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Curcumin incorporated NR latex film; Mechanical property enhancement and degradability

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Curcumin incorporated NR latex film; Mechanical property enhancement and degradability

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The datasets used during the current study are available from the corresponding author on reasonable request.

Competing Interests Declaration

The authors declare that they have no competing interests.

Abstract

Curcumin (CUR) is a remarkable natural product having multiple biological and pharmacological importance. Furthermore, it is an excellent photosensitizer. Considering its photosensitizing ability, this endeavor highlights CUR incorporation into natural rubber (NR) latex with the expectation of developing degradable NR products and further to analyze its mechanical properties. CUR was extracted from turmeric using solvent extraction method and FTIR and UV-visible spectroscopy confirmed the extraction of CUR. Incorporation of CUR into NR latex was achieved by preparing a curcumin – tween 80 dispersion. The thermal stability of CUR-NR is comparable to that of conventional NR films. Incorporation of CUR into NR latex has enhanced the mechanical properties exceptionally compared to the control. Curcumin incorporated NR latex (CUR-NR) film exhibited maximum tensile strength of 5.26 ± 0.98 MPa, hardness of 69.6 ± 0.4 shore A and tear strength of 63.49 ± 13.09 kN/m. Degradability of NR latex films with the incorporation of CUR was investigated by weight loss percentage, FTIR analysis and microscopic surface analysis at outdoor weathering and accelerated aging tests. Accelerated degradability of the NR films were observed with the incorporation of CUR. CUR incorporated NR latex films display enhanced mechanical properties and degradability as an excellent value addition strategy for NR latex.

Key words; Curcumin, Natural Rubber, Film, Mechanical properties, Photodegradation

1. Introduction

Turmeric (*Curcuma longa*) has been utilized as an herb, spice and pigment for centuries. Most of these properties are imparted by the major natural polyphenol curcuminoid present in turmeric known as Curcumin (CUR). It is a promising natural product that has gained immense attention owing to its various functional activities such as antioxidant, anti-inflammatory and antibacterial properties.

CUR undergoes photodegradation when exposed to UV-visible radiation[1]. Photodegradation of CUR mainly proceeds through dissociation of the β-diketone group to byproducts such as phenolic compounds. Furthermore, structural changes such as demethoxylation and isomerization of “keto-enol” to “di-keto” form and the formation of small sub-products such as methanol or acetate could be observed through curcumin photodegradation process[2]. CUR has exhibited its extensive potential to act as a photosensitizer. The capability of curcumin to function as a photosensitizer has been used in photodynamic therapy as it absorbs blue light and generates reactive oxygen species[3].

CUR has been incorporated into different polymers to impart the properties of curcumin into the polymer composite. Polymer based materials loaded with curcumin such as hydrogels, films or membranes, bandages and nanofibers have been developed to obtain wound healing applications[4-7]. CUR has been combined with polyvinyl butyral (PVB), cellulose, alginate, gelatin and polyurethane to enhance the antibacterial activity of the polymer composite[8-10].

Moreover, CUR has been employed as a photosensitizer in photodynamic therapy and food preservation. Sarih et al. developed CUR incorporated wearable natural rubber latex gloves to detect torn gloves in clinical settings utilizing the fluorescence yield[11]. A cosmetic anti-aging face mask combining CUR with Natural rubber (NR) latex with antioxidant properties was developed by de Souza Silva et al[12]. However, CUR incorporated into NR latex films with the expectation of enhancing its degradability has not been explored to the best of the authors' knowledge.

Natural rubber is a sustainable material which has many applications. NR latex has been widely utilized in industrial submissions such as tires, mattresses, gloves, rubber bands, balloons and shoes owing to its unique properties such as high elasticity with stretch recovery, tensile strength and tear strength. However, lack of degradability of NR products has increased the concern of utilizing them due to the accumulation of waste and thus environmental pollution. In literature, different types of fillers have been utilized to improve the degradability of NR latex. Bio based fillers such as nano cellulose, chitosan and sugarcane bagasse have been reported to accelerate the biodegradation of NR latex[13-15]. Moreover, encapsulated benzophenone has been used as a photosensitizer to study the controlled degradation of cured NR films[16]. Furthermore, oxo-biodegradable rubber films were developed utilizing iron (III) stearate and cobalt (II) stearate as pro-degradant additives (PDA)[17, 18]. Enhanced degradability on NR products would increase the utilization of them and expand the applications.

Thus, this endeavor highlights the development and characterization of the CUR-NR film. Furthermore, the degradability of the developed CUR-NR was evaluated through accelerated aging and weathering tests. The film's physical and mechanical properties were assessed by analyzing tensile strength, hardness, and tear strength to identify variations in performance. These findings not only demonstrate the material's robustness and stability but also contribute to enhancing the functional value of sustainable NR-based materials, thereby expanding their potential applications within the rubber industry.

EXPERIMENTAL

1.1 Material

Turmeric powder was purchased from the local market in Colombo, Sri Lanka. Natural rubber latex (60% centrifuged) was provided by the Dipped Products PLC, Kottawa, Sri Lanka. Tween 80 was purchased from HiMedia Laboratories Pvt. Ltd. Sulphur and ZnO were purchased from Daejung chemicals and metals CO., LTD. TMTD was purchased from Glorchem enpterprises. 96% ethanol was purchased from Lanka Sugar company Pvt. Ltd. All the chemicals employed were in analytical grade.

2.2 Extraction of curcumin

Turmeric powder was soaked in ethanol for 7 days at room temperature[19]. Then curcumin dissolved ethanol layer was separated from the turmeric, dispersed onto a petri dish using a syringe. Finally, ethanol was evaporated to obtain curcumin semidry oily mass.

2.3 Preparation of curcumin – tween 80 dispersion

The dispersion of curcumin was prepared by dispersing extracted curcumin with hydrophilic tween 80 surfactant in distilled water as in table 1. The mixture was sonicated using an ultrasonic sonication bath until the curcumin is well dispersed.

Table 1: The composition of curcumin dispersion.

Sample (phr)	Curcumin (g)	Tween 80 (ml)	Distilled water (ml)
CUR-1	0.5	2	50
CUR-2.5	1.0	5	50
CUR-5	2.5	10	50

2.4 Preparation of curcumin incorporated NR latex film

CUR - NR latex films were prepared by adding dispersions of curcumin (1 phr, 2.5 phr and 5 phr) into 60% centrifuged NR latex containing the conventional vulcanizing system consisting of 50% aqueous dispersions of sulfur, ZnO and TMTD as in table 2. The compounding ingredients were added in the sequence of ZnO, curcumin dispersion, TMTD and sulfur while stirring the NR latex. The latex mixture was stirred for 2 hours at room temperature to achieve a homogeneous mixture. Then it was poured evenly into a glass plate with an area of 30 cm×15 cm and allowed to dry. After the film formation, samples were analyzed using a moving die rheometer to determine the optimum T90 value. Then CUR - NR latex films were vulcanized in an air circulation oven at 140 °C according to the obtained T90. Reference NR latex sample was prepared by conventional vulcanizing system without the addition of curcumin.

Table 2: Formulation of prepared NR latex sheets.

Sample Name	Curcumin dispersion (phr)	NR latex (phr)	ZnO (phr)	Sulfur (phr)	TMTD (phr)
CUR – 0 (Control)	0	100	2	1	0.6
CUR – 1	1	100	2	1	0.6
CUR – 2.5	2.5	100	2	1	0.6
CUR – 5	5	100	2	1	0.6

2.5 Characterization

2.5.1 Fourier transforms infrared spectroscopy

Infrared spectroscopy data of curcumin, NR latex and CUR - NR latex film samples before and after the degradation were obtained by BRUKER ALPHA (1 003 1705) FTIR spectrometer within the scan range of 4000 - 500 cm^{-1} at a resolution of 4 cm^{-1}.

2.5.2 UV-visible spectrometer

SHIMADZU UV-1900I spectrometer, was utilized to confirm the presence of curcumin in turmeric extract with the concentration of 10 μg/ml, within the wavelength range of 300 nm to 550 nm using a quartz cell.

2.5.3 Thermogravimetric analysis (TGA)

Thermal analysis of developed films was observed by TA SDT Q600 V20.9 Build 20 thermogravimetric analyzer within the temperature range of 30 °C to 600 °C at a heating rate of 10 °C/min under a nitrogen atmosphere at a flow rate of 10 mL/min.

2.5.4 Swelling test

The swelling index of the test samples was determined by immersing the test piece with a weight of 0.2 g in toluene for 24 hours. Swollen samples were wiped by a tissue and weighed. Four trials were carried out and averaged the results.

2.5.5 Mechanical properties

Tensile strength was determined by Marx test, a computerized universal testing machine. Dumbbell-shaped test pieces were cut from prepared films. The crosshead speed of the machine was set at 50 mm/min until the test piece failed. Three test pieces were tested and averaged the results. The tear strength of prepared samples was tested using Marx test, a computerized universal testing machine according to ASTM D624 standard. The crosshead speed of the machine was set to 500 mm/min until the test sample failed. Two test samples were tested and averaged the results. The hardness of the prepared films was measured according to ASTM D 2240 using Hardness Tester HT 3000 (MonTech). Four measurements were taken and averaged the results.

2.5.6 Degradation study

The outdoor weathering degradation test of prepared 5 phr curcumin incorporated NR latex films was studied to determine the extent of degradation. Cured NR latex film without CUR was utilized as the control sample.

2.5.7 Degradation test

The accelerated degradation study for CUR-tween 80 dispersion was performed under high pressure mercury lamp which has a closer output to sunlight (around 400 nm). The samples were held 5 cm away from the high-pressure mercury lamp. During the time intervals of 2 hours, 4 hours and 6 hours, the FTIR spectrum was obtained to observe the extent of degradation.

CUR - NR latex film samples and the control samples were kept at an outdoor area for 3 months starting from the month of January 2024 to April 2024. Samples were displaced to have a maximum exposure of sunlight throughout the day (Panadura, Sri Lanka).

2.5.7.1 FTIR analysis

FTIR spectra were obtained for each sample periodically with different time intervals using ATR mode to observe chemical changes during the degradation process.

2.5.7.2 Percentage weight loss

The percentage weight loss of all aged samples was calculated using equation 1 periodically by measuring the weight of samples with respect to time.

Equation 1: Weight percentage loss = $\frac{Wi - Wt}{Wi} \times 100\ \%$

W_i = Weight of the sample before exposure to degradation

W_t = Weight of the sample after degradation time, t

The percentage weight loss of the control and 5 phr CUR - NR latex samples were obtained in outdoor weathering test.

2.5.7.3 Visual observation and microscopic analysis of the surface

The surface of the samples was observed using the naked eye and Nikon SMZ1270 Stereomicroscope before and after the outdoor weathering test.

2. RESULTS AND DISCUSSION

2.1 Extraction of curcumin

Curcumin was extracted from turmeric using solvent extraction method. This method was used because it is simple and have low operational cost[20]. Curcumin was extracted with a yield of 9.774% and it was characterized by FTIR and UV-visible spectroscopy.

FTIR spectroscopy was used for the qualitative analysis of the extract of turmeric (Fig. 1). The broad peak in 3000-3500 cm^{-1} indicated the presence of phenolic OH stretching. The peak at 2924 cm^{-1} could be related to CH_2 stretching. The carbonyl group displayed its characteristic peak at 1678 cm^{-1} and aromatic C=C stretching vibration could be observed at 1580 cm^{-1}. The peaks at 1508 cm^{-1} and 1438 cm^{-1} were due to the aromatic groups and CH_2 bending vibrations respectively. The peak at 1378 cm^{-1} represented CH_3 bending. Enol C-O peak could be observed at 1266 cm^{-1}. The peak at 1030 cm^{-1} was given by C-O-C stretching. Another two characteristic peaks appeared at 964 cm^{-1} and 815 cm^{-1} indicating the benzoate trans-CH and aromatic CH in curcumin. These FTIR observations were similar to literature reported by Wilczewski et al[21]. The FTIR spectrum confirms the presence of all the functional groups of CUR in the extract of turmeric.

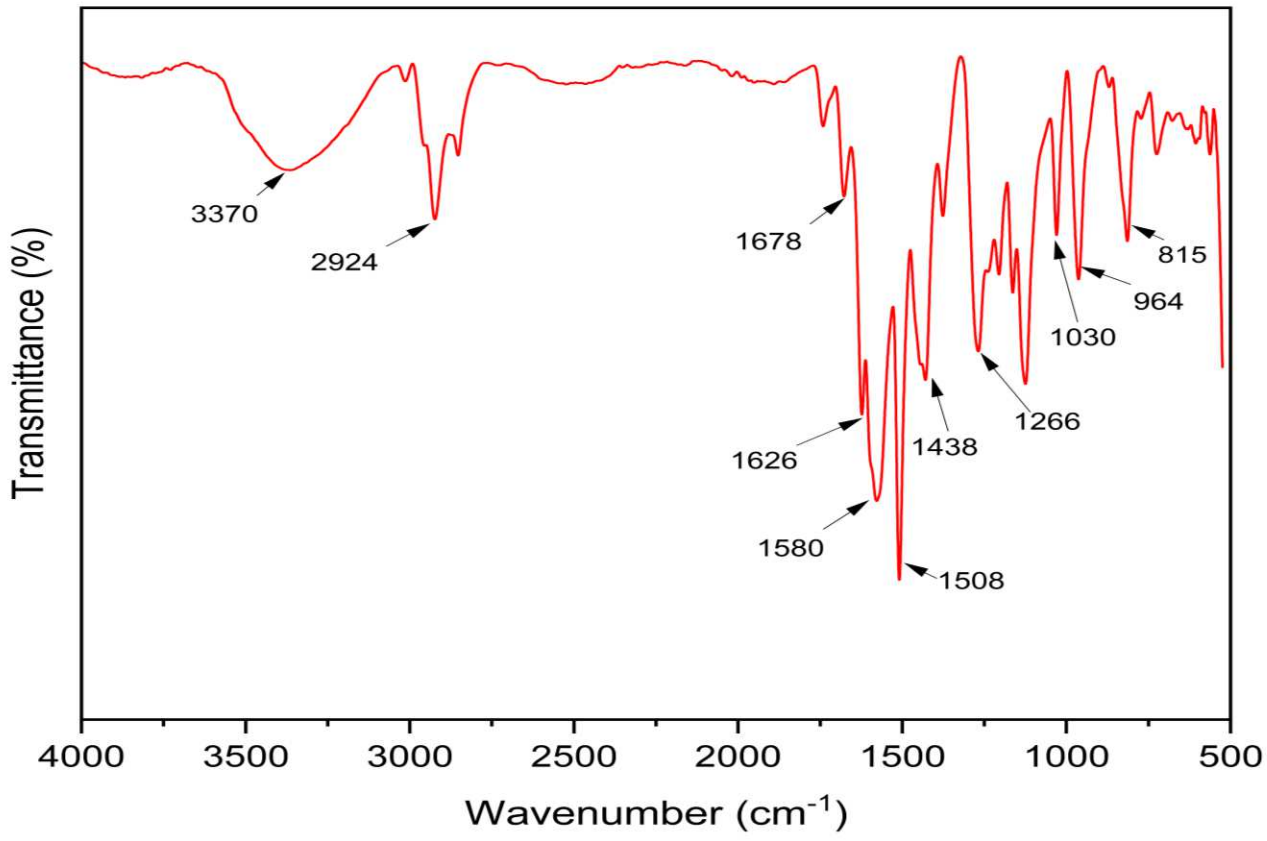


Fig. 1: The FTIR spectrum of extract of curcumin extract.

UV-visible spectroscopy of curcumin dissolved in ethanol in Fig. 2 shows the characteristic peak at 425 nm. This typical absorption band of CUR could be assigned to the low energy π to π^* transition. Similar observation has been reported in the literature by Van Nong, H., et al[22].

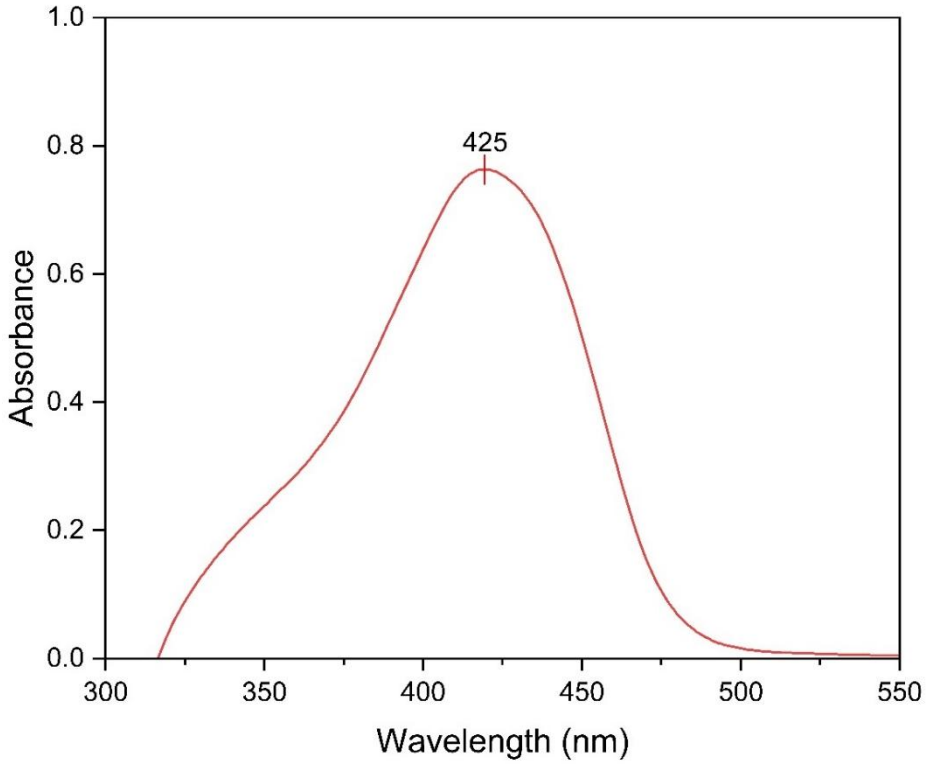


Fig. 2: The UV-visible spectrum of the extract of curcumin dissolved in ethanol.

2.2 Characterization of CUR - NR latex films

CUR-NR latex films are orange-red in color while the NR latex films without CUR are white in color as in Fig. 3. As the CUR concentration increases the color of CUR-NR latex film has shifted from orange to red. Further, CUR-NR latex films have smooth and shiny surface compared to NR latex films without CUR.

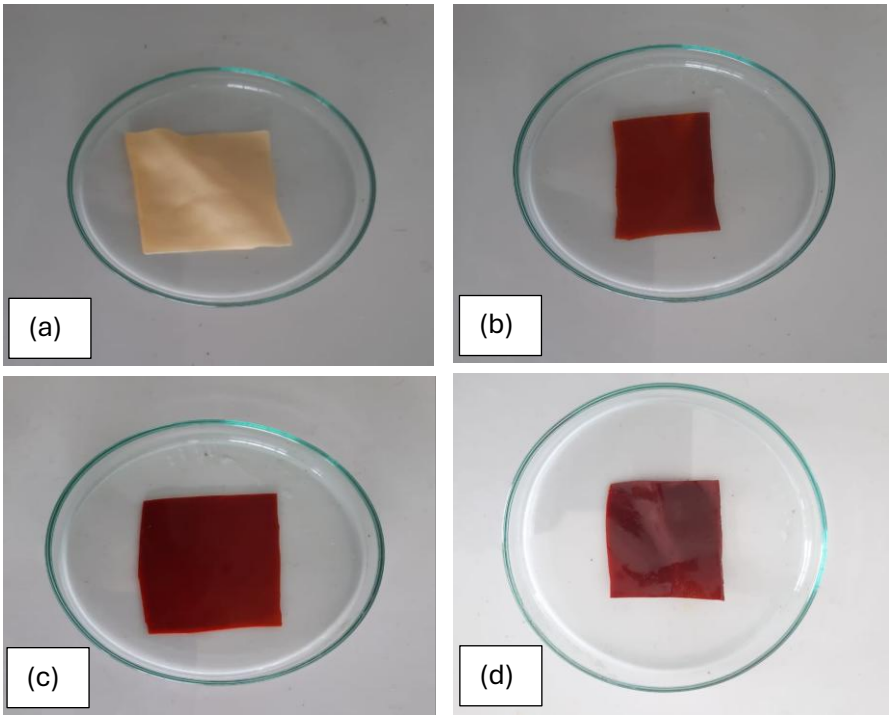


Fig. 3: Prepared NR latex film (a) Cured NR latex film (control), (b) 1 phr CUR - NR latex film, (c) 2.5 phr CUR - NR latex film and (d) 5 phr CUR - NR latex film.

3.2.1 FTIR spectroscopy

The FTIR spectroscopy was utilized to study the incorporation of CUR into NR latex (Fig 4). In the control sample, the sulfur cured NR latex film spectrum peaks at 2960 cm^{-1}, 2915 cm^{-1} and 2852 cm^{-1} were attributed to C-H stretching vibrations. The peak in 1661 cm^{-1} corresponds to the C=C stretching. The peaks at 1442 cm^{-1}, 1375 cm^{-1} and 839 cm^{-1} indicated the functional groups of C-H bending of CH_2, C-H bending of CH_3 and C-H bending of C=C-H respectively. The spectrum of CUR - NR latex film exhibits the combination of characteristic bands of CUR and cured NR latex. The broad band within the range of 3000-3500 cm^{-1} showed the phenolic O-H stretching of CUR and the band at 1661 cm^{-1} showed C=C stretching vibrations of NR. The peak corresponding to enol C-O was obtained at 1249 cm^{-1}. Peaks at 1094 cm^{-1} and 946 cm^{-1} were due to the -COO-CH_2 stretching vibration and -CH_2-O-CH_2- stretching vibration of tween 80 surfactant. Thus, the results of FTIR analysis confirm the incorporation of CUR into the NR latex.

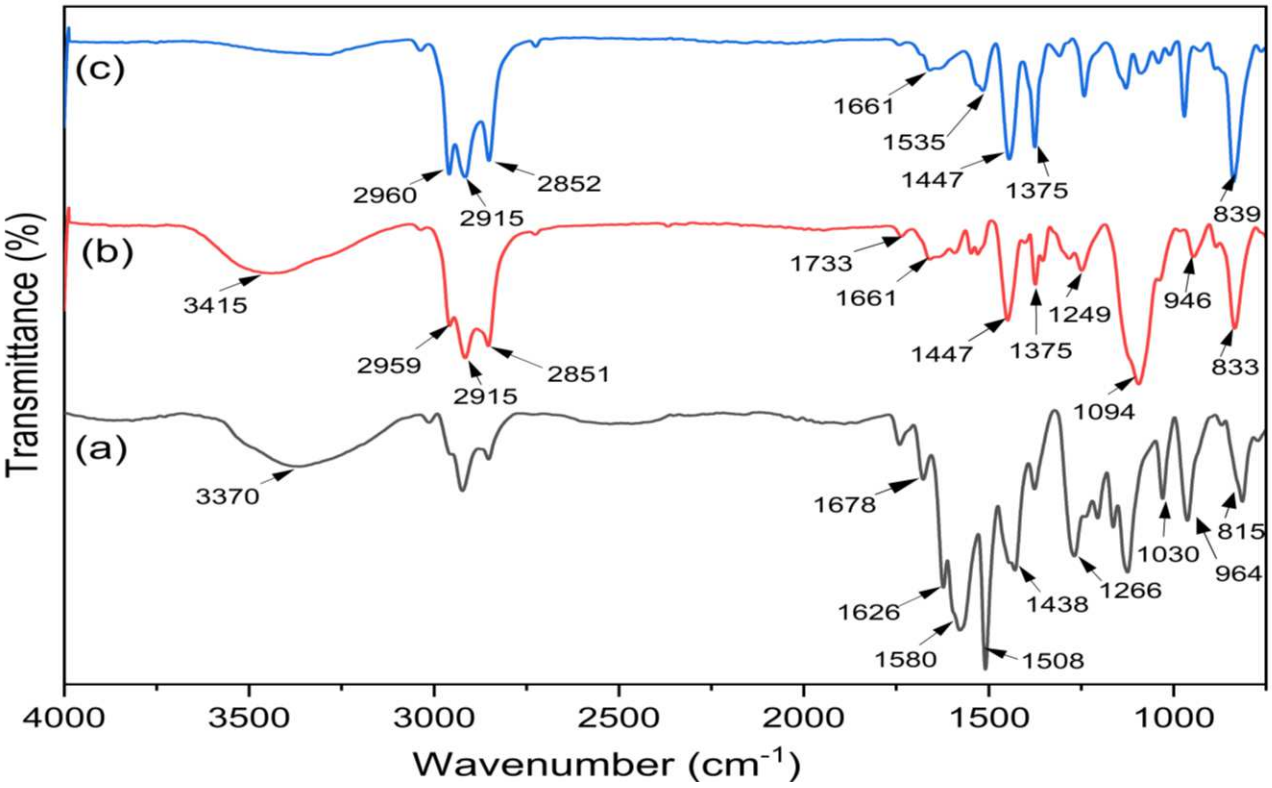


Fig. 4: FTIR spectra of (a) curcumin, (b) 5 phr curcumin incorporated cured NR latex and (c) cured NR latex without CUR (Control).

3.2.2 Thermogravimetric analysis

The thermal analysis of CUR-NR latex films was studied by thermogravimetric analysis (TGA) (Fig. 5). The polymer decomposition of the NR curves was observed at 347 ºC while complete decomposition displayed at 425 ºC. The difference in the onset temperatures of the two curves could be attributed to the different amount of trapped volatile materials. Thermal stability has not been altered by the incorporation of CUR into NR.

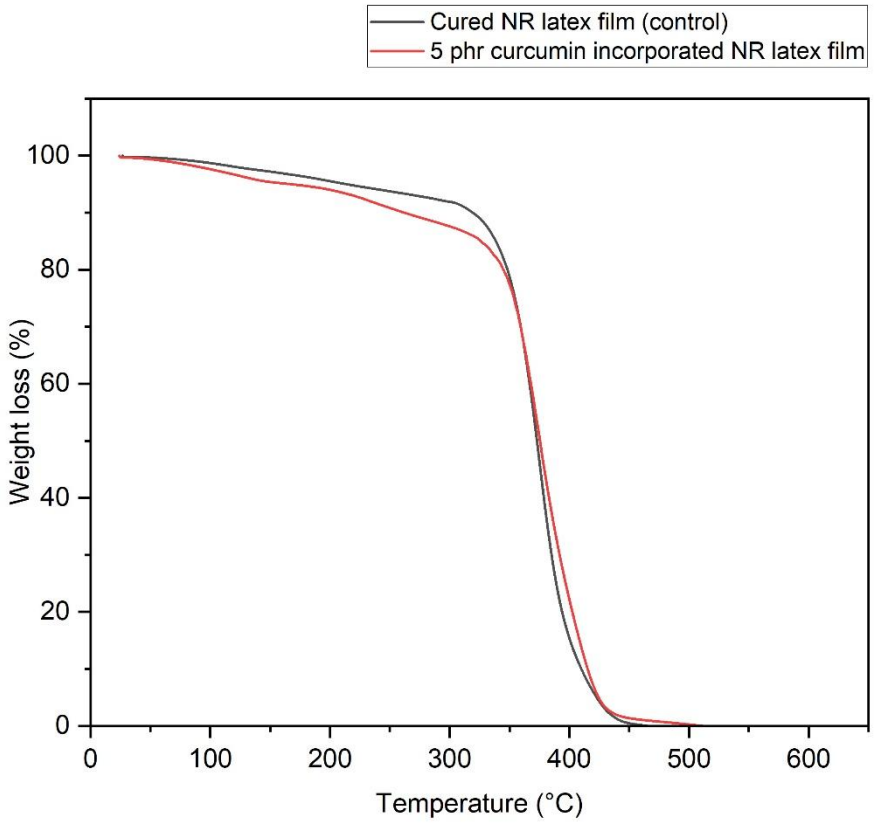


Fig. 5: TGA curves of cured NR latex film (control) and 5 phr CUR-NR latex film.

3.2.3 Swelling test

The swelling test was carried out to study the effect of CUR in NR latex cross-linking process. With the addition of CUR, the swelling index of NR latex film samples has been reduced as in Fig. 6 which implies a higher degree of cross-linking. There can be three different kinds of interactions in the CUR - NR latex films such as secondary interactions between rubber-rubber molecules, CUR-rubber molecules and CUR-CUR molecules. These interactions are capable of restricting chain mobility affecting the swelling index of the test samples. Interactions between rubber-rubber molecules are present in both NR latex film sample (control) and CUR - NR latex film samples. The lower swelling index in CUR - NR latex film samples compared to the control sample is due to the secondary interactions between CUR–rubber molecules. Further, CUR can impart physical crosslinking such as chain entanglements which also could lower the swelling index. However, with higher concentrations of CUR, interactions between CUR-CUR molecules can be dominant causing the aggregation of CUR. These aggregated curcumin can hinder the toluene diffusion and penetration process resulting in low swelling[23].

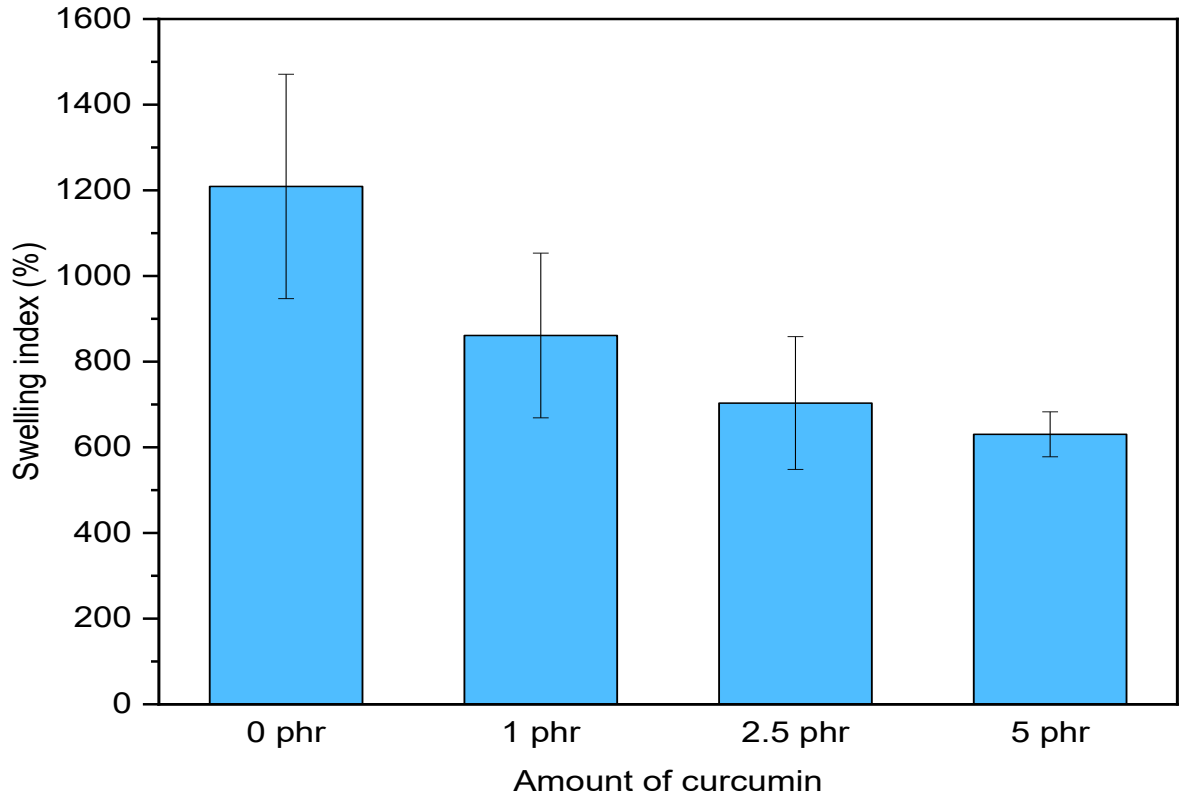
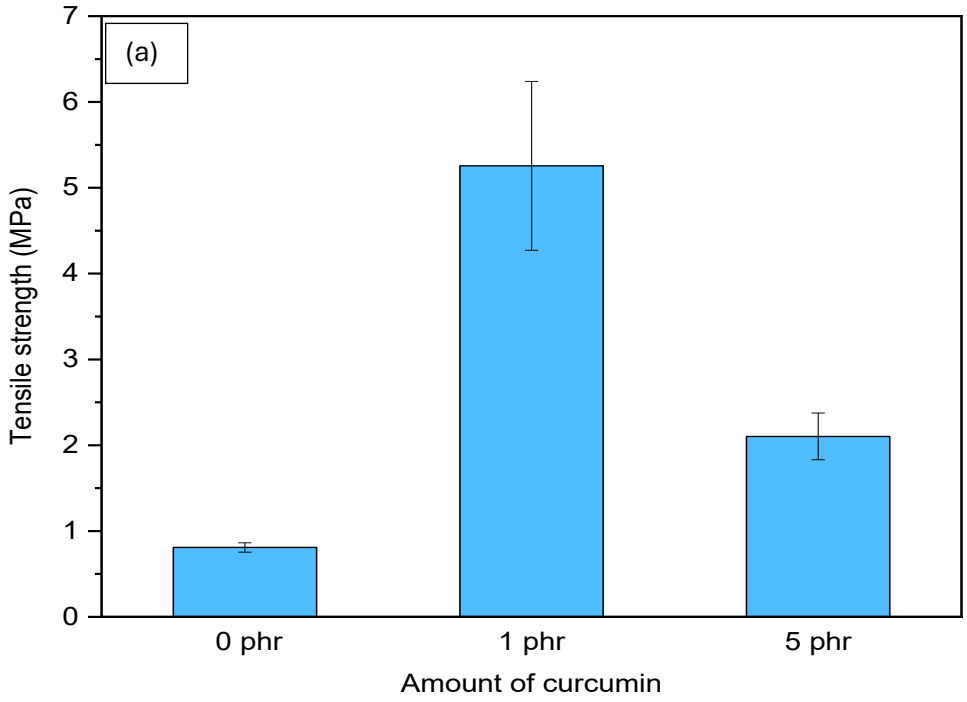
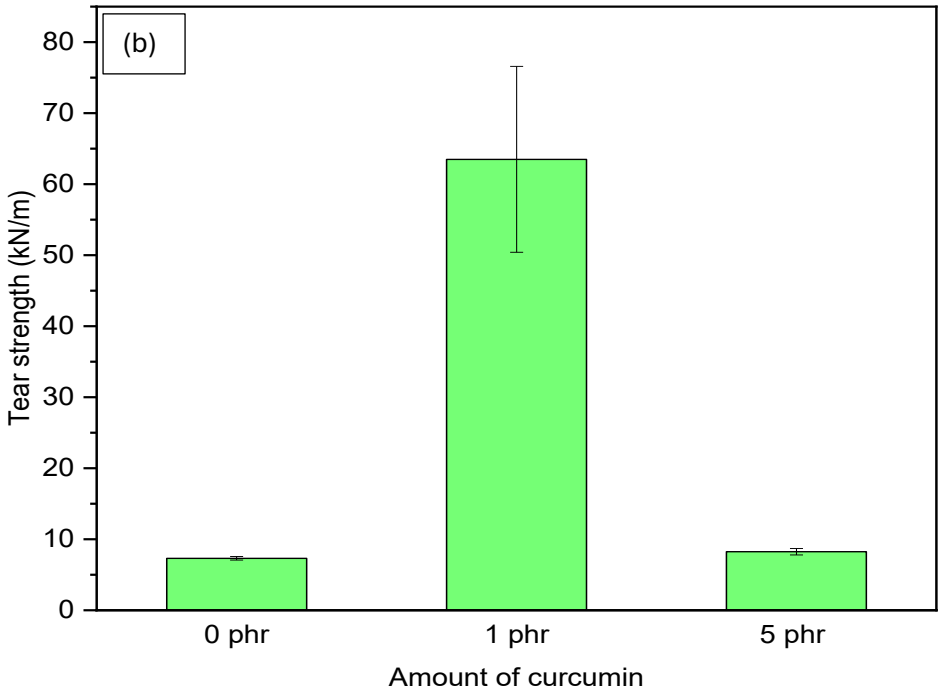


Fig. 6: The swelling index of prepared NR latex films.

3.2.4 Mechanical properties

Mechanical properties of developed films were evaluated using tensile strength, hardness and tear strength. According to Fig. 7, mechanical properties were significantly improved by the incorporation of CUR into NR latex. Highest mechanical properties were shown by 1 phr CUR - NR latex film with tensile strength of 5.255 ± 0.983 MPa, tear strength of 63.49 ± 13.09 kN/m and hardness of 69.6 ± 0.39 shore A. However, further addition of CUR has reduced the mechanical properties of the NR latex film. In 1 phr CUR -NR latex sample, CUR is well dispersed throughout the rubber matrix. This allows better interactions between CUR molecules and rubber chains. Also, CUR can impart secondary interactions as well as physical chain entanglements. These factors increase the mechanical properties of the sample. Nevertheless, in 5 phr CUR - NR latex film, interactions between CUR–CUR molecules have become more dominant in contrast to interactions between CUR–rubber chains. These CUR-CUR interactions lead to aggregation of CUR. Due to these agglomerates of CUR in the rubber matrix, which lessen the CUR-rubber interactions, the mechanical properties of the 5 phr CUR - NR latex film has been reduced. Nevertheless, the remaining interactions between CUR–rubber chains result in higher mechanical properties than the control NR latex film.


(a)
Tensile strength (MPa)
0
1
2
3
4
5
6
7
0 phr
1 phr
5 phr
Amount of curcumin


(b)
Tear strength (kN/m)
0
10
20
30
40
50
60
70
80
0 phr
1 phr
5 phr
Amount of curcumin

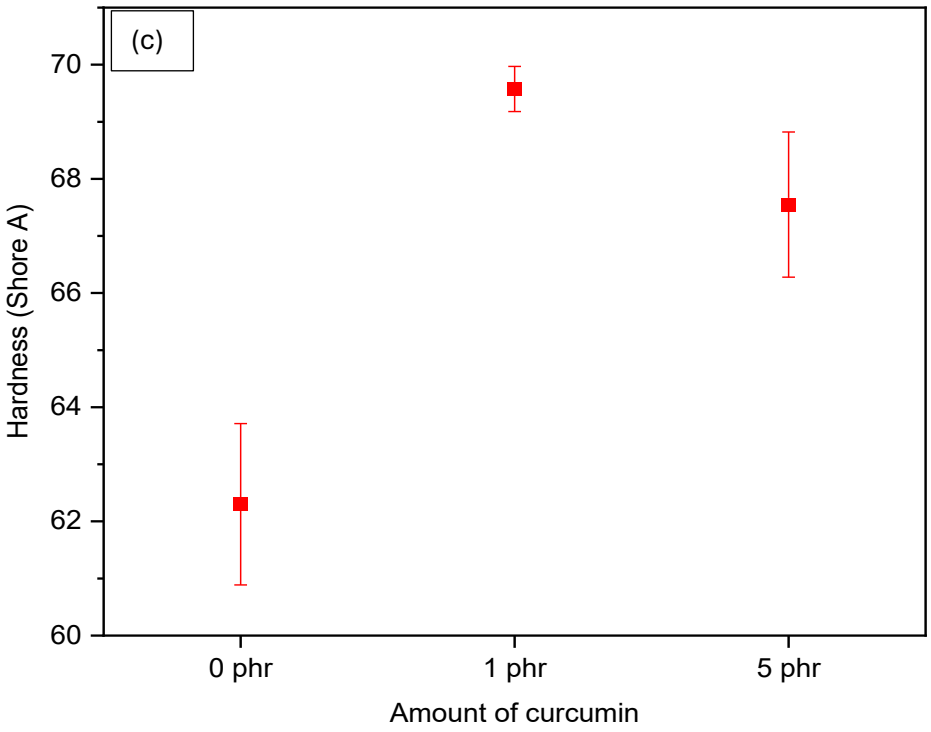


Fig. 7: (a) Tensile strength, (b) Tear strength and (c) Hardness of developed films.

3.3 Accelerated degradation test of CUR-tween 80 dispersion

The accelerated degradation test of CUR – tween 80 dispersion was studied using FTIR spectroscopy. According to Fig. 8, after exposure to the high-pressure mercury lamp, significant spectral changes could be seen in contrast to the FTIR spectrum of CUR – tween 80 dispersion before irradiation. The broad peak at 1599 cm^{-1} can be attributed to the overlapping of the aromatic C=C bond and the C=O group in CUR in aqueous tween 80 medium. Therefore, the disappearance of this band after irradiation indicates the loss of the aromatic C=C bond and the C=O group in CUR. Significant weakening of the peak at 1460 cm^{-1} could be seen after the irradiation. This suggests the chemical changes occurring in C-H stretching in the methylene group. After irradiation, the reduction in peak intensities at 1380 cm^{-1} and 1253 cm^{-1} indicate chemical changes associated with C-H stretching in the methoxy group and aromatic C-O-C respectively. These spectral changes confirm the structural modifications that occur when curcumin is exposed to light. The observed changes closely resemble those reported in the literature for degraded curcumin. After 6 hours of irradiation, it is evident from spectrum (d) that the aromatic rings and conjugated structure have been significantly disrupted.

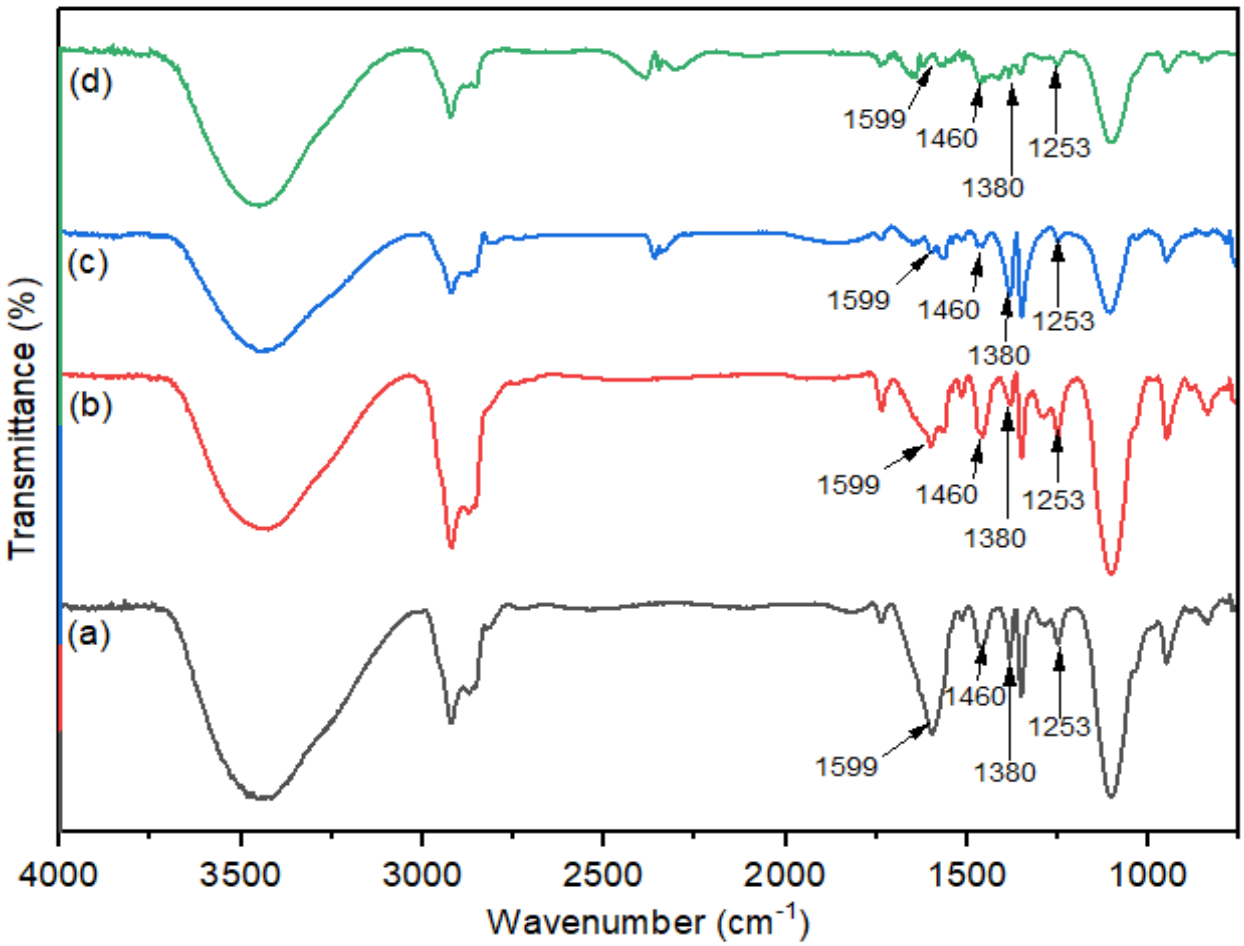


Fig. 8: FTIR spectra of CUR–tween 80 dispersion vs time exposed to high-pressure mercury lamp (a) before irradiation, (b) after 2 hour irradiation, (c) after 4 hour irradiation and (d) after 6 hour irradiation.

The photodegradation of curcumin can be attributed to two possible mechanisms. First, the excited curcumin molecule may react with oxygen or the surrounding solvent to generate reactive oxygen species. Second, radical formation may occur at the central bridge between the two carbonyl groups. Furthermore, the molecule may undergo cleavage along the α,β-unsaturated β-diketone chain, leading to smaller degradation products[24]. In addition, the phenolic –OH and methoxy $–OCH_3$ groups can be cleaved through demethoxylation, generating radicals on the curcumin moiety. Continued UV irradiation further disrupts the conjugated aromatic system of the molecule[2]. Overall, several pathways exist that can generate a significant number of radicals during the degradation process.

Our expectation, in this context, is that these generated radicals from curcumin will contribute to the degradation of natural rubber (NR).

3.4 Photodegradation studies of CUR - NR latex film

An outdoor weathering test was carried out to determine the extent of degradation of CUR- NR latex films.

3.4.1 FTIR analysis

3.4.1.1 Outdoor weathering test

Fig. 9 displays the FTIR spectra of cured NR latex film after weathering for 90 days. Their peaks at 1244 cm^{-1} and 973 cm^{-1} have disappeared. They are assigned to C-C bending and C=C-H bending of rubber chain respectively. Furthermore, the peak at 1661 cm^{-1} has not shown any change, indicating that the C=C bond in the rubber chain in the control NR film has remained intact throughout the weathering test.

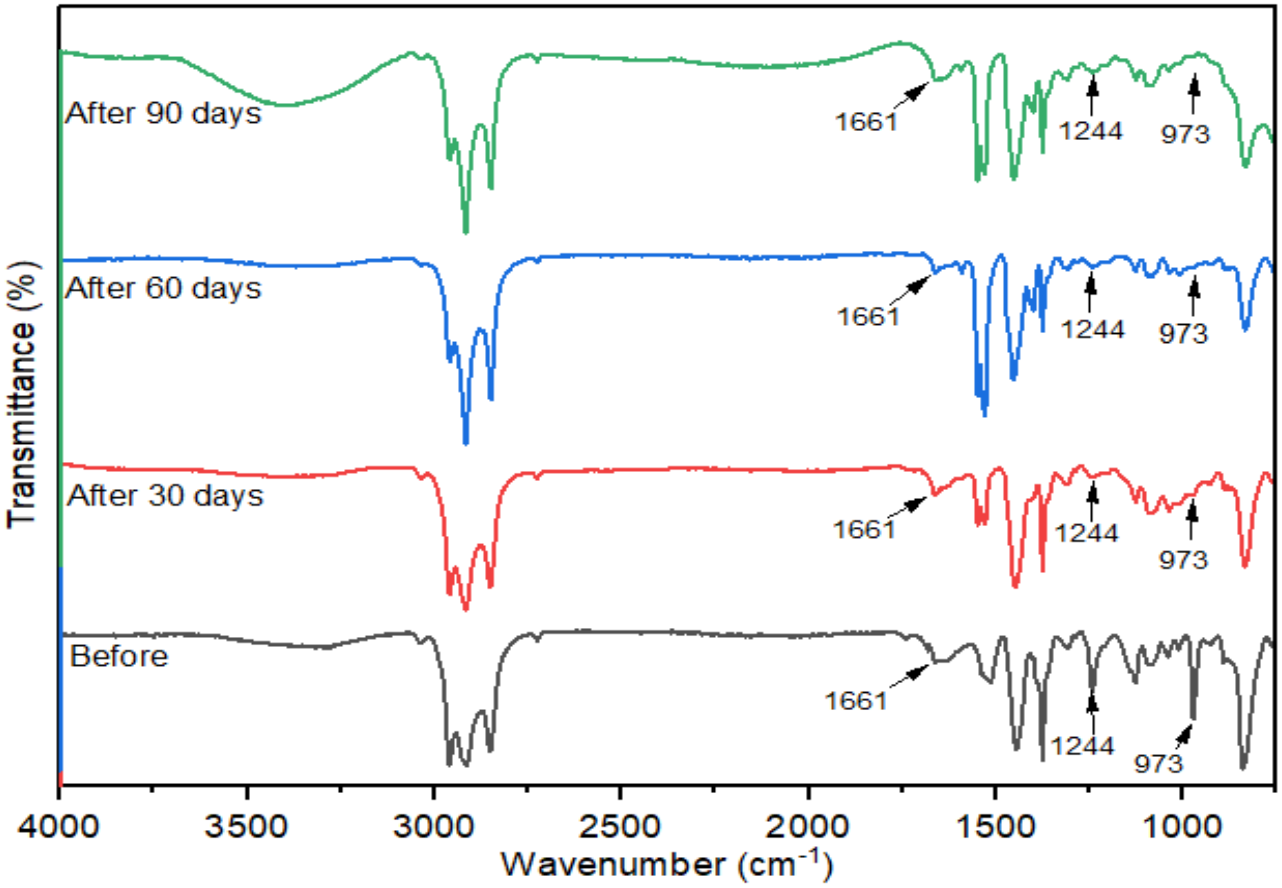


Fig. 9: FTIR spectra of control NR latex film samples against weathering time (Days).

However, in Fig.10, loss of peak at 1596 cm^{-1} in 5 phr CUR-NR latex film indicates the disappearance of aromatic C=C and C=O group in CUR. The decrease in the intensity of the peak at 1380 cm^{-1} implies the reduction in the

amount of aromatic C-O peak in CUR. The intensity of the peak at 1661 cm^{-1}, corresponding to the C=C bond in the rubber chain has shown significant decrease compared to the control NR sample. Further, the rise in peak intensity of 1733 cm^{-1} implies possible the formation of a new carbonyl group. These changes were due to the structural decomposition of rubber chains due to the formed radicals by CUR. Outdoor weathering can impart multiple types of degradation pathways through verity of initiating and propagations scenarios. Thus, different functional group changes could be attributed to the complex degradation at weathering.

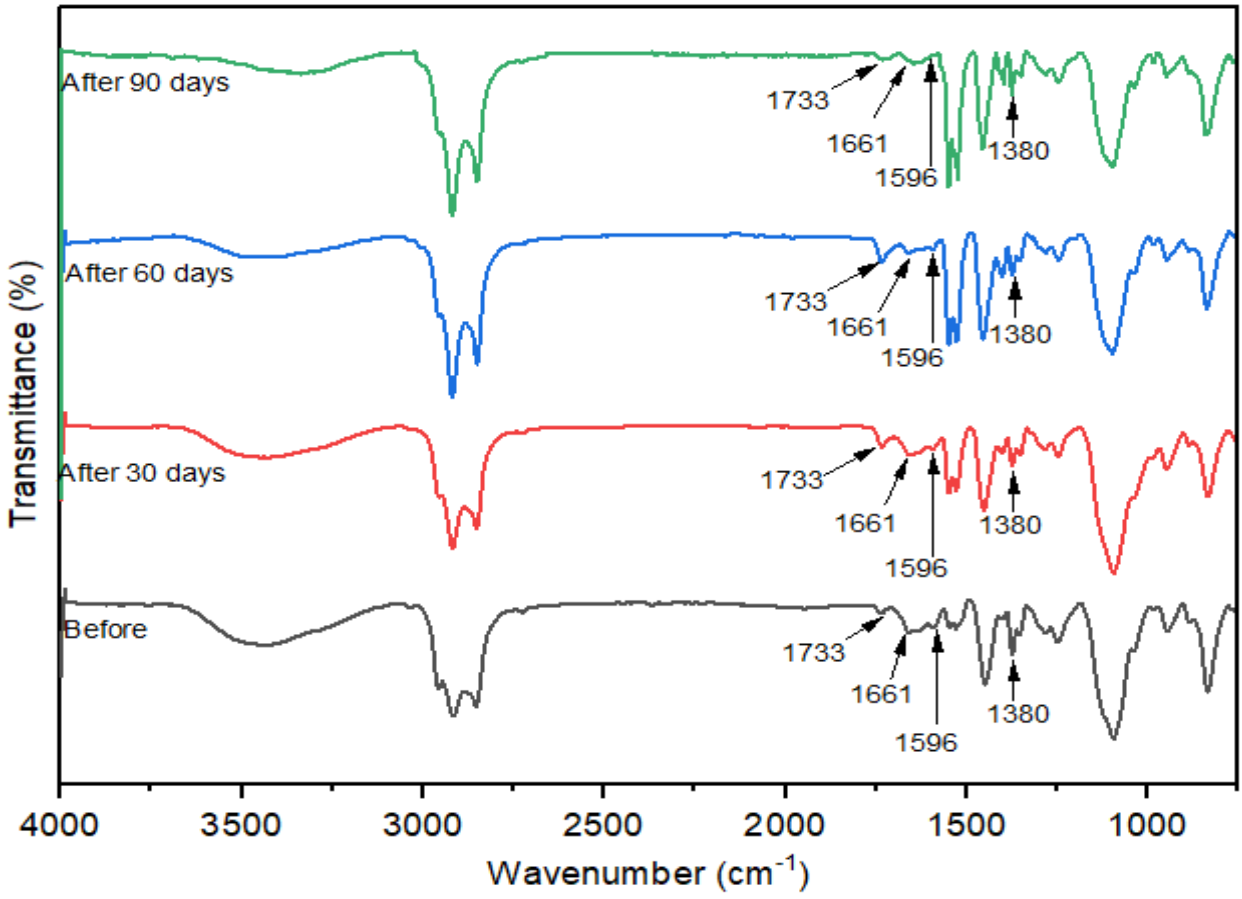


Fig. 10: FTIR spectra of CUR - NR latex film samples against weathering time (Days).

3.4.2 Percentage of weight loss

Percentage weight loss measurement is an established testing methods in degradation studies. The test was conducted to observe the extent of degradation of the material.

Fig. 11 illustrates the weight loss percentage of cured NR latex film (control) and 5 phr CUR - NR latex films after the outdoor weathering test. CUR incorporated NR latex film has shown substantial weight loss compared to control NR latex film. These results confirm the higher extent of degradation shown by CUR - NR latex film contrast to the control NR latex film.

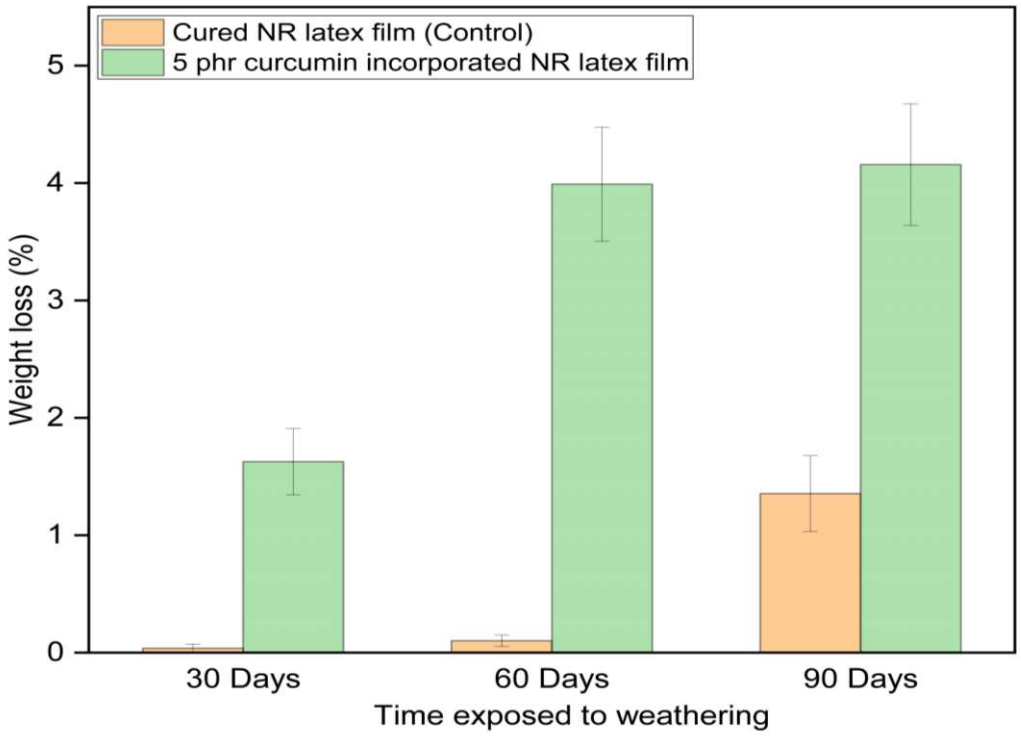


Fig. 11: The percentage of weight loss over time in outdoor weathering**.**

3.4.3 Visual observation and microscopic analysis of films

Figure 12 depicts the appearance of NR latex (control) film samples and CUR-NR film samples after outdoor weathering test. All the samples were softened after exposure to weather conditions. The color of the films has faded with time and samples have softened after exposure to the weather conditions. The micro cracks were not visible due to the darkened color.

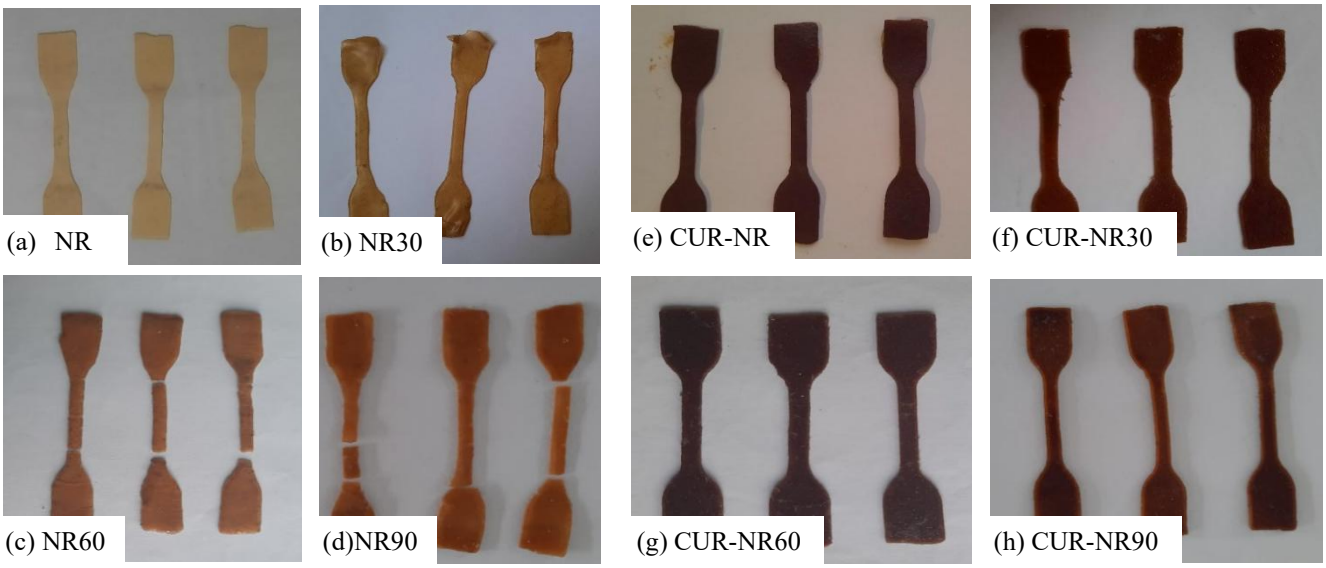


Fig. 12: Appearance of cured NR latex (a) before, (b) after 30 days, (c) after 60 days and (d) after 90 days of weathering and appearance of 5 phr CUR - NR latex (e) before, (f) after 30 days, (g) after 60 days and (h) after 90 days of weathering.

Microscopic analysis (Fig. 13) was completed to observe the surface changes of the NR latex films after exposure to outdoor weather conditions. Control NR latex film has displayed microscopic surface cracking after 60 days of outdoor weathering. This is due to the complex degradation mechanism of the outdoor weather conditions.

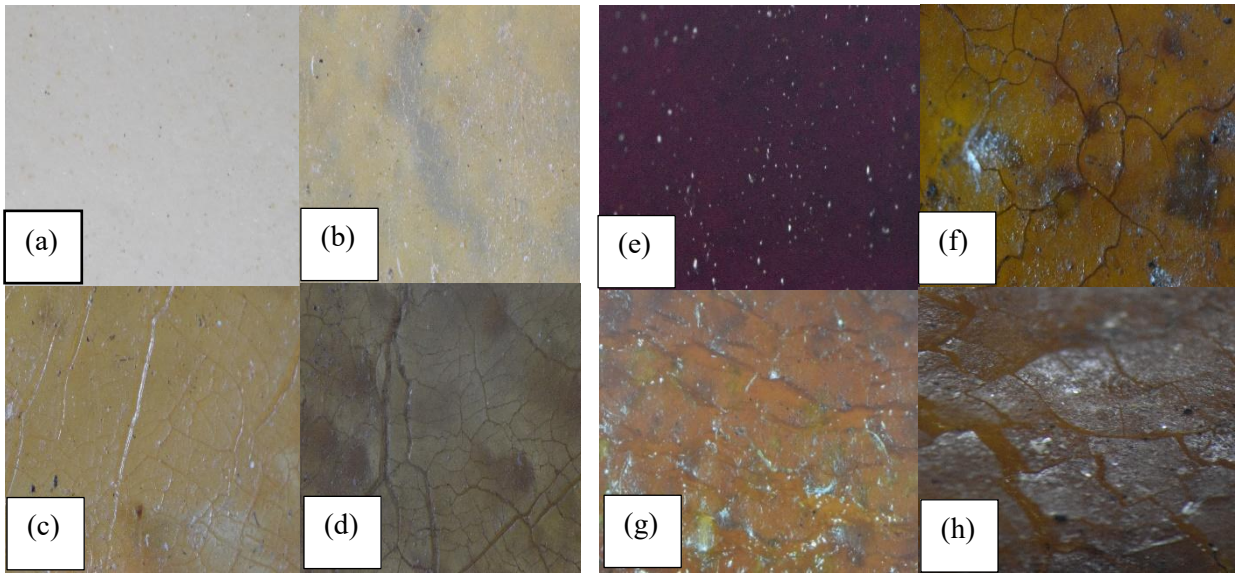


Fig. 13: Microscopic analysis of cured NR latex (a) before, (b) after 30 days, (c) after 60 days and (d) after 90 days of weathering test and 5 phr CUR-NR latex (e) before, (f) after 30 days, (g) after 60 days and (h) after 90 days of weathering test.

CUR-NR latex sample has exhibited surface cracking after 30 days of outdoor weathering. Further, it has shown much larger surface cracking compared to control NR latex samples. These visual observations and microscopic analysis of prepared NR latex films further prove the higher extent of degradation shown by CUR-NR latex film contrast to control NR latex films.

The FTIR spectroscopic data, weight loss percentage and visual observations and microscopic analysis prove the higher extent of degradation undergone by CUR-NR latex film contrasted to control NR latex film. Considering all the spectral changes in FTIR spectra, a mechanism in Fig. 14 for degradation of curcumin incorporated NR latex film could be proposed. This mechanism illustrates the fragmentation of rubber chains via a radical formed through demethoxylation or a radical formed through cleavage of the α,β-unsaturated β-diketone group during the photodegradation of curcumin.

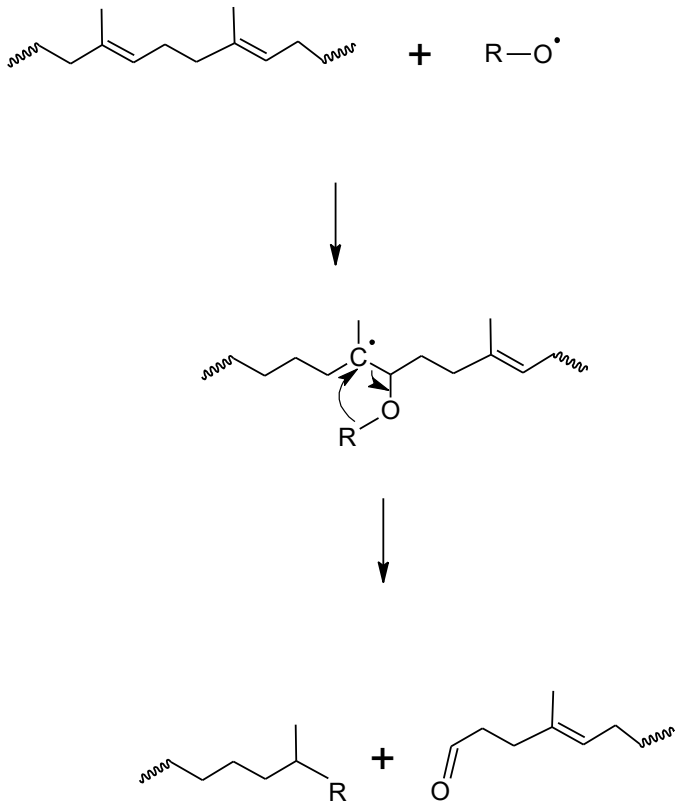


Fig. 14: Proposed mechanism of degradation of rubber matrix.

According to FTIR observations, the increased intensity of the C=O peak indicates the formation of chain fragments with the carbonyl end group. It can be presumed that degradation of the rubber matrix proceeds through the double bond present in the rubber chains owing to the loss of C=C peak in CUR-NR latex films.

Conclusion

In summary, it was able to develop and characterize a CUR-NR latex film addressing the low aqueous solubility of curcumin. Tween 80 as a dispersing agent was used to achieve the better dispersion of curcumin throughout the rubber matrix. The FTIR spectroscopic data confirms the successful incorporation of curcumin into NR latex. Thermal stability of NR latex film was not affected by the addition of curcumin. The swelling index of NR latex film has decreased with the incorporation of curcumin due to the secondary interactions and physical crosslinking between curcumin and rubber and the formation of curcumin agglomerates. Curcumin incorporated NR latex film has shown remarkable enhancement in mechanical properties compared to control NR latex film; however, with further incorporation of curcumin, the mechanical properties were reduced. Outdoor weathering study has proved that the incorporation of curcumin has accelerated the degradation of NR latex film. These results indicate the CUR-NR films with excellent mechanical properties are capable of addressing the lack of degradability of NR latex products.

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Curcumin incorporated NR latex film; Mechanical property enhancement and degradability

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