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Full Paper

The Effect of Hydrogen Peroxide based Hand Sanitizing Chemicals on the Physicomechanical Properties of the NBR Gloves

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Abstract

During the Covid-19 pandemic, according to the guidelines given by the World Health Organization (WHO), all industrial and examination gloves are subjected to disinfection globally using hand sanitizers. This may affect the physicomechanical properties of the gloves. However, limited data are available regarding the aforesaid issue. This research is focused on investigating the effect of hydrogen peroxide-based hand sanitizer formulations, recommended by WHO on the chemical and physicomechanical properties of NBR gloves. NBR gloves were exposed to sanitizing chemicals with different application frequencies for eight hours and the properties were evaluated after 48 hours. The results revealed that there is no significant effect of sanitizer formulation on the mechanical properties of NBR gloves such as tensile strength, tear resistance, elongation at break, modulus at 100%, and 300% even at high frequent applications. Physical properties such as discoloration, swelling, and leakages were also not affected by the application of sanitizers. Further, DSC and TGA test results revealed that there is no significant change in crystallinity and thermal properties between control and test samples. However, FT-IR analysis indicated a change in the chemical environment of the surface of the glove specimens. Since FT-IR is a surface analysis technique, it can be identified as the surface of the gloves has been affected by the exposure to sanitizer formulations. Nevertheless, the inadequate time for the hand sanitizing chemicals to be penetrated to the core of the gloves might result in unchanged physicomechanical properties within 48 hours. Knowing the fact that the examination gloves have a very short usage time, it can be concluded that the effect of hydrogen peroxide-based hand sanitizer formulations on NBR examination gloves is negligible. However, we highlight the importance of conducting further research for an extended period to evaluate the effect of the exposure on heavy-duty NBR gloves such as industrial gloves.

Keywords: Hand sanitizers, NBR gloves, physicomechanical properties

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Introduction

In recent years, there has been a huge increase in the development of latex allergy among workers. Many glove manufacturers are now manufacturing powder-free, latex-free synthetic gloves as response to this health-care crisis. The selection of examination and industrial gloves is based on specific performance parameters that include glove thickness, tensile properties, resistance to puncture, the force required to don the gloves, and tactile discrimination as discussed by Jackson et al. [1]. There are a number of substitutes to natural rubber latex for the manufacture of gloves such as nitrile, neoprene, plasticized PVC, Polyurethane and Styrene Block Copolymer gloves. But none of them have the same unique combination of properties as NR latex [2]. Synthetic rubbers use for the production of industrial gloves intended to be able to protect the user against particular chemical products or against mechanical risks. The most commonly used synthetic latexes are polychloroprene latex and nitrile rubber latex in the production of gloves as discussed by Renaud [3]. Nitrile Gloves are made from Nitrile Rubber. Nitrile rubber, also known as acrylonitrile butadiene rubber, is a synthetic rubber copolymer of acrylonitrile (ACN) and butadiene. Its physical and chemical properties vary depending on the ACN composition, and they generally resistant to oil, fuel, and other chemicals (the higher ACN content within the polymer, the higher the resistance to oils and lower the flexibility of the polymer material). Nitrile rubber is less likely to cause an allergic reaction than natural rubber.

During the pandemic outbreak, alcohol-based hand sanitizers are used for disinfecting purposes such as area disinfecting, vehicles disinfecting and PPE disinfecting**.** Hence during the covid-19 pandemic, hydrogen peroxide-based hand sanitizers are mostly used to maintain personal hygiene. Agencies such as the World Health Organization promotes the use of alcohol-based hand sanitizers over alcohol-free products [4]. The formulation recommended by World Health Organization for making hand sanitizing chemical contains Isopropyl alcohol 75% (v/v), Hydrogen peroxide 0.125% (v/v), Glycerol 1.45% (v/v) and sterile water [5]. Although people have used hand sanitizers in unlimited quantity on the gloves without knowing because it is not estimated yet the effect of hand sanitizing chemical on various types of glove materials. Therefore, the consumer and the manufacturer are required to know about the effect on glove material which exposes to hand sanitizing chemical.

However, according to our knowledge, there is limited data available regarding this problem. Therefore, in our research, we mainly focus to find the effect (physical, chemical, and mechanical) of hand sanitizers on the wide range of applications of non-latex gloves.

Experimental Section

Materials

Glove samples were selected randomly as control and testing samples. The chemicals required to make sanitizer formulation were collected and prepared according to Table 1, following the WHO recommendation.

Table 1. Materials required for hand sanitizer formulation as discussed by [5]

Reagents for sanitizer formulation	The final concentration for the formulation
Isopropyl alcohol 99.8%	Isopropyl alcohol 75% (v/v)
Hydrogen peroxide 3%	Hydrogen peroxide 0.125% (v/v)
Glycerol 98%	Glycerol 1.45% (v/v)
Sterile water or boiled cold water	Sterile water or boiled cold water

Method

Initial Characterization of Glove Samples

The thickness of gloves was measured using a Digital Thickness Gauge (thickness range from 0-0.5 mm). The color of control and test gloves samples were measured from visual inspection and taken photos from a 13-megapixel primary rear camera.

Test Samples Preparation

Glove samples were prepared by dipping them into the sanitizer around 3 minutes according to the following test conditions at room temperature; Test sample 1- once in every 15 minutes, Test sample 2-once in every 30 minutes, Test sample 3-once in every 1 hour, Test sample 4-once in every 2 hours, Test sample 5-once in every 3 hours for 8 hours.

Characterization of Prepared Glove Samples

The test samples were matured 24 hours at room temperature and the resulted specimens were characterized for their chemical and physicomechanical properties using Tensile Tester (to measure tensile strength, tear resistance, elongation at break, modulus at 100%, and 300%), Fourier Transform Infrared Spectroscopy (FTIR), Thermogravimetric analysis (TGA), and Differential Scanning Calorimetry (DSC) for sanitizer treated glove samples along with control. Physical properties such as discoloration, swelling, and leakages were also measured.

Results and Discussion Section

Characterization of Prepared NBR Glove Samples

Discoloration

There was no any significant color change between control (unexposed) NBR glove sample and the test NBR glove samples. A photo of control glove sample and test glove samples of NBR gloves are shown Figure 1.

Figure 1. NBR latex glove samples; (S) control and HS treated (A) once in 15 min, (B) once in 30 min, (C) once in 1 hour, (D) once in 2 hours (E) once in 3 hours

Effect of the Hand Sanitizer Treatment on the Tensile Properties and Tear Resistance of NBR Gloves

According to Figure 2, there is no significant difference in tensile properties such as tensile strength, elongation at break, and tear resistance of the control and HS treated NBR glove samples. The modulus at 100% elongation (M100) and 300% elongation (M300) indicate the changes in stiffening effect in the rubber matrix. Two main factors that influence the stiffening are reported as crosslink concentration and glass transition temperature of the rubber by Andrew & Jones [6]. An insignificant slight reduction of the modulus values (Figure 2 C) may be due to a slight increment of swelling over the sanitizer application. However, it can be considered as insignificant as this effect was not reflected in the other mechanical properties discussed earlier. Therefore, it can be concluded that the sanitizer exposure does not make any detectable effect on the mechanical properties of NBR during the period examined.

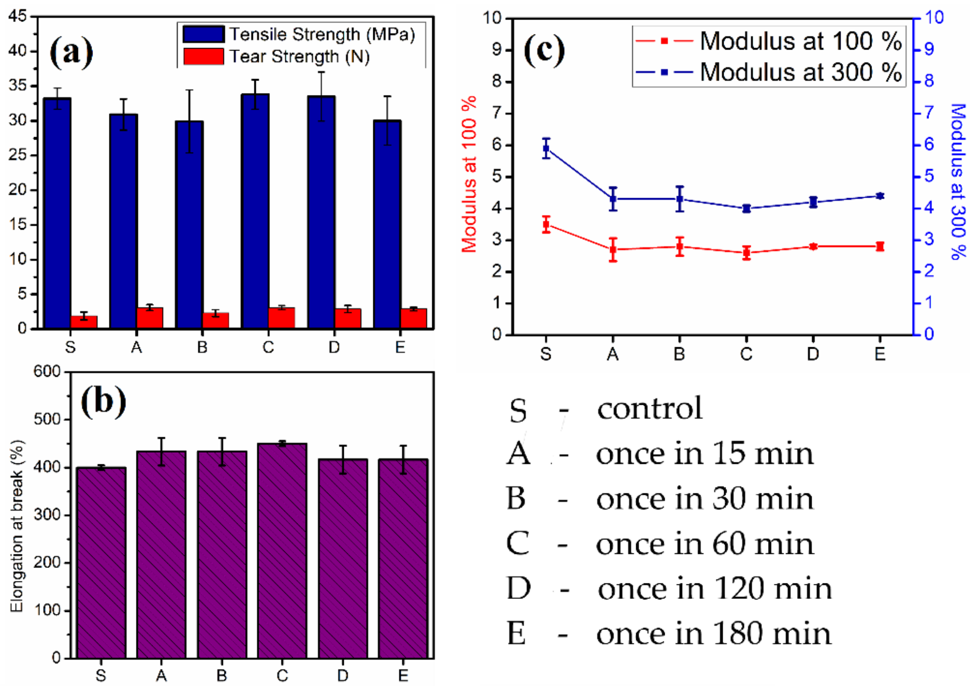

Figure 2. Variation of tensile properties and tear resistance of the control and HS treated NBR gloves

Effect of the Hand Sanitizer Treatment on Chemical Properties of Glove Samples

Figure 2 shows the FTIR spectra of NBR Glove with (NBR-A) and without (NBR-S) treated by HS are shown in Figure 3 (a). Figures 3(b) and 3(c) show the FTIR spectra of selected wavenumber ranges for NBR glove samples with different frequencies of application of HS.

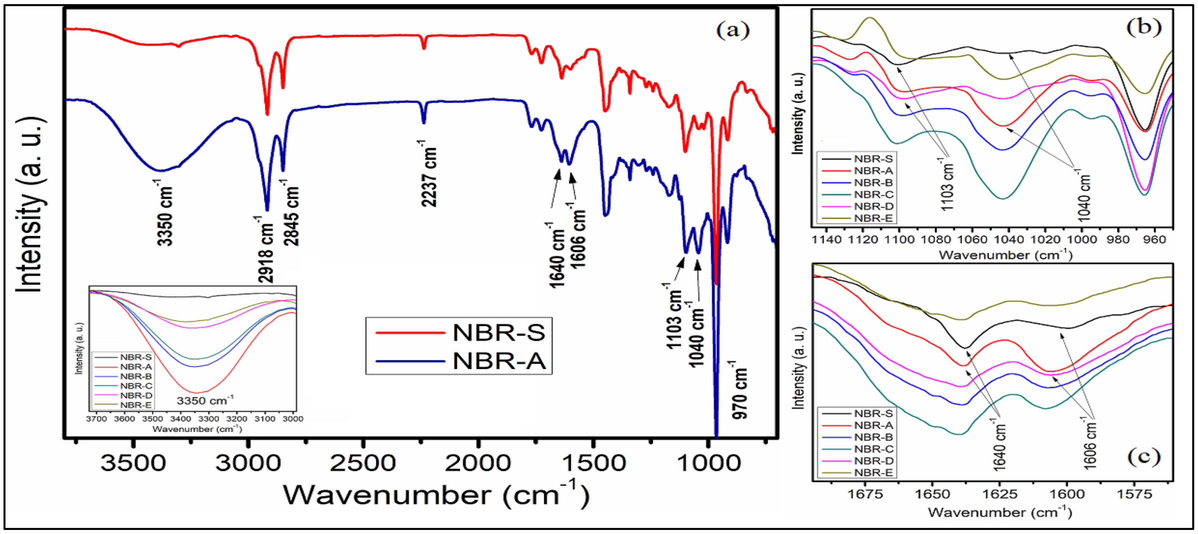

Figure 3. FTIR analysis of the NBR glove samples with and without HS treatment

Peaks assigned for each vibrational mode are presented in Table 2. FTIR spectrum of NBR-S in Figure 3 shows various peaks that are normally present in the nitrile rubber. The FTIR results show a peak at 2239 cm^{-1} which is attributed to the -CN bond of the nitrile group [7]. The peak at 3342 cm^{-1} is due to OH stretching group. Two sharp bands appearing at 2918 and 2845 cm^{-1} are attributed to the asymmetric and symmetric stretching frequencies of $-CH_2$ (in methylene groups) [8] of NBR, respectively.

Table 2. Peaks of the ATR-FTIR spectra for NBR glove samples with and without HS treatment [9]

Wavenumber (cm^{-1})	Assignment
3350	Symmetric stretching of hydroxyl groups (-OH)
2918	Asymmetric stretching of the methylene group ($-CH_2$)
2845	Symmetric stretching of the methylene group ($-CH_2$)
2237	Stretching vibration of nitrile triple bonds in NBR
1640	Stretching of -C=C-
1606	Stretching of C=O in carboxylate ions ($–CO-O^-$)
1103	Wagging and twisting of methylene groups ($-CH_2$)
1040	Stretching of C–O groups in carboxylate ions ($–CO-O^-$)
970	Out-of-plane –CH=CH– deformations in trans units

According to Figure 3, the control sample shows a very less intense peak at 3342 cm^{-1} which may be related to O-H stretching vibrations while HS exposed samples show gradual increment in the intensity whereas the maximum intensity is reported by the NBR sample treated with HS more frequently. This may be due to HS exposed samples has got hydrogen peroxide and isopropyl alcohol molecules which are rich in O-H groups on their surface. These excess hydroxyl groups on the surface of the NBR glove will affect the hydrophobic nature of the glove surface and leads to convert it into more hydrophilic, which would facilitate the further interactions of the glove surface with the H_2O_2 oxidizing agent.

It was observed that two peaks around 1606 cm^{-1} and 1040 cm^{-1} due to stretching of C=O in carboxylate ions

(–CO-O⁻) and stretching of C–O groups in carboxylate ions (–CO-O⁻), respectively are appearing with the treatment of HS, while the peaks attributed to –C=C- stretching, out-of-plane –CH=CH– deformations, and wagging and twisting of methylene groups (-CH_2) at around 1640 cm^{-1}, 970 cm^{-1}, and 1103 cm^{-1}, respectively [9] have remained relatively unchanged. This is in an agreement with that the –CN group attached to the backbone carbon chain of the NBR is likely to be oxidized in the presence of H_2O_2. Therefore, according to FTIR analysis, there is a significant effect on the surface layer which may cause chemical structure change.

However, it was not shown significant alteration in mechanical properties. That may be due to the lack of time for the sanitizer chemicals to be penetrated the depth of the glove material. Therefore, these all data as a combination will provide an interesting conclusion that is if the glove material being exposed longer period to these sanitizing chemicals, there will be a tendency for the material to have deteriorated. Nevertheless, the examination gloves have a very short usage time. Therefore, it can be concluded that the effect of hydrogen peroxide-based hand sanitizer formulations on NBR examination gloves is negligible.

Effect of the Hand Sanitizer Treatment on Glass Transition Temperature and Crystallinity of Glove Samples (DSC Analysis)

According to DSC results (Figure 4), there is no significant effect on crystallinity and T_g of NBR glove over the exposure to HS formulations.

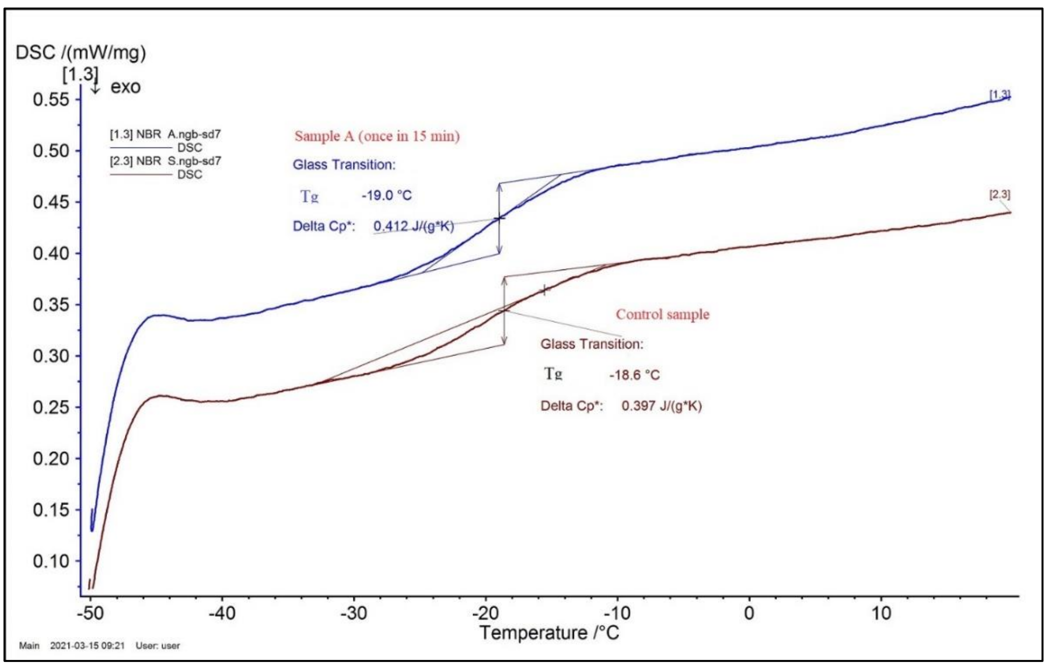

Figure 4. Variation of DSC spectra between NBR control and sample A (once in 15 min)

Conclusion

According to the data obtained for NBR glove materials with and without being subjected to HS treatments, it can be concluded that the treatments with even higher frequencies of application were not affected the physicomechanical properties of the gloves. However, the FTIR analysis data suggest that there is a trend of altering the chemical environment of the surface of the glove material. However, as the physicomechanical properties were measured within a short period, the HS chemicals were believed not to have enough time to migrate into the depth of the glove material. Considering the usage period of these gloves in day-to-day applications, it can be highlighted that the effect of HS treatment on the NGR examination gloves is negligible, Nevertheless, the mechanical and thermal properties of industrial gloves which are used for a longer period might be affected by H_2O_2 based HS exposure.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this research.

Acknowledgment

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