

**SUDAN UNIVERSITY OF SCIENCE
AND TECHNOLOGY
COLLEGE OF GRADUATE STUDIES**

Characterization and Thermodynamic
Studies
of *Acacia Nilotica* Gum of Sudanese Origin

دراسة توصيفية ثيرموديناميكية
لصمغ السنط من أصل سوداني

A thesis Submitted in Partial Requirement
of the Degree of Master of Science
(Chemistry)

By :

Amira Osman Abd Elhadi
(B. Sc., Higher diploma in Chemistry)

Supervisor:

Dr. Elfatih Ahmed Hassan
Chemistry Department
College of Science

(2009)



يقول جل وعلا شأنه في محكم تنزيله

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿ وَظَلَّلْنَا عَلَيْكُمُ الْغَمَامَ وَأَنزَلْنَا عَلَيْكُمُ الْمَنَّاءَ
وَالسَّلْوى كُلُوا مِن طَيِّبَاتِ مَا رَزَقْنَاكُمْ وَمَا
ظَلَمُونَا وَلَكِن كَانُوا أَنفُسَهُمْ يَظْلِمُونَ ﴾



قرآن كريم ، الجزء الأول سورة البقرة ، الآية (57)

DEDICATION

To My Parents ,,,,,

To My Family ,,,,,

To My Friends ,,,,,

ACKNOWLEDGEMENT

All praise is raised to Allah; the merciful and the biggest helper, who gave me the strength and determination to complete this work.

I would like to express my deepest gratitude to my supervisor Dr. Elfatih Ahmed Hassan for his persistent encouragement, continuous, support, advice and indispensable help throughout this work.

I would like to express my deep thanks and sincere gratitude and indebtedness to Dr. Malik Abd Alla Abd Elrahman.

Special thanks to Amira Abd Elaziz , Chemistry department – Sust

I would like to thank Hassanien Gumaa , for typing .

I wish to thank the teaching staff and members of department of chemistry (Faculty of Science – Sudan University of Science and Technology) for their continuous assistance.

And last but not least I wish to thank the teaching staff of Almnsora Primary School.

ABSTRACT

A number of physicochemical properties (moisture, ash, pH, nitrogen and protein content, specific rotation, intrinsic viscosity) and total sugars content were used to characterize *Acacia nilotica* gum of Sudanese origin.

The general characteristic of *A. nilotica* gum and the mean values of all properties studied are as follows : moisture content 9.3%, ash content 1.7 %, nitrogen 0.1%, protein 0.6 %, specific rotation +107, intrinsic viscosity $8.117\text{cm}^3\text{g}^{-1}$ and pH 5.05. Cationic composition of gum samples was also determined and results show that calcium has the highest value followed by magnesium, sodium, potassium, iron and zinc.

Sugar composition was estimated using HPLC technique where galactose and arabinose content were found to be 15.5% and 81.9% respectively.

Molecular weight of *A. nilotica* gum was determined using osmometric technique and was found to be 2.3×10^6 Dalton.

Thermodynamic parameters including the density, the partial specific volume of *A. nilotica* gum and solvent (water) and the volume fraction were estimated and found to be 2.32 gcm^{-3} and 0.99 gcm^{-3} , $0.0003\text{cm}^3\text{g}$ and $0.0005\text{ cm}^{-3}\text{g}$, 0.625 and 0.375 respectively. Chemical potential range have been calculated from osmotic pressure measurement for

different concentration of gum solutions and was found to be 1.16 erg g^{-1} . Second virial coefficient and free energy of mixing were found to be $0.64 \text{ cm}^2 \cdot \text{mole/g}^2$ and 1.78 erg g^{-1} respectively.

الخلاصة

لقد تم توصيف صمغ السنط (اكشيا نيلوتيكا) باستخدام العديد من الطرق الفيزيوكيميائية (نسبة الرطوبة والرماد والنتروجين والبروتين، الدوران الضوئي، اللزوجة الضمنية، المعادن الرئيسية وتم تقدير السكريات.

الصفات العامة لصمغ السنط وجدت كالآتي (الرطوبة 9.3 %، الرماد 1.7 %، النتروجين 0.1 %، البروتين 0.6 %، الدوران الضوئي النوعي +107، الأس الهيدروجيني 5.05، اللزوجة الضمنية $8.117 \text{ cm}^3 \text{g}^{-1}$.

المعادن الرئيسية بالترتيب كانت كالآتي الكالسيوم < المغنسيوم < الصوديوم < البوتاسيوم < الحديد < الزنك.

تم تقدير محتوى السكريات باستخدام تقنية HPLC وأظهرت النتائج أن محتوى سكر الجلاكتوز يبلغ 15.5 % وسكر الأرينوز يبلغ 81.9 %.

تم قياس الوزن الجزيئي (M_n) للصمغ باستخدام تقنية الضغط الاسموزي ووجد أنه يساوي 2.3×10^6 دالتون.

تم إجراء دراسة ترموديناميكية شملت حساب الكثافة، الحجم النوعي الجزيئي، والكسر الحجمي للصمغ والمذيب التي وجدت كالآتي 2.3253 gcm^{-3} و $0.0005 \text{ cm}^3 \text{g}^{-1}$. 0.9938 gcm^{-3} و 0.625 و $0.0003 \text{ cm}^3 \text{g}^{-1}$ و 0.375 بالترتيب.

تم إيجاد الجهد الكيميائي من قياسات الضغط الاسموزي لتراكيز مختلفة للمحاليل المائية للصمغ وقد وجد أنه 1.16 erg g^{-1} . تم حساب معامل معدل طاقة الحركة الثاني وجد أنه يبلغ $0.64 \text{ cm}^2 \cdot \text{mole/g}^2$ وطاقة جيس الحرة 1.78 ergg^{-1} .

Table legends

No	Title	Page No
1.1	Functions of Gums	6
1.2	Nomenclature of solution viscosity	11
3.1	Results of some physico chemical properties	33
3.2	Reduced viscosity – concentration data of <i>A.nilotica</i> / solution	35
3.3	Comparison of intrinsic viscosity of some Acacia gums	36
3.4	Comparison of some physico-chemical & thermodynamic properties of some <i>Acacia</i> gums	38
3.5	Partial specific volume of <i>A.nilotica</i> in <i>A.nilotica</i> gum solution	40
3.6	Partial specific volume of water in <i>A.nilotica</i> gum solution	41
3.7	Osmotic pressure of <i>A.nilotica</i> of different concentration	42
3.8	Osmotic pressure of <i>A.nilotica</i> , <i>A.seyal</i> , <i>A.senegal</i> and <i>A.polycantha</i>	43
3.9	Density of some gums	44
3.10	Osmotic pressure, chemical potential (μ_1) and weight fraction of water in <i>A.nilotica</i> gum solution	45
3.11	Data for plotting w_1/w_2 versus μ_1 of <i>A.nilotica</i> gum solution	46
3.12	Data for plotting μ_2 versus μ_1 of <i>A.nilotica</i> gum solution	47
3.13	Chemical potential of <i>A.nilotica</i> gum μ_2 in <i>A.nilotica</i> gum solution after correction	48
3.14	Calculating the free energy of mixing of <i>A.nilotica</i> gum solution	48

Figure legends

Fig No	Title	Page No
1.1	Dependence of reduced viscosity of a dilute polymer solution on concentration	11
1.2	Determination partial molar or specific thermodynamic quantities (tangent method)	17
1.3	Dependence of π/c_2 on concentration for polymer solutions in various solvents <i>A. nilotica</i>	22
1.4	Graph for calculating \bar{M}_2	23
1.5	\bar{M}_2 versus \bar{M}_1 graph	24
3.1	Intrinsic viscosity of <i>A. nilotica</i> gum solution	35
3.2	comparison of intrinsic viscosity	36
3.3	partial specific volume of gum	40
3.4	partial specific volume of water	41
3.5	Osmotic pressure concentration of gum solution	42
3.6	Chemical potential of <i>A. nilotica</i> gum ($\Delta\mu_2$)	46
3.7	Segment A to correct the chemical potential of <i>A. nilotica</i> gum $\Delta\mu_2$	47

Table of Content

No	Title	Page No
	الآية	
	Dedication	I
	Acknowledgment	II
	Abstract (English)	III
	Abstract (Arabic)	IV
	Chapter One	
	Introduction	1
1.1	Colloidal systems	1
1.2	Macromolecular colloids	2
1.3	Origin of gums	2
1.4	Acacia nilotica	3
1.4.1	Main attributes	3
1.4.2	Description	3
1.4.3	Environmental requirements	4
1.4.3.1	Temperature	4
1.4.3.2	Altitude	4
1.4.3.3	Rain fall	4
1.4.3.4	Soil	4
1.4.4	Pests and diseases	4
1.4.5	Limitation	5
1.4.6	Function in food applications	5
1.5	Properties and uses of acacia nilotica gum	7
1.6	Physicochemical properties	7
1.6.1	Moisture content	8
1.6.2	Acidity and pH measurement	8
1.6.3	Ash	8
1.6.4	Ashing and dissolution techniques for trace metals	8
1.6.4.1	Atomic spectroscopy	9
1.6.5	Viscosity	10
1.6.5.1	Solution viscosity and molecular size	10
1.6.6	Optical activity	12
1.6.7	Determination of sugar composition	13
1.6.7.1	Chromatography	13

No	Title	Page No
1.6.7.2	High performance liquid chromatography	13
1.6.7.2.1	Principle	13
1.6.7.2.2	Applications	13
1.6.7.2.3	Disadvantages	13
1.6.8	Determination of protein content	14
1.6.8.1	Protein	14
1.6.8.2	Nitrogen	14
1.7	Thermodynamic properties	15
1.7.1	Thermodynamic of polymer solutions	15
1.7.2	Partial molar (specific) functions	16
1.7.2.1	Mole fraction	17
1.7.2.2	Weight fraction	17
1.7.2.3	Volume fraction	17
1.7.3	Chemical potential	18
1.7.4	Ideal and non ideal solutions	19
1.7.5	Membrane osmometry	19
1.7.5.1	Osmosis	19
1.7.6	Free energy of mixing of a polymer with a solvent	23
1.7.7	Density	25
	Chapter two	
2	Experimental	26
2.1	Determination of physicochemical properties	26
2.1.1	Moisture	26
2.1.2	pH	26
2.1.3	Total Ash	26
2.1.4	Cationic composition	26
2.1.4.1	Sample preparation	26
2.1.5	Viscosity	27
2.1.6	Optical rotation	27
2.1.7	Sugar analysis	27
2.1.7.1	Sample preparation	27
2.1.8	Determination of protein	28
1	Digestion	28

2	Titration	29
---	-----------	----

VIII

No	Title	Page No
2.2	Determination of Thermodynamic Properties	30
2.2.1	Osmotic pressure	30
2.2.2	Density of solid gums	30
2.2.3	Partial specific volume of the gum	31
2.2.4	Partial specific volume of solvent	31
	Chapter three	
3	Results & discussion	32
3.1	Characterization of <i>Acacia nilotica</i>	32
3.1.1	Moisture content	33
3.1.2	pH	33
3.1.3	Ash content	34
3.1.4	Cationic composition	34
3.1.5	Intrinsic viscosity	34
3.1.6	Specific optical rotation	36
3.1.7	Sugars composition	37
3.1.8	Nitrogen & protein content	37
3.2	Thermodynamic properties of <i>A.nilotica</i> gum solution	38
3.2.1	Volume fraction	38
3.2.2	Partial specific volume of water and gum	38
3.3.3	Osmotic pressure	41
3.3.4	The second virial coefficient	43
3.3.5	The number average molecular weight	43
3.3.6	Density	44
3.3.7	Chemical potential	44
3.3.8	Free energy	48
	References	49

Chapter one

Chapter Two

Chapter Three

References