Journal of Engineering Research and Reports

16(1): 22-28, 2020; Article no.JERR.60212
ISSN: 2582-2926

A Preliminary Study on Tensile Properties of Gellan Gum/KCF Biocomposite Films

Ahmad Adlie Shamsuri[1*], Khalina Abdan[1] and Tatsuo Kaneko[2]

[1]*Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.*
[2]*Energy and Environment Area, Japan Advanced Institute of Science and Technology, 1-1 Asahidai, 923-1292 Nomi and Ishikawa, Japan.*

Authors' contributions

This preliminary study was carried out in collaboration among all authors. Authors AAS and KA designed and conceived the study. Author AAS performed most of the experiments. Authors AAS and TK collected and analyzed the data. All authors contributed to the writing of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2020/v16i117156
Editor(s):
(1) Dr. Guang Yih Sheu, Chang-Jung Christian University, Taiwan.
Reviewers:
(1) Soumiya Sukumar, National Institute of Technology Calicut, India.
(2) Sarita Nunes Loureiro, Universidade Federal do Pará, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/60212

Short Communication

Received 06 June 2020
Accepted 11 August 2020
Published 18 August 2020

ABSTRACT

In this preliminary study, kenaf core fiber (KCF) was utilized as a natural filler for the preparation of the gellan gum/KCF biocomposite films. The films were prepared by casting gellan gum solutions containing glycerol and KCF, followed by gelation and drying. The weight ratio of gellan gum and glycerol was fixed at 2:3, while the content of KCF varied from 6 to 15 wt.% relative to the weight of gellan gum. The tensile properties of the prepared films have been determined by using a universal testing machine. The tensile test results demonstrated that the tensile extension and tensile energy at break of the biocomposite films have significantly increased with the incorporation of KCF. Nevertheless, the tensile stress and tensile modulus at maximum load have drastically decreased with the increase of KCF content. This study implied that the incorporation of KCF had enhanced the ductility of the gellan gum/KCF biocomposite films and at the same time, reduced the stiffness of the films.

Keywords: Gellan gum; kenaf core fiber; biocomposite film; tensile properties.

**Corresponding author: Email: adlie@upm.edu.my;*

1. INTRODUCTION

Biocomposites are composite materials that are filled with natural fibers [1]. They were produced by using numerous types of natural fibers such as bamboo [2], cellulose [3], kenaf [4], oil palm empty fruit bunch [5], rice husk [6], etc. Biocomposites possibly can be applied in various applications, including automotive, aviation, construction, and additive manufacturing, for the fabrication of 3D objects as well [7]. Synthetic polymers are usually used as polymer matrices in the production of composite materials [8-11]. Moreover, biopolymers can also be employed in the polymer composite and blend systems [12-14].

Gellan gum is a biopolymer produced by the bacterium *Sphingomonas elodea*; it is commonly applied in the food industry as a thickening agent and gelling agent that could substitute agar [15]. The previous study by Yang and Paulson [16] indicated that gellan gum could be used to produce films with good mechanical and transparent properties. On the other hand, gellan gum seems to have exceptional potential as a matrix for polymer composites. Still, until now, there has been a lack of information on its polymer biocomposite films.

In this preliminary study, kenaf core fiber (KCF) has been utilized as a natural filler for the preparation of the gellan gum/KCF biocomposite films. Moreover, the use of this natural fiber in the biocomposites system is advantageous because of its inexpensiveness, which could reduce the manufacturing cost of the biocomposite products [17]. The major objective of this study is to determine the tensile properties of the prepared films with different content of KCF. The biocomposite films with enhanced properties possibly may be applied in the production of biodegradable packaging materials.

2. MATERIALS AND METHODS

2.1 Materials

The polymer matrix used was a gellan gum, purchased from Sigma-Aldrich (M) Sdn. Bhd., Malaysia. The natural filler of the biocomposites was kenaf core fiber, KCF (420 μm), acquired from the National Kenaf and Tobacco Board (NKTB), Malaysia. Glycerol (≥99%) was utilized as a plasticizer, procured from Fisher Scientific (M) Sdn. Bhd., Malaysia. All materials obtained were used without any further modification.

2.2 Preparation of Biocomposite Films

The gellan gum/KCF biocomposite films were prepared by placing 2.4 g of glycerol into a 100 mL beaker, followed by 0.10 g of KCF and 56 g of distilled water. They were then stirred by using a magnetic stirring apparatus. 1.6 g of gellan gum was added little by little to the mixture, followed by heating at 90°C and stirring at 1500 rpm until all gellan gum dissolved. The solution was immediately cast into a 14 cm internal diameter glass Petri dish and allowed to cool to room temperature (25°C) for the gelation process [18]. Later the gel was slowly dried in an oven at a temperature of 40°C for 48 hours [12] to obtain a freestanding biocomposite film containing 6 wt.% of KCF. The weight ratio of gellan gum and glycerol was fixed at 2:3, while the content of KCF varied from 6 to 15 wt.% relative to the weight of gellan gum. A film containing only gellan gum and glycerol (0 wt.% of KCF) was also prepared for comparison purposes.

2.3 Tensile Test of Biocomposite Films

The biocomposite film samples were cut by using a die cutter into a rectangular shape with a length and width of 60 mm and 12.7 mm, respectively. Fig. 1 shows the film samples containing 0 to 15 wt.% of KCF that have been cut for the tensile test. The tensile properties such as tensile extension and tensile energy at break, as well as tensile stress and tensile modulus at maximum load, were determined according to the ASTM D638-10 by using a universal testing machine (Instron, model 5567) equipped with a 30 kN load cell. The crosshead speed was 5 mm min^{-1} [19] with a 30 mm gauge length. The tensile test was carried out at a temperature range of 21–25°C and relative humidity of 40–60%. The resultant films were conditioned in an oven at a temperature of 40°C for at least 24 hours prior to the tensile test. Ten samples from each KCF content were tested to ascertain the mean values, and the error bars were included to show the error range [20]. The tensile test results were analyzed by using a Microsoft® Excel of Microsoft 365 statistical software program. Single-factor analysis of variance (ANOVA) was employed to discover a statistically significant difference in the tensile extension and tensile energy mean values with a 95% confidence level between the different gellan gum/KCF biocomposite film samples.

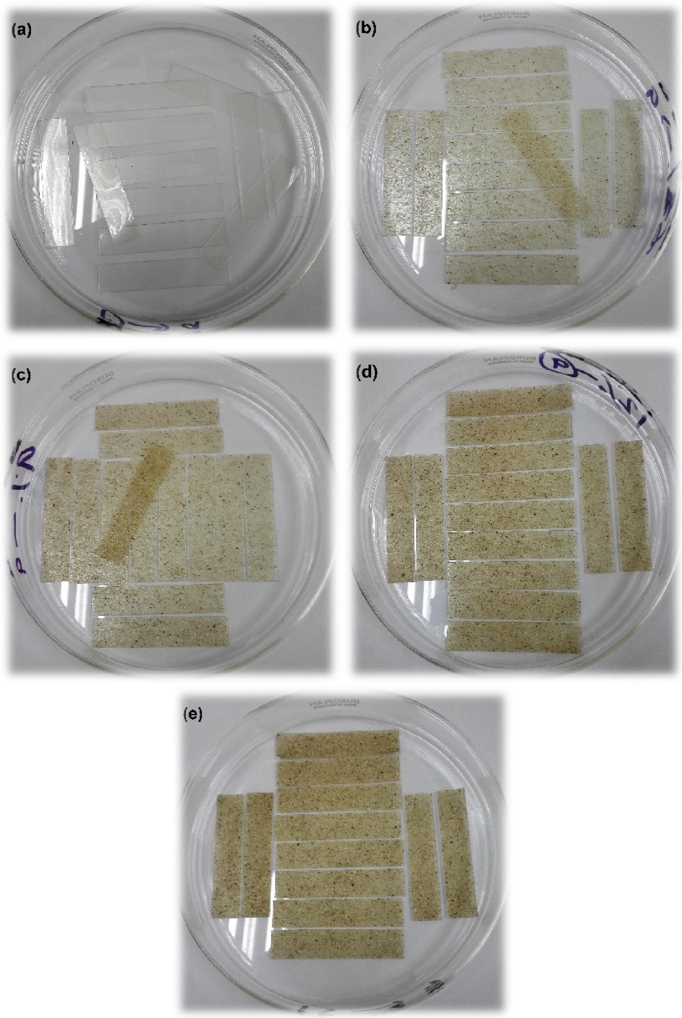

Fig. 1. Film samples containing (a) 0 wt.%, (b) 6 wt.%, (c) 9 wt.%, (d) 12 wt.% and (e) 15 wt.% of KCF

3. RESULTS AND DISCUSSION

The tensile extension and tensile energy at break of the gellan gum/KCF biocomposite films without and containing KCF are displayed in Figs. 2 and 3, respectively. It can be perceived that the tensile extension and tensile energy of the film without KCF are lower than the biocomposite films containing KCF. Therefore, the incorporation of KCF has significantly increased the tensile extension and tensile energy properties of the biocomposite films. These results clearly indicated that the movement of gellan gum molecular chains was improved by KCF particles, which was unexpected. The incorporation of KCF into the gellan gum matrix was supposed to provide a reinforcing effect on the biocomposite films and decrease the tensile extension of the films. However, the contradiction was observed, whereby the tensile extension had typically reduced with the incorporation of natural filler [21].

On the other hand, the tensile extension and tensile energy were further improved with the increase of KCF content. The biocomposite film containing 15 wt.% of KCF had an approximately 50% higher tensile extension and tensile energy compared to the film without KCF. Hence, the incorporation of KCF could enhance the ductility of the biocomposite films at fixed plasticizer content. Furthermore, the ductility of the films was determined based on the percentage of elongation. The film must elongate at least 5% to be considered as the ductile film. Biocomposite film containing 6 wt.% of KCF has elongated up to 21%. Thus, the biocomposite films incorporated with KCF have higher ductility than the film without KCF.

The tensile stress and tensile modulus at maximum load of the gellan gum/KCF biocomposite films without and containing KCF are shown in Figs. 4 and 5, respectively. It can be seen that the incorporation of KCF has considerably decreased the tensile stress and tensile modulus properties of the biocomposite films; this is due to the stiffness of the films has been reduced. On the other hand, the incorporation of KCF causes the gellan gum/KCF biocomposite films to turn ductile and flexible; thus, it cannot act as a reinforcing filler as it behaves more like an extending filler. Furthermore, the tensile stress and tensile modulus of the films have drastically decreased with higher KCF content. From the tensile test results, it can be concluded that the incorporation of KCF has significantly decreased the stiffness of the gellan gum/KCF biocomposite films, and simultaneously increased the ductility of the films. Moreover, the biocomposite films with the improved ductile property have the potential to be used for packaging, wrapping, holding, dividing, barring, and so on.

Statistical analysis was conducted by employing a single-factor analysis of variance (ANOVA) to discover a statistically significant difference in the tensile extension and tensile energy at break between the different gellan gum/KCF biocomposite film samples. Tables 1 and 2 show the ANOVA results of the tensile extension and tensile energy of the gellan gum/KCF biocomposite films without and containing KCF. The total numbers of the film samples were five, and ten replicates were tested for each sample. The source of variation of the tensile extension and tensile energy had been divided into two categories, namely, between groups (BG) and within groups (WG). *F*-value is the ratio of the mean square of BG to the mean square of WG. The *P*-value was less than 0.05 in Tables 1 and 2, which rejected the zero hypothesis [13]. Therefore, it can be deduced that there is a statistically significant difference in the tensile extension and tensile energy among the different gellan gum/KCF biocomposite film samples at a 95% confidence level.

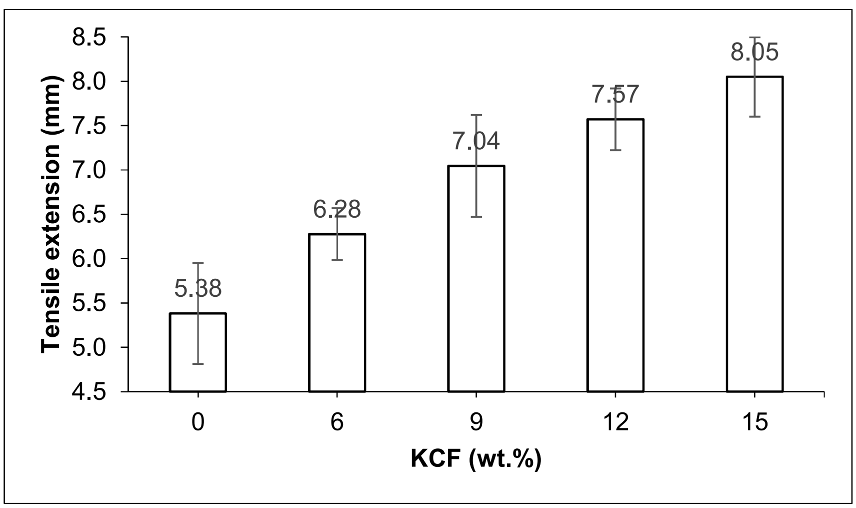

Fig. 2. Tensile extension at break of the gellan gum/KCF biocomposite films without and containing KCF

Table 1. ANOVA result of the tensile extension of the gellan gum/KCF biocomposite films without and containing KCF

Source of variation	SS	df	MS	F	*P*-value
BG	44.82460991	4	11.20615248	53.03084943	1.8219×10^{-16}
WG	9.509122838	45	0.211313841	-	-

SS = sum of square, df = degree of freedom, MS = mean square, F = F-value, Number of samples = 5, Number of observations = 50

Table 2. ANOVA result of the tensile energy of the gellan gum/KCF biocomposite films without and containing KCF

Source of variation	SS	df	MS	F	*P*-value
BG	0.022408349	4	0.005602087	21.72933982	4.8958×10^{-10}
WG	0.011601546	45	0.000257812	-	-

SS = sum of square, df = degree of freedom, MS = mean square, F = F-value, Number of samples = 5, Number of observations = 50

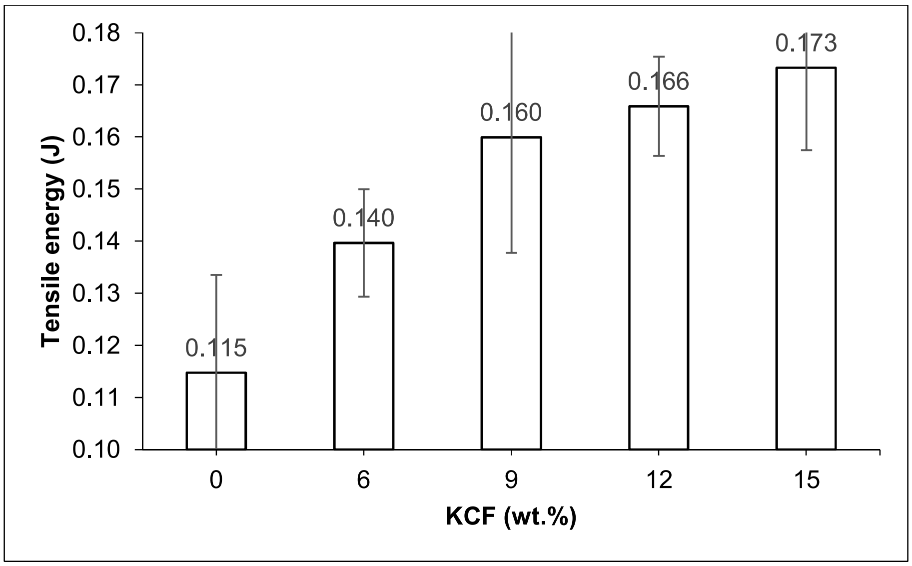

Fig. 3. Tensile energy at break of the gellan gum/KCF biocomposite films without and containing KCF

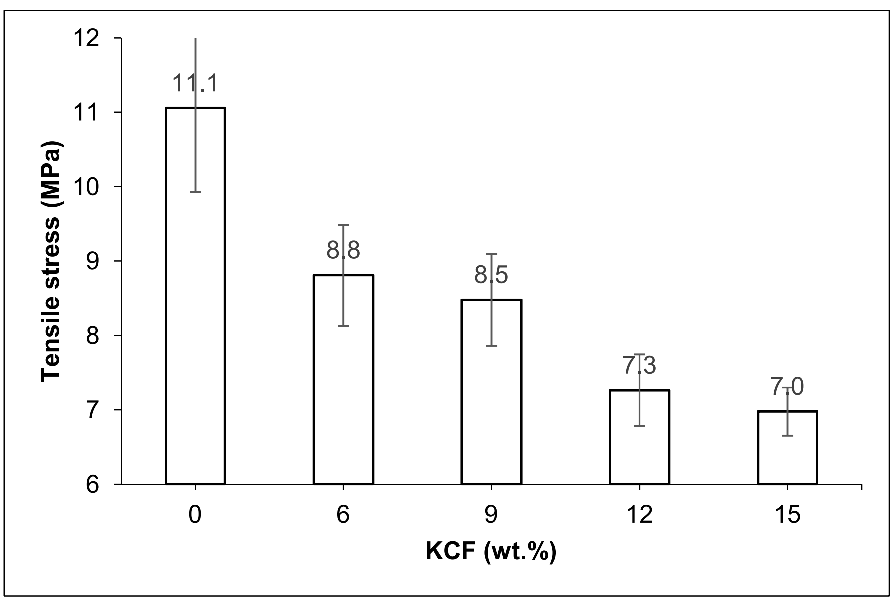

Fig. 4. Tensile stress at maximum load of the gellan gum/KCF biocomposite films without and containing KCF

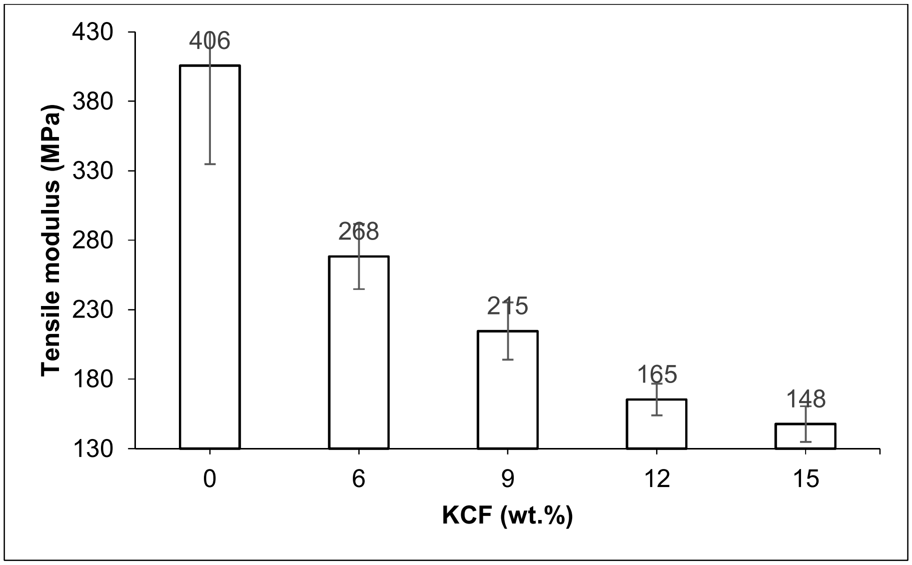

Fig. 5. Tensile modulus at maximum load of the gellan gum/KCF biocomposite films without and containing KCF

4. CONCLUSIONS

In this preliminary study, the gellan gum/KCF biocomposite films with different content of KCF were prepared through a solution casting method. The biocomposite films were cut into a rectangular shape, and the tensile test was conducted according to the ASTM D638-10. The tensile extension and tensile energy at break of the biocomposite films had significantly increased with the incorporation of KCF. However, the tensile stress and tensile modulus at maximum load of the biocomposite films had decreased with the increase of KCF content as displayed by the tensile test results. It can be inferred that the ductility of the gellan gum/KCF biocomposite films has been enhanced with the incorporation of KCF. Conversely, the stiffness of the films is lower compared to the film without KCF.

ACKNOWLEDGEMENTS

The authors would like to thank the Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia. This preliminary study was funded by the Ministry of Higher Education, Malaysia, under the Higher Institution Centre of Excellence (HICoE) research grant (project number: UPM/INTROP/100-13/9/3/6369115C).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Shamsuri AA. Compression moulding technique for manufacturing biocomposite products. Int. J. Appl. Sci. Technol. 2015;5(3):23-26.
2. Darus SAAZM, Ghazali MJ, Azhari CH, Zulkifli R, Shamsuri AA. Mechanical properties of *Gigantochloa scortechinii* bamboo particle reinforced semirigid polyvinyl chloride composites. Jurnal Teknologi. 2020;82(2):15-22.
3. Sudari AK, Shamsuri AA, Zainudin ES, Tahir PM. Exploration on compatibilizing effect of nonionic, anionic and cationic surfactants on mechanical, morphological and chemical properties of high-density polyethylene/low-density polyethylene/ cellulose biocomposites. J. Thermoplast. Compos. Mater. 2017;30(6):855-884.
4. Shamsuri AA, Darus SAAZM. Effect of [C_2mim][OTf] ionic liquid on tensile properties of HDPE/KCF biocomposites: A primary research. Asian J. Appl. Chem. Res. 2020;6(2):1-6.
5. Shamsuri AA, Awing MI. An initial investigation on microwaves reflection and transmission coefficients of oil palm empty

fruit bunch biocomposites incorporated with nickel zinc ferrite. J. Mater. Sci. Res. Rev. 2020;5(1):42-49.
6. Shamsuri AA, Sudari AK, Zainudin ES, Ghazali M. Effect of alkaline treatment on physico-mechanical properties of black rice husk ash filled polypropylene biocomposites. Mater. Test. 2015;57(4): 370-376.
7. Shamsuri AA. Important criteria for preparation of 3D printer filaments from polymer biocomposites. SVOA Mater. Sci. Technol. 2019;1(1):1-3.
8. Shamsuri AA, Daik R, Zainudin ES, Tahir PM. Compatibilization of HDPE/agar biocomposites with eutectic-based ionic liquid containing surfactant. J. Reinf. Plast. Compos. 2014;33(5):440-453.
9. Shamsuri AA. Is the polymer orientation can influence the mechanical properties of thermoplastic composites? Global J. Mater. Sci. Eng. 2019;1(1):1-2.
10. Shamsuri AA, Azid MK, Ariff AH, Sudari AK. Influence of surface treatment on tensile properties of low-density polyethylene/ cellulose woven biocomposites: A preliminary study. Polymers. 2014;6(9):2345-2356.
11. Shamsuri AA, Md. Jamil SNA. A short review on the effect of surfactants on the mechanico-thermal properties of polymer nanocomposites. Appl. Sci. 2020;10(14): 4867-4882.
12. Shamsuri AA, Daik R. Utilization of an ionic liquid/urea mixture as a physical coupling agent for agarose/talc composite films. Materials. 2013;6(2):682-698.
13. Shamsuri AA, Md. Jamil SNA. Compatibilization effect of ionic liquid-based surfactants on physicochemical properties of PBS/rice starch blends: An initial study. Materials. 2020;13(8):1885-1897.
14. Shamsuri AA, Daik R, Ahmad I, Jumali MHH. Nylon-6/liquid natural rubber blends prepared via emulsion dispersion. J. Polym. Res. 2009;16(4):381-387.
15. Shamsuri AA, Abdullah DK, Daik R. Fabrication of agar/biopolymer blend aerogels in ionic liquid and co-solvent mixture. Cell. Chem. Technol. 2012; 46(1-2):45-52.
16. Yang L, Paulson AT. Mechanical and water vapour barrier properties of edible gellan films. Food Res. Int. 2000;33(7): 563-570.
17. Shamsuri AA, Zolkepli M, Naqiuddin M, Ariff M, Hanim A, Sudari AK, Abu Zarin M. A preliminary investigation on processing, mechanical and thermal properties of polyethylene/kenaf biocomposites with dolomite added as secondary filler. J. Compos. 2015;2015:1-7.
18. Shamsuri AA, Daik R. Plasticizing effect of choline chloride/urea eutectic-based ionic liquid on physicochemical properties of agarose films. Bio Resources. 2012;7(4): 4760-4775.
19. Shamsuri AA, Sumadin ZA. Influence of hydrophobic and hydrophilic mineral fillers on processing, tensile and impact properties of LDPE/KCF biocomposites. Compos. Commun. 2018; 9:65-69.
20. Shamsuri AA, Awing MI, Tawil ML. Calculation of measurement uncertainty for tensile strength and flexural strength of thermoplastic. Asian Res. J. Math. 2016;1(3):1-11.
21. Shamsuri AA, Daik R. Mechanical and thermal properties of Nylon-6/LNR/MMT nanocomposites prepared through emulsion dispersion technique. J. Adv. Res. Fluid Mech. Therm. Sci. 2020;73(1): 1-12.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/60212