STUDY ON MECHANICAL PROPERTIES OF NATURAL RUBBER LATEX CHITOSAN COMPOSITES

Mi Myat Su Mon[1], Cho Cho[2], Thinzar Nu[3]

Abstract

The focus of this research mainly concerned with mechanical properties of natural rubber (NR) latex chitosan composites. The physicochemical properties of natural rubber (NR) latex were also determined. In the preparation of rubber chitosan composites, various ratios of chitosan were used. The mechanical properties of prepared unfilled and filled chitosan in natural rubber composites such as specific gravity, tensile modulus (MPa), tensile strength (MPa), elongation at break (%) and tear strength (kN/m) were determined by standard rubber testing and compared to their properties.

Keywords: natural rubber, latex, chitosan, chemical properties, mechanical properties, natural rubber latex chitosan composites

Introduction

Natural polymers exhibit unique characteristics. They comprise polymers with a variety of chemical formula like polysaccharides (starch, chitin, chitosan, natural cellulose, alginate, and carrageenan), protein (polypeptides, keratin, collagen, and elastin) and polyisoprenes (gutta-percha, balata, natural rubber) (Carraher, 2010).

Myanmar is one of the largest natural rubber producer and exporter in South East Asia. Natural rubber (NR) has been cultivated in Myanmar since the British Colonial period in the early 20th century mostly in Mon State (Jefferson and Jean-Christophe, 2013).

Natural rubber is an elastomer (an elastic hydrocarbon polymer) that was originally derived from latex, a milky colloid produced by some plants. The plants would "tapped" that is, an incision made into the bark of the tree and the sticky, milk coloured latex sap collected and refined into a usable rubber. The purified form of natural rubber is the chemical polyisoprene, which can also be produced synthetically. Natural rubber is used extensively

[1.] 3 PhD Candidate, Assistant Lecturer, Department of Chemistry, University of Yangon
[2.] Dr, Professor and Head, Department of Chemistry, Yenanchaung Degree College
[3.] Dr, Associate Professor, Department of Chemistry, University of Yangon

in many applications and products, as is synthetic rubber. It is normally very stretchy, flexible and extremely water proof (Greve, 2000).

Fresh hevea latex contains about 25-45 % rubber hydrocarbon and 5-6 % non-rubber substances such as amino acids, proteins, carbohydrates, neutral and polar lipids, and inorganic salts; the remaining being water. After collection, the latex is stabilized with ammonia and transported from the plantation to a factory where it undergoes continuous centrifugation to produce concentrated NR latex containing ~60 % rubber.

Natural rubber latex has invariably become the first choice for the production of most of latex dipped products as well as it is widely used in the production of many daily-used and medical products, due to its good comprehensive properties such as excellent wet-gel strength, film-forming ability, elasticity flexibility, have antivirus protection and biodegradable (Lu *et al.*, 2015). Despite its good performance, significant research is directed at using biodegradable fillers such as starch, banana fibers and oil palm to replace common filler used such as carbon black, silica and synthetic fibers (Norhazariah *et al*., 2016). The addition of biodegradable fillers offers a solution to waste disposal problem, which affects human health and the quality of the environment. The biodegradable fillers are chosen because they are readily available at abundant and have good intrinsic properties with natural rubber latex products.

Chitosan is a modified natural carbohydrate polymer derived from chitin by deacetylation which is found in a wide range of natural sources such as crustaceans, fungi, insects and some algae and it is one of the most abundant natural polymers. As a polysaccharide of natural origin, chitosan has many useful features such as non-toxicity, biocompatibility and antimicrobial properties. Chitosan can be used in different areas from health care to agriculture and dyes for fabrics and it is soluble in most dilute acids. Chitosan has a high modulus of elasticity, owning to the high class transition temperature and crystallinity (Dutta *et al*., 2004).

This research work concerned with the preparation and characterization of a natural rubber latex chitosan composites made up by the association of natural rubber latex and chitosan fillers. The compatibility between the matrix and the filler was investigated.

Materials and Methods

In this research work, natural rubber latex was purchased from Tharkayta Industrial Zone (Yangon).Commercial chitosan purchased from Ever GreenCo. Ltd. (Yangon)was used in the present work (Figure 1 and 2).

Figure 1: Natural rubber (NR) Latex

Figure 2: Purchased Chitosan

Preparation of Samples

In the purchased latex, which contained a lot of water thus it was necessary to be concentrated. Then, it was centrifuged to get concentrated latex at room temperature. In this work, centrifugation technique was used for preparation of latex cream. The purchased chitosan was dried in oven (100 °C, 2 h) and ground into powder by a grinding machine.

Preparation of Chemicals Required

All chemicals used in this research work consist of the products British Drug House Ltd., including sulphur, ZnO, TiO_2, ZDEC, BHT and KOH. To obtain 40 % of chemicals, 40 g of the respective chemicals and 60 mL of distilled water were placed in a porcelain jar containing either porcelain ball (various ceramic balls). The jar was closed air-tight. The materials were milled for 24 h in the motorized ball mill machine under 3450 rpm as shown in Figure 3. In all of the experiments, the recommended methods and standard procedures involving both conventional and modern techniques were employed (Chandar and Mishra, 1995).

Figure 3: Ball mill machine

Determination of Physicochemical Investigation of Natural Rubber Latex

The physicochemical investigation was carried out on natural rubber latex in order to determine total solid content (TSC), dry rubber content (DRC), mechanical stability testing (MST) and alkalinity (% of NH_3) by standard methods.

Preparation of Natural Rubber Latex Chitosan Composites

The natural rubber latex was pre-vulcanized by compounding the ingredients as shown in Table 1. The mixture was placed in the thermoplastic water bath at 60 ℃ ±2 for 2 h. The compound obtained was removed from water bath and cooled for 2h under stirring to prevent surface coagulation. A chloroform number test was used to determine the degree of pre-vulcanization of the compound whereas the chitosan was mixed with 1 % acetic acid under high stirring speed (400 rpm) of homogenizer and the pH was adjusted with KOH. After the test, the latex compound was mixed with various ratios of chitosan (0,2.5,5,7.5 and 10) respectively to form five composites (A, B, C, D and E).The composite films were poured into the glass plate to dry at room temperature for 1 week. Then, the films were stripped off from the glass plate.

Table 1: Composition of Ingredients in the Prepared Natural Rubber Latex Chitosan Composites

Ingredients	Composition of Ingredients in natural rubber chitosan composites (pph)				
	A	B	C	D	E
Natural Rubber Latex (42.18 %)	100	100	100	100	100
Zinc Oxide (ZnO)(40 %)	0.75	0.75	0.75	0.75	0.75
TiO_2 (40 %)	1.0	1.0	1.0	1.0	1.0
ZDEC (40 %)	1.0	1.0	1.0	1.0	1.0
BHT (40 %)	0.5	0.5	0.5	0.5	0.5
10% KOH solution	0.6	0.6	0.6	0.6	0.6
Sulphur (S) (40 %)	1.2	1.2	1.2	1.2	1.2
Chitosan	0	2.5	5	7.5	10

pph = parts per hundred
A-E = Natural Rubber latex composites with variousratios of chitosan0 to 10 pph
TiO_2 = Titanium Oxide
ZDEC = Zinc Diethyldithiocarbamate
BHT = Butylated Hydroxy Toluene
KOH = Potassium Hydroxide

Determination of Mechanical Properties of Natural Rubber Latex Chitosan Composites

Mechanical properties of natural rubber latex chitosan composites are those physical properties that related to strength, toughness and durability. The properties were determined at Rubber Research and Development Center in Ministry of Agriculture, Livestock and Irrigation Department of Agriculture (Yangon).

Determination of Specific Gravity

The specific gravity of the composites was measured by Wallace direct reading specific gravity balance. The test piece was suspended on a needle form at one end of the beam which was zeroed by means of quickly adjustable sliding weights. The test piece was then immersed in water contained in a glass beaker locked on a frication-clamped platform. This platform can be raised and lowered easily and remained in position without on additional clamping. When the test piece was immersed, the specific gravity was calculated. The results are shown in Figure 5 and Table 3.

Determination of Tensile Strength, Elongation at Break and Tensile Modulus (M_{300}, M_{400}, M_{500})

The tensile test was done according to H.5000 F tensile testing machine. The test was performed to determine the capability of a material to resist the deformation during stretch. The important data obtained from tensile test were tensile modulus at 300 % (M_{300}), modulus at 400 % (M_{400}), modulus at 500 % (M_{500}), tensile strength and elongation at break. The prepared composites were cut off according to JISK 7127.The both ends of the test pieces were firmly clamped in the jaw of tensile strength testing machine. One jaw was fixed and other was movable. The movable jaw moved at the rate of 10 mm min^{-1}. The resultant data were shown at the recorder. This procedure was repeated three times for each composite. The results are presented in Figures 6, 7 and 8 and Table 3.

Determination of Tear Strength

The tear strength was measured by tear strength testing machine. The specimen to be tested was cut out by the die from the above sheets. Specimen was cut with a single nick (0.05 mm) at the entire of the inner concave edge by a special cutting device using a razor blade. The clamping of the specimen in the jaw of test machine aligned with travel direction of the grip at the rate of 100 mm min^{-1}. The recorder of the machine showed the highest force to tear from a specimen nicked. The procedure was repeated three times for each result. The results are presented in Figure 9 and Table 3.

Results and Discussion

Physicochemical Properties of Natural Rubber Latex

In order to evaluate the quality of natural rubber latex, the physicochemical properties were determined according to the standard methods. From these experiments, total solid content (TSC) was 42.180 %. It is the content of dry matter including the suspended solids and dissolved salts. Natural rubber latex that has a dry rubber content (DRC) varying from roughly 20 % to 40 % is a colloidal dispersion of rubber particles, in an aqueous serum. The DRC of latex is important quality parameter as it required being accurately and rapidly for chemical additions during processing, quick payment to latex producers. Dry rubber content in this work (DRC) was

40.578 %. Mechanical stability testing (MST) is 1170 s. It is perhaps one of the indicative to evaluate whether preserved latex is suitable or not for further use. Ammonia content is important due to coagulate of NRL within few hours due to development of acidity through microorganisms when the pH falls to around 5.0. The content of ammonia in this sample was 0.373 %. The results are shown in Table 2

Table 2: Physicochemical Properties of Natural Rubber Latex

No.	Properties	Observed values
1	Total solid content (%)	42.180
2	Dry rubber content (%)	40.578
3	Mechanical stability testing (s)	1170
4	Alkalinity (% of NH_3)	0.373

Physicomechanical Properties of Natural Rubber Latex Chitosan Composites

This present work concerned with the effect of various ratios of chitosan filler (0, 2.5, 5, 7.5 and 10 %) on the mechanical properties of natural rubber (NRL) latex (100 pph). The mechanical tests were usually used to evaluate the properties of rubber materials including tensile strength, elongation at break, specific gravity, tear strength and tensile modulus (300, 400 and 500) were evaluated. The increase in the level of chitosan fillers, there were slightly decreased in the tensile strength, elongation at break and tear strength as compared to unfilled (chitosan) sample. These may be due to the poor NR latex-filler interaction and also due to the non-uniform in the filler distribution. However, the values of specific gravity and tensile modulus (M_{300}, M_{400} and M_{500}) were slightly increased with increasing the filler ratios. Among the filler results, the tensile strength and elongation at break in the range for 2.5 pph of chitosan filler were higher as compared to 5, 7.5 and 10 pph of the filler. The tear strength of the range obtained for all samples were 20.2-23.6 kN/m. The range of the tensile modulus values obtained for all samples was 0.6-1.7. The results are illustrated in Table 3 and Figures 5-9.

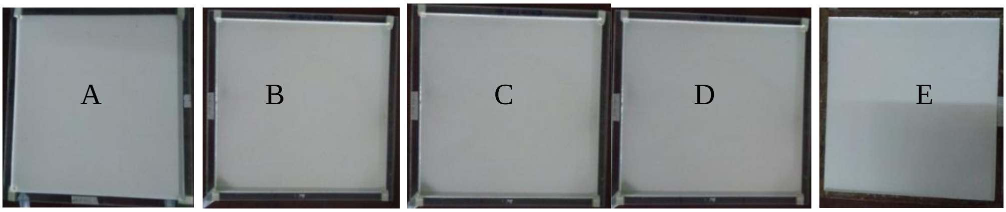

Figure 4: Natural rubber latex chitosan composites A, B, C, D and E

Table 3: Mechanical Properties of Natural Rubber Latex Chitosan Composites

No.	Test	Resultant data of various natural rubber latex chitosan composites				
		A	B	C	D	E
1.	S.G	0.93	0.96	0.95	0.96	0.95
2.	Tensile Strength(MPa)	4.8	4.3	3.3	2.9	3.0
3.	Elongation at Break(%)	793	630	628	625	619
4.	M_{300}	0.8	0.8	0.7	0.6	0.7
5.	M_{400}	1.1	1.1	1.0	0.9	0.9
6.	M_{500}	1.5	1.7	1.5	1.3	1.4
7.	Tear strength(kN/m)	22.1	21.0	19.7	23.6	20.2

S.G = Specific gravity
M_{300} = Tensile Modulus at 300 %
M_{400}= Tensile Modulus at 400 %
M_{500}= Tensile Modulus at 500 %

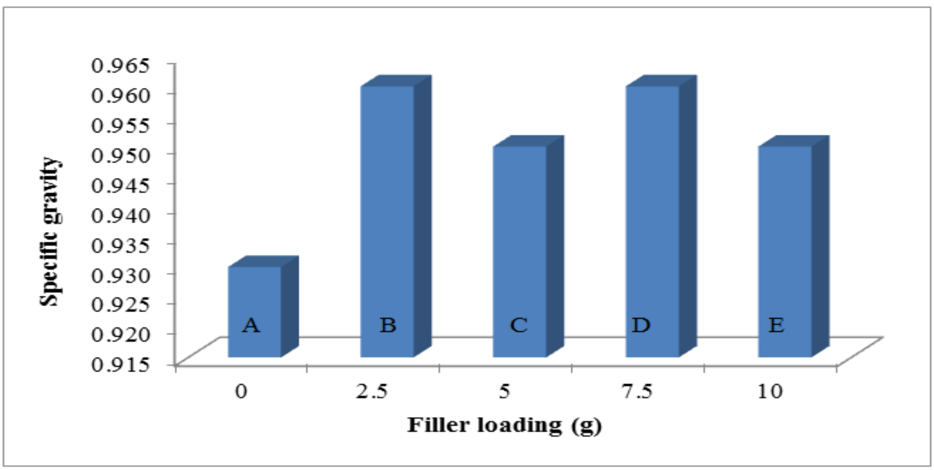

Figure 5: Specific gravity of natural rubber latex chitosan composites (A-E)

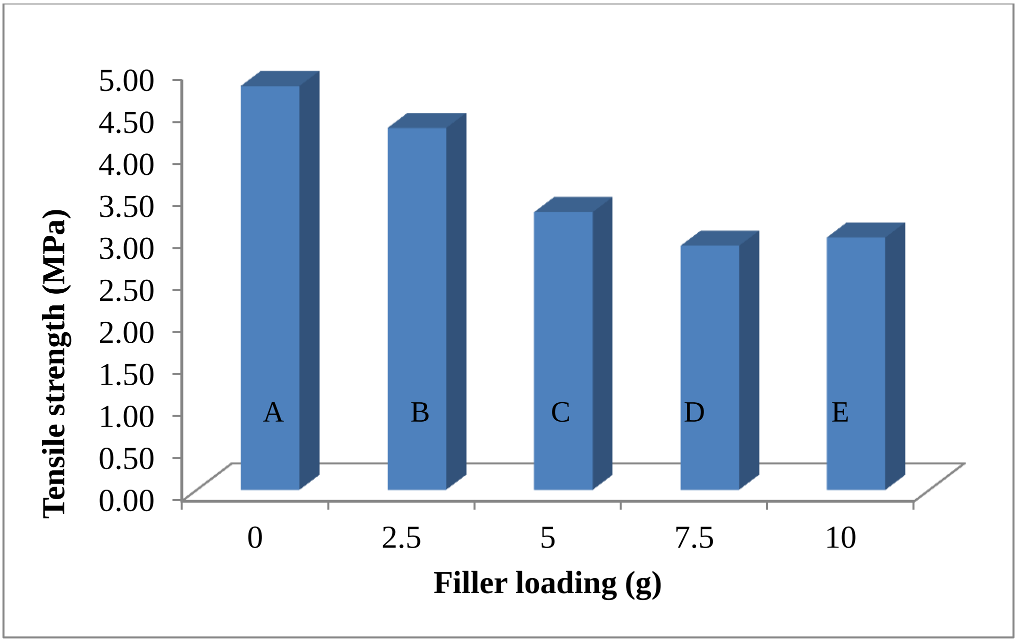

Figure 6: Tensile strength of natural rubber latex chitosan composites (A-E)

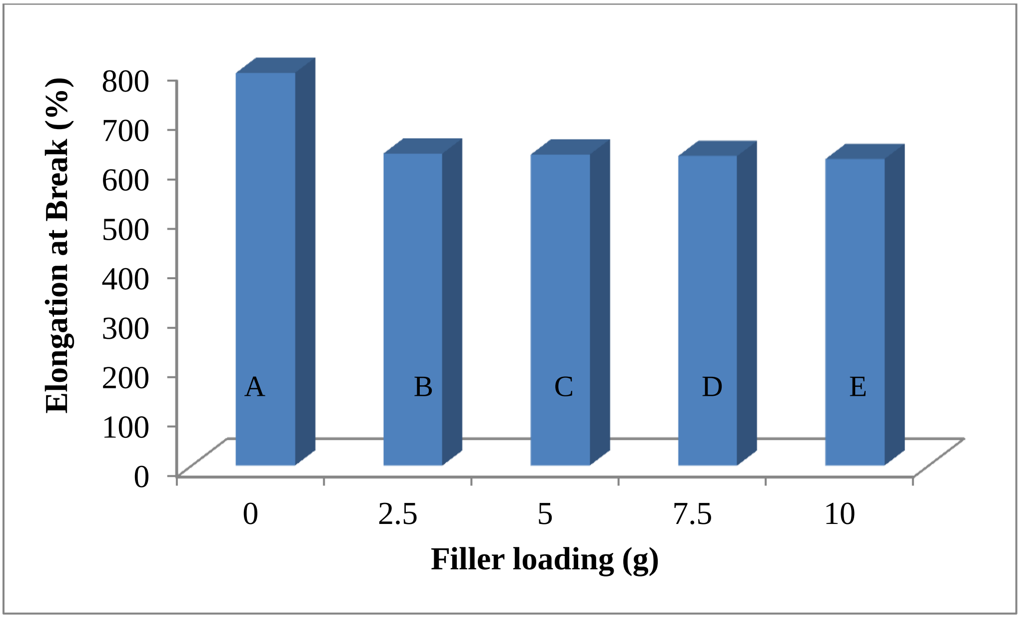

Figure 7: Elongation at break of natural rubber latex chitosan composites (A-E)

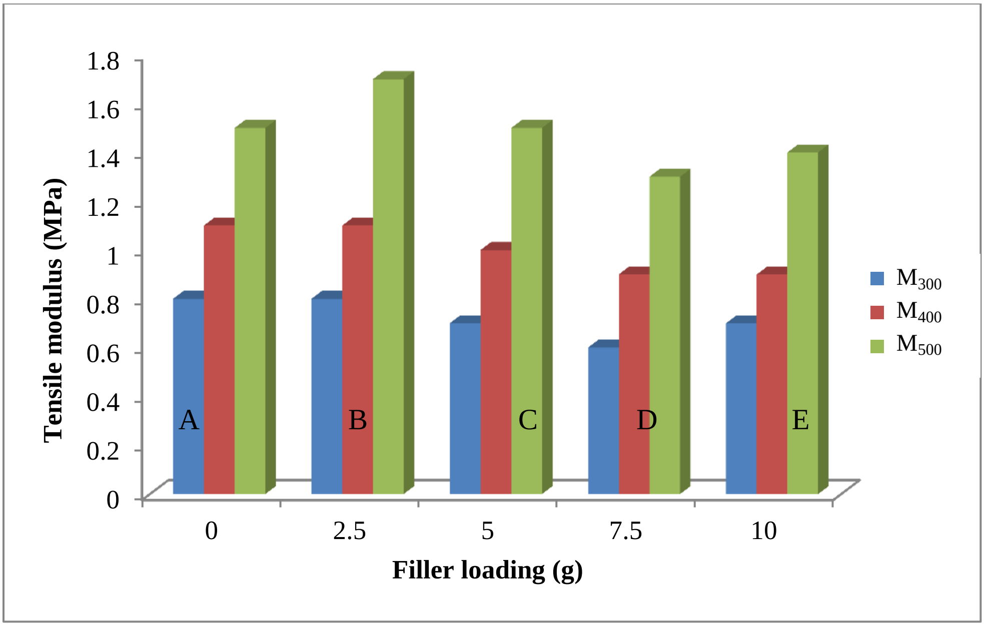

Figure 8: Tensile modulus of natural rubber latex chitosan composites (A-E)

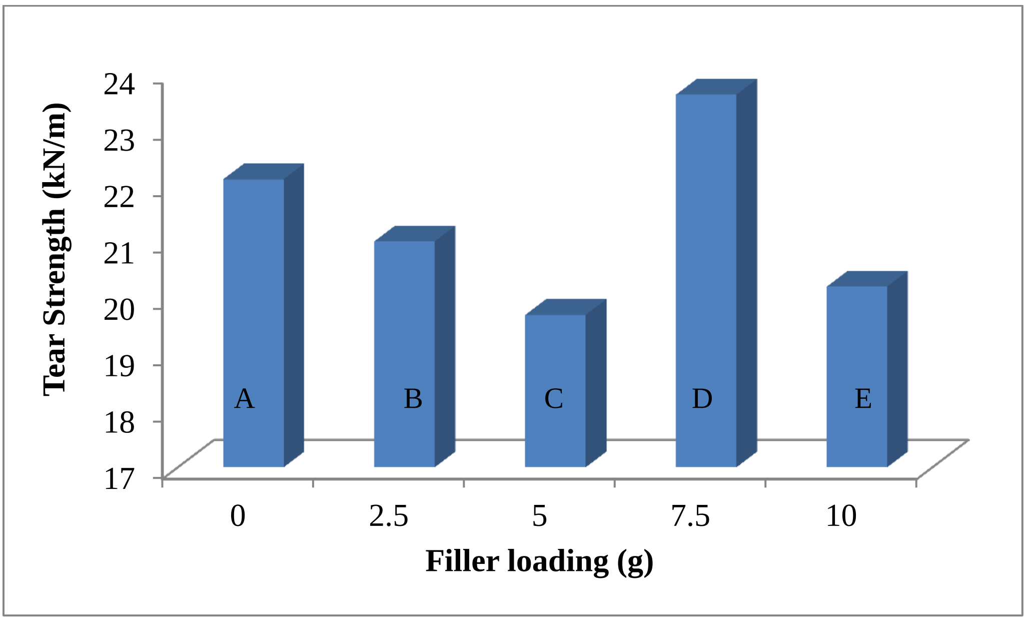

Figure 9: Tear strength of natural rubber latex chitosan composites (A-E)

Conclusion

The chitosan was incorporated as bio-fillers in natural rubber latex composites. The physicochemical properties of natural rubber latex such as total solid content (42.108 %), dry rubber content (40.578 %), alkalinity (0.373 %) and mechanical stability testing (1170 s) respectively were investigated. The natural rubber latex chitosan composites consist of 0 to 10 parts by weight of chitosan to 100 parts of natural rubber latex were examined. As for the mechanical properties, the tensile strength and elongation at break of chitosan natural rubber latex composites decreased with an increase in filler loading. Modulus (M_{300}, M_{400} and M_{500}) and specific gravity were slightly increased with increasing chitosan loading. Moreover, results revealed that natural rubber latex containing 2.5 pph of chitosan loading provided optimum properties.

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