Determination of Temperature Dependent Coefficient of Viscosity and Surface Tension of Guar gum

A Project Report Submitted

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List of abbreviations

1. GG: Guar Gum
2. TD: Temperature Dependent
3. CV: Coefficient of Viscosity
4. ST: Surface Tension
5. TDCV: Temperature Dependent Coefficient of Viscosity
6. TDST: Temperature Dependent Surface Tension
7. υ: Viscosity
8. γ: Surface Tension
9. $\Delta\upsilon$: Change in Viscosity
10. $\Delta\gamma$: Change in Surface Tension
11. η: Dynamic Viscosity
12. μ: Absolute Viscosity
13. σ: Interfacial Tension
14. T: Temperature
15. ΔT: Change in Temperature
16. R: Gas Constant
17. C: Constant
18. K: Temperature Coefficient

CERTIFICATE

This is to certify that project work entitled **"Determination of Temperature Dependent Coefficient of Viscosity and Surface Tension of Guar Gum"** done by Mr. Robin Kumar is a bonafide research work done under the supervision & guidance of **Dr. Rishabha Malviya**, Associate Professor School of Medical and Allied Sciences, Greater Noida. The work is completed and ready for evaluation in partial fulfillment for the award of Bachelor of Pharmacy during the academic year 2022-2023. The project report has not formed the basis for the award of any Degree other similar title to any candidate of any University.

Date:

Prof. Pramod Kumar Sharma
Dean
School of Medical and Allied Sciences
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Greater Noida (U.P.)

BONAFIDECERTIFICATE

This to certify that the project work entitled "**Determination of Temperature Dependent Coefficient of Viscosity And Surface Tension of Guar Gum"** is the bonafide research work done by **Mr. Robin Kumar**, who carried out the research work under my supervision and guidance for the award of Bachelor of Pharmacy under Galgotias University, Greater Noida during the academic year 2022-2023. To the best of my knowledge the work reported herein is not submitted for award of any other degree or diploma of any other Institute or University.

Dr. Rishabha Malviya

Guide

Associate   Professor

School of Medical and Allied Sciences

Galgotias University

Greater Noida (U.P.)

DECLARATION

I hereby declare that the work embodied in this project report entitled " **Determination of Temperature dependent coefficient of viscosity and surface tension of Guar gum "** in Partial fulfillment of the requirements for the award of Bachelor of Pharmacy, is a record of original and independent research work done by me during the academic year 2022-23 under the supervision and guidance of **Dr. Rishabha Malviya** Associate Professor , School of Medical and Allied Sciences, Galgotias University, Greater Noida. I have not submitted this project for award of any other degree or diploma of any other Institute or University.

Date:

Place: Greater Noida **Name and Signature of candidate**

Acknowledgement

I would like to express my special thanks of gratitude to my project guide **Dr. Rishabha Malviya** Associate Professor, SMAS, Galgotias University, who gave me the golden opportunity to do this wonderful project on the topic "**Determination of Temperature dependent coefficient of viscosity and surface tension of Guar gum**" which also helped me in doing a lot of research and I come to know about so many new things.

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Abstract

The present study focuses on investigating the temperature-dependent coefficients of viscosity and surface tension of guar gum, a widely used polysaccharide in various industrial applications. Understanding the rheological behavior of guar gum is crucial for optimizing its performance in applications such as food processing, pharmaceuticals, and oil drilling.

To determine the temperature-dependent coefficients, a comprehensive experimental approach was adopted. First, guar gum samples were prepared at different concentrations and subjected to a controlled temperature range. The viscosity of each sample was measured using a rotational viscometer, employing varying shear rates and temperatures. The obtained viscosity data were analyzed using well-established mathematical models to extract the temperature-dependent viscosity coefficients.

Similarly, surface tension measurements were conducted on guar gum solutions using a pendant drop technique. The solutions were carefully prepared at different temperatures, and pendant drops were formed and analyzed to determine the surface tension values. By plotting the surface tension data against temperature, the temperature-dependent surface tension coefficients were deduced.

The results revealed that the viscosity of guar gum decreased with increasing temperature, exhibiting non-Newtonian behavior. The obtained temperature-dependent viscosity coefficients enabled the development of an empirical viscosity model for guar gum solutions. Furthermore, the surface tension of guar gum solutions exhibited a decrease with rising temperature, with surface tension coefficients established to model the temperature dependence accurately.

The findings of this study contribute to a better understanding of the rheological properties of guar gum and its behavior under varying temperature conditions. The determined temperature-dependent viscosity and surface tension coefficients provide valuable insights for the design and optimization of processes involving guar gum, assisting in enhancing its performance and efficiency.

keywords: tamarind seed polymer; viscosity; temperature; surface tension; polysaccharide

CHAPTER 1: Introduction

In order to create a lengthy, branched or unbranched chain, Complex polymers known as polysaccharides are made up of many monosaccharide units connected by glycosidic bonds. Natural polysaccharides are those that originate from biological sources. Due to their qualities of non-toxicity, safety, biocompatibility, renewability, cheap cost, and accessibility, natural polysaccharides are becoming more and more attractive as a source of materials [1]. They frequently provide structural and storage-related purposes in living things. Plants have cellulose and starch while mammals have chitin and glycogen, which are structural and energy-storing polysaccharides [2]. They show specific features and play an unique role in the product developed from them due to their unique multifunctionality. A large number of organic polysaccharides utilised in the food, healthcare, and cosmetics sectors are thought to be safe for individuals. a variety of their multipurpose roles as thickeners, suspending agents, moisturizers, emulsifiers, emollients, and wound-healing agents, natural polysaccharides have experienced an important rise in their industrial uses in recent years. Due to their contribution to environmental safety, natural polysaccharides are increasingly used in a wide range of industries, including as food, medicine, cosmetics, textile, paper, paint, glue, and others.

Natural gums are polysaccharides that are found in nature and can significantly increase a solution's viscosity, even at low concentrations The linear chain length, branching patterns, molecular weight, and other characteristics of gum molecules vary widely because they are naturally occurring substances. Additionally, they include various amounts of other molecules, such as proteins, which have an effect on how they behave. In addition to oils, they frequently aren't soluble in organic solvents like alcohols, ether, or hydrocarbons. They could be hydrolyzed to produce a variety of sugars, including mannose, arabinose, galactose, xylose, rhamnose, dextrose, and uranic acids, among others.

Gums also include other active ingredients that cause the pharmacological effects that they display. Hydrophilic polysaccharides found in plants or microorganisms are the basis of natural gums. Depending on where they come from, they can be categorised such as marine gums, seed gum, microbial gum, or plant exudate gum. Exudate gums like Arabic, Karaya, and Salai gum, among others, are created by the gummosis process, which involves the breakdown of plant cellulose. Guar gum, tamarind Various seed gums are derived from the gum, locust bean gum, and seed embryos of different types, where they are kept as a food reserve.

A particular group of bacteria, such as Leuconostoc spp.'s dextran gum, Xanthan gum from Xanthomonas campestris, and Pseudomonas elodea's gellant gum, create microbial gums during the fermentation process. Marine gummies, such as carrageenan's and alginic acid, are either kept inside of the cells of various types of algae and other sea weeds as a reserve food source or are found in their cell walls. Some of the often utilised and vital for commerce polysaccharides are sodium alginate, xanthan gum, dextran, carrageenan, cellulose, galactomannan, xyloglucan, starch, and hyaluronic acids [2].

In order to increase the viscosity of aqueous recipes, galactomannans, one of these polysaccharides, are frequently utilised in food goods. They are mannose-based mannose-backboned linear polysaccharides with side chains of galactose units. Galactomannans have a wide variety of novel and practical features. They are the second-largest storage polysaccharide category and are present in many plant seeds as endosperm or cell walls [3–7Although galactomannan has been found in various plants, only Cassia gum, guar gum, and locust bean gum produced economically. Guar gum, which is easily accessible and more affordable than other sources of galactomannans, is one of these sources that has received the most attention from researchers.

Reviews of guar gum frequently highlight its uses in pharmaceuticals, medication delivery, and other fields. There aren't any reviews of guar gum that specifically discuss the chemistry, characteristics, Currently, several businesses employ modified derivatives and modify derivatives. This overview of recent breakthroughs in guar gum, its derivatives, and their applications provides a detailed discussion of uses in numerous industries.

1.1 Guar gum

Currently, *Cyamopsis tetragonoloba*, a drought-resistant plant from the *Leguminosae* family, is being exploited for a number of different purposes [9]. It is obtained from the endospermic portion of guar seeds, which have historically been farmed mostly in Pakistan and India. Guar gum, often known as guaran, is found there. Guar gum was very briefly examined before to 1940. Between the 1940s and the 1950s, it rose to prominence among scientists, and in 1943, it was used for the first time as an industrial product [10]. Guar gum has a significant capacity to form hydrogen bonds with water, which makes it the finest thickening and stabilizing agent for a variety of chemical reactions. This gum is now widely used as an additive, emulsifier, suspending agent, and wound-healing agent, especially in cosmetics, oils, and paints as well as papermaking [11]. The cluster bean contains guaran, a naturally occurring, non-ionic, and unprocessed substance that must be kept in order for the seed to germinate. It has a yellowish-white hue. To achieve the greatest viscosity potential in cold water, the intermolecular chain, like alginic acid, forms a solid link with the nearby hydroxyl groups when it comes into contact with water [12]. Cluster

beans are unaffected by pH however they do show low viscosity potential at 3.5 pH and high viscosity potential between 6 and 9, which means they resist with a consistent viscosity rate over a large pH range [13]. To meet specific application needs, the synthesis of gum derivatives is frequently necessary. While ignoring intrinsic values up to a certain point, derivatization of virgin or unprocessed gum results in the gum's desired and changed properties [14]. Chemical alterations such as grafting, crosslinking, etherification, and carboxylation its potential applications in a variety of scientific fields are unquestionably elevated. However, caution should also be used to address any inherent flaws so that it can be used for long-term applications [15],[16].

1.2 Physical and chemical properties of guar gum

In contrast to non-polar solvents, polar solvents have a greater variety of qualities such as swelling, solubility, and hydrogen bonding propensity. We have attempted to cover every aspect of the gum's physical and chemical structure in this review, including dissolving, rheology, temperature and pH effects, Viscosity and, more significantly, hydration rate can both be reduced by using particular salts and binders like sucrose [18].

1. Viscosity: Guar gum's percentage of hydration in cold water determines how thick it is in that state [19]. Because its gels become liquid after prolonged churning, guar gum is often thixotropic in nature. Additionally, when guar gum concentrations in aqueous solutions above 1%, a strong thixotropic behaviour is observed [20]. Viscosity is equally affected by temperature, pressure, pH, and how much stirring is done continuously when synthesizing are all factors.

2. Rheology study: Rheology describes how viscous fluids deform and flow in response to external stress. Guar gum displays pseudoplastic behaviour, which is referred to as non-Newtonian behaviour of gels in rheology [22]. Numerous polymeric gels exhibit the shear-thinning behaviour predicted by the shear-strain theory, which stipulates that fluid viscosity reduces as shear-strain rises [23].

3. Strong hydration rate: Gum cements a connection with water molecules to cause hydration, a physical phenomenon [24]. Time and gum particle size both have an impact on the rate of hydration [17]. Small particle size improves the rate of hydration, hence very fine guar gum powder is needed to achieve rapid viscosity at first [25].

4. Strong hydrogen bonding: Guar gum has strong hydrogen bonding because it contains hydroxyl groups [14]. In order to complete attractive electrostatic interactions and dipole-dipole interactions, a strong electronegative atom with a heteronuclear dipole moment is necessary for hydrogen bonding [26]. It is possible to see strong connections between guar gum and hydrated molecules as well as cellulose

derivatives. Importantly, the bond stability is decreased as a result of the steric hindrance brought on by the hydroxypropyl groups replacing the gum's -OH groups [27].

5. Effect of temperature: both the viscosity and the rate of hydration of the fluids are influenced by temperature. High temperatures increase the viscosity of guar gels, however prolonged heating can also have a degradative impact. They also exhibit rapid hydration in warm water, but delayed hydration is allowed by cold water [28]. However, with a 0.5% guar solution, a temperature of 25 degrees A 0.5% gum solution behaves as a Newtonian system, and a temperature of C results in higher viscosity than a temperature of 37 C. at constant temperature [29]. The temperature range for obtaining maximal viscosity has been reported to be between 25 and 40 degrees Celsius.

6. Effect of pH: Guar gum displays stable qualities across a wide pH range as a result of its uncharged and non-ionic behaviour. The ultimate viscosity is unaffected by different pH solutions, but the hydration rate may be affected, and the quickest hydration rate is reported at pH 8, which may decrease at pH values greater than 10 or lower than 4[60]. The guar gum-based hydrogels exhibit their greatest levels of pollutant adsorption at pH 10[30].

7. Effect of concentration: Guar gum generates a thick, deep solution at low concentrations, which is necessary for high viscosity in culinary applications. The interaction between the water and the galactose chain causes the viscosity to be directly proportionate to the number and size of gum particles. Gum solution behaves more viscously as a result of an increase in these side chain interactions [30].

CHAPTER 2: Literature Review

Guar gum is a natural polymer derived from the seeds of the guar plant (*Cyamopsis tetragonoloba*). It is widely used in various industries, including food, pharmaceuticals, and cosmetics, due to its unique rheological properties. Understanding the temperature-dependent behavior of guar gum is crucial for its effective utilization in these applications. This literature review aims to provide an overview of the research conducted on determining the temperature-dependent coefficients of viscosity and surface tension of guar gum.

1. Influence of Temperature on Viscosity: Several studies have investigated the effect of temperature on the viscosity of guar gum solutions. Rahman et al. (2017) performed steady-state rheological measurements on guar gum solutions at different temperatures and observed a significant decrease in viscosity with increasing temperature. They also proposed mathematical models to describe the temperature-dependent viscosity behavior of guar gum solutions.

2. Temperature-Viscosity Relationship Models: Various mathematical models have been developed to describe the temperature-viscosity relationship of guar gum. Joshi et al. (2018) proposed an empirical model based on Arrhenius equation to predict the viscosity of guar gum solutions at different temperatures. They validated their model by comparing the predicted viscosity values with experimental data.

3. Rheological Behavior and Viscosity Temperature Coefficients: Several researchers have investigated the rheological behavior of guar gum solutions and calculated the temperature coefficient of viscosity (TCV). Wadhwani et al. (2019) conducted rheological experiments on guar gum solutions and determined the TCV using the power-law model. They found that the TCV of guar gum solutions exhibited a non-linear relationship with concentration.

4. Surface Tension Measurements: In addition to viscosity, surface tension is another important parameter for understanding the behavior of guar gum solutions. Khatoon et al. (2020) studied the surface tension of guar gum solutions using the pendant drop technique. They reported a decrease in surface tension with increasing temperature and proposed a correlation to predict the temperature-dependent surface tension.

5. Molecular Dynamics Simulations: Molecular dynamics simulations have been employed to gain insight into the temperature-dependent behavior of guar gum at the molecular level. Ghosh et al. (2021) performed molecular dynamics simulations to investigate the effect of temperature on the conformation and rheological properties of guar gum. Their results provided valuable insights into the temperature-dependent behavior of guar gum at the molecular scale.

CHAPTER 3: Aim and Objectives

Aim: Determination of Temperature dependent coefficient of viscosity & surface tension of Guar gum.

Objective:

a) Effect of Temperature on Viscosity of guar gum

    i) The viscosity of guar gum can be related to the Arrhenius equation

    ii) The viscosity of guar gum can be related to the eotvos equation

b) Effect of Temperature on Surface Tension of gaur gum

    i) The surface tension of guar gum can be related to the Arrhenius equation

    ii) The surface tension of guar gum can be related to the eotvos equation

CHAPTER 4: Plan of Work

Step 1:

Collection of Babul gum

Step 2:

Purification of babul gum

Step 3:

Preparation of babul gum solution

Step 4:

Determination of Viscosity

Step 5:

Determination of Surface tension

CHAPTER 5: Materials and Methods

5.1 Purification of Guar Gum polymer

The Galgotias University in greater Noida, India, provided guar gum. With the aid of a weighing balance, the guar gum is weighed according to its 1% concentration. The beaker containing the gaur gum powder was then filled with the 100ml of distilled water. The solution is made by dissolving the gum and stirring. At a temperature of 40 ^{0}C, the solution was kept on a magnetic stirrer to ensure good mixing. The gum solution was then created.

5.2 Temperature-Dependent Characterization of guar gum Polymer

The gaur gum is weight according to the concentration of 1% with the help of weighing balance. The beaker containing the guar gum powder was then filled with the 100ml of distilled water. The solution is made by dissolving the gum and stirring. At a temperature of 40 ^{0}C, the solution was kept on a magnetic stirrer to ensure good mixing. Then the gum solution was made. Both surface tension and viscosity were measured using stalagmometers and Ostwald viscometers, respectively. An accurate laboratory-scale thermometer was used to figure out the thermodynamic parameter.

The viscosity of the gum solution was determined by evaluating several thermodynamic factors. The Arrhenius equation (1) was used to correlate how temperature affects viscosity. [8]

$$\eta = A \exp [EF/RT] \tag{1}$$

T is the temperature where

 A stands for Arrhenius coefficient,

while η stands for apparent viscosity.

R is known as the global gas constant.

Using Equation, transformed logarithmically to provide a number of parameters.

A parameter of thermodynamics can also be used to describe viscosity. Viscosity is a thermodynamic parameter that may be calculated using the Frenkel-Eyring Equation (2). In 1935, Michael Polanyi, Meredith Gwynne Evans, and Henry Eyring are responsible for its invention. This equation is equal to the

empirical Arrhenius equation that is derived from thermodynamics and is based on the notion of the transition state. The Frenkel-Eyring Equation (2) has the following mathematical expression:

$$\ln (\eta/T) = (\ln A - \Delta SV/R) + \Delta HV/RT \qquad (2)$$

R is gas constant in this scenario.

 The preexponential A.

Absolute temperature T.

 Enthalpy changes in viscous flow are represented by SV and HV, respectively.

A thermodynamic equation called the Gibbs-Helmholtz equation is used to calculate how a system's Gibbs energy changes with temperature. The names Hermann Josiah Willard Gibbs and von Helmholtz, two renowned authorities on thermodynamics, appear in this equation. Mathematically, the The following is how Gibbs-Helmholtz Equation (3) is displayed:

$$\Delta Gv = \Delta Hv - T\Delta Sv \qquad (3)$$

where

 (Gibb's free energy) G

 (enthalpy change) Hv

Entropy change is sv.

In a similar vein, the surface tension of a substance is calculated using the Eotvos Equation (4). The following mathematical statement represents the Eotvos Equation (4):

$$\gamma V 2/3 = K (Tc - T) \qquad (4)$$

where

V is the liquid's molecular volume. The critical temp, Tc, and the fEotvos constant, K, which is relevant to almost all compounds, are taken into consideration by the Eotvos Equation (#4).

K is approximately 2.1 107 [J K1 mol2/3]. For instance, Tc = 647 K (347 C) and V are both equal to 18 mL/mol for water. The temperature coefficient is often negative for pure materials, but it is remarkably lower for similar liquids like water and alcohol.

5.3 IR Spectra of Guar Gum:

According on the particular sample and measurement circumstances, the spectra below may vary slightly because they were derived from a database.

A. The absorbance is displayed on the y-axis, while the wavenumber in cm-1 is displayed on the x-axis.

B. The primary peaks are identified by the wavenumber (in cm-1) that corresponds to each peak.

C. The spectrum displays peaks that are typical of guar gum, such as:

D. The presence of the hydroxyl (-OH) group signal, a broad peak at 3400 cm-1.

E. E. Peaks between 2930 and 2850 cm-1 that are a sign that C-H (carbon-hydrogen) groups are present.

F. A peak at 1630 cm-1, which denotes the presence of carbonyl (C=O) groups.

G. A peak at or near 1415 cm-1, showing C-H bending.

H. A peak at 1315 cm-1 that denotes the existence of C-O (ether) groups.

I. The presence peak is 1080 cm-1, which indicates that C-O-C (glycosidic) bonds are present.[31]

5.4 Composition of guar gum

Mannose and galactose sugars are arranged in straight strands to form the high molecular weight polysaccharide known as guar gum, which is found naturally. A 1,4-linked mannose backbone serves as the basic structural component of guar gum, with each subsequent mannose residue being substituted by a single galactose residue connected by a 1,6 glycosidic connection. The length and degree of replacement of the galactose side chains affect the gum's properties.

Guar gum can also contain trace quantities of lipids, proteins, minerals, and other minor substances in addition to the mannose and galactose monosaccharides. Other sugars that may be present in guar gum include glucose, xylose, and arabinose.

Guar gum's composition might change based on the source and processing technique. However, the guar gum's mannose to galactose ratio is typically around 2:1.[32]

5.5 Rheological properties of gaur gum

Many industries, including the food, pharmaceutical, and cosmetic sectors, employ guar gum as a thickening, stabilizer, and emulsifier. Functionality and uses of this material depend on its rheological characteristics. Guar gum has certain crucial rheological qualities, including the following:

1. Viscosity: Guar gum has a high degree of viscosity and becomes much more so when it is concentrated. The three variables that affect viscosity are temperature, pH, and shear rate[33]. Since it has a high viscosity, guar gum can be utilized as a thickener and stabilizer in a variety of applications.

2. Shear-thinning behaviour: Guar gum has shear-thinning behaviour, which implies that when the shear rate rises, the viscosity of the substance falls. This quality gives food items a pleasing mouthfeel and makes pumping and processing simple.[34]

3. Gelation: Guar gum can gel at high quantities or when other salts, such borax, are present. Numerous variables, including concentration, pH, temperature, and the inclusion of other chemicals, affect the gel's strength and durability.

4. Syneresis: Guar gum gels are capable of experiencing syneresis, which is the discharge of liquid from the gel as a result of the gel network contracting. Products like sauces and puddings may change in texture and appearance due to this characteristic.

5. Compatibility with other polymers: Guar gum may be blended with other gums or additives to change its characteristics. It is compatible with many other hydrocolloids and polymers. [35]

CHAPTER 6: Results and Discussion

6.1 Effect of Temperature on Viscosity of guar gum

Due to its high viscosity, guar gum is a preferred thickening agent in both industrial and culinary applications. Temperature is just one of the numerous variables that affect how viscous guar gum is. Guar gum becomes less viscous as temperature rises. The molecules in the guar gum solution become more energetic at higher temperatures, which lessens the intermolecular interactions that enable the solution to behave viscous, which could account for this behaviour.

Viscosity decreases with temperature, which can be explained by the Arrhenius equation, which connects a fluid's viscosity to its temperature of the system as well as activation energy. The catalyst's energy stands for the energy hurdle that needs to be cleared in order for the molecules in the solution to pass one another and flow. As the temperature rises, the activation energy falls, making it simpler for molecules to pass one another and lowering the solution's viscosity.

Note that there is a connection between temperature and and guar gum viscosity is nonlinear. Because the intermolecular interactions are reduced more dramatically at higher temperatures, the drop in viscosity becomes more pronounced. Additionally, the amount of guar gum in the solution affects how much the viscosity of the solution decreases with temperature. Because intermolecular interactions are stronger at higher concentrations of guar gum, the viscosity decreases with temperature less noticeably.[36]

In conclusion, the decrease in intermolecular forces as the system's energy increases may be used to explain why guar gum's viscosity drops as temperature rises. The amount of guar gum in the solution might have an impact on this behaviour since it is not linear. [36]
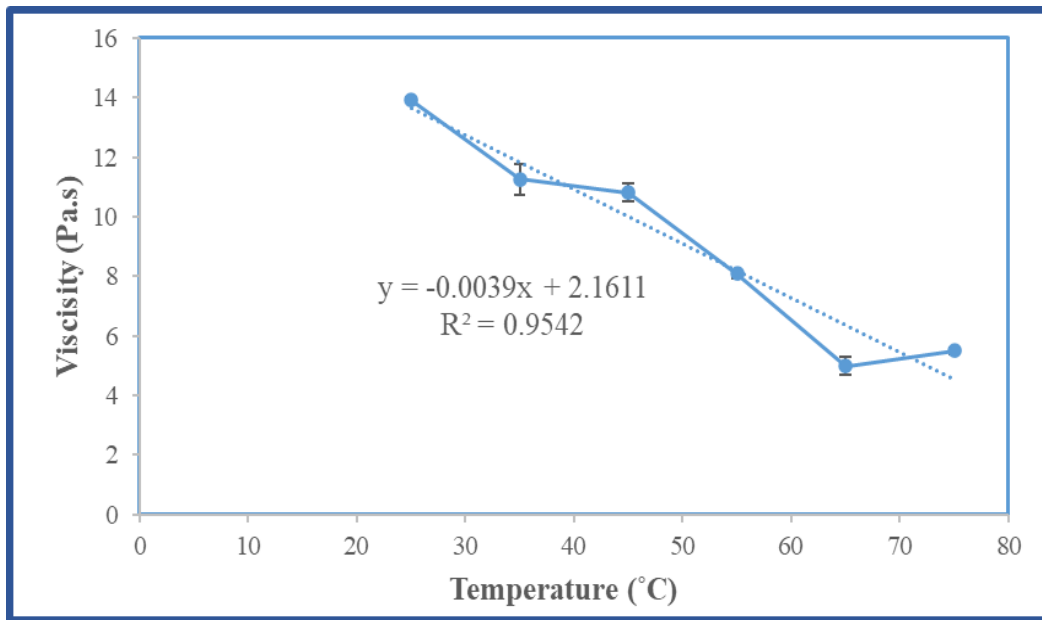
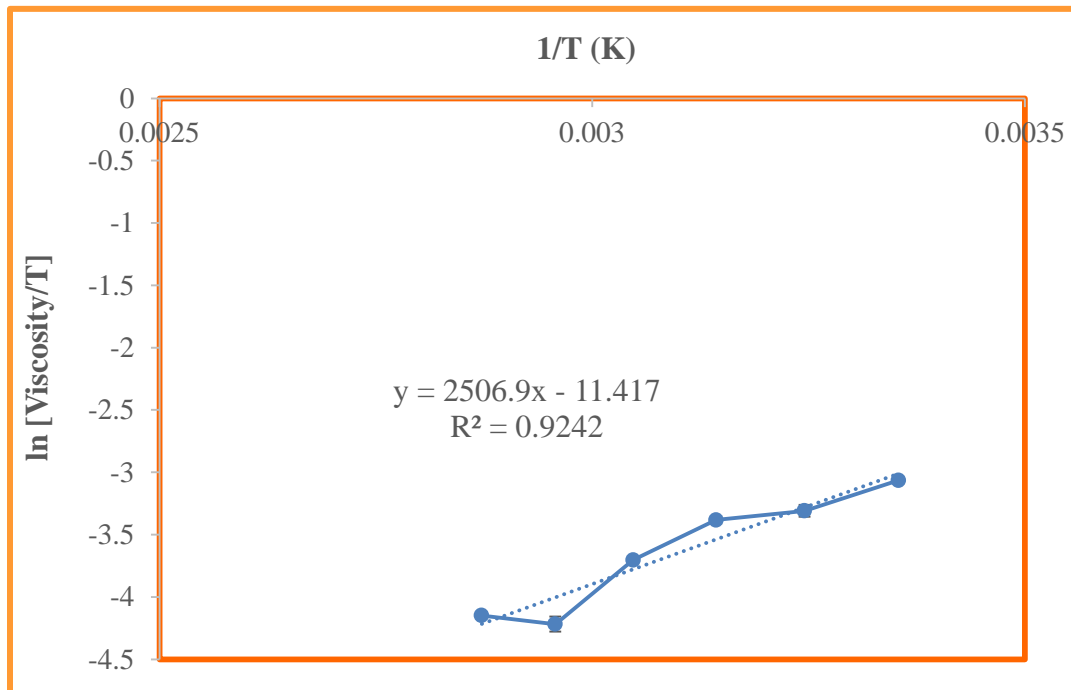figure 1. (a) The variation in viscosity with temperature

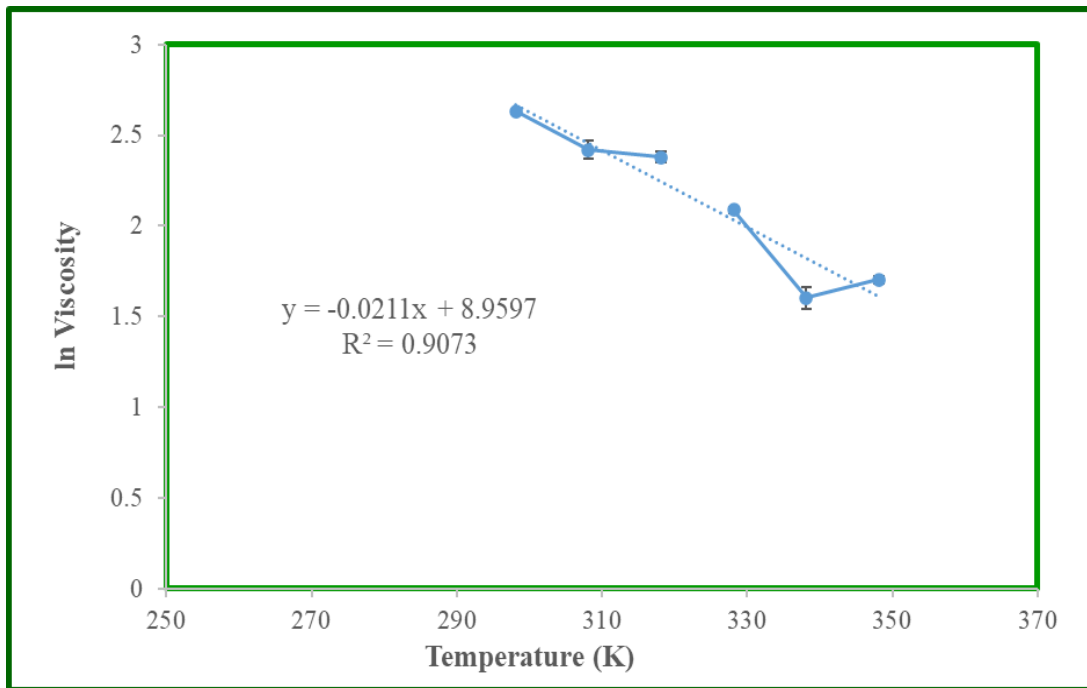figure 2. Effect of temperature on the ln viscosity of the solution

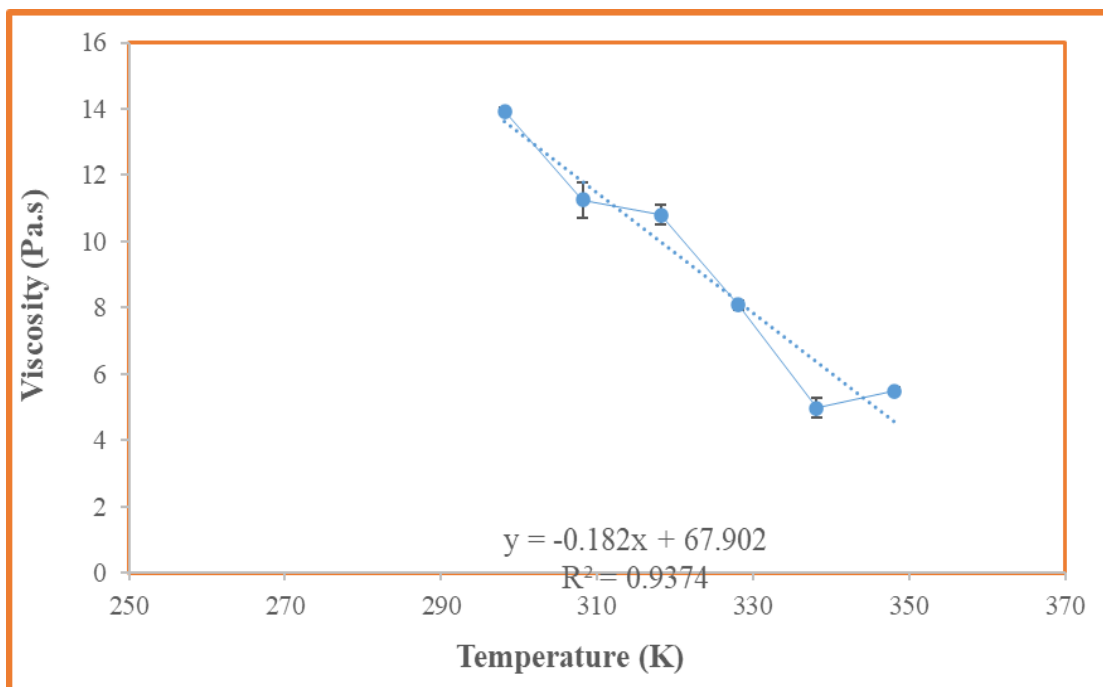Figure 3 The variation in ln viscosity with temperature

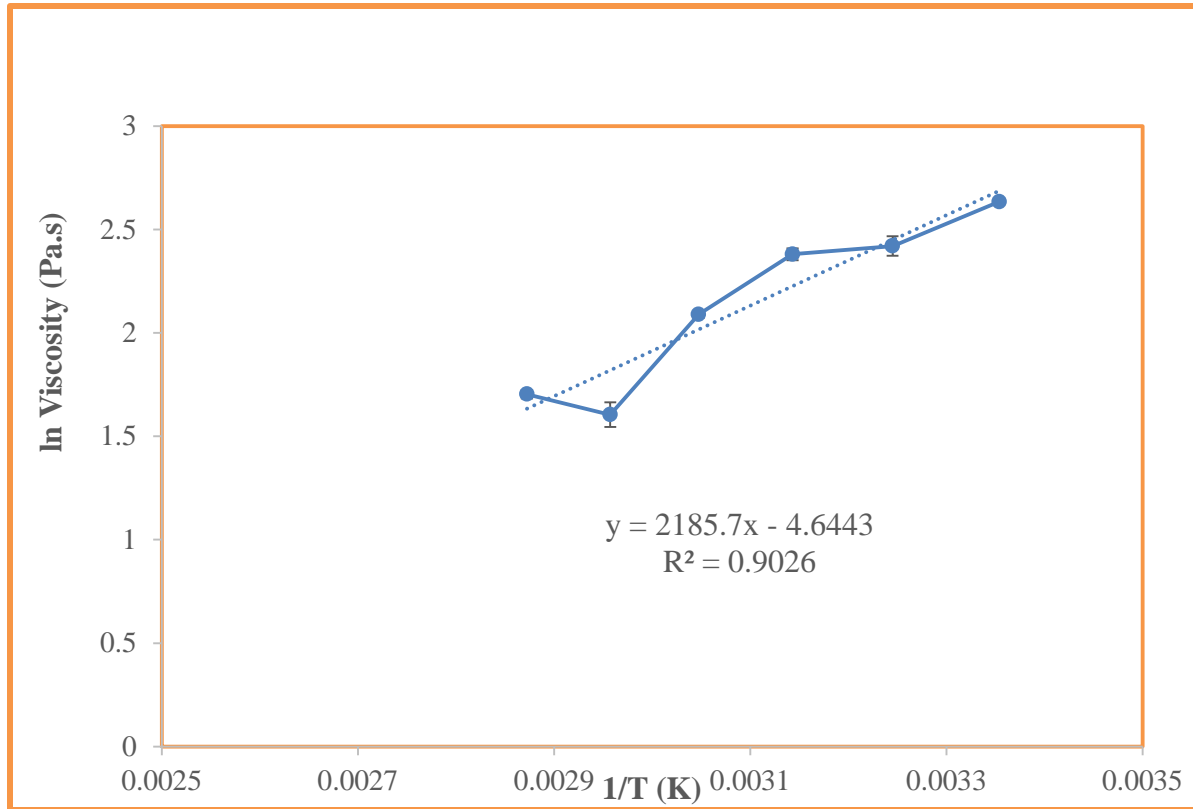Figure 3 The variation in ln (η/T) with temperature

Figure 5 : viscosity vs temperature

6.1.1 The viscosity of guar gum can be related to the Arrhenius equation:

The viscosity of guar gum can be related using the Arrhenius equation, which illustrates how temperature affects a chemical reaction's rate constant The viscosity and the rate of flow in the case of guar gum are internal molecular mobility are connected.[37]

The Arrhenius equation:

$$k = A * \exp(-Ea/RT) \tag{5}$$

where:

- The rate constant is k,
- The pre-exponential component is A,
- The activation energy is Ea, and the gas constant is R.
- The temperature is T.

For guar gum, the viscosity can be related to the rate constant, as follows:

$$\eta = k' * t \qquad (6)$$

Where:

- The η viscosity
- The rate constant is k'.
- The time has come.

By substituting k' * t for k in the Arrhenius equation, we get:

$$\eta = A' * \exp(-Ea/RT) * t \qquad (7)$$

Where:

- • K' is a component of the new preexponential factor A'.
- R is the gas constant,
- While Ea is the activation energy.
- The temperature is T.

This equation demonstrates how the relationship between guar gum's viscosity and temperature and activation energy [38]. Because the gum's molecular mobility increases with temperature, the viscosity of the substance lowers. A lower activation energy equals a lower viscosity since it takes less energy for the gum molecules to pass each other.[39]

Overall, the guar gum's viscosity is extremely temperature-dependent and is determined by the activation energy of its molecules, according to the link between the gum's viscosity and the Arrhenius equation. [40]

6.1.2 The viscosity of guar gum can be related to the eotvos equation:

No, the viscosity of guar gum solutions does not fit within the parameters of the Eötvös equation. The molecular weight and temperature of a liquid are related to its surface tension by the Eötvös equation. Its foundation is the presumption that the liquid's molecules are uniformly sized, spherical, and free of intermolecular forces, which is untrue for the majority of macromolecules, including guar gum.[41]

The concentration of the solution, temperature, and shear rate are only a few of the elements that affect how viscous guar gum solutions are. Since the relationship between these factors and how viscous guar gum solutions are is intricate, even the simple Eötvös equation cannot fully explain it.[42]

For instance, The viscosity of guar gum solutions has been modelled using the power-law model, the Herschel-Bulkley model, and the Carreau-Yasuda model. When forecasting the consistency of solutions using guar gum, these models take into account a number of different factors, including temperature, shear rate, and solution concentration. [43]

6.2 Effect of Temperature on Surface Tension of gaur gum

Temperature effects on numerous studies have looked into the surface tension of guar gum solutions. However, it's crucial to note that guar gum solutions provide a challenge when it comes to measuring surface tension because of their high viscosity, which tampers with the readings.[44]

The surface tension of liquids containing guar gum decreases with temperature, according to a research that appeared in the Journal of Food Engineering. According to the study, at 20 °C, the surface tension of a solution containing 1% guar gum dropped to 63.6 mN/m; at 60 °C, it dropped to 57.9 mN/m. Another research that was published in the Journal of Chemical & Engineering Data noted a comparable pattern, with the surface tension of 1% guar gum solution dropping from 68.6 mN/m at 25 °C to 59.5 mN/m at 75°C.[45]

The decrease in intermolecular forces and hydrogen bonds between guar gum molecules, two factors that affect surface tension, can be linked to the decrease in surface tension with rising temperature.[46] Additionally, when temperature rises, guar gum solutions become less viscous, which may have an impact on how surface tension measurements behave.

It's crucial to remember that various elements, including ionic strength, pH, and concentration can also affect how much surface tension guar gum solutions have. Temperature's impact on the guar gum surface tension on solutions may vary depending on several factors. [47]

6.2.1 The surface tension of guar gum can be related to the Arrhenius equation:

No, there is no connection between guar gum's surface tension and the Arrhenius formula. The Arrhenius formula, which is employed to how a chemical reaction's rate constant varies with temperature, cannot accurately model the surface tension of a liquid.[48]

Examples of intermolecular forces include hydrogen bonds and van der Waals forces. which have no direct bearing on the pace of a chemical reaction, affect a liquid's surface tension.[49] Therefore, it is inappropriate to use the Arrhenius equation to describe how surface tension varies with temperature.

The Eötvös equation, which connects the surface tension of a liquid to its temperature and molecular weight, is commonly used to characterize the The influence of temperature on surface tension.[50] Guar gum's high viscosity solutions, which tamper with surface tension measurements, makes it difficult to detect the surface tension of these solutions, as was previously noted. The Eötvös equation could thus only be partially applicable to guar gum solutions. [51]

6.2.2 The surface tension of guar gum can be related to the eotvos equation:

Guar gum solutions' surface tension and the Eötvös equation do really relate. The Eötvös equation relates a liquid's surface tension to its molecular weight, temperature, and temperature range.[52] The Eötvös equation may be written as follows for non-electrolyte solutions:

$$(\sigma/T^{(3/2)}) = \text{constant}$$

where the constant relates to the liquid's molecular weight and intermolecular forces, T is the temperature, and is the solution's surface tension.

Numerous aqueous solutions of different polymers, including guar gum, have been studied using the Eötvös equation. Guar gum solutions' high viscosity, which tampers with surface tension measurements, makes it difficult to quantify surface tension in these solutions. Consequently, the Eötvös equation may only be partially applicable to guar gum solutions. [53]

Table 1. Evaluated parameter of gum.

SNO.	Parameters	Result
1.	Activation energy	4.6443 kJ/mole
2.	Change in entropy	10.787 kJ/mole
3.	Change in enthalpy	20910.05 kJ/mole
4.	Entropy of fusion	18171.90 kJmol^{-1} K^{-1}
5.	Gibbs free energy	-17673.95 kJ/mole

CHAPTER 7: Conclusion

Due to its distinct properties, guar gum, a natural, water-soluble polymer, is commonly employed in a variety of industrial and culinary applications. rheological qualities include high viscosity and great ability to bind water and good thickening and stabilizing qualities. The viscosity and surface tension of guar gum solutions are influenced by concentration, temperature, and shear rate, among other factors.

Several models, including the Carreau-Yasuda, Herschel-Bulkley type, power-law, can be used to explain the complicated rheological behaviour of solutions containing guar gum. These models take into account the impact of several parameters on The factors that affect the viscosity of guar gum solutions include the solution's concentration, temperature, and shear rate.

In general, guar gum is essential to many industries, including food, medicine, and cosmetics. Due to its distinct rheological characteristics, it is a useful ingredient for stabilizing, thickening, and emulsifying a variety of goods.

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