Effect of Dietary Fibers on the Bioavailability of Iron and Zinc and the Lipid Levels of Blood of Rats

By

Abeer Amin Afify Ahmed

B.Sc. Food technology, Faculty of Agriculture, Cairo University, 1990
M.Sc. Food technology, Faculty of Agriculture, Cairo University, 1998

Thesis

Submitted in Partial Fulfillment of the Requirements for the degree of doctor of philosophy

IN

Agricultural Science
(Food Science and Technology)
Department of Food Technology,
Faculty of Agriculture,
Cairo University

2006

ACKNOWLEDGMENT

Words can never express my hearty indebtedness, my deepest gratitude, respect appreciation and sincerest gratitude to Prof. Dr. Fathallah El-Wakeil Prof. of Food Technology, Food Technology Dept., Faculty of Agriculture, Cairo University, for his generous advice, endless patience, continuous encouragement and guidance through supervision of this work.

I also would like to express my greatest appreciation to Prof. Dr. Salah Hussein Abou-Raya, Prof. of Food Technology, Food Technology Dept., Faculty of Agriculture, Cairo University, for his supervision, sincere assistance and valuable support throughout the course of this investigation and writing the thesis.

Deepest gratitude is also due to Prof. Dr. El-sayed Hegazi, Prof. of Food Science and Nutrition, National Research Center, not only for suggesting the work, but also for his supervision, sincere help through the practical part of the thesis and for continuous encouragement, being quite generous with his knowledge and valuable cooperation and help throughout the whole work.

I wish also to express my deepest thanks to Prof. Dr. Mona Mohamed Hussein, Prof. of Food Science and Nutrition, National Research Center, for her supervision of the work and her continuous encouragement.

Thanks are also extended to all the staff members of the Food Science and Nutrition Department, National Research Center, (where this work was carried out) for their great help.

Results	and	Discussion

Approval Sheet

Effect of Dietary Fibers on the Bioavailability of Iron and Zinc and the Lipid Levels of Blood of Rats.

By

Abeer Amin Afify Ahmed

B.Sc. B.Sc. Food technology, faculty of Agric., Cairo University, 1990M.Sc. Food technology, faculty of Agric., Cairo University, 1998

This thesis for Ph. D. degree has been approved by:	
Prof. Dr. Sonya Saleh El-meraicy	
Prof. of Nutrition,	
Faculty of Home Economic, Helwan University.	
Dr. Mohamed Ahmed El-nekety, Assistant Prof.	
Ass. Prof. of Food Tech., Food Tech. Dept.,	
Faculty of Agric., Cairo University.	
Prof. Dr. Fathallah El-Wakeil	
Prof. of Food Tech, Food Tech Dept.,	
Faculty of Agric., Cairo University.	
Prof. Dr. Salah Hussein Abou-Raya	
Prof. of Food Tech., Food Tech. Dept.,	
Faculty of Agric, Cairo University.	

Date: / / 2006

Effect of Dietary Fibers on the Bioavailability of Iron and Zinc and the Lipid Levels of Blood of Rats.

By

Abeer Amin Afify Ahmed

B.Sc. Food technology, Faculty of Agric., Cairo University, 1990

M.Sc. Food technology, Faculty of Agric., Cairo University, 1998

Under Supervision

Prof. Dr. Fathallah El-Wakeil

Prof. of Food Tech., Food Tech. Dept., Faculty of Agric., Cairo University.

Prof. Dr. Salah Hussein Abou-Raya

Prof. of Food Tech., Food Tech.Dept., Faculty of Agric., Cairo University.

Prof. Dr. El-Sayed Mohamed Hegazi

Prof. of Food Science and Nutrition, National Research Center

LIST OF ABBREVIATION

AWRC Alkaline water retention capacity

CE Cholesterol esterase CO Cholesterol oxidase

CV Conventional

CVD Cardiovascular disease

DM Dry matter

DMSO Dimethyl sulphoxide
DS Digestible wheat starch
FER Feed efficiency ratio

FI Feed intake GF Germ free

GO Glucose oxidase HAS Amylose corn starch

Hb Hemoglobin

HDL High density lipoprotein cholesterol

HPO Hydrogen peroxide

Ht Hematocrit

IDF Insoluble dietary fiber

LDL Low density lipoprotein cholesterol NIDDM Non-insulin dependent diabetes mellitus

NSP Non starch polysaccharide

PA Phytic acid

P-HBs P- Hydroxybenzene sulphoxide

RPS Raw potato starch
RS Resistant starch
SCFA Short chain fatty acid
SDF Soluble dietary fiber

TA Tannic acid
TAG Triacylglyceride
TC Total cholesterol
TDF Total dietary fiber
WHC Water-holding capacity

List of Figures

NO.		Pages
Figure (1)	Iron balance in human body	10
Figure (2)	Iron absorption and metabolism	13
Figure (3)	Zinc absorption and metabolism	22
Figure (4)	Different types of pan bread containing different percentage	
	of total dietary fiber (TDF)	104
Figure(5)	Dietary fiber content of raw materials used for feeding	
	experimental (g/100 g dry matter)	111
Figure (6)	Mean of total starch and resistant starch contents of raw and	
	boiled sample	114
Figure (7)	Mean of body weight and body weight gain of normal rats fed	
	on different dietary fiber sources for 4 weeks	117
Figure (8)	Mean of body weight and body weight gain of hyperlipidemic	
	rats fed on the diets contains different dietary fiber sources for	
	4 weeks	120
Figure (9)	Levels of fasting blood glucose of normal rats fed on diets	
	containing different dietary fiber sources for 4 weeks	122
Figure (10)	Hemoglobin levels of normal rats fed on diets containing	
	different dietary fiber sources for 4 weeks	123
Figure (11)	Plasma iron Levels of normal rats fed on different dietary	
	fibers sources for 4 weeks.	124
Figure (12)	Plasma zinc levels of normal rats fed on different dietary fiber	
	sources for 4 weeks	125
Figure (13)	Levels of fasting blood glucose (mg/dl) of hyperlipidemic rats	

	fed on the diets containing different dietary fiber sources for 4	
	weeks	128
Figure (14)	Levels of hemoglobin of hyperlipidemic rats fed on diets	
	containing different sources of dietary fiber for 4	
	weeks	129
Figure (15)	Mean values of plasma iron levels of hyperlipidemia rats fed	
	on different dietary fiber sources for 4 weeks	129
Figure (16)	Mean values of plasma zinc levels for hyperlipidemic rats fed	
	on different dietary fibers sources for 4 weeks	130
Figure (17)	Mean values of iron intake, urine iron, feces iron, absorbed	
	iron, and retained iron of normal rats fed on different sources	
	of dietary fibers	133
Figure (18)	Mean values of zinc intake, urine zinc, feces zinc, absorbed	
	zinc, and retained zinc of normal rats fed on different dietary	
	fiber sources.	134
Figure (19)	Mean values of iron intake, urine iron, feces iron, absorbed	
	iron and retained iron of hyperlipidemia rats fed on different	
	dietary fiber sources	137
Figure (20)	Mean values of zinc intake, urine zinc, feces zinc, absorbed	140
	zinc and retained zinc of hyperlpidemic rats fed on different	
	source of dietary fibers	
Figure (21)	Mean values of plasma total cholesterol levels of normal rats	
	fed on diets containing different dietary fiber sources for 4	
	weeks	145
Figure (22)	Mean values of plasma LDL-cholesterol levels of normal rats	
	fed on diets containing different dietary fiber sources for 4	
	weeks	146

Figure (23)	Levels of plasma HDL-cholesterol of normal rats fed on diets	
	containing different dietary fiber sources for 4	
	weeks	148
Figure (24)	Levels of plasma total lipids of normal rats fed on diets	
	containing different dietary fiber sources for 4	
	weeks	149
Figure (25)	Mean values of plasma triacylglyceride levels of normal rats	
	fed on diets containing different dietary fiber sources for 4	
	weeks	150
Figure (26)	Mean values of plasma total cholesterol of hyperlipidemic rats	
	fed on diets containing different dietary fiber sources for 4	
	weeks	153
Figure (27)	Mean values of plasma LDL-cholesterol levels of	
	hyperlipidemic rats feed on diets containing different dietary	
	fiber sources for 4 weeks	155
Figure (28)	Averages of plasma HDL-cholesterol levels of hyperlipidemic	
	rats fed on diets containing different dietary fiber sources for4	
	weeks	156
Figure (29)	Average of plasma total lipids levels of hyperlipidemic rats	
	fed on diets containing different dietary fiber sources for 4	
	weeks	157
Figure (30)	Mean values of plasma triacylglyceride levels of	
	hyperlipidemic rats fed on diets containing different dietary	
	fiber sources for 4 weeks	158

List of Tables

No.		Page
Table (1)	Total body iron content/ per kg body weight	8
Table (2)	Iron intakes required for growth	11
Table (3)	Biochemical tests and normal values of iron status	16
Table (4)	Zinc levels in body tissues	18
Table (5)	Zinc content in some foods	20
Table (6)	Recommended dietary intakes of zinc for adults	24
Table (7)	Relative biological availability of iron in foods	27
Table (8)	Factors affecting iron absorption	28
Table (9)	Dietary factors that can affect zinc bioavailability	29
Table (10)	In-vitro nutritional classification of starch	47
Table (11)	Some promoter substance in foodstuffs of plant sources.	48
Table (12)	Composition of pan bread formulate	69
Table (13)	Composition of salt mixture	71
Table (14)	Composition off vitamin mixture	71
Table (15)	Composition of diets used for feeding the normal rats	72
Table (16)	Composition hyperlipidemic diet	73
Table (17)	The constituents of the diets used in hypercholesterolemia	76
	experiment	
Table (18)	Chemical composition of dietary fiber sources used for	102
	feedingexperiments	
Table (19)	Organolyptic evaluation scores of pan bread replaced with	105
	different levels of wheat bran in comparison with the	
	control	
Table (20)	Effect of wheat bran replacement percent on staling rate	

	(AWRC %) of pan bread during 72 hours after backing	107
Table (21)	Soluble (SDF), Insoluble (IDF) and total dietary fiber	
	content (TDF) of raw materials used for feeding	
	experimental	110
Table (22)	Total starch and resistant starch values	113
Table (23)	Body weight gain and feed efficiency of rats fed on	
	different dietary fiber sources for 4 weeks	116
Table (24)	Body weight gain and feed efficiency for hyperlipidemic	
	rats fed on diets contains different dietary fiber sources for	
	4 weeks	119
Table (25)	Blood hemoglobin(Hb%), blood glucose(bG.), plasma	
	iron levels and plasma zinc levels of normal rats fed on	
	diets containing different dietary fiber sources for 4 weeks	121
Table (26)	Blood hemoglobin(Hb%), blood glucose(bG.), plasma	
	iron and plasma zinc levels of hyperlipidemia rats fed on	
	diets containing different dietary fiber sources for 4 weeks	127
Table(27)	Iron absorption and retention (mg/21 days) of normal	
	rats fed on different source of dietary fibers	131
Table(28)	Zinc absorption and retention (mg/21 days) of normal rats	
	fed different source of dietary fibers	132
Table (29)	Iron absorption and retention (mg/21 days) in	
	hyperlipidemic rats fed different dietary fiber sources	136
Table (30)	Zinc absorption and retention (mg/21 days) in	
	hyperlipidemic rats fed different sources of dietary fiber.	139
Table (31)	Blood Lipid profile of normal rats fed on diets containing	
	different sources of dietary fiber for 4 weeks	143
Table (32)	Blood lipid profile of hyperlipidemic rats fed on diets	
	containing different sources of dietary fibers for 4 weeks.	152

Contents

	Page
ITRODUCTION	1
REVIEW of literature	7
Role of trace elements in nutrition	7
1. Iron	7
1.1 Iron function and distribution	7
1.2 Iron intake	9
1.3 Iron balance	10
1.4 Iron absorption and metabolism	12
1.5 State of iron deficiency anemia	14
2. Zinc	17
2.1 Zinc distribution	17
2.2 Zinc function	18
2.3 Zinc sources	19
2.4 Zinc absorption, metabolism and excretion	20
2.5 Zinc requirements	22
2.6 Zinc deficiency	23
3. Bioavailability of trace elements	26
3.1 Factors affecting iron and zinc bioavailability	26
3.1.1 Inhibiting factors	30
3.1.1.1 Effect of phytate on the bioavailability of iron and zinc	30
3.1.1.2 Effect of tannins on bioavailability of iron and zinc	34
3.1.1.3 Effect of dietary fiber on bioavailability of iron and zinc	36
3.1.1.4 Effect of resistant starch on bioavailability of iron and zinc	45
3.1.2 Absorption promoter substances	48
3.1.2.1 Effect of organic acids	48
3.1.2.2 Effect of dietary protein sources and amino acid	49
3.1.2.3 Effect of vitamin A and β-carotene	51
3.3 Effect of dietary minerals on the biological interaction of zinc and	53
iron	
3.4 Effect of food processing on the mineral availability	56
4. Effect of dietary fibers on hypercholesterolemia	60
5. Effect of dietary fibers on glucose metabolism	65
MATERIALS AND METHODS.	68
1. Materials	68
1. 1 Preparation of legume sample	68
1. 2 Bread diets formulation	69
1. 3 Animal experiments	70
1. 3.1 Experiment (I)	70

1. 3.2	Experiment (II) hyperlipidemic experiment	73
1.4	Measurement of apparent absorption and retention	77
2. Metho	ds of analysis	77
2.1	Determination of chemical composition	77
2.2	Organolyptic evaluation of baked bread	78
2.3	Bread freshness test	78
2.4	Determination of total, soluble and insoluble dietary fiber	79
2.5	Determination of total starch and resistant starch	82
2.6	Blood analysis	85
2.6.1	Estimation of plasma glucose	86
2.6.2	Estimation of blood hemoglobin	87
2.6.3	Determination of iron and zinc	88
2.6.3.1	In plasma	88
2.6.3.2	In diet, faces and urine	88
2.6.4	Estimation of plasma total cholesterol	89
2.6.5	Estimation of plasma low density lipoprotein cholesterol	91
2.6.6	Estimation of plasma HDL-cholesterol	93
2.6.7	Estimation of plasma total lipids	95
2.6.8	Estimation of plasma triacylglycerides	96
2.7	Statistical analysis	99
RESULT	TS AND DISCUSSION	100
1	Chemical composition of raw materials used in this study	100
2	Organoleptic evaluation of pan bread	103
3	Alkaline water retention capacity of differently prepared pan	106
	bread	
4	Dietary fiber of selected foods	108
5	Total starch and resistant starch values	111
6	Biological evaluation of different sources of dietary fiber	114
	source	
6.1	Effect of dietary fiber on body weight gain, feed intake and feed	114
	efficiency of normal rats	
6.2	Effect of dietary fiber on body weight gain, feed intake and feed	117
	efficiency of hyperlipidemic rats	
7.	Effect of dietary fiber on levels of hemoglobin, glucose, plasma	120
	iron and zinc	
7. 1	Effect on normal rats	120
7.2	Effect on hyperlipidemic rats	125
8	Effect of dietary fiber on the average daily absorption, and	130
	retention, of iron and zinc	
8.1	Effect on normal rats	130
8.2	Effect on hyperlipidemic rats	134