Effect of Sepiolite Clay on Reinforcement and Chemical Performance of NR Latex Films

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Keywords—Natural rubber, Sepiolite clay, Nanocomposites, Chemical resistance, Protective gloves

I. INTRODUCTION

Natural rubber (NR) latex is extensively used in dipped products such as gloves due to its high elasticity and flexibility. However, its low resistance to chemicals and moderate mechanical properties restrict its wider use [1]. Traditional fillers such as silica improve properties but are costly and less sustainable [2]. Sepiolite clay, a naturally occurring fibrous magnesium silicate, provides high surface area and active silanol groups that can enhance filler–matrix interactions [3]. This study investigates the potential of sepiolite clay to reinforce NR latex films and improve chemical resistance, targeting optimized formulations for protective glove applications.

This study aims to investigate how sepiolite clay reinforces natural rubber gloves and how its concentration affects their chemical performance. Gloves will be formulated with varying sepiolite loadings using a newly developed incorporation method. The reinforcing effect, mechanical strength, and chemical resistance will be evaluated to identify the optimal sepiolite loading.

II. LITERATURE REVIEW

Natural rubber (NR) is valued for its elasticity and resilience, but its mechanical and chemical limitations restrict its use in demanding applications. Traditionally, fillers like silica and carbon black have been used to enhance NR properties, yet these materials are energy-intensive to produce and raise sustainability concerns [4]. Nanofillers have emerged as promising alternatives, offering high surface area and reinforcement at low concentrations. Among these, sepiolite clay which is a naturally occurring fibrous magnesium silicate stands out for its unique needle-like morphology, high porosity, and reactive silanol groups, which enable superior stress transfer and interaction with polymer matrices [4].

Research by Bokobza et al. and Tadiello et al. has shown that sepiolite provides better reinforcement than conventional spherical silica, improving dynamic modulus, thermal stability, and reducing rolling resistance in NR composites [2, 3]. Masa et al. further demonstrated that sepiolite enhances tensile strength and dispersion, with its magnesium oxide content acting as a vulcanization activator [5]. Despite these advantages, the use of sepiolite in NR latex systems, particularly for dipped products like gloves, remains underexplored. This study addresses this gap by evaluating the reinforcing and chemical resistance properties of sepiolite in NR latex films, aiming to establish it as a sustainable, high-performance alternative to traditional fillers.

III. MATERIALS AND METHODS

To achieve the research objectives, low-ammonia NR latex was compounded with 0–10 phr sepiolite clay using a newly developed dispersion method. The clay was characterized by FTIR, SEM, EDX, and particle size analysis, while dispersion quality was optimized through microscopic observation to ensure uniform particle distribution. Rheological studies were then conducted to assess the reinforcement potential of the dispersions incorporated into NR latex compounds. Based on these results, compounds with 2–10 phr sepiolite were formulated and matured for 0–48 hours, as illustrated in Table I. Processability was evaluated through pH, TSC, viscosity, chemical stability, and gelling time to determine the ideal maturation period. After compounding, reinforcement and chemical resistance were assessed by testing tensile strength, elongation at break, modulus, crosslinking density (Flory-Rehner equation), abrasion, tear, puncture resistance, and chemical permeation. Finally, the optimum sepiolite content identified was applied in natural rubber gloves (0.45 mm thickness), and both mechanical and chemical protection properties were evaluated according to relevant standards.

TABLE I. FORMULATION USED FOR THE COMPOUNDING

Ingredient	phr level
Centrifuged latex (NR)	100
KOH (as stabilizers)	0.3
Secondary alcohol ethoxylate	0.4
Curing dispersions with sulphur, ZDEC and ZnO	3.0
Ammonium polyacrylates	0.24
Antioxidant dispersion	0.7
Antifoaming agent	0.05
10% Sepiolite clay	2 - 10

IV. RESULTS AND DISCUSSION

This section presents the characterization of sepiolite clay and its aqueous dispersion, followed by the evaluation of its reinforcing and chemical resistance effects on NR latex films and gloves.

Characterization of sepiolite clay: FTIR confirmed the presence of Si–O, Mg–OH, and hydroxyl groups, indicating a fibrous silicate structure [6]. SEM imaging revealed elongated, needle-like fibers with high surface area and porosity [7], as illustrated in Fig. 1, while EDX validated the elemental composition, showing oxygen (44.19%), magnesium (19.98%), aluminum (3.90%), silicon (31.01%), and trace iron (0.92%) [8]. Particle size analysis further showed a median diameter of 15.24 µm, confirming the fine particle distribution suitable for uniform dispersion in latex systems [6].

Characterization of sepiolite dispersion: Microscopic observation showed that 10% sepiolite dispersions had the most uniform distribution with minimal agglomeration. Rheological testing indicated that among the tested dispersions, 10% wt. sepiolite showed the highest relative viscosity at low speed, confirming uniform distribution and strong filler–matrix interaction. In contrast, 20% and 30% wt. dispersions suffered from fiber aggregation, reducing dispersibility and reinforcement potential. Thus, 10% wt. is the optimum dispersion level for achieving effective reinforcement in NR latex, as illustrated in Fig. 2 & 3.

Processability of NR latex composite containing sepiolite clay: Latex compounds with 2–10 phr sepiolite were evaluated at different maturation times. The optimal processability was achieved at 24 hours, with stable pH, increased viscosity, and consistent gelling time, especially at 8 phr loading [3].

Effect of sepiolite clay on film formation and reinforcement properties of NR latex films: Wet gel strength and mechanical properties such as tensile strength, modulus, tear, abrasion, and puncture resistance all peaked at 8 phr sepiolite. Crosslinking density was also highest at this loading, while higher levels led to agglomeration and reduced performance. Permeation resistance against acids, bases, and solvents was greatest at 8 phr, attributed to sepiolite's fibrous morphology.

Thermo-oxidative stability of sepiolite clay containing NR latex films: Thermo-oxidative tests showed tensile retention declined from 96% in unfilled samples to 90% in films and 86% in gloves with 10 phr sepiolite, due to iron oxide impurities accelerating degradation. Surface modification or purification is recommended to enhance long-term durability [6].

Sepiolite clay in glove application: Gloves with 8 phr sepiolite showed superior mechanical and chemical protection, confirming sepiolite's value as a sustainable, high-performance filler for protective gloves.

V. CONCLUSION

This study demonstrated that sepiolite clay is an effective and sustainable nanofiller for natural rubber (NR) latex, significantly enhancing mechanical strength, crosslink density, and chemical resistance at an optimal loading of 8 phr. Comprehensive characterization confirmed sepiolite's fibrous morphology and suitable dispersion properties, while processability and mechanical testing established the ideal conditions for reinforcement. However, the presence of iron oxide impurities was found to limit thermo-oxidative stability, indicating the need for further purification or surface modification to maximize long-term durability. Glove applications validated the improvements in both mechanical and chemical protection, supporting sepiolite's potential for advanced protective products.

Future work should examine sepiolite in other rubbers such as NBR and SBR, evaluate surface-modified grades for improved compatibility, and explore hybrid systems with nanomaterials like carbon nanotubes or graphene for synergistic effects. With such advancements, sepiolite could further strengthen its role as a sustainable, high-performance filler for rubber composites.

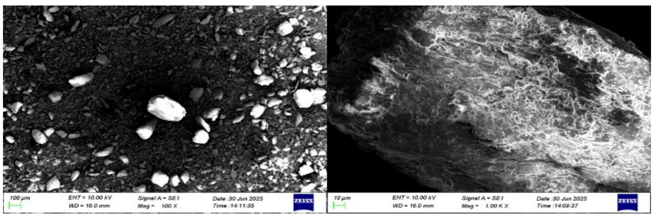

Fig. 1. SEM images of sepiolite clay at different magnifications.

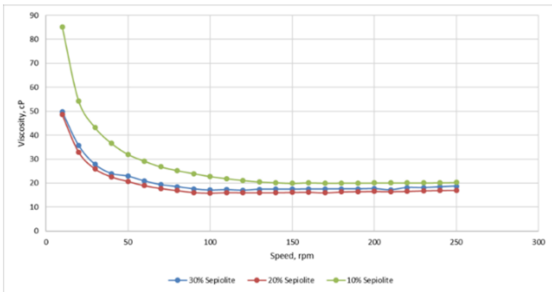

Fig. 2. Viscosity behavior of latex compounds with 10%, 20% and 30% sepiolite dispersions across varying speed.

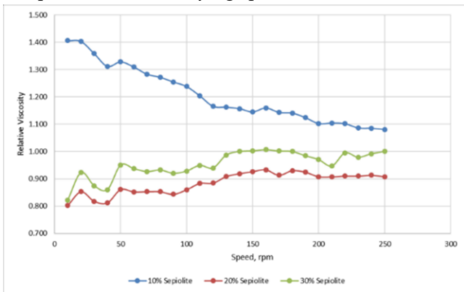

Fig. 3. Relative viscosity of latex compounds with 10%, 20% and 30% wt. sepiolite dispersions across varying speed.

ACKNOWLEDGMENT

The authors gratefully acknowledge the R&D Department of Dipped Products PLC for resources and facilities, to colleagues for constructive feedback, and to family and friends for their unwavering encouragement.

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