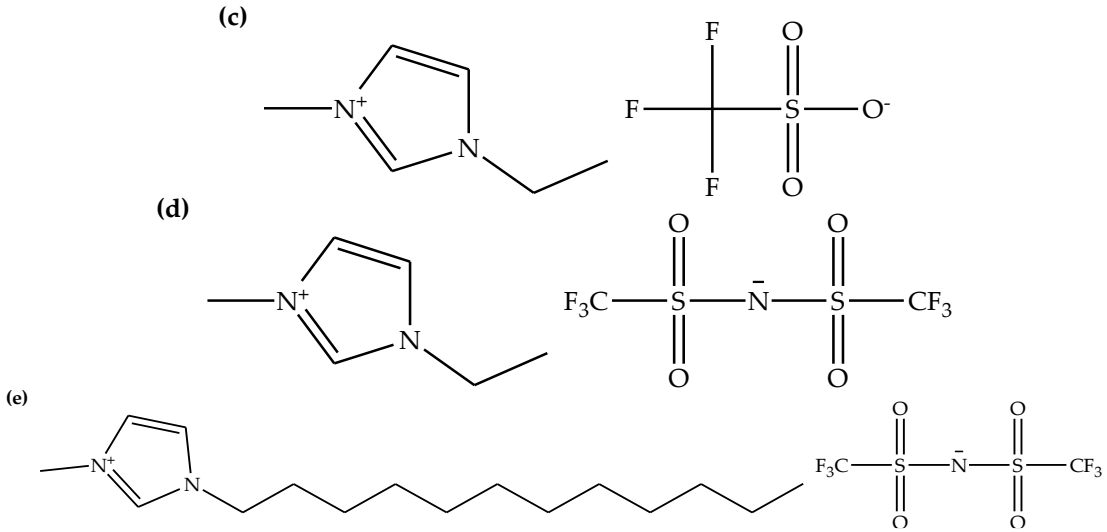

Figure 3. Chemical structures of organic salts (a) BmimCl, (b) HTAB, (c) EmimOTf, (d) $EmimNTf_2$, and (e) $DmimNTf_2$

3. Tensile Properties of Polymer Biocomposites Containing Organic Salts

Table 2 shows the organic salts, tensile stress, tensile modulus, and tensile extension of polymer biocomposites. The agarose/talc biocomposites were prepared by adding BmimCl ionic liquid (Shamsuri & Daik, 2013). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5566). The tensile stress and tensile modulus of the biocomposites increased by up to 26% and 62%, respectively, compared to the biocomposite without BmimCl. This was due to BmimCl has increased the stiffness character of the biocomposites, which acted as a coupling agent. Nevertheless, the tensile extension of the biocomposites slightly decreased by 3.6%, ascribed to the presence of BmimCl, which restrained the motion of agarose molecular chains by talc particles. On the other hand, the HDPE/agar biocomposites were prepared by adding HTAB surfactant (Shamsuri et al., 2014). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567) (Shamsuri & Darus, 2020). The tensile stress and tensile modulus of the biocomposites decreased by 27% and 25%, respectively, caused by the softening effect of ionic liquid. However, the tensile extension of the biocomposites significantly increased by up to 72% in comparison to the biocomposite without HTAB. This was attributed to the presence of HTAB, which acted as a compatibilizing agent and induced the biocomposites to become ductile.

Besides that, the LDPE/cellulose biocomposites were prepared by treating cellulose with HTAB surfactant (Shamsuri et al., 2014). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567). The tensile stress and tensile extension of the biocomposites increased by up to 14% and 23%, respectively, than that of the biocomposite without HTAB. This was because HTAB acted as an intermediary between LDPE and cellulose, consequently enhanced the pliability and tautness of the biocomposites. Nonetheless, the tensile modulus of the biocomposites decreased by 43%, due to the

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improvement of tensile extension of the biocomposites, which deteriorated their rigidity character. In addition, the gellan gum/kenaf biocomposites were prepared by adding EmimOTf ionic liquid (Shamsuri et al., 2021). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567). The tensile stress and tensile modulus of the biocomposites significantly increased by up to 136% and 758%, respectively, compared to the biocomposite without EmimOTf. This was ascribed to the enhancement of the stiffness and rigidity characters of the biocomposites containing EmimOTf. Nevertheless, the tensile extension of the biocomposites decreased by 68%, attributed to the presence of EmimOTf, and it cannot be acted as a plasticizing agent for the biocomposites.

On the other hand, the HDPE/kenaf biocomposites were prepared by adding $EmimNTf_2$ ionic liquid (Shamsuri et al., 2021). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567). The tensile stress and tensile modulus of the biocomposites decreased by 55% and 54%, respectively, caused by the ability of $EmimNTf_2$ to interact with the components of the biocomposites, which gave a low rigidity property. However, the tensile extension of the biocomposites substantially increased by up to 58% in comparison to the biocomposite without $EmimNTf_2$. This was induced by the formation of free volume by $EmimNTf_2$ in the biocomposites, which allowed the mobility of the HDPE molecular chains. Besides that, the PBS/starch biocomposites were prepared by adding $DmimNTf_2$ ionic liquid (Shamsuri & Md. Jamil, 2020). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567). The tensile stress and tensile modulus of the biocomposites slightly decreased by 9% and 38%, respectively, because $DmimNTf_2$ marginally influenced their stiffness property. Nonetheless, the tensile extension of the biocomposites significantly increased by up to 233% than that of the biocomposite without $DmimNTf_2$. This was ascribed to the capability of $DmimNTf_2$ to interact with both non-polar PBS and polar starch since it has an amphiphilic character.

In addition, the PE/cellulose biocomposites were prepared by adding HTAB surfactant (Sudari et al., 2017). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567). The tensile stress and tensile modulus of the biocomposites increased by up to 25% and 25%, respectively, compared to the biocomposite without HTAB. This was due to HTAB has improved the interfacial adhesion between PE and cellulose, which acted as a compatibilizing agent. Nevertheless, the tensile extension of the biocomposites decreased by 64%, attributed to the presence of the crystal lattice of HTAB in the biocomposites, which caused the brittleness to the biocomposites. On the other hand, the HDPE/kenaf biocomposites were prepared by adding EmimOTf ionic liquid (Shamsuri & Darus, 2020). The tensile properties of the biocomposites were characterized using a universal testing machine (Instron, model 5567). The tensile stress and tensile modulus of the biocomposites decreased by 48% and 52%, respectively, because of the increase in the sliding of kenaf in the HDPE matrix, which induced the biocomposites to become softer. Nevertheless, the tensile extension of the biocomposites significantly increased by up to 71% than that of the biocomposite without EmimOTf. This was caused by the high mobility of EmimOTf, which acted as a plasticizing agent for the biocomposites.

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Table 2. Organic salts, tensile stress, tensile modulus, and tensile extension of polymer biocomposites.

Organic Salt	Polymer Biocomposite	Tensile Stress	Tensile Modulus	Tensile Extension	References
BmimCl	Agarose/talc	⇧ (26%)	⇧ (62%)	⇩ (3.6%)	(Shamsuri & Daik, 2013)
HTAB	HDPE/agar	⇩ (27%)	⇩ (25%)	⇧ (72%)	(Shamsuri et al., 2014)
HTAB	LDPE/cellulose	⇧ (14%)	⇩ (43%)	⇧ (23%)	(Shamsuri et al., 2014)
EmimOTf	Gellan gum/kenaf	⇧ (136%)	⇧ (758%)	⇩ (68%)	(Shamsuri et al., 2021)
$EmimNTf_2$	HDPE/kenaf	⇩ (55%)	⇩ (54%)	⇧ (58%)	(Shamsuri et al., 2021)
$DmimNTf_2$	PBS/starch	⇩ (9%)	⇩ (38%)	⇧ (233%)	(Shamsuri & Md. Jamil, 2020)
HTAB	PE/cellulose	⇧ (25%)	⇧ (25%)	⇩ (64%)	(Sudari et al., 2017)
EmimOTf	HDPE/kenaf	⇩ (48%)	⇩ (52%)	⇧ (71%)	(Shamsuri & Darus, 2020)

4. Conclusions

This review found that some organic salts have significantly increased and decreased the tensile stress, tensile modulus, and tensile extension of polymer biocomposites, based on the calculated percentages of change. This observation implied that the use of organic salts could considerably alter the tensile properties of polymer biocomposites. Moreover, the majority of changes made by organic salts are attributed to the existence of interactions between organic salts and polymer biocomposite components. Therefore, it can be concluded that organic salts have provided a positive impact on polymer biocomposites by acting as coupling agent, compatibilizing agent, and plasticizing agent for polymer biocomposites.

Acknowledgments

The authors would like to thank the Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia. This review was funded by the Universiti Putra Malaysia under the Grant Putra IPM Scheme (project number: GP-IPM/2021/9697900).

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