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THE TEMPERATURE EFFECT ON THE VISCOSITY AND DENSITY OF XANTHAN GUM SOLUTION

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Abstract

Xanthan gum is a nontoxic polysaccharide with a good gelling, thickening and stabilizing attributes, and used widely in food and cosmetic industries. Effect of temperature on the viscosity and density of various solutions of xanthan gum (0.1 ,0.2,0.3,0.4 and 0.5 w/v %) were studied experimentally with temperatures range of 30 to 60°C. The experimental tests were performed using DV-II+Pro viscometer at different speeds (50, 100 and 150rpm). It has been noticed by measuring the viscosity changes, that efficiency of higher polymer concentrations , lower speeds and lower temperatures also.

The density increase by increasing concentration and decrease with temperatures.

Xanthan Gum , Temperature , Viscosity , Density , Concentration

تأثير الحرارة على اللزوجة والكثافة لمحلول XANTHAN GUM

الخلاصة :

يمتاز لبان الزانثان بأنه من عديدات السكريات غير السامة ذات الهلامية والكثافة والاستقرار الجيد، ويستخدم لتراكيز مختلفة بشكل واسع في الأطعمة وصناعة مستحضرات التجميل .تمت دراسة أثر درجة الحرارة عملياً على اللزوجة و الكثافة لمختلف التراكيز ٠,١ -٠,٢-٠,٣-٠,٤. و٠,٥ وزن / حجم ، لمديات درجة حرارة من ٣٠ إلى ٦٠ درجة سليزية باستخدام جهاز اللزوجة DV-II+Pro وبسرع زمنية مختلفة (٥٠,١٠٠,١٥٠) دورة \ دقيقة . نلاحظ نقصان اللزوجة عند تعريض المحاليل لسرع ودرجات حرارة عالية وزيادة اللزوجة عند زيادة التركيز. وزيادة الكثافة عند درجات الحرارة المنخفضة والتراكيز العالية .

Introduction

Xanthan gum is a polysaccharide used as a food additive and rheology modifier **(Davidson, Robert L,1980)**. It is produced by fermentation of glucose or sucrose by the Xanthomonas campestris bacterium. After a fermentation period, the polysaccharide is precipitated from a growth medium with isopropyl alcohol, dried, and ground into a fine powder. Later, it is added to a liquid medium to form the gum. **(Cohan, Wendy,2010)**

It was discovered by an extensive research effort by Allene Rosalind Jeanes and her research team at the United States Department of Agriculture, which involved the screening of a large number of biopolymers for their potential uses. It was brought into commercial production by the Kelco Company under the trade name Kelzan in the early 1960s. **(Whistler, Roy, L, and BeMiller, James N.,1973)** It was approved for use in foods after extensive animal testing for toxicity in 1968. It is accepted as a safe food additive in the USA, Canada, Europe, and many other countries, with E number E415.

Xanthan gum is added to some diets for its fiber content. Gum fiber, although not a true fiber, is considered a part of the dietary fiber complex because it elicits similar effects. Numerous studies, particularly of the epidemiological variety, have suggested an adequate supply of dietary fiber protects against obesity, diabetes mellitus and coronary heart disease. Xanthan gum has particular clinical value in Dumping syndrome, diabetes and hyper-cholesterolemia, due to its viscosity. Xanthan gum has a therapeutically glutinous or viscous Numerous studies, particularly of the epidemiological variety, have suggested an adequate supply of dietary fiber protects against obesity, diabetes mellitus and coronary heart disease. **(Baig, M. & Cerda,1983)**

Xanthan is a white to cream colored free flowing powder soluble in both hot and cold water to give viscous solutions at low concentrations. Its industrial importance is based upon its ability to control the rheology of water based systems. Even at low concentrations xanthan gum solutions show a high viscosity in comparison with other polysaccharide solutions. This property makes it a very effective thickener and stabilizer**.(B.R. Sharma, Naresh L., N.C. Dhuldhoya, S.U. Merchant and U.C. Merchant,2006)**

Due to the extraordinary properties as stabiliser and thickener xanthan gum is used in the food, cosmetic and pharmaceutical industry. Also, xanthan gum is used in various industrial

applications and for oil drilling. In all these areas xanthan gum is accepted as an excellent stabiliser and a useful processing aid. syneresis; contributes body to gravy **(Jungbunzlauer)**

Table 1 Food Application

Food Application	Usage in %	Function
Salad Dressings	0.1 - 0.5	provides easy pour ability and good cling; suspends spices
Bakery Products	0.05 - 0.3	binds water; improves texture
Beverages	0.05 - 0.2	enhances mouthfeel; suspends fruit pulp
Instant Products	0.05 - 0.2	contributes body; quick viscosity build up in cold and hot water
Prepared Foods	0.1 - 0.3	Stabilizes avoids syneresis
Soups, Sauces and Gravies	0.05 - 0.5	gives good temperature stability; prevents separation
Frozen Food	0.05 - 0.2	Provides good freeze/thaw stability; contributes smooth texture
Dairy Products	0.05 - 0.2	inhibits syneresis ; stabilises emulsions
Toppings	0.05 - 0.3	stabilises foams and emulsions; good flow and cling
Meat Products	0.2 - 0.5	binds water; inhibits syneresis
Low-calorie Products	0.1 - 0.5	improves texture; stabilizes

Personal Care Application	Usage in %	Function
Toothpaste	0.7 – 0.1	provides easy pumpability and gives good stand on the brush
Creams and Lotions	0.2 - 0.5	stabilises emulsions; gives creamy consistency
Shampoos	0.2 - 0.5	controls rheology; suspends insolubles

Industrial Applications	Usage in %	Function
Agricultural Chemicals	0.1- 0.3	suspends active ingredients; controls drift and cling
Cleaners	0.2 - 0.7	provides good pH-stability; extends contact time
Polishes	0.2 - 0.7	suspends abrasive components
Water Based Paints	0.1 - 0.3	controls rheology; stabilises pigments
Textile and Carpet Printing migration	0.2 - 0.5	improves processing; controls colour
Adhesives	0.1 - 0.3	controls rheology and penetration
Paper Industry	0.1 - 0.2	acts as suspension aid and rheology control
Ceramic	0.3 - 0.5	Glazes suspends solids effectively
Oil Drilling	0.1 - 0.4	provides good stability against salt, temperature and shear
Enhanced	0.05 - 0.2	Oil functions as mobility control agent Recovery

Animal Feed	Usage in %	Function
Liquid Milk Replacers	0.05 - 0.2	stabilises water insoluble ingredients
Pet Food	0.1 - 0.4	prevents syneresis; contributes body to gravy

Pharmaceuticals	Usage in %	Function
Suspensions and Emulsions flow	0.1 - 0.5	provides excellent stability and good
Tablets	1.0 - 3.0	retards drug release
Lozenges	1.0 - 3.0	prolongs contact time of active ingredients

The powder of xanthan gum can be easily and safely stored over several years. Xanthan gum solutions, however, although more resistant to microbial attack than most other water soluble

polymers, should be protected by adequate preservatives when storage time shall exceed 24 hours. Xanthan gum is compatible with most commonly used preservatives.

The main object of this work is to study the effect of the temperature on the viscosity and density of xanthan gum solution to obtain good substance storage .

Experimental Work :

1-Preparation of polymer solution

The dissolving of polymers were carried out in a shaking machine type KOTTERMANN 4010, Germany,100 rpm at room temperature. This condition was used to avoid any polymer molecular degradation since the shaker has no blade or sharp edge that could expose the polymer to high shear forces.

The method of solution preparation adopted here was to make 0.1%, 0. 2%,0.3% ,0.4% and 0.5% g/ml concentrations in a separate container. Corresponding 0.5, 1,1.5 , 2 and 2.5g polymer was placed in a one liter conical flask and mixed with 500ml of the corresponding solvent. The container was placed in the electrical shaker.

A homogenous solution was obtained after 5 days for XG. These solutions were allowed to stand at least 24 hours at room temperature prior to further investigation.

2-Viscosity and density measurements

The polymeric solutions of different concentrations were exposed to high speed at different temperature. The viscosity and density of the solutions were measured as a function of temperature and speed .The viscosity was measured by using Brookfield DV-II+Pro viscometer, which measures fluid viscosity at a given shear rate. The principle of operation of the DV-II+Pro viscometer is to rotate a spindle, which is immersed in the test fluid until the fluid is at the immersion groove on the spindles shaft through calibrated spring. The viscous drag of fluid against the spindle is measured by the spindle deflection. The viscosity measurements of DV-II+Pro viscometer is in centipoises. The viscometer was set in either speed select or spindle select mode. When set in the left position, the operator may select speed of rotation. When set in the right position the operator may select spindle. The viscometer DV-II+Pro is shown in figure (1). The viscometer joined with temperature bath to obtain different temperature are shown in figure (2) .

DV-II+Pro viscometers are provided with a set of six spindle. Each spindle must have entry code number to calculate viscosity value. The viscometer memory contains parameters for all spindle and the digit entry code for each spindle .There are 54 rotational custom speed available on DV-II+Pro viscometer when press the (set speed) key , those are:
0.01,0.03,0.05,0.07,0.09,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1.1,1.2,1.4,1.5,1.8,2,2.5,3,4,5,6,7.5,8,10,12,15,17,20,22,25,30,35,40,45,50,60,70,75,80,90,100,105,120,135,140,150,160,180and200rpm

DV-II+Pro viscometers are provided with a set of four spindle. Each spindle must have entry code number to calculate viscosity value. The viscometer memory contains parameters for all spindle and the digit entry code for each spindle are listed in table 1.

Table 2 Code of spindles for DV-II+Pro viscometer

Spindle	LV1	LV2	LV3	LV4
Code	**61**	**62**	**63**	**64**

The density of polymeric solution experiments was measured by using hydrometer . The sample weights were measured by a sensitive digital balance type (METTLER, AE 163, GERMANY) to the range of 0.1 mg.

Figure (1) DV-II+Pro viscometer

Figure (2) DV-II+Pro viscometer with temperature bath

Results and Discussion

Xanthan Gum (XG) as a water soluble polysaccharide polymer, there viscosity are changed with high speed stirring and the solution become thinner and less viscous(**Viscosity Overview, 2007).**The viscosity changes of xanthan gum polymers dissolved in water was investigated during changes the concentrations solution. The results of the five different concentrations, 0.1,0.2,0.3,0.4 and 0.5 at 30°C are illustrated in figure (3),The figure shows the lowering of viscosity as the speed increases for all five concentrations ,While the sensitivity of viscosity with speed variations depends on the polymer concentration and hence on the solution viscosity. Thus the high viscous solution as in concentration of 0.5%w/v of xanthan gum is affected more by speed decrease. the viscosity of its solution decreases more an gradually with temperature .

Table 3 Effect speed on viscosity of xanthan gum at 30°C

speed(rpm)	0.5 w\v%	0.4 w\v%	0.3 w\v%	0.2 w\v%	0.1 w\v%
50	41	36	23.3	10.1	4.5
100	30.4	25	19	8.5	4.22
150	24.7	18.8	16.3	7.72	3.39

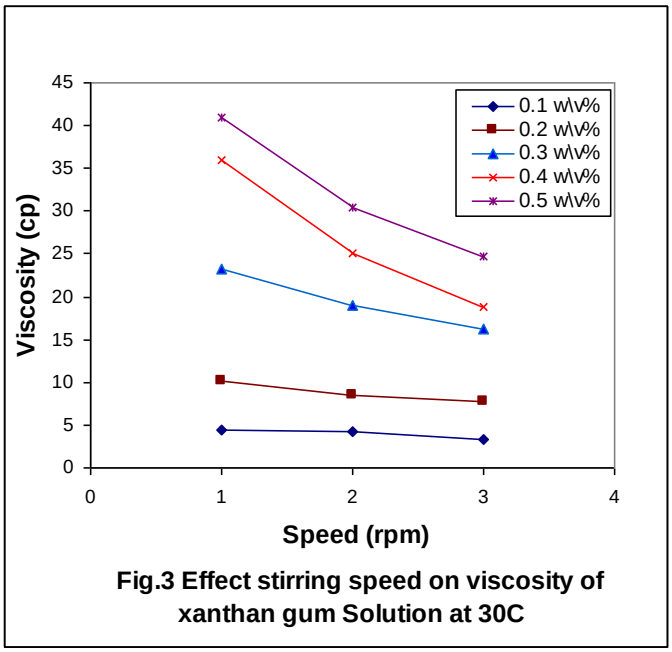

Fig.3 Effect stirring speed on viscosity of xanthan gum Solution at 30C

The decrease in the polymer solution viscosity with increasing the temperature is shown in figure (4) to figure (8). viscosity increases gradually as temperature decreases for all concentration. Maximum viscosity of 41.4 centi poise was observed by using 0.5 %(w\v) at 30°C. Viscosity increases as speed decreases and as temperature decreases also.

Table 4 Effect of Temperature on Viscosity of xanthan gum at 0.1 w\v%

Temperature(°C)	Viscosity at 150 rpm	Viscosity at 100 rpm	Viscosity at 50 rpm
30	3.39	4.2	4.5
40	3.24	3.33	3.7
50	2.63	2.69	3.2
60	1.88	1.9	2.26

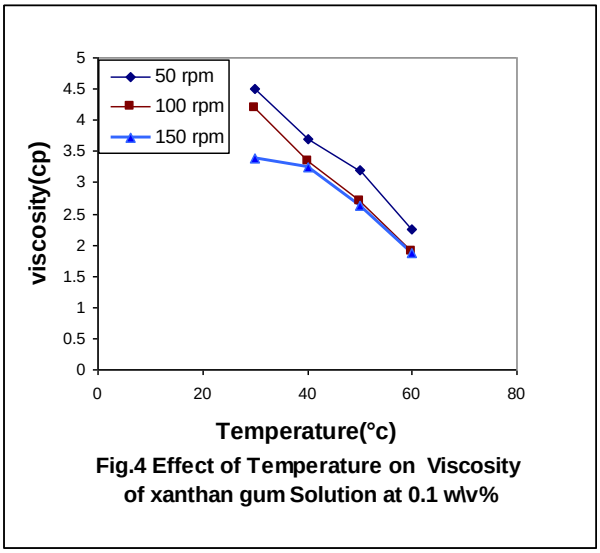

Fig.4 Effect of Temperature on Viscosity of xanthan gum Solution at 0.1 w\v%

Table 5 Effect of Temperature on Viscosity of xanthan gum at 0.2 w\v%

Temperature(°C)	Viscosity at 150rpm	Viscosity at 100 rpm	Viscosity at 50 rpm
30	7.72	8.5	10.1
40	6.66	6.85	7.68
50	6.15	6.43	7.1
60	5.85	6.27	6.57

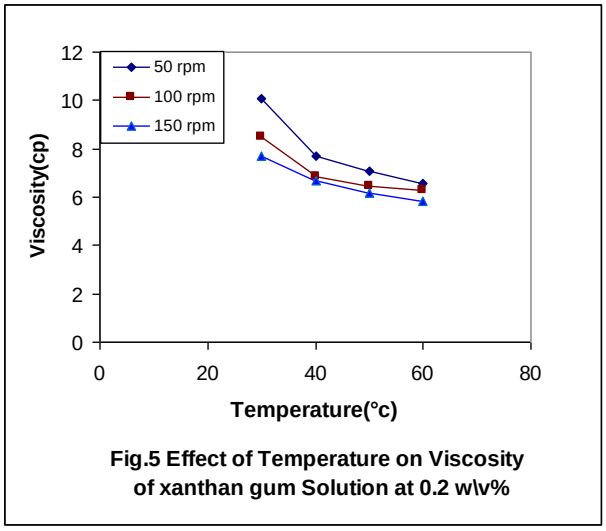

Fig.5 Effect of Temperature on Viscosity of xanthan gum Solution at 0.2 w\v%

Table 6 Effect of Temperature on Viscosity of xanthan gum at 0.3 w\v%

Temperature(°C)	Viscosity at 150rpm	Viscosity at 100rpm	Viscosity at 50rpm
30	16.3	19	23.3
40	11.2	13	14.6
50	10.5	12	13.6
60	10.1	11.15	12.4

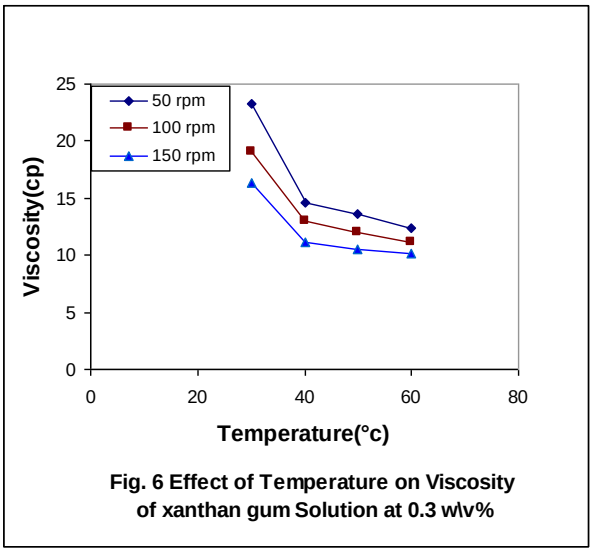

Fig. 6 Effect of Temperature on Viscosity of xanthan gum Solution at 0.3 w\v%

Table 7 Effect of Temperature on Viscosity of xanthan gum at 0.4 w\v%

Temperature(°C)	Viscosity at 150rpm	Viscosity at 100rpm	Viscosity at 50rpm
30	18.8	25	36
40	15.9	18.4	23.4
50	12	14	17
60	10.78	11.3	14.6

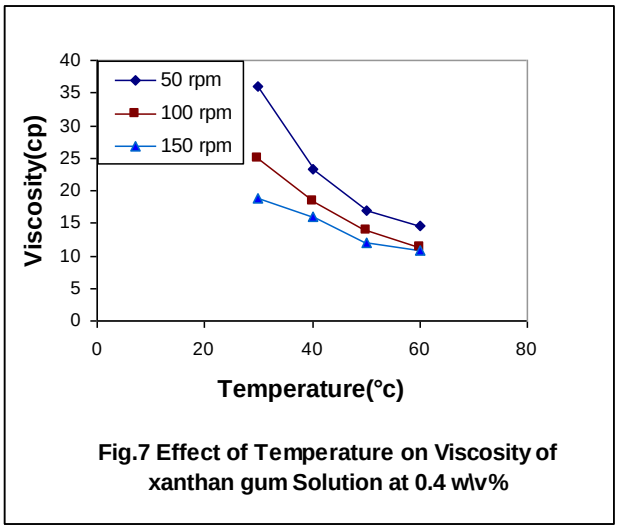

Fig.7 Effect of Temperature on Viscosity of xanthan gum Solution at 0.4 w\v%

Table 8 Effect of Temperature on Viscosity of xanthan gum at 0.5 w\v%

Temperature(°C)	Viscosity at 50rpm	Viscosity at 100rpm	Viscosity at 150rpm
30	41.4	30.4	24.7
40	39	29.6	23.8
50	34.1	24	20.2
60	27	21.6	18

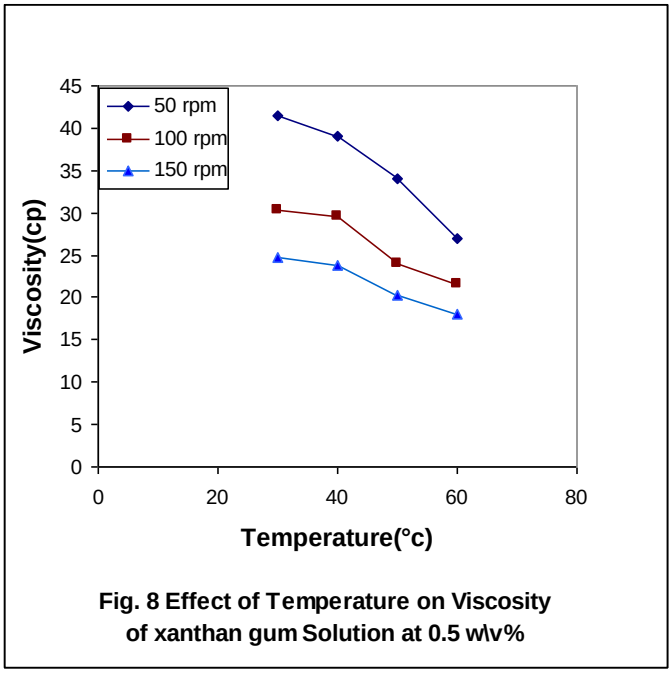

Fig. 8 Effect of Temperature on Viscosity of xanthan gum Solution at 0.5 w\v%

The effect of concentration of polymer solutions on the scission of polymer chains by high and low speed had been investigated by change of viscosities, as shown in figure 9 and 10. The results indicate that viscosity of polymeric solutions increase dramatically with the increase in the concentration.

Table 9 Effect Temperature on Viscosity of xanthan gum at 50 rpm

Temperature(°C)	0.5 w\v%	0.4 w\v%	0.3w\v %	0.2 w\v%	0.1 w\v%
30	41.4	36	23.3	10.1	4.5
40	39	23.4	14.6	7.68	3.7
50	34.1	17	13.6	7.1	3.2
60	27	14.6	12.4	6.57	2.26

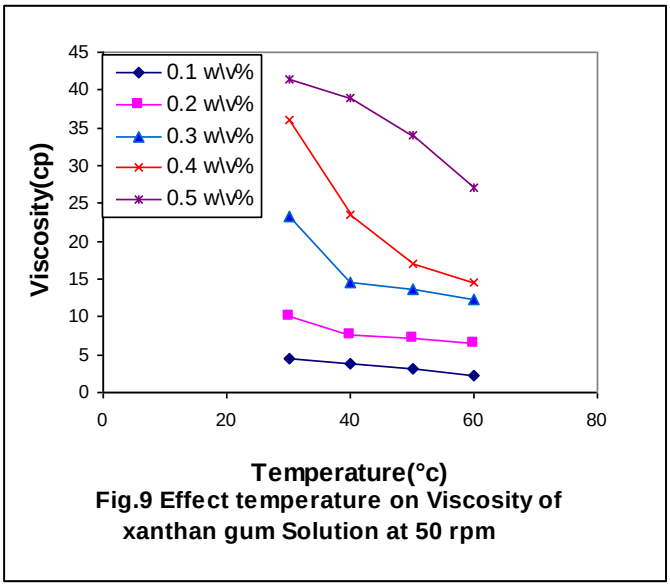

Fig.9 Effect temperature on Viscosity of xanthan gum Solution at 50 rpm

Table 10 Effect Temperature on Viscosity of xanthan gum at 150 rpm

Temperature(°C)	0.5 w\v%	0.5 w\v%	0.5 w\v%	0.5 w\v%	0.5 w\v%
30	24.7	18.8	16.3	7.72	3.39
40	23.8	15.9	11.2	6.66	3.24
50	20.2	12	10.5	6.15	2.63
60	18	10.78	10.1	5.85	1.88

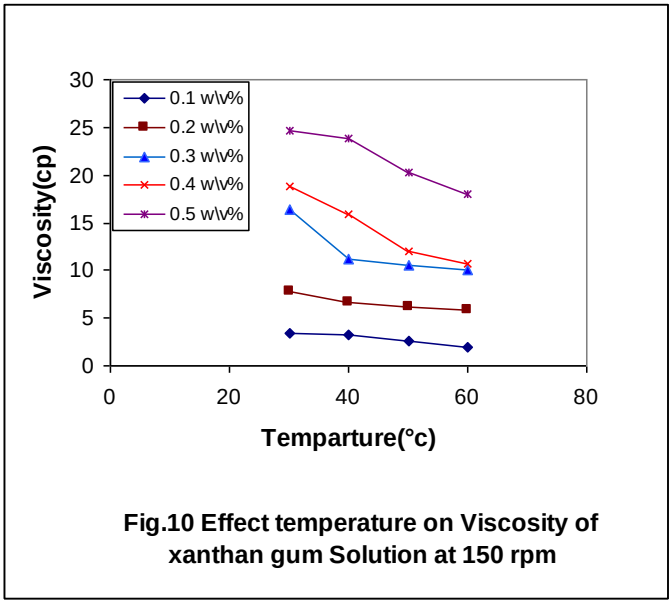

Fig.10 Effect temperature on Viscosity of xanthan gum Solution at 150 rpm

The combined effect of concentration and temperature on the density changes of polymer solutions are illustrated in figure(11),the density of the polymeric solutions decreases gradually with

temperature increases . Thus, at 0.5w/v% concentration the density values are 1.061, 1.056 , 1.037 and 1.029 for temperature 30,40,50 and 60°C respectively.

Table 11 Effect of Temperature on Density of xanthan gum

Temperature(°C)	0.5 w\v%	0.4 w\v%	0.3 w\v%	0.2 w\v%	0.1 w\v%
30	1.053	1.034	1.015	0.99	0.932
40	1.048	1.021	1.0093	0.98	0.926
50	1.0376	1.01	0.987	0.95	0.9235
60	0.965	0.94	0.92	0.89	0.8808

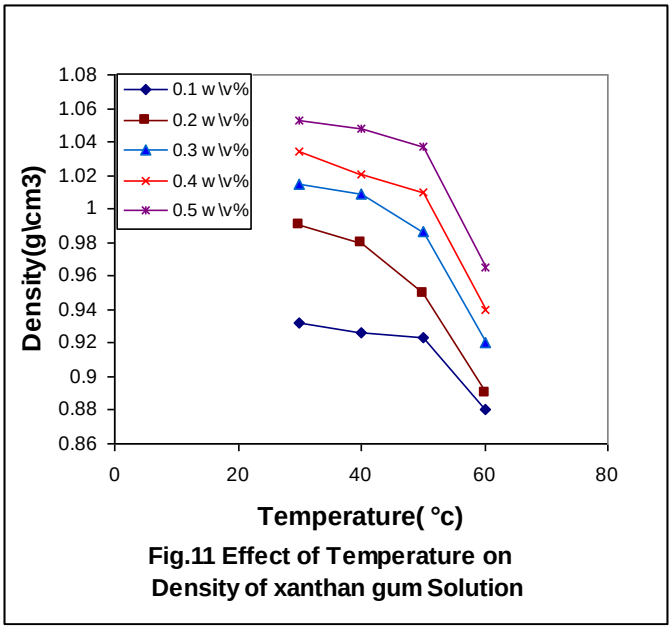

Fig.11 Effect of Temperature on Density of xanthan gum Solution

Conclusions

The main concluding remarks that have been achieved in this study may be summarized as follow is:

1- Xanthan Gum (XG) as a water soluble polysaccharide polymer, the study showed that the viscosity of Xanthan Gum (XG) solution increases with higher polymer concentrations and lower speeds and lower temperatures. viscosity increases gradually as temperature decreases for all concentration. Maximum viscosity of 41.4 centi poise was observed by using 0.5 %(w\v) at 30°C .

2- It was observed the density increase by increasing concentration and decreasing with Temperatures, at 0.5w/v% concentration the density values are 1.061and 1.029 for temperature 30and 60°C respectively.

3- Xanthan gum is tasteless and does not affect the taste of other food ingredients. The caloric value of xanthan gum is very low (0.6 kcal/g).

Recommendations

1- Further work can be carried out to prepare Xanthan gum solutions have unusually good compatibility and stability in the presence of most salts. The addition of electrolytes, such as sodium and potassium chloride.

2- Develop a correlation between temperature and viscosity, density at various conditions (concentration, speed).

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