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Developing Natural Rubber Latex Characteristics Using Radiation Technology

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Abstract

Radiation vulcanized natural rubber latex films show good physical properties compared to the non-irradiated natural rubber films. With increasing the total solid content of rubber under irradiation, tensile properties increased and elongation at break decreased remarkably. Protein content was found less for the samples, which were irradiated and leached in water for 48 hours.

Keywords: Elongation at Break, Irradiation, Tensile Strength, Protein Content, Latex, Total Solid Content.

1. Introduction

Natural Rubber Latex (NRL) is formed in the cytoplasm of laticiferous cells which occur beneath the bark of the rubber tree, *Hevea Brasiliensis*. Fresh NRL consists of rubber hydrocarbon particles in an aqueous solution commonly called as the "serum phase" [1]. Rubber hydrocarbon (cis-1, 4-polyisoprene) is surrounded by proteins and lipids, and these together form the rubber particles. Non-rubber substances include proteins (1-1.8%), carbohydrates, lipids, and inorganic constituents. NRL is obtained from the rubber trees by tapping in which the bark is cut and then liquid latex flows from the rubber trees by tapping in which the bark is cut and then liquid latex flows from the cut along a spout to a cup. Soon after tapping and collecting the latex, a stabilizer (e.g. ammonia) [2] is added to prevent bacterial growth. The NRL is processed to either a solid, dry rubber or a liquid latex concentrate. Products such as conveyor belts, car tires and rubber hoses are manufactured from dry rubber. Dipped products like gloves, condoms, catheters and balloons are made from latex concentrate [3]. A significant progress has been observed in developing rubber material using radiation technology. The technology is called Radiation Vulcanization of Natural Rubber Latex, RVNRL [4]. It uses high energy gamma (γ) radiation to initiate vulcanization, a process that chemically bonds molecule to produce rubber elasticity and strength. In the RVNRL process, radiation energy replaces the use of sulphur based process and produces a material that retains all properties of the conventional product. However, it has some additional remarkable qualities: the absence of carcinogenic nitrosamines; extremely low cytotoxicity; absence of sulphur and zinc oxide; and high transparency and softness. These properties are important for many products, particularly catheters, protective gloves, and other medical and hospital supplies. For such uses, it is important that products are free of contaminants, and toxic and carcinogenic components to avoid harmful effects in people.

In order to produce RVNRL with suitable strength and quality for the production of dipped goods, especially hand gloves, various schemes were adopted in irradiating latex with gamma (γ) rays.

2. Experimental

2.1 Collection and Preservation of Natural Rubber Latex

Natural rubber latex was collected from nearby garden of the Atomic Energy Research Establishment vicinity area. After collection of latex it was treated with ammonia solution to avoid coagulation and putrefaction. This latex contains dirt, barks, coagulant matters etc. These are removed by passing the latex through a 200 mesh aluminium sieve.

2.2 Preparation of Natural Rubber Latex for Irradiation

Natural rubber latex sample with different total solid content (TSC) were taken in a beaker and then placed on a magnetic stirrer (model 78-1, UK). Ammonium laurate was used as the stabilizing agent and it was prepared by mixing 5% aqueous ammonia solution with lauric acid. 5 phr normal butyl acrylate (*n*-BA) was added as radiation vulcanization accelerator (RVA) for an hour during stirring. The mixture was then taken in a test tube and exposed to gamma radiation for doses 5, 7, 10, 12, 15 and 20kGy.

2.3 Preparation of Rubber Film

After irradiated, rubber latex was poured over a previously labeled glass plate. The latex was dried at room temperature. After drying, the rubber films were leached with water for 24 hrs and 48 hrs. The leached samples were dried in air and then in oven at 70°C for one hour and then stored in a desiccator. The method was also applied for non-irradiated rubber latex.

2.4 Measurement of Tensile Strength

Tensile strength was measured by universal testing machine (model 1011, INSTRON, England) integrated to a computer. For determination of tensile strength, films were cut into dumbbell shaped test pieces (model ASTN-D-1822-L, Japan).

Tensile Strength (N/mm^2) = Maximum Force/Area

Where, Area of the dumbbell shape stripe = Thickness of the stripe × Width of stripe

Width for all the stripe = 5 mm (narrow portion of the test piece)

2 5 Measurement of Elongation at Break

Elongation at break of the sample was measured along the tensile strength measurement with the same test pieces. It requires measurement of the length of the stripe at the breaking time, which was measured by the testing machine automatically.

Elongation at break (%) = L-Lo × 100/ Lo

Where, Lo = Original distance between reference line, L = Length of the specimen between the reference lines at the breaking time.

2.6 Measurement of Protein Content

Most proteins estimation techniques use Bovin Serum Albumin (BSA) [5] universally as a standard protein, because of its low cost, high purity and readily availability. The method is sensitive down to about 10 μg/ml and is probably the most widely used protein assay despite its being only a relative method, subjected to interference from tris-buffer, EDTA, non-ionic and cationic detergents, carbohydrate, lipids and some salts. 25ml volumes of latex films were prepared for protein analysis. These films were leached to two different times i.e., 24 and 48 hrs. Irradiated and non- irradiated latex films with different %TSC under variable leaching period was performed and protein content was measured by spectroscopic method. Approximately 1gm of rubber film from each sample was cut into tiny, small pieces, kept in glass bottles and stored in oven at temperature 60°C till a constant weight is obtained. Each bottle filled with 10ml water and kept in a water bath at 36° C for an hour. Bottles are cooled then 500μl sample for each bottle was taken into another vials. Reagents were added to it and they were kept in dark for 30 minutes. After that they were subjected to UV spectrophotometric experiments. Virtually all proteins exhibit a strong UV absorbance method, which is most often used in a quantitative way to determine concentrations of an absorbing species in solution, using the Beer-Lambert Law:

$$A = \log (I/Io) = \varepsilon\, c\, L$$

Where, A = the measured absorbance

Io = the intensity of the incident light at a given wavelength

I = the transmitted intensity

L = the path length through the sample

C = the concentration of the absorbing species

ε = molar coefficient

3. Results and Discussion

3.1 Characterization of NR Film

The irradiated latexes were cast on raised rimmed glass plates for making rubber films. The films were air dried until transparent. They were leached with distilled water for 24 hours at room temperature and then air dried again until transparent. Then the films were heated at 80°C for 1 hour. The film thickness of the prepared NR latex was measured by using a digital micrometer. The films which were examined for the tensile properties i.e., tensile strength, elongation at break etc. were made from 30ml volume of latex. It was observed that, with increasing the value of total solid content (30, 40, 50% TSC), film thickness was changed. That is with increasing the %TSC the thickness of film increased.

Table 1: Film thickness data for different % TSC

%Total Solid Content (TSC)	Film thickness (mm)
30	0.45
40	0.59
50	0.73

From figure 1, it was found that natural rubber latex film has very poor tensile strength. The tensile strength of the rubber films increased gradually with increasing the radiation and with increasing the % total solid content. 30% TSC without radiation the value of Tensile Strength shows around 2 MPa whereas at 12kGy the value of Tensile Strength is 15MPa. For 50% TSC rubber film the values of Tensile Strength at 0 and 12kGy are around 10 MPa and 28 MPa respectively. This may be explained that increasing tensile strength from 0 to 12kGy for the cross-linking of rubber hydrocarbon is due to irradiation. The probable mechanism of radiation cross-linking of natural rubber latex is the cleavage of C-H bond of polymeric chain which forms a hydrogen free radical $H^\bullet$ and a free radical $R^\bullet$. Hydrogen free radical ($H^\bullet$) has a high mobility than the polymeric free radical. The polymeric free radical ($R^\bullet$) can propagate and combine with adjacent polymeric radical forming a cross-link through R-R bond.

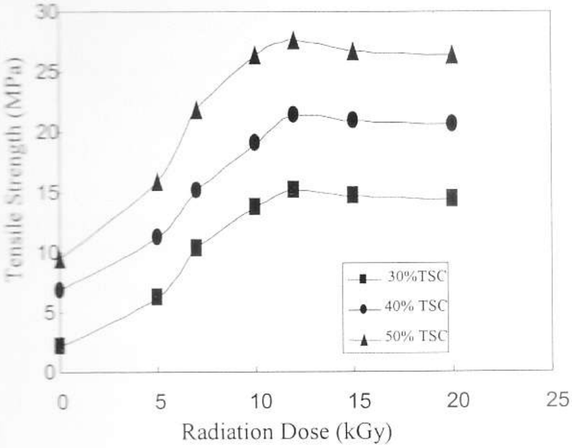

Fig. 1: Tensile Strength of natural rubber film at various radiation doses

3.2 Elongation at Break

Elongation at break of the rubber films were measured parallel with the measurement of tensile strength. Elongation is a property of considerable importance, which meant the percent increase in length of a measured stripe of rubber at the breaking point. Elongation of rubber polymer is very important considering the application of rubber. From figure 2, it has found that the non irradiated rubber film has high elongation value compared to irradiated rubber film. The highest value of elongation at break was found to be around 12.44% and decrease with the increase of radiation dose up to the optimum value. The elongation at break decreased due to increasing cross-link of rubber hydrocarbon in rubber molecule by radiation. A film that has high cross-link density is stiff and possesses low elongation ability. A long chain polymer film with less cross- link density possesses high elongation ability.

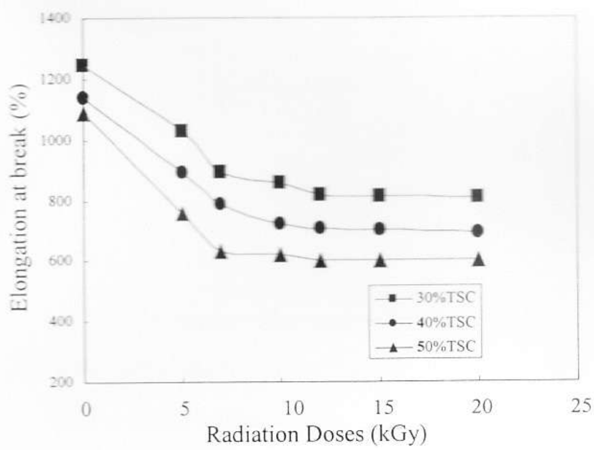

Fig. 2: Elongation at break of natural rubber film at various radiation doses

3.3 Films for protein analysis

Figure 3 shows, that protein content is increased with the increase of total solid content. 45% TSC of 24 hours leaching time the rubber film contains 3.07 ppm protein whereas 58% TSC the rubber film contain 8.54 ppm protein. It was also found that, the films which were dipped in water for 24 hours, they contain more protein than the films which were dipped in water for 48 hours. Yip *et al* [6] showed that high extractable protein (EP) levels are associated with positive skin prick test responses same as for the sample. 25ml samples show the higher protein content in this experiment.

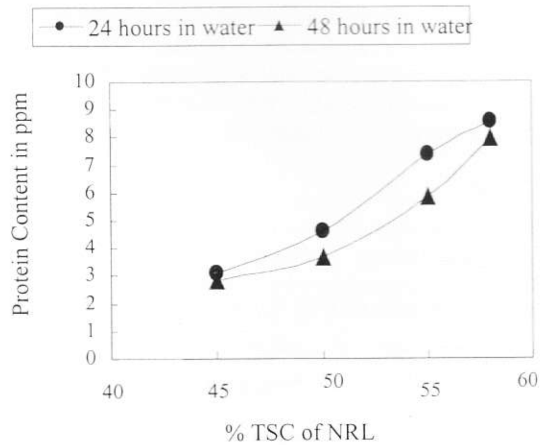

Fig. 3: Protein content of NRL film without radiation with different leaching time in water

Figure 4 shows, all protein concentrations found after irradiation. The latex was irradiated at a dose of 5 kGy. Normal butyl acrylate (*n*-BA) was used as radiation vulcanization accelerator (RVA) because it might destabilize the natural rubber latex [7]. *n*-BA increases the viscosity of the latex and the latex may coagulate upon storage for a short time period. It is assumed that, after radiation most protein is degraded and since the polymer was grafting with *n*-BA and leaching was difficult. Here from the figure 4 it has observed that for irradiated samples, protein content is reduced to almost one-fourth than that of non-irradiated one.

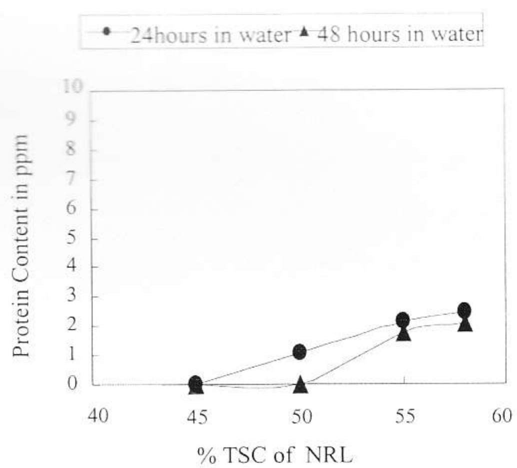

Fig. 4: Protein content of NRL film at 5 kGy with different leaching time in water

4. Conclusion

The results showed that the properties of NRL films are changing with the change of percent of total solids content as well as the change of radiation dose. Tensile strength increased with increasing the percent of total solids content (TSC) and radiation doses. The increase in tensile strength is due to the cross-linkage between the rubber chains by the action of radiation. Protein content of NRL film has found less for the samples which were leached for 48 hours than that of 24 hours in water. This is because, during 48 hours period protein were washed out with water. The results also showed that irradiated latex film had less protein content compared to the non-irradiated one.

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