

RHEOLOGICAL PROPERTIES OF FOOD GELS

By

NADA YOUSSEF ISMAIL ABDO

B. Sc. Agric. Sc. (Agric. Engineering), Ain Shams University, 2009

A Thesis submitted in partial fulfillment

of

The Requirements for the Degree of

MASTER IN AGRICULTURE SCIENCE

(Biological Agriculture Engineering)

Department of Agricultural Engineering

Faculty of Agriculture

Ain Shams University

2016

Approval Sheet

RHEOLOGICAL PROPERTIES OF FOOD GELS

By

NADA YOUSSEF ISMAIL ABDO

B. Sc. Agric. Sc. (Agric. Engineering), Ain Shams University, 2009

This thesis for M. Sc. degree has been approved by:

Dr. Manal Abd El-rahman Ali Sorour

Head Research of Agricultural Engineering and packaging foods, Food
Technology Institute

Dr. Mubarak Mohammed Moustafa

Prof. Emeritus of Agricultural Engineering, Faculty of Agriculture, Ain
Shams University

Dr. Hany Idress Khalil

Prof. of Food Engineering, Faculty of Agriculture, Ain Shams
University

Dr. Moustafa Faheem Mohamed

Associate Prof. of Agricultural Engineering, Faculty of Agriculture,
Ain Shams University

Date of Examination: / /

RHEOLOGICAL PROPERTIES OF FOOD GELS

By

NADA YOUSSEF ISMAIL ABDO

B. Sc. Agric. Sc. (Agric. Engineering), Ain Shams University, 2009

Under the supervision of:

Dr. Mahmoud Ahmed El-Nono (Late).

Prof. Emeritus of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University (Principal Supervisor)

Dr. Moustaf Faheem Mohamed

Associate Prof. of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University

Dr. Hany Idress Khalil

Prof. of Food Engineering, Department of Food Science, Faculty of
Agriculture, Ain Shams University

ABSTRACT

Nada Youssef Ismail Abdo: Rheological Properties of Food Gels. Unpublished M. Sc. Thesis, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, 2016.

The rheological properties of strawberry jam puree as a sample of some food gels were investigated using rotational viscometer over the range (30 – 70°C), different solid concentration of 40, 45, 50, 55 and 63 %. Shear rate – shear stress data indicate that the puree behaves as a Non-Newtonian pseudoplastic behavior, and fitted well to the power law model. The effect of concentration on the apparent viscosity of strawberry jam puree was fitted well to power law equation, the results observed that apparent viscosity increased with increasing the concentration of strawberry jam puree at all temperatures studied. The effect of temperature on the apparent viscosity of strawberry samples was fitted well to Arrhenius law. The activation energy was found in the range of 25.26–97.78 KJ/mol.

Keywords: Rheological properties; Viscosity; Food Gels; Activation energy; strawberry Creamy jam; Gels.

ACKNOWLEDGEMENT

First of all, thanks to **ALLAH** for his blessings.

I would like to express my sincere gratitude and appreciation to the spirit of the late **Prof. Dr. Mahmoud Ahmed El-Nono**, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, for his kind supervision, problem suggestion, continuous encouragement and valuable advices throughout this work.

I would like to express my sincere gratitude and appreciation to **Dr. Moustafa Faheem Mohamed**, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, for his kind supervision, problem suggestion, continuous encouragement and valuable advices throughout this work.

I would like to express my sincere gratitude and appreciation to **Prof. Dr. Hany Idress Khalil**, Department of Food Science, Faculty of Agriculture, Ain Shams University for his kind supervision, problem suggestion, continuous encouragement and valuable advices throughout this work.

I would like to express my deep appreciation and gratitude to Agricultural Research Center, Food Technology Institute for kindly help throughout the course of investigation. The author is grateful for valuable discussions, suggestions and helpful ideas, which helped me to finish this work.

Finally, deepest appreciations are going towards my family for their support, understanding, patience, loving and continuous encouragement.

CONTENTS

	Page
LIST OF TABLES	II
LIST OF FIGURES	VI
LIST OF ABBREVIATIONS	XI
1. INTRODUCTION	1
2. REVIEW OF LITERATURE	3
2.1 Rheology of food	3
2.2 Fundamental properties of fluids	6
2.3 Types of fluids	6
2.3.1 Newtonian fluids	7
2.3.2 Non-Newtonian fluids	9
2.3.2.1 Bingham plastic fluids	10
2.3.2.2 Shear -thinning fluids	13
2.3.2.3 Shear thickening fluids	19
2.4 Time dependent fluids	21
2.4.1 Thixotropic fluids	21
2.4.2 Rheopectic fluids	28
2.5 Viscoelastic fluids	29
2.6. Effect of temperature on viscosity	29
2.7 Effect of solid concentration on rheology	37
2.8 Rheology measurements	38
2.8.1 Brookfield synchroelectric - viscometer	39
3. MATERIALS AND METHODS	40
3.1 Preparation of strawberry puree jam concentrations in Vitrac factory.	40
3.2 Rheological measurements	41
4. RESULTS AND DISCUSSION	44
4.1 Stress - Strain Rate Relations	44
4.2 Effect of shear rate on viscosity	49
4.3 Effect of temperature on apparent viscosity of strawberry jam puree concentrates	52
4.4 Effect of concentration on viscosity	59
V- SUMMARY AND CONCLUSION	68
VI- REFERENCES	70
VII- APPENDIX	78
ARABIC SUMMARY	

LIST OF TABLES

Table No.	Subject	Page
Table (1)	Relation between shear stress and shear rate at 40% solid concentration of strawberry jam puree at different temperatures.	78
Table (2)	Relation between shear stress and shear rate at 45% solid concentration of strawberry jam puree at different temperatures.	78
Table (3)	Relation between shear stress and shear rate at 50% solid concentration of strawberry jam puree at different temperatures.	79
Table (4)	Relation between shear stress and shear rate at 55 % solid concentration of strawberry jam puree at different temperatures.	79
Table (5)	Relation between shear stress and shear rate at 63% solid concentration of strawberry jam puree at different temperatures.	80
Table (6)	Values of flow behaviour index (n) and consistency coefficient (k) at different temperatures and concentrations	80
Table (7)	Effect of shear rate on viscosity at different temperatures and 40 % solid concentration of strawberry jam puree.	81
Table (8)	Effect of shear rate on viscosity at different temperatures and 45 % solid concentration of strawberry jam puree.	81
Table (9)	Effect of shear rate on viscosity at different temperatures and 50 % solid concentration of strawberry jam puree.	82

Table (10)	Effect of shear rate on viscosity at different temperatures and 55 % solid concentration of strawberry jam puree.	82
Table (11)	Effect of shear rate on viscosity at different temperatures and 63 % solid concentration of strawberry jam puree.	83
Table (12)	Effect of temperature on viscosity at 40 % solid concentration of strawberry jam puree at different shear rates.	83
Table (13)	Effect of temperature on viscosity at 45% solid concentration of strawberry jam puree at different shear rates.	84
Table (14)	Effect of temperature on viscosity at 50 % solid concentration of strawberry jam puree at different shear rates.	84
Table (15)	Effect of temperature on viscosity at 55 % solid concentration of strawberry jam puree at different shear rates.	84
Table (16)	Effect of temperature on viscosity at 63 % solid concentration of strawberry jam puree at different shear rates.	85
Table (17)	Relation between $\ln \mu$ and $1/T$ at 40 % solid concentration of strawberry jam puree at different shear rates.	85
Table (18)	Relation between $\ln \mu$ and $1/T$ at 45 % solid concentration of strawberry jam puree at different shear rates.	86
Table (19)	Relation between $\ln \mu$ and $1/T$ at 50 % solid concentration of strawberry jam puree at different shear rates.	86
Table (20)	Relation between $\ln \mu$ and $1/T$ at 55 % solid concentration of strawberry jam puree at different shear rates.	87

Table (21)	Relation between $\ln \mu$ and $1/T$ at 63 % solid concentration of strawberry jam puree at different shear rates.	87
Table (22)	Activation energy at different shear rates and concentrations.	88
Table (23)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 9.3 sec^{-1} .	88
Table (24)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 18.6 sec^{-1}	89
Table (25)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 27.9 sec^{-1}	89
Table (26)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 37.2 sec^{-1} .	89
Table (27)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 46.5 sec^{-1} .	90
Table (28)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 55.8 sec^{-1} .	90
Table (29)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 65.1 sec^{-1} .	90
Table (30)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 74.4 sec^{-1} .	91
Table (31)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and	91

shear rate = 83.7 sec^{-1} .

Table (32)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 93 sec^{-1} .	91
Table (33)	The constants a and b values at different temperatures.	92

LIST OF FIGURES

Figure No.	Subject	Page
Figure (1)	Comparison of some typical Newtonian, shear thinning and shear thickening power law fluids and a Bingham plastic fluid. Busamri (S2012).	7
Figure (2)	Typical shear thinning behavior: (a) viscosity versus shear rate; shear stress versus shear rate. Sorour (2005).	8
Figure (3)	Model to illustrate Newtonian flow Steffe and Daubert (2006).	9
Figure (4)	Typical shear thinning behavior: (a) viscosity versus shear rate; shear stress versus shear rate. Sorour (2005).	14
Figure (5)	Characteristics of pseudoplastic, type flow in Non-Newtonian systems. Sorour (2005)	16
Figure (6)	Typical shear- thickening behaviour of a concreted suspension of non aggregating particles Rielly (1997).	20
Figure (7)	Reversible Gel-Sol-Gel transition in non-Ne' systems. Kramer and Twigg (1970).	23
Figure (8)	Time dependent non-Newtonian behavior. This fluid show hysteresis, characteristic of thixotropy during a ramp test. Kramer and Twigg (1970).	23
Figure (9)	Concentric –cylinder viscometer flow curve of a rheopectic pigment suspension temperature 300 C. (Eirich , 1975).	28
Figure (10)	Brookfield Viscometer.	39
Figure (11)	Flow diagram of producing strawberry jam puree	40

Figure (12)	Photography picture of Brookfield Digital Viscometer model	42
Figure (13)	A Thermostatic Water Bath	43
Figure (14)	Relation between shear stress and shear rate at 40% solid concentration of strawberry jam puree at different temperatures.	45
Figure (15)	Relation between shear stress and shear rate at 45% solid concentration of strawberry jam puree at different temperatures.	46
Figure (16)	Relation between shear stress and shear rate at 50% solid concentration of strawberry jam puree at different temperatures.	46
Figure (17)	Relation between shear stress and shear rate at 55% solid concentration of strawberry jam puree at different temperatures.	47
Figure (18)	Relation between shear stress and shear rate at 63% solid concentration of strawberry jam puree at different temperatures.	47
Figure (19)	Relation between n and temperature of strawberry jam puree at different concentrations.	48
Figure (20)	Relation between K and temperature of strawberry jam puree at different concentrations.	48
Figure (21)	Effect of temperature on apparent viscosity at 40 % solid concentration of strawberry jam puree at different shear rates.	49
Figure (22)	Effect of temperature on apparent viscosity at 45% solid concentration of strawberry jam puree at different shear rates.	50

Figure (23)	Effect of temperature on apparent viscosity at 50 % solid concentration of strawberry jam puree at different shear rates.	50
Figure (24)	Effect of temperature on apparent viscosity at 55 % solid concentration of strawberry jam puree at different shear rates.	51
Figure (25)	Effect of temperature on apparent viscosity at 63 % solid concentration of strawberry jam puree at different shear rates.	51
Figure (26)	Effect of temperature on apparent viscosity at 40 % solid concentration of strawberry jam puree at different shear rates.	52
Figure (27)	Effect of temperature on apparent viscosity at 45 % solid concentration of strawberry jam puree at different shear rates.	53
Figure (28)	Effect of temperature on apparent viscosity at 50 % solid concentration of strawberry jam puree at different shear rates.	53
Figure (29)	Effect of temperature on apparent viscosity at 55 % solid concentration of strawberry jam puree at different shear rates.	54
Figure (30)	Effect of temperature on apparent viscosity at 63 % solid concentration of strawberry jam puree at different shear rates.	54
Figure (31)	Relation between temperature and $\ln \mu$ at different shear rates and 40 % solid concentration of strawberry jam puree.	56
Figure (32)	Relation between temperature and $\ln \mu$ at different shear rates and 45% solid concentration of strawberry jam puree.	57

Figure (33)	Relation between temperature and $\ln\mu$ at different shear rates and 50% solid concentration of strawberry jam puree.	57
Figure (34)	Relation between temperature and $\ln\mu$ at different shear rates and 55% solid concentration of strawberry jam puree.	58
Figure (35)	Relation between temperature and $\ln\mu$ at different shear rates and 63% solid concentration of strawberry jam puree.	58
Figure (36)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 9.3 sec^{-1} .	62
Figure (37)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 18.6 sec^{-1}	63
Figure (38)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 27.9 sec^{-1}	63
Figure (39)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 37.2 sec^{-1} .	64
Figure (40)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 46.5 sec^{-1} .	64
Figure (41)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 55.8 sec^{-1} .	65
Figure (42)	Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 65.1 sec^{-1} .	65

- Figure (43)** Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 74.4 sec^{-1} . 66
- Figure (44)** Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 83.7 sec^{-1} . 66
- Figure (45)** Effect of concentration on apparent viscosity of strawberry jam puree at different temperatures and shear rate = 93 sec^{-1} . 67