DEDICATION

To my parents, Brothers, and Sister for their constructive support and for being a source of encouragement and moral support.

To my Wife Ayat Omer Wageealla for her understanding, support, and encouragement during the period of this study.

Special love to my Son Mohammed.

ACKNOWLEDGEMENTS

I thank Allah Almighty for giving me the health to accomplish this work. It is a pleasure to thank the many people who made this thesis possible. I would like to express my sincere thanks and appreciation to my supervisor Associate Professor Dr. Mohammed Elmubark Osman for his helpful supervision, suggestion, encouragement, sound advice, good company, good ideas and support during the study.

Acknowledge to my co-supervisor Dr.Malik Abdella Abdelrahman for his suggestion and encouragement.

I also extend my heartfelt respect and deepest love to my friends and colleges for their support and encouragement throughout my studies.

Abstract

Fourty gum samples from *A.nilotrca* var. *nilotica* and *A.seyal* var. *seyal* represented by eight composite samples were collected from eight locations within the sudan gum belt with different soil types. The locations are Eldamazien, Eldinder ,Sinnar and Elgazira. Which represented the clay soil areas where as Alnihud ,Alobied, Abuzabad and Aburay represented the sandy soil areas of the belt .

Characterization studies, which are partly used for authentication of samples and resources, include the determination of moisture, ash, pH, nitrogen and protein content . Average moisture, ash, pH, nitrogen and protein content of *A.nilotica var. nilotica* were found to be 10.87%, 1.86%, 5.1, 0.023% and 0.151% respectively. For *A.seyal var. seyal* they were found to be 11.3%, 2.82%, 3.4, 0.133%, and 0.88%. Intrinsic viscosities, specific rotation, acid equivalent weight and total uronic acid of *A.nilotica var. nilotica* were found to be 10.1 cm^3 g^{-1},+92.6 ,1866.76 and 10.42 % respectively . While for *A.seyal var.seyal* they were found to be 12.12cm^3 g^{-1}, +55.25, 1449.93 and 13.38% respectively. Cationic composition studies show that potassium has the highest value followed by calcium, magnesium, sodium, lead, iron and zinc. Sugar composition shows average values of galactose content of *A.nilotica var. nilotica* and *A.seyal var. seyal* were found to be 16.34% and 38.06% respectively ,and arabinose content were found to be 45.90% and 42.33% respectively. While rhamnose was found to be10.33% and 3.67% respectively.

The number average molecular weight value was found to be $2.10\times10^5$for composite samples of *A.nilotica var. nilotica*. For composite samples of *A.seyal var. seyal* was found to be 2.97×10^5.

Thermodynamic studies involved the estimation the partial specific volume of gum, partial specific volume of the solvent and the volume fraction. For composite samples of *A.nilotica var. nilotica* average was found to be 0.642 cm^3 g^{-1}, 0.998cm^3g^{-1}, 0.39024, and 0.61584 respectively. While average for composite samples of *A.seyal var. seyal* were found to be 0.647cm^3g^{-1}, 0.998cm^3g^{-1}, 0.3931, and 0.6065 respectively.

Chemical potential range have been calculated from osmotic measurement for different concentrations and was found to be -1.610715×10^{-3} to -2.13658×10^{-3} joule g^{-1} on average for composite samples of *A.nilotica var.nilotica*. For composite samples of *A.seyal var.seyal* the average it was found to be -1.17945×10^{-3} to -1.57519×10^{-3} joule g^{-1}.

Second virial coefficient (A_2) average for composite samples of *A.nilotica var.nilotica* were found to be 1.11×10^{-3}. Where as for composite samples of *A.seyal var.seyal* was found to be 3.51×10^{-3}.

Free energy of mixing range of composite samples of *A.nilotica var. nilotica* average was found to be (-1.33470×10^{-3} to -3.40428×10^{-3}). For composite samples of *A.seyal var.seyal* average was found to be (-2.112877×10^{-3} to -5.966130×10^{-3}).

الملخص

جمعت أربعون عينة من صمغ السنط صنف السنط و صمغ الطلح صنف الطلح تمثل ثمانية عينات خليط من ثمانية مواقع داخل حزام الصمغ العربي في السودان ، و من أنواع مختلفة التربة و المواقع هي النيل الأزرق، الدندر ، سنار و الجزيرة و التي تمثل مناطق التربة الطينية في حين أن مناطق النهود، الأبيض، أبوزبد و أبوراي تمثل مناطق التربة الرملية في الحزام .

أجريت الدراسة التوصيفية للتثبت من موثوقية العينات ، و قد إشتملت الدراسة على تحديد محتوى الرطوبة و الرماد و الأس الهيدروجيني و النتروجين و البروتين و قد وجد متوسط محتوى الرطوبة و الرماد و الأس الهيدروجيني و النتروجين و البروتين لصمغ السنط ١٠.٨% ، ١.٨٦% ، ٥.١، ٠.٠٢٣% و ٠.١٥١% على الترتيب . أما لصمغ الطلحة فقد وجدت النتائج ١١.٣% ، ٢.٨٢% ، ٣.٤، ٠.١٣٣% و ٠.٨٨% . و كانت نتائج اللزوجة الضمنية و الدوران النوعي و الوزن المكافئ و حامض الجلكورنيك لصمغ السنط صنف السنط $10.1cm^3\ g^{-1}$ ، ٩٢.٦+ ، ١٨٦٦.٧٦ و ١٠.٤٢% على الترتيب . بينما لصمغ الطلحة صنف الطلحة $12.12cm^3\ g^{-1}$ ، ٥٥.٢٥+ ، ١٤٤٩.٩٣ و ١٣.٣٨% .

أظهرت دراسة محتوى بعد العناصر الفلزية وجد أن عنصر البوتاسيوم سجل أعلى قيمة يليه الكالسيوم ثم الماغنيسيوم ثم الصوديوم ثم الرصاص ثم الحديد ثم الزنك . تم تقدير محتوى السكريات و أظهرت النتائج أن متوسط محتوى سكر الجلاكتوز لصمغ السنط صنف السنط و الطلحة صنف الطلحة ١٦.٣٤% و ٣٨.٠٦% على الترتيب ، و لسكر الأربينوز ٤٥.٩٠% و ٤٢.٣٣% على الترتيب بينما لسكر الرامانوز ١٠.٣٣% و ٣.٦٧% على الترتيب .

تم قياس Mn و كان متوسط القيم $٢.١٠ \times ١٠^{\circ}$ لخليط عينات صمغ السنط صنف السنط . بينما لخليط عينات من صمغ الطلحة صنف الطلحة $٢.٩٧ \times ١٠^{\circ}$ على الترتيب .

في الدارسة الثيرموديناميكية تم إيجاد الحجم النوعي الجزيئي للصمغ و الحجم النوعي الجزيئي للمزيب و الكسر الحجمي و كانت النتائج لخليط عينات صمغ السنط صنف السنط $0.998cm^3\ g^{-1}$,$0.642cm^3\ g^{-1}$ ، ٠.٣٩٠٢٤ ، و ٠.٦١٥٨٤ على الترتيب . بينما لخليط عينات صمغ الطلحة صنف الطلحة و جددت $0.647cm^3\ g^{-1}$,g^{-1} $0.998cm^3$ ، ٠.٣٩٣١, و ٠.٦٠٦٥ على الترتيب .

تم إيجاد الجهد الكيميائي من قياسات الضغط الإسموزي لتراكيز مختلفة وقد وجد المتوسط كما يلي : joule g^{-1} (-2.13658×10^{-3} إلى -1.610715×10^{-3}) لخليط عينات صمغ السنط صنف السنط . أما لخليط عينات صمغ الطلحة صنف الطلحة وجد المتوسط joule g^{-1} (-1.575519×10^{-3} إلى -1.17945×10^{-3}) على الترتيب .

تم حساب متوسط معامل الحد الثاني من العلاقة لخليط عينات صمغ السنط صنف السنط وقد وجد ١.١١×10^{-3} بينما لخليط عينات صمغ الطلحة صنف الطلحة ٣.٥١×10^{-3} على الترتيب .

طاقة جبس الحرة لخليط عينات صمغ السنط صنف السنط وجد المتوسط $joule\ g^{-1}$($\times 10^{-3}$ 1.33470- الى $\times 10^{-3}$ ٣.٤٠٤٢٧-) بينما لخليط عينات صمغ الطلحة صنف الطلحة وجد المتوسط $joule\ g^{-1}$($\times 10^{-3}$ ٢.١١٢٨٧٧- الى $\times 10^{-3}$ ٥.٩٦٦١٣-) على الترتيب .

Table of contents

Title	page
Dedication	i
Acknowledgement	ii
Abstract	iii
Abstract (Arabic version)	v
Tables of contents	vii
Tables legends	xi
Figures legends	xiii
Abbreviations	xvi
CHAPTER ONE: GENERAL INTRODUCTION	1
CHAPTER TWO: LITERATURE REVIEW	3
2.1 Definition of *Acacia* gums	3
2.2 Geographical location of the gum belt	4
2.3 *Acacia* distribution	5
2.4 Gum sources	6
2.5 *Acacia Senegal* and *Acacia seyal*	7
2.5.1 Classification of *Acacia seyal* tree	8
2.5.2 Description	8
2.6 Physicochemical properties of gum	9
2.6.1 Moisture content	9
2.6.2 Ash content	13
2.6.3 pH value	13
2.6.4 Specific optical rotation	14
2.6.5 Viscosity	15
2.6.6 Nitrogen and protein content	16
2.6.7 Acid equivalent weight and uronic acid	18
2.6.8 Sugar composition	19
2.6.9 Cationic composition	20
2.6.10 Molecular weight of *A. senegal, A. seyal* and *A. nilotica*	20
2.7 *Acacia nilotica* var. *nilotica* Tree (Sunt)	24
2.7.1 Botanical classification of *Acacia nilotica* tree	24
2.7.2 Description of *Acacia nilotica* var. *nilotica* tree	25
2.7.3 Distribution of *Acacia nilotica* var. *nilotica* tree	25
2.7.4 Phytochemical constituents of *Acacia nilotica* tree	26
2.7.5 Chemical properties of *Acacia nilotica* gum	27
2.7.6 Uses of *Acacia nilotica* tree	31

2.8 Gum *Acacia* processing	33
2.8.1 Kibbled or granular gum	33
2.8.2 Mechanical gum powder	33
2.8.3 Spray dried gum	33
2.8.4 Specifications for gum	34
2.9 Properties and application of gums	35
2.9.1 Food uses	35
2.9.2 Non-food uses	36
2.9.3 Environmental issues	37
2.10 Pre and post-harvest practices of gum	37
2.10.1 Seed Germination	37
2.10.2 Traditional agroforesty or bush fallow system	38
2.10.3 Gum tapping and collection	39
2.10.3.1 Farm stage	39
2.10.3.2 Farmers ,middle trader, and big trader stage	41
2.10.3.3 Cleaning, sorting and grading	42
2.10.3.4 The exporting process	42
2.10.3.5 packing and exporting stage	43
2.11 Factors affecting gum production and supply	43
2.12 Structural features of gum	45
2.12.1 Chemical constituent of *Acacia* gum	45
2.12.2 Molecular structure of gum	45
2.13 Factors affecting physiochemical and functional properties of gum	52
2.14 Thermodynamic properties of *Acacia gums* solutions	55
2.14.1 Introduction	55
2. 14.2 Weight fraction (ω)	55
2. 14.3 The molar fraction (n)	56
2. 14.4 Volume fraction (Φ)	56
2. 14.5 Density of solid gum	56
2. 14.6 Partial molar (specific) volume ($\overline{V}$)	56
2. 14.7 Chemical potential (μ)	58
2. 14.8 Ideal and non-ideal solutions	59
2. 14.9 Osmotic pressure (π)	*59*
5. 14.10 free energy of mixing of polymer with a solvent	63
CHAPTER THREE: MATERIALS AND METHODS	66
3.1 Introduction	66
3.2 Material and methods	66
3.2.1 Gum samples	66

3.2.2 Preparation of the gum samples	66
3.2.3 Methods	66
3.2.4 Determination of moisture content	68
3.2.5 Determination of ash content	68
3.2.6 pH measurement	68
3.2.7 Determination of specific optical rotation $[\alpha]_D^T$	68
3.2.8 Determination of intrinsic viscosity	69
3.2.8.1 Theoretical consideration	69
3.2.8.1.1 Huggins equation	71
3.2.8.1.2 Salt tolerance (S) and relative stiffness parameter (B)	72
3.2.8.2 Method	73
3.2.9 Nitrogen and protein Content	74
3.2.9.1 Method	74
3.2.10 Determination of acid equivalent weight and uronic acid	75
3.2.11 Determination of cationic composition	76
3.2.11.1 Method	76
3.2.12 Determination of sugar composition	76
3.2.12.1 Sample preparation	76
3.2.12.2 Method	77
3.2.13 Determination of number average molecular weight	77
3.2.14 Partial specific volume of solvent	79
3.2.15 Partial specific volume of gum	79
3.2.16 Density of solid gums	80
3.2.17 Osmotic pressure	80
3.2.17.1 Method	80
CHAPTER FOUR: RESULTS AND DISCUSSIONS	81
4.1 Physiochemical properties	81
4.1.1 Moisture content	81
4.1.2 Ash content	81
4.1.3 pH value	82
4.1.4 Specific optical rotation	82
4.4.5 Viscosity	83
4.1.6 Nitrogen and protein content	85
4.1.7 Acid equivalent weight and uronic acid	**85**
4.1.8 Cationic composition	86
4.1.9 Sugar composition	87
4.2 Thermodynamic properties	89
4.2.1 Partial specific volume of the solvent and solute	89
4.2.2 Volume fractions of water φ_1 and gums φ_2	94

4.2.3 The second virial coefficient (A_2)	97
4.2.4 Number average molecular weight	97
4.2.5 Chemical Potential	98
4.2.6 Free energy of mixing	108
4.3 Conclusion and Suggestions For Further Work	112
4.3.1 Conclusions	112
4.3.2 Suggestions for further work	114
References	115
Appendix	121

Table legends

Table	Title	page
Table 2.1	Classification of Gums according to their source	7
Table 2.2	Chemical analysis of some African *Acacia* species gums (Younes, 2009)	11
Table 2.3	Analytical data of the gum exudates from different *Acacia* species of the Sudan. (Karamalla, 1999).	12
Table 2.4	Cationic composition of some gum samples (ppm).	23
Table 2.5	Data for *A.nilotica* and some *Gammiferae* species. (Anderson, 1977)	29
Table 2.6	Constiuent sugar analysis of *Acacia nilotica* gum exudates compared with *Acacia Senegal* and *Acacia seyal*. (Kapoor, et al 1991)	29
Table 2.7	Analytical parameters of the authentic *Acacia* gum samples from the FAO study. (Al-Assaf et al, 2005)	30
Table 2.8	Analytical data for *A. nilotica* gum.	30
Table 2.9	Factors effecting gum arabic production and supply	44
Table 2.10	Chemical compositions of gum Arabic (Lawson et al., 1998)	47
Table 3.1	Sample code, location, date of collection, soil type and rain fall of *Acacia nilotica var.nilotica* gum, season 2013	67
Table 3.2	Sample code, location, date of collection, soil type and rain fall of *Acacia seyal var.seyal* gum, season 2013	67
Table 4.1	Physicochemical properties of *Acacia nilotica var. nilotica* gum Season 2012/2013	84
Table 4.2	Physicochemical properties of *Acacia Seyal var.Seyal* gum Season 2012/2013	84
Table 4.3	Cationic composition of *Acacia nilotica var. nilotica* gum season 2012/2013	86
Table 4.4	Cationic composition of *Acacia seyal var. seyal* gum season 2012/2013	86
Table 4.5	Sugar composition of *Acacia nilotica var. nilotica* gum season 2012/2013	87
Table 4.6	Sugar composition of *Acacia seyal var. seyal* gum season 2012/2013	87
Table 4.7	Partial specific volume of water (V_1), of gum (V_2), volume fraction of water (φ_1), of gum (φ_2) for composite samples of *A. nilotica var.nilotica* and *A.seyal var.seyal* gums aqueous solution	94
Table 4.8	Number average molecular weight (Mn) of samples by osmotic method of *A. nilotica* var. *nilotica* gum and *A. seyal* var. *seyal* and second virial coefficient (A_2) season 2012/2013	97

Table 4.9	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.nilotica var.nilotica* gum solutions (composite sample A)	99
Table 4.10	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.nilotica var. nilotica* gum solutions(composite sample B)	100
Table 4.11	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.nilotica var.nilotica* gum solutions (composite sample C)	101
Table 4.12	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.nilotica var.nilotica* gum solutions (composite sample D)	102
Table 4.13	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.seyal var. seyal* gum solutions (composite sample W)	103
Table 4.14	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.seyal var.seyal* gum solutions (composite sample X)	104
Table 4.15	chemical potential $\Delta\mu_1$ and weight fractions of water in *A.seyal var.seyal* gum solutions (composite sample Y)	105
Table 4.16	chemical potential Δμ1 and weight fractions of water in *Acacia seyal var. seyal* gum solutions (composite sample Z)	106
Table 4.17	Chemical potential of composite samples of *A. nilotica var.nilotica* in joule g^{-1}	107
Table 4.18	Chemical potential of composite samples of *Acacia seyal var.seyal* in joule g^{-1}	107
Table 4.19	Chemical potential of *A. Oerfota, A. senegal* and *A. polyacantha* in joule g^{-1}	107
Table 4.20	calculating the free energy of mixing of *Acacia nilotica var.nilotica* gum solutions (composite sample A)	109
Table 4.21	calculating the free energy of mixing of *Acacia nilotica var.nilotica* gum solutions (composite sample B)	109
Table 4.22	calculating the free energy of mixing of *Acacia nilotica var. nilotica* gum solutions (composite sample C)	109
Table 4.23	calculating the free energy of mixing of *Acacia nilotica var.nilotica* gum solutions (composite sample D)	109
Table 4.24	calculating the free energy of mixing of *Acacia seyal var.sey* gum solutions (composite sample W)	110
Table 4.25	calculating the free energy of mixing of *Acacia seyal var.seyal* gum solutions (composite sample X)	110
Table 4.26	calculating the free energy of mixing of *Acacia seyal var.seyal* gum solutions (composite sample Y)	110
Table 4.27	calculating the free energy of mixing of *Acacia seyal var.seyal* gum solutions (composite sample Z)	110
Table 4.28	Free energy of mixing composite samples of *A. nilotica var. nilotica* with water in joule g^{-1}	111
Table 4.29	Free energy of mixing composite samples of *A. seyal var.seyal* with water in joule g^{-1}	111
Table 4.30	Free energy of mixing of *A. Oerfota, A. senegal* and *A. polyacantha* with water in joule g^{-1}	111

Figures legends

Table	Title	page
Figure 2.1	African gum belt	4
Figure 2.2	Sudan gum belt	5
Figure 2.3	*Acacia seyal* tree	9
Figure 2.4	*Acacia nilotica* tree	24
Figure 2.5	Gum arabic tapping and collection	40
Figure 2.6	The Twisted hairy rope"model of gum Arabic glycoprotien	51
Figure 2.7	The Wattle blossom model of the arabinogalactan –protein (Fincher, 1983)	51
Figure 2.8	Dependence of π/C_2 on concentration of polymer solutions in various solvents	63
Figure 2.9	Variation of ω_1/ω_2 $with\Delta\mu_1$.	63
Figure 2.10	correction of $\Delta\mu_2$	64
Figure 3.1	Dependence of reduced viscosity of a dilute polymer solution on concentration	73
Figure 4.1	Partial Specific Volume of water (Comps. Sample A) *Acacia nilotica*	90
Figure 4.2	Partial Specific Volume of water (Comps. Sample B) *Acacia nilotica*	90
Figure 4.3	Partial Specific Volume of water (Comps. Sample C) *Acacia nilotica*	90
Figure 4.4	Partial Specific Volume of water (Comps. Sample D) *Acacia nilotica*	90
Figure 4.5	Partial Specific Volume of Gum (Comps. Sample A) *Acacia nilotica* in *Acacia nilotica* solution	91
Figure 4.6	Partial Specific Volume of Gum (Comps. Sample B) *Acacia nilotica* in *Acacia nilotica* solution	91
Figure 4.7	Partial Specific Volume of Gum (Comps. Sample C) *Acacia nilotica* in *Acacia nilotica* solution	91
Figure 4.8	Partial Specific Volume of Gum (Comps. Sample D) *Acacia nilotica* in *Acacia nilotica* solution	91
Figure 4.9	Partial Specific Volume of water (Comps. Sample W) *Acacia Seyal*	92
Figure 4.10	Partial Specific Volume of water (Comps. Sample X) *Acacia Seyal*	92
Figure 4.11	Partial Specific Volume of water (Comps. Sample Y) *Acacia Seyal*	92
Figure 4.12	Partial Specific Volume of water (Comps. Sample Z) *Acacia Seyal*	92
Figure 4.13	Partial Specific Volume of Gum (Comps. Sample W) *Acacia Seyal* in *Acacia Seyal* solution	93
Figure 4.14	Partial Specific Volume of Gum (Comps. Sample X) *Acacia Seyal* in *Acacia Seyal* solution	93

Figure 4.15	Partial Specific Volume of Gum (Comps. Sample Y) *Acacia Seyal* in *Acacia Seyal* solution	93
Figure 4.16	Partial Specific Volume of Gum (Comps. Sample Z) *Acacia Seyal* in *Acacia Seyal* solution	93
Figure 4.17	Osmotic pressure Concentration profile of *Acacia nilotica* composite sample A	95
Figure 4.18	Osmotic pressure Concentration profile of *Acacia nilotica* composite sample B	95
Figure 4.19	Osmotic pressure Concentration profile of *Acacia nilotica* composite sample C	95
Figure 4.20	Osmotic pressure Concentration profile of *Acacia nilotica* composite sample D	95
Figure 4.21	Osmotic pressure Concentration profile of *Acacia Seyal* composite sample W	96
Figure 4.22	Osmotic pressure Concentration profile of *Acacia Seyal* composite sample X	96
Figure 4.23	Osmotic pressure Concentration profile of *Acacia Seyal* composite sample Y	96
Figure 4.24	Osmotic pressure Concentration profile of *Acacia Seyal* composite sample Z	96
Figure4.25	variation of $\omega_1/\omega_2$with the chemical potential of water (sample A)	99
Figure 4.26	segment A to correct the chemical potential of acacia nilotica($\Delta\mu_2$)(composite sample A)	99
Figure 4.27	variation of $\omega_1/\omega_2$with the chemical potential of water (sample B)	100
Figure 4.28	segment A to correct the chemical potential of acacia nilotica ($\Delta\mu_2$)(composite sample B)	100
Figure 4.29	variation of $\omega_1/\omega_2$with the chemical potential of water (sample C)	101
Figure 4.30	segment A to correct the chemical potential of nilotica($\Delta\mu_2$) (composite sample C)	101
Figure 4.31	variation of $\omega_1/\omega_2$with the chemical potential of water (sample D)	102
Figure 4.32	segment A to correct the chemical potential of nilotica($\Delta\mu_2$) (composite sample D)	102
Figure 4.33	variation of $\omega_1/\omega_2$with the chemical potential of water (sample W)	103
Figure 4.34	segment A to correct the chemical potential of seyal ($\Delta\mu_2$)(composite sample W)	103
Figure 4.35	variation of $\omega_1/\omega_2$with the chemical potential of water (sample X)	104
Figure 4.36	segment A to correct the chemical potential of Seyal gum ($\Delta\mu_2$)(composite sample X)	104
Figure 4.37	variation of $\omega_1/\omega_2$with the chemical potential of water	105

	(sample Y)	
Figure 4.38	segment A to correct the chemical potential of seyal gum ($\Delta\mu_2$)(composite sample Y)	105
Figure 4.39	variation of $\omega_1/\omega_2$with the chemical potential of water (sample Z)	106
Figure 4.40	segment A to correct the chemical potential of seyal gum ($\Delta\mu_2$)(composite sample Z)	106

ABBREVATIONS

FAO	Food and Agriculture Organization of the United Nation
WHO	World Health Organization
JECFA	The joint Expert Committee of Food additives of the FAO/WHO
A	*Acacia*
RI	Refractive Index
FDA	Federal drugs administration
UV	ultra violet
Sol	Solution
Comps.	Composite sample
Mn	Number Average Molecular Weight
Mw	Weight Average Molecular Weight
ND	Not detected
Conc	Concentration
Fig	Figure