



Cairo University

USE OF DIFFERENT MODELS TO PREDICT ADULTERATION OF SOME EGYPTIAN HONEY

By

Eman Emad Mohammed Abd El-Kader Mostafa

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Chemical Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

USE OF DIFFERENT MODELS TO PREDICT ADULTERATION OF SOME EGYPTIAN HONEYS

By

Eman Emad Mohammed Abd El-Kader Mostafa

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Chemical Engineering

Under the Supervision of

Prof. S. R. Mostafa

Chemical Engineering Department
Faculty of Engineering, Cairo University

Prof. M. A. Sorour

Food Engineering and Packaging
Department
Food Technology Institute, Agricultural
Research Centre

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

USE OF DIFFERENT MODELS TO PREDICT ADULTERATION OF SOME EGYPTIAN HONEYS

By

Eman Emad Mohammed Abd El-Kader Mostafa

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Chemical Engineering

Approved by the
Examining Committee

Prof. Salwa R. Mostafa

Thesis Main Advisor

Prof. Manal A. Sorour

Advisor

Food Technology Institute, Agricultural Research Centre

Prof. Magdi F. Abadir

Internal Examiner

Prof. Maher G. Soliman

External Examiner

The Higher Technological Institute

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2017

Engineer's Name: Eman Emad Mohammed Abd El-Kader Mostafa
Date of Birth: 30 / 10 / 1989
Nationality: Egyptian
E-mail: emanemad89@hotmail.com
Phone: 01008799781
Address: 12 Ibn Katheer st. from the end of Hijaz st.,
Heliopolis, Cairo, Egypt.
Registration Date: 1 / 3 / 2013
Awarding Date: / / 2017
Degree: Master of Science
Department: Chemical Engineering



Supervisors:

Prof. Salwa Raafat Mostafa.
Prof. Manal Abdel Rahman Sorour
(Food Technology Institute, Agricultural Research Centre)

Examiners:

Prof. Salwa Raafat Mostafa (Thesis main advisor)
Prof. Manal Abdel Rahman Sorour (Advisor)
(Food Technology Institute, Agricultural Research Centre)

Prof. Magdi Foad Abadir (Internal examiner)
Prof. Maher Gamal El-Deen Soliman (External examiner)
(Professor at the Higher Technological Institute)

Title of Thesis:

Use of Different Models to Predict Adulteration of Selected Egyptian Honeys

Key Words:

Honey, Rheology, Adulteration, Thixotropy.

Summary:

This research elaborates the physical properties of some Egyptian honeys; samples of these honey types were adulterated with starch solution, glucose, molasses and distilled water respectively. The physical properties, rheological properties, the effect of volume of adulterant on apparent viscosity, effect of temperature on apparent viscosity, activation energy and effect of thixotropy of pure and adulterated samples were determined and compared.

Acknowledgments

Sincere gratitude and appreciation to Prof. Salwa R. Mostafa, for her supervision, guidance, valuable advice, constructive criticism and continuous help during the course of this study.

Deep appreciation should also be expressed to Prof. Manal A. Sorour, for her supervision, support, patience, continuous help, valuable suggestions and advice throughout the course of this study.

Many thanks should be extended to Prof. Magdi F. Abadir, for his help and valuable insights.

Special gratitude to the head and all staff members of Engineering Process Department, Food Technology Institute, Agricultural Research Center, for offering their laboratory and staff assistance during the completion of this work.

Dedication

To Dad, Mom and Meran with love, hope I make you proud.

Table of Contents

List of Figures	vi
List of Tables	xiii
Nomenclature	xv
Abstract	xvii
Chapter One: Introduction	1
Chapter Two: Literature Review	3
2.1. Chemical Composition of Honey	3
2.2. Seasons of Honey in Egypt.....	3
2.3. Uses of Honey.....	4
2.4. Adulteration of Honey	4
2.5. Physicochemical Properties of Honey	5
2.6. Rheological Characteristics of Food.....	8
2.7. Rheological Characteristics	9
2.8. Types of Fluid.....	9
2.8.1. Newtonian Fluid	9
2.8.2. Non-Newtonian Fluid	11
2.8.2.1. Bingham Fluid	11
2.8.2.2. Shear Thinning Fluid	13
2.8.2.3. Shear Thickening Fluid.....	14
2.8.2.4. Herschel-Bulkley Fluid.....	16
2.8.3. Time Dependent Fluid	16
2.8.3.1. Rheopectic Fluid.....	17
2.8.3.2. Thixotropic Fluid.....	18

Chapter Three: Experimentation and Methods	23
3.1. Materials	23
3.2. Methods	23
3.2.1. Preparation of Starch Solution.....	23
3.2.2. Preparation of Adulterated Honey Samples.....	23
3.3. Physical Properties Measuring Methods.....	24
3.3.1. Density	24
3.3.2. Refractive Index and Concentration as Total Suspended Solids (T.S.S.).....	24
3.3.3. Moisture Content	25
3.3.4. pH and Electrical Conductivity.....	25
3.3.5. Surface Tension	26
3.3.6. Rheological Properties	26
Chapter Four: Results and Discussion	28
4.1. Physical Properties of Honey.....	28
4.1.1. Physical Properties of Pure, Purchased and Adulterated Black Seed Honey	28
4.1.2. Physical Properties of Pure, Purchased and Adulterated Clover Honey.....	31
4.1.3. Physical Properties of Pure, Purchased and Adulterated Desert Honey	33
4.1.4. Physical Properties of Pure, Purchased and Adulterated Mountain Flower Honey.....	35
4.2. Rheological Properties of Different Honey Types	37
4.2.1. Rheological Properties of Pure, Purchased and Adulterated Black seed Honey	38
4.2.2. Rheological Properties of Pure, Purchased and Adulterated Clover Honey	45
4.2.3. Rheological Properties of Pure, Purchased and Adulterated Desert Honey	52
4.2.4. Rheological Properties of Pure, Purchased and Adulterated Mountain Flower Honey	59
4.3. Combined Effect of Shear Rate and Volume of Adulterant on Shear Stress.....	66
4.4. Effect of Volume of Adulterant on Apparent Viscosity	67
4.4.1. Effect of Volume of Adulterant on Apparent Viscosity for Black Seed Honey	67
4.4.2. Effect of Volume of Adulterant on Apparent Viscosity for Clover Honey	69
4.4.3. Effect of Volume of Adulterant on Apparent Viscosity for Desert Honey	71
4.4.4. Effect of Volume of Adulterant on Apparent Viscosity for Mountain Flower Honey	73
4.5. Effect of Temperature on Apparent Viscosity	75
4.5.1. Effect of Temperature on Apparent Viscosity of Black Seed Honey	76
4.5.2. Effect of Temperature on Apparent Viscosity of Clover Honey	80
4.5.3. Effect of Temperature on Apparent Viscosity of Desert Honey.....	84

4.5.4. Effect of Temperature on Apparent Viscosity of Mountain Flower Honey	88
4.6. Thixotropy effect	93
4.6.1. Thixotropic Effect of Adulterated Desert Honey at 20°C.....	94
4.6.2. Thixotropic Effect of Adulterated Desert Honey at 30°C.....	98
4.6.3. Thixotropic Effect of Adulterated Desert Honey at 40°C.....	102
4.6.4. Thixotropic Effect of Adulterated Desert Honey at 50°C.....	106
4.7. Thixotropy Models	110
4.7.1. Effect of Time on Apparent Viscosity	110
4.7.1. Weltman Model	116
Chapter Five: Conclusion and Recommendations	125
5.1. Conclusion	125
5.2. Recommendations.....	126
References	127
Appendixes	131
Appendix A.....	131
Appendix B.....	139

List of Figures

Figure (2.1) Shear Diagram for Time Independent Fluid.....	9
Figure (2.2) Bingham Ideal Plastic Behavior Compared to Real Plastic Behavior	12
Figure (2.3) Schematic Demonstration of Shear Thinning Behavior	13
Figure (2.4) Shear Thickening Behavior	15
Figure (2.5) Shear Diagram for time dependent Fluid	16
Figure (2.6) Rheopectic Behavior of Polyester	17
Figure (2.7) Thixotropic Behavior of Red Mud Suspension	18
Figure (2.8) Thixotropic Behavior of Cement Paste.....	19
Figure (3.1) Abbe 60 Refractometer	24
Figure (3.2) Sensodirect 150 Digital PH Meter with Probes	25
Figure (3.3) Brookfield (DVIII Ultra) Rheometer	26
Figure (4.1) Viscosity versus Shear Rate of Black Seed Honey with 4% Starch Solution.....	38
Figure (4.2) Shear Stress versus Shear Rate of Black Seed Honey with 4% Starch Solution.....	39
Figure (4.3) Viscosity versus Shear Rate of Black Seed Honey with Glucose.....	40
Figure (4.4) Shear Stress versus Shear Rate of Black Seed Honey with Glucose.....	40
Figure (4.5) Viscosity versus Shear Rate of Black Seed Honey with Molasses.....	41
Figure (4.6) Shear Stress versus Shear Rate of Black Seed Honey with Molasses.....	42
Figure (4.7) Viscosity versus Shear Rate of Black Seed Honey with Distilled Water.....	43
Figure (4.8) Shear Stress versus Shear Rate of Black Seed Honey with Distilled Water.....	44
Figure (4.9) Viscosity versus Shear Rate of Clover Honey with 4% Starch Solution.....	45
Figure (4.10) Shear Stress versus Shear Rate of Clover Honey with 4% Starch Solution.....	46
Figure (4.11) Viscosity versus Shear Rate of Clover Honey with Glucose.....	47
Figure (4.12) Shear Stress versus Shear Rate of Clover Honey with Glucose.....	48

Figure (4.13) Viscosity versus Shear Rate of Clover Honey with Molasses.....	49
Figure (4.14) Shear Stress versus Shear Rate of Clover Honey with Molasses.....	49
Figure (4.15) Viscosity versus Shear Rate of Clover Honey with Distilled Water.....	50
Figure (4.16) Shear Stress versus Shear Rate of Clover Honey with Distilled Water.....	51
Figure (4.17) Viscosity versus Shear Rate of Desert Honey with 4% Starch Solution.....	52
Figure (4.18) Shear Stress versus Shear Rate of Desert Honey with 4% Starch Solution.....	53
Figure (4.19) Viscosity versus Shear Rate of Desert Honey with Glucose.....	54
Figure (4.20) Shear Stress versus Shear Rate of Desert Honey with Glucose.....	54
Figure (4.21) Viscosity versus Shear Rate of Desert Honey with Molasses.....	55
Figure (4.22) Shear Stress versus Shear Rate of Desert Honey with Molasses.....	56
Figure (4.23) Viscosity versus Shear Rate of Desert Honey with Distilled Water.....	57
Figure (4.24) Shear Stress versus Shear Rate of Desert Honey with Distilled Water.....	58
Figure (4.25) Viscosity versus Shear Rate of Mountain Flower Honey with 4% Starch Solution.....	59
Figure (4.26) Shear Stress versus Shear Rate of Mountain Flower Honey with 4% Starch Solution.....	60
Figure (4.27) Viscosity versus Shear Rate of Mountain Flower Honey with Glucose.....	61
Figure (4.28) Shear Stress versus Shear Rate of Mountain Flower Honey with Glucose.....	62
Figure (4.29) Viscosity versus Shear Rate of Mountain Flower Honey with Molasses.....	63
Figure (4.30) Shear Stress versus Shear Rate of Mountain Flower Honey with Molasses.....	63
Figure (4.31) Viscosity versus Shear Rate of Mountain Flower Honey with Distilled Water.....	64
Figure (4.32) Shear Stress versus Shear Rate of Mountain Flower Honey with Distilled Water.....	65
Figure (4.33) Apparent Viscosity of Black Seed Honey at Different Volumes of 4% Starch Solution.....	67
Figure (4.34) Apparent Viscosity of Black Seed Honey at Different Volumes of Glucose.....	68
Figure (4.35) Apparent Viscosity of Black Seed Honey at Different Volumes of Molasses.....	68
Figure (4.36) Apparent Viscosity of Black Seed Honey at Different Volumes of Distilled Water...	69

Figure (4.57) Temperature versus Viscosity of Clover Honey with 4% Starch Solution at Shear Rate 4.2033s^{-1}	80
Figure (4.58) Activation Energy of Clover Honey Adulterated with 4% Solution Starch Solution.....	81
Figure (4.59) Temperature versus Viscosity of Clover Honey with Glucose at Shear Rate 4.2033s^{-1}	81
Figure (4.60) Activation Energy of Clover Honey Adulterated with Glucose.....	82
Figure (4.61) Temperature versus Viscosity of Clover Honey with Molasses at Shear Rate 4.1976s^{-1}	82
Figure (4.62) Activation Energy of Clover Honey Adulterated with Molasses.....	83
Figure (4.63) Temperature versus Viscosity of Clover Honey with Distilled Water at Shear Rate 4.1976s^{-1}	83
Figure (4.64) Activation Energy of Clover Honey Adulterated with Distilled Water.....	84
Figure (4.65) Temperature versus Viscosity of Desert Honey with 4% Starch Solution at Shear Rate 4.2033s^{-1}	84
Figure (4.66) Activation Energy of Desert Honey adulterated with 4% Starch Solution.....	85
Figure (4.67) Temperature versus Viscosity of Desert Honey with Glucose at Shear Rate 4.2111s^{-1}	85
Figure (4.68) Activation Energy of Desert Honey Adulterated with Glucose.....	86
Figure (4.69) Temperature versus Viscosity of Desert Honey with Molasses at Shear Rate 4.1976s^{-1}	86
Figure (4.70) Activation Energy of Desert Honey Adulterated with Molasses.....	87
Figure (4.71) Temperature versus Viscosity of Desert Honey with Distilled Water at Shear Rate 4.1976s^{-1}	87
Figure (4.72) Activation Energy of Desert Honey Adulterated with Distilled Water.....	88
Figure (4.73) Temperature versus Viscosity of Mountain Flower Honey with 4% Starch Solution at Shear Rate 4.2033s^{-1}	88

Figure (4.74) Activation Energy of Mountain Flower Honey Adulterated with 4% Starch Solution.....	89
Figure (4.75) Temperature versus Viscosity of Mountain Flower Honey with Glucose at Shear Rate 4.2130s^{-1}	89
Figure (4.76) Activation Energy of Mountain Flower Honey Adulterated with Glucose.....	90
Figure (4.77) Temperature versus Viscosity of Mountain Flower Honey with Molasses at Shear Rate 4.2059s^{-1}	90
Figure (4.78) Activation Energy of Mountain Flower Honey Adulterated with Molasses.....	91
Figure (4.79) Temperature versus Viscosity of Mountain Flower Honey with Distilled Water at Shear Rate 4.2059s^{-1}	91
Figure (4.80) Activation Energy of Mountain Flower Honey Adulterated with Distilled Water.....	92
Figure (4.81) Thixotropy Effect (Shear Stress - Shear Rate) of Different Honey Types at Room Temperature.....	93
Figure (4.82) Thixotropy Effect of Desert Honey with 4% Starch Solution at $20\text{ }^{\circ}\text{C}$	94
Figure (4.83) Thixotropy Effect of Desert Honey with Glucose at $20\text{ }^{\circ}\text{C}$	95
Figure (4.84) Thixotropy Effect of Desert Honey with Molasses at $20\text{ }^{\circ}\text{C}$	96
Figure (4.85) Thixotropy Effect of Desert Honey with Distilled Water at $20\text{ }^{\circ}\text{C}$	97
Figure (4.86) Thixotropy Effect of Desert Honey at $30\text{ }^{\circ}\text{C}$	98
Figure (4.87) Thixotropy Effect of Desert Honey with 4% Starch Solution at $30\text{ }^{\circ}\text{C}$	98
Figure (4.88) Thixotropy Effect of Desert Honey with Glucose at $30\text{ }^{\circ}\text{C}$	99
Figure (4.89) Thixotropy Effect of Desert Honey with Molasses at $30\text{ }^{\circ}\text{C}$	100
Figure (4.90) Thixotropy Effect of Desert Honey with Distilled Water at $30\text{ }^{\circ}\text{C}$	101
Figure (4.91) Thixotropy Effect of Desert Honey at $40\text{ }^{\circ}\text{C}$	102
Figure (4.92) Thixotropy Effect of Desert Honey with 4% Starch Solution at $40\text{ }^{\circ}\text{C}$	102
Figure (4.93) Thixotropy Effect of Desert Honey with Glucose at $40\text{ }^{\circ}\text{C}$	103
Figure (4.94) Thixotropy Effect of Desert Honey with Molasses at $40\text{ }^{\circ}\text{C}$	104

Figure (4.95) Thixotropy Effect of Desert Honey with Distilled Water at 40 °C.....	105
Figure (4.96) Thixotropy Effect of Desert Honey at 50 °C.....	106
Figure (4.97) Thixotropy Effect of Desert Honey with 4% Starch Solution at 50 °C.....	106
Figure (4.98) Thixotropy Effect of Desert Honey with Glucose at 50 °C.....	107
Figure (4.99) Thixotropy Effect of Desert Honey with Molasses at 50 °C.....	108
Figure (4.100) Thixotropy Effect of Desert Honey with Distilled Water at 50 °C.....	109
Figure (4.101) Effect of Time on the Viscosity of Desert Honey with 4ml of 4% Starch Solution at 20 °C	110
Figure (4.102) Effect of Time on the Viscosity of Desert Honey with 6ml of 4% Starch Solution at 20 °C	111
Figure (4.103) Effect of Time on the Viscosity of Desert Honey with 10ml of 4% Starch Solution at 20 °C	111
Figure (4.104) Effect of Time on the Viscosity of Desert Honey with 2ml Glucose at 20 °C	112
Figure (4.105) Effect of Time on the Viscosity of Desert Honey with 4ml Glucose at 20 °C	112
Figure (4.106) Effect of Time on the Viscosity of Desert Honey with 6ml Glucose at 20 °C	113
Figure (4.107) Effect of Time on the Viscosity of Desert Honey with 8ml Glucose at 20 °C	113
Figure (4.108) Effect of Time on the Viscosity of Desert Honey with 10ml Glucose at 20 °C	114
Figure (4.109) Effect of Time on the Viscosity of Desert Honey with 4ml Molasses at 20 °C	114
Figure (4.110) Effect of Time on the Viscosity of Desert Honey with 6ml Molasses at 20 °C	115
Figure (4.111) Effect of Time on the Viscosity of Desert Honey with 2ml Distilled Water at 20 °C	115
Figure (4.112) Effect of Time on the Viscosity of Desert Honey with 4ml Distilled Water at 20 °C	116
Figure (4.113) Relation between Shear Stress of Desert Honey with 4ml of Starch Solution and Ln (Time)	117