The viscosity behavior of biocompatible solutions including riboflavin and gelatin

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Abstract: The purpose of this study is to investigate the viscosity behavior of the solutions including gelatin and riboflavin. Riboflavin is a biocompatible material which can make crosslinking since its chemical structure have light sensitive components called “flavins”, in particular at ultraviolet light (UV) experimentally. In our study, first of all, the absorbance of the liquid stated substances were obtained which then the viscosity behavior of the solutions which consist of gelatin and riboflavin were investigated and compared before and after UV exposure.

Keywords: riboflavin, gelatin, crosslinking, biocompatibility, absorbance, shear stress, shear rate, UV

1 Introduction

The viscosity of the liquid stated materials is the foremost parameters in order to understand the biocompatible materials in medicine, industry and so on. In corneal disorders, in particular the disease called keratoconus, the proper use of beneficial biocompatible materials as riboflavin were investigated depending on whether the material is viscosity additive or not by the help of other chemicals like dextran [1]. In biological studies, viscosity was used as parameter in terms of “solvent viscosity” in anaerobic photolysis while degradation of riboflavin was being researched [2]. Apart from those studies, we focused on the effect of the applied light that has a wavelength value which has maximum absorbance of prepared solution, on viscosity before and after carrying out of it.

2 Experiment

In this chapter, the brief information about chemical which have used during the experiments, experimental procedure, measurements, data and results were given step by step.

2.1. Materials

Riboflavin, additionally known as vitamin B2, is kind of an tricyclic molecule which can constitutes phosphorylation in order to turns into flavin mononucleotide (FMN) and flavin dinucleotidite (FAD) in biological systems and can be solved in water and ethanol while the material is insoluable in ether, acetone and chloroform respectively [3]. Riboflavin has a molecule weight as 376.37 g/mol and has a chemical formula that is can be denoted as C_{17}H_{20}N_{4}O_{6} [4]. One of the most significant role of riboflavin as an application is being have light sensitive components that can be defined as flavins which have peaks around 370 nm and 450 nm in absorption spectroscopy [5]. In addition to this, used riboflavin under light crosslinks with the other substances in the presence of the proper solution with ideal cases and it is strengthening the material where the solution turned into the form of film [6]. The other used material as a reactant of a solution is gelatin. Gelatin can be defined as a protein stated substance that can be obtained from skin, connective tissues and bones of animals as a result of hydrolysis process [7]. It can be solved in water as well as riboflavin and can be derived from collagen with the thermal denaturation. Gelatin can be classified into two different categories on the basis of pretreatment. Type A gelatin is pretreated with acid while alkali is used in order to produce type B gelatin in a thermal hydrolysis [8]. In consideration, the pH value of type A gelatin has a range from 3.8 to 5.5 while type B gelatin has a range from 5 to 7.5. Gelatin is a combination of four essential elements with different proportions that can be listed as 50.5 % carbon, 6.8 % hydrogen, 17 % nitrogen and 25.2 % oxygen.
respectively. Degradation of the gel and film forms of gelatin may be occurred due to extreme level of pH values and microorganisms [9].

2.2. Viscosity formulation

Viscosity can be defined the internal resistance of a liquid to flow [10]. Shear stress or per strain which can be denoted as \( \eta \), shows the dynamic viscosity for Newtonian behavior. Assume that \( \tau \) is shear stress and \( \dot{\gamma} \) shows the strain rate. The relation between shear stress and strain is given in the following formula:

\[
\tau = \eta \dot{\gamma}
\]  

(1)

At this point, the strain rate can be written by using other terms which are given below:

\[
\dot{\gamma} = \frac{1}{x} \frac{dx}{dt} = \frac{v}{x}
\]  

(2)

where, \( x \) shows the length while the time is represented by \( t \) and the term \( \frac{dx}{dt} \) gives the velocity. There is another representation of dynamic viscosity which follows [11]:

\[
\eta = \frac{\tau}{\dot{\gamma}}
\]  

(3)

According to the shear stress exchanges with respect to shear rate, it can be understood that a solutions is Newtonian or Non-Newtonian. Fluid’s flow behaviors are explained with Power-Law generally for non-Newtonian fluids. This law is defined as;

\[
\tau = \kappa \dot{\gamma}^n
\]  

(4)

where \( \tau \) is shear stress, \( \kappa \) is a material-based constant, \( n \) is a power-law index and \( \dot{\gamma} \) is the applied shear rate.

2.3. Measurements

Before performing viscosity measurement experiments, absorbance measurements of prepared solutions which consists of %0.1 riboflavin with 1:20 and 1:50 gelatin were done separately by using Shimadzu UV-150-02 model of spectrophotometer in order to investigate peak absorbance values. The solutions which included gelatin with the proportion of % 0.1 while riboflavin had a proportion of % 0.05 in prepared solutions. The prepared solution which included gelatin and riboflavin were stirred on magnetic stirrer between 20 and 25 minutes at 37°C. As the second step of experiment, the rotational viscometer which has model of “Fungilab” was used to investigate the viscosity of solutions. The hysteresis curve for each solution, values of torque, viscosity, shear stress, and shear rate were measured in increasing and decreasing speeds between the range of 10 and 180 rpm (rotation per minute) for 1:20 gelatin while the 1:50 gelatin has the speed range between 10 and 200 rpm. This range were done between the range of 10 and 220 rpm for solution including gelatin and riboflavin. The effect of exposure time to viscosity, the same type solutions were placed in front of UV at 378 nm which has a maximum peak value of absorbance for 15, 30, 45 and 60 minutes respectively and viscosity of the solutions were investigated all corresponding minutes separately and the graph of values were plotted as a result of experiment. Finally, the hysteresis curves of 1:20 and 1:50 pure gelatin, 1:20 and 1:50 gelatin-riboflavin solutions were evaluated after exposure time 30 minutes at 378 nm. All the measurements were done at room temperature that is 23°C.

2.4. Experiment results and analysis

According to the measurements, the peak absorbance values of prepared solution including gelatin and riboflavin were investigated depending on two different proportions which are 1:20 gelatin with %0.1 riboflavin and 1:50 gelatin with %0.1 riboflavin. The figure 1 which is given below, shows the absorbance values of those proportions:

As an two common data, the peak is shown at 378 nm for both solutions. Thus, 378 nm was
determined as reference wavelength for placing the prepared solutions in front of the wolfram in the different time intervals. The viscosity of solution which was kept in front of wolfram light, were investigated for each 15 minutes until 60 minutes completed.

Fig. 2 Shear Stress vs Shear Rate measurements for different exposure time.

All the data were plotted according to shear stress versus shear rate in the same graph which is given in figure 2.

Figure 2 also demonstrates that before carrying out of UV light to the solution have greater shear stress values at shear rate between 27 and 100. At this point the curve behaves as pseudoplastic until 100. From 100 to 277 behaves as dilatant. The solution which had kept in front of light for 15 minutes, is denoted by red curve, shows the material behaves as Newtonian fluid since the curve is a linear. Apart from this curve, the blue curve illustrates the data of the solution which was kept for 30 minutes and it is behaves as linear from 0 to 200 which then behaves as pseudoplastic in the following values of shear rate. The green curve shows the data of solution which was kept for 45 minutes, behaves as the blue curve. Finally, the solution that was kept for 60 minutes, is denoted by pink curve, shows that the material behaves as the previous data: from 0 to 200 acts as Newtonian while at the following values behaves as pseudoplastic.

The energy loss is equal to the area between loading-discharge curve at 1:20 gelatin which transforms into heat. When RF is added the energy loss is reduced. Newtonian behavior has been observed in all three 1:20 samples. Energy loss is almost nothing at 1:50 gelatin and 1:50 gelatin with riboflavin. Usually 1:50 shows Newtonian behavior; however, when we add RF before and after UV, it transforms into non-Newtonian and shows dilutant behavior.

Fig. 3 Hysteresis curves

In this type of flow, the very act of deforming a material can cause a rearrangement of its microstructure such that the resistance to flow increases with any increase in shear rate. In other words, the viscosity increases with applied shear rate and the flow curve can be fitted with the power law shown in the equation (4) where \( n > 1 \). In this type of fluids, the increase of the deformation velocity cause the increase of the viscosity.

3 Conclusion

As a result, the viscosity behavior of the solutions can be changed depending on whether the used material is kept in front of the light or not, experimentally. According to experimental data, the solution have a greater shear stress before applying the UV light than other cases. Each time arrival caused the change in viscosity behavior of the prepared solution as a result of application of the UV light where the maximum value of absorbance is observed. In our study, the wavelength that is 378 nm, allowed us to observe the effect on the change in behavior of the liquid material which included riboflavin and gelatin.

The initial and final points of loading and unloading curves on hysteresis graphics are overlapping and viscosities are independent of time as can be seen Figure 3 This reason show an elastic change in their shapes with an internal friction. An infinitesimal small area observed between the loading and unloading curves indicate that there is no energy loss.

The expectation for the following experiments is to observe new cases by using different proportions of riboflavin by taking the amount of gelatin as the
same later in this study. Furthermore, the other kind of materials as NaCl, glucose and so on can be investigated instead of riboflavin in order to analyze the change in elasticity in the future.

4 References