

**EFFECTS OF MACRONUTRIENTS
AND PHYSICOCHEMICAL
PROPERTIES OF CARBOHYDRATES
ON GLYCAEMIC INDICES (GI) OF
SOME SRI LANKAN FOODS**

By

Usha Pushkala Kumari Hettiaratchi

Ph.D.

2009

**EFFECTS OF MACRONUTRIENTS
AND PHYSICOCHEMICAL
PROPERTIES OF CARBOHYDRATES
ON GLYCAEMIC INDICES (GI) OF
SOME SRI LANKAN FOODS**

By

Usha Pushkala Kumari Hettiaratchi

Thesis submitted to the University of Sri Jayewardenepura
for the award of the degree of Doctor of Philosophy in
Biochemistry on 02nd July, 2009.

DECLARATION

The work described in this thesis was carried out by me under the supervision of Dr. S. Ekanayake and Prof. J. Welihinda and a report on this has not been submitted in whole or in part to any University or any other Institution for another Degree/Diploma.

.....U.P.K. Hettiaratchi.....

.....22/01/2010.....

U.P.K. Hettiaratchi

Date

We certify that the candidate has incorporated all possible corrections, amendments and additions recommended by the examiners.

.....S. Ekanayake.....

Dr. Sagarika Ekanayake

.....J. Welihinda.....

Prof. J. Welihinda

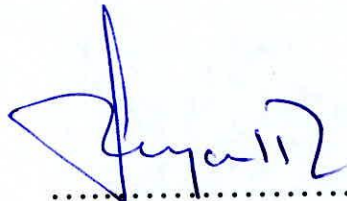
CERTIFICATION

We certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University for the purpose of evaluation.



.....

Dr. S. Ekanayake



.....

Prof. J. Welihinda

TABLE OF CONTENTS

List of tables	xii
List of figures	xiv
List of plates	xvi
Abbreviations	xvii
Acknowledgements	xix
Abstract	xxii
1. INTRODUCTION	1
1.1 Scope and objectives of the study	3
2. LITERATURE REVIEW	6
2.1 Glycaemic Index	6
2.2 Determination of Glycaemic Index values of foods <i>in vivo</i>	7
2.2.1 Quantity of carbohydrate	7
2.2.2 Time of the day to carry out GI study	7
2.2.3 Number of subjects to be employed in a GI study	8
2.2.4 Health status of the subjects	8
2.2.5 Duration an individual could be included in the study	9
2.2.6 Preparation of subjects	9
2.2.7 Standard foods given in GI studies	10
2.2.8 Number of times the standard should be given	11

2.2.9	Other components of the meal	11
2.2.10	Time of ingestion of food	11
2.2.11	Blood sampling time	12
2.2.12	Source of blood	12
2.2.13	Analysis of glucose	13
2.2.14	Area under the curve	13
2.2.15	Calculation of GI	14
2.3	Insulin responses to starchy foods	14
2.3.1	Determination of Insulinaemic Index	15
2.4	Effect of glucagon on foods	16
2.5	Glycaemic Index values of foods	16
2.5.1	Glycaemic Indices of basic foods	16
2.5.2	Glycaemic Indices of mixed meals	18
2.6	Mechanisms of low Glycaemic Index diets in improving glycaemic response	20
2.7	Glycaemic Load	22
2.7.1	Relationship between Glycaemic Load with glucose and insulin responses	23
2.8	Second meal effect of starchy foods	24
2.9	Factors influencing Glycaemic Index	26
2.9.1	Factors associated with food	26
2.9.1.1	Nutrients present in meals	26

2.9.1.2	Different sources of carbohydrates	29
2.9.1.3	Amylose-amylopectin content	30
2.9.1.4	Fate of the starch granule with processing	31
2.9.1.5	Types of sugars	32
2.9.1.6	Particle size	33
2.9.1.7	Cooking method/processing	34
2.9.1.8	Anti nutritional compounds	35
2.9.1.9	Organic acids	35
2.9.1.10	Resistant starch (Undigestible starch)	36
2.9.1.11	Patterns of blood glucose curves	37
2.9.2	Extrinsic factors affecting Glycaemic Index	37
2.9.2.1	Inter individual variations	37
2.9.2.2	Intra individual variations	38
2.9.2.3	Gastric emptying	38
2.9.2.4	Meal frequency	39
2.10	<i>In vitro</i> procedures used to determine glycaemic responses	39
2.11	Carbohydrates and health issues	41
2.11.1	Metabolic syndrome	41
2.11.2	Diabetes Mellitus	42
2.11.2.1	Prevalence of diabetes	42
2.11.2.2	Classification of diabetes	44
2.11.2.3	Complications with diabetes	47

2.11.3	Observational studies, short and long term trials of low and high Glycaemic Index diets	48
2.11.4	Glycaemic Indices and satiety	49
2.11.5	Glycaemic Indices and disease correlation	50
2.11.6	Relationship between Glycaemic Load and diseases	53
2.12	Dietary recommendations regarding Glycaemic Index	54
2.13	Dietary recommendations for diabetes	54
2.14	Nutrient density	56
2.15	Food items analyzed in the present study	56
2.15.1	Rice	56
2.15.2	Bread	57
2.15.3	String hoppers	57
2.15.4	Manioc (<i>Manihot esculenta</i>)	57
2.15.5	Jackfruit (<i>Artocarpus heterophyllus</i>)	58
2.15.6	Bananas (<i>Musa spp.</i>)	58
2.15.7	Meal accompaniments	58
3.	MATERIALS AND METHODS	60
3.1	Materials	60
3.1.1	Water	60
3.1.2	Chemicals	60
3.1.3	Solvents	60

3.1.4	Enzymes	60
3.1.5	Enzyme kits	61
3.1.6	Glucometer, lancets and needles	61
3.1.7	Instruments	61
3.1.8	Human subjects	62
3.1.8.1	Healthy individuals	62
3.1.8.2	Type 2 Diabetes Mellitus patients	62
3.1.9	Raw materials	63
3.1.9.1	Flour varieties	63
3.1.9.2	Red rice	63
3.1.9.3	Bread varieties	63
3.1.9.4	Vegetables, meal accompaniments, fruits and ingredients for curry preparation	64
3.1.9.5	Legumes	64
3.2	Methods	65
3.2.1	Preparation of food and food flour	65
3.2.1.1	Bread varieties	65
3.2.1.2	Red rice	65
3.2.1.3	String hoppers (wheat and rice flour)	66
3.2.1.4	Manioc	66
3.2.1.5	Jackfruit and bread fruit	66

3.2.1.6 Lentil curry	67
3.2.1.7 <i>Kiri hodi</i>	67
3.2.1.8 Eggs	68
3.2.1.9 Fresh salads (sambols)	68
3.2.1.10 <i>Roti</i> and <i>pittu</i>	68
3.2.1.11 Legumes (Chick pea, mung beans, cowpea)	69
3.2.1.12 Banana varieties	69
3.2.2 Analysis of proximate compositions of foods	70
3.2.2.1 Determination of moisture of fresh and dried food samples	70
3.2.2.2 Determination of ash content	70
3.2.2.3 Determination of digestible starch content	70
3.2.2.4 Estimation of glucose concentrations using enzymatic kit method (GOD-PAP)	71
3.2.2.5 Determination of total starch content	72
3.2.2.6 Determination of fat content	72
3.2.2.7 Estimation of Insoluble Dietary Fibre and Soluble Dietary Fibre contents	73
3.2.2.8 Determination of protein content	74
3.2.2.9 Estimation of sucrose content	75
3.2.2.10 Estimation of reducing sugar content	75
3.2.3 Estimation of Glycaemic Indices of foods	78
3.2.3.1 Calculation of 50 g available carbohydrate portions of	

basic foods	78
3.2.3.2 Calculation of 50 g available carbohydrate portions of	
mixed meals	79
3.2.3.3 Foods analyzed	79
3.2.3.4 Determination of Glycaemic Index values	81
3.2.3.5 Estimation of serum glucose concentrations using enzymatic	
kit method	81
3.2.3.6 Standard curves of glucose	83
3.2.3.7 Estimation of blood glucose concentrations using the glucometer	83
3.2.3.8 Glucose response graphs of foods	84
3.2.3.9 Calculation of Glycaemic Indices	84
3.2.4 Analysis of factors affecting Glycaemic Indices	86
3.2.4.1 Estimation of amylose and amylopectin contents	
of raw and processed foods	86
3.2.4.2 Estimation of Water Absorption and Water Solubility Indices	87
3.2.4.3 Microscopic examination of starch granules (qualitative study)	88
3.2.4.4 Rate of digestion of different carbohydrates	88
3.2.5 Prediction of glycaemic responses of foods with <i>in vitro</i> hydrolysis	
of starch	94
3.2.5.1 Standard curve of maltose	95
3.2.5.2 Determination of <i>in vitro</i> hydrolysis of starch	95
3.2.6 Estimation of the effect of edible portion of dietary fibre and bulk	

of a meal on Glycaemic Index	98
3.2.7 Determination of glycaemic and insulinaemic responses of type 2 diabetic patients to breakfast meals	99
3.2.8 Determination of the effect of different breakfast meals on the glycaemic and insulinaemic responses to lunch (second meal effect) in type 2 diabetic patients	102
3.2.9 Establishment of a data base of Glycaemic Index values of Sri Lankan foods	102
3.2.10 Statistical analysis	103
4. RESULTS	104
4.1 Proximate compositions of foods	104
4.1.1 Moisture, ash, fat and protein contents of processed foods	104
4.1.2 Digestible, undigestible starch contents and dietary fibre of processed foods	107
4.1.3 Chemical compositions of banana (<i>Musa spp.</i>) varieties	107
4.1.4 Proximate contents of meal accompaniments	109
4.2 Glycaemic Indices of foods	112
4.2.1 Portion sizes of food items	112
4.2.2 Incremental Area Under Curves and Glycaemic Indices of foods	112
4.2.3 Serum glucose responses to foods with enzymatic kit method	113
4.2.4 Incremental Area Under Curves and Glycaemic Indices of foods with	

glucose as the standard using enzymatic kit method and glucometer	118
4.2.5 Factor to convert Glycaemic Index values obtained with one standard to another	118
4.2.6 Categorization of Glycaemic Indices of foods	118
4.2.7 Energy levels of meals	119
4.2.8 Glycaemic Load values of basic foods, mixed meals and bananas	119
4.3 Factors affecting Glycaemic Indices	123
4.3.1 Amylose and amylopectin content	123
4.3.1.1 Correlation between Glycaemic Index values and amylose contents	123
4.3.2 Water Absorption and Water Solubility Indices of raw and processed foods	123
4.3.3 Microscopic examination of starch granules	124
4.3.4 Correlations between Glycaemic Indices of processed foods and nutrient contents	130
4.3.5 Rate of digestion of different carbohydrates	137
4.3.5.1 Correlations between glucose or starch fractions with Glycaemic Indices or Incremental Area Under Curves	137
4.4 Prediction of glycaemic responses with <i>in vitro</i> hydrolysis of starch	142
4.4.1 Rate of hydrolysis of starch of basic foods and mixed meals	142
4.4.2 Correlation between <i>in vivo</i> Glycaemic Indices and <i>in vitro</i> Hydrolysis Indices	144

4.5	Effect of dietary fibre and bulk of a meal on Glycaemic Indices	148
4.5.1	Dietary fibre contents of meals	148
4.5.2	Glycaemic responses to meals	148
4.6	Glycaemic and insulinaemic responses of type 2 diabetic patients to breakfast meals	152
4.6.1	The differences of glucose responses to standard with type 2 diabetic patients and healthy individuals	152
4.7	Effect of different breakfast meals (4.6) on the glycaemic and insulinaemic responses of lunch (second meal effect) in type 2 diabetic patients	153
5.	DISCUSSION	159
6.	CONCLUSIONS	194
7.	REFERENCES	197
8.	APPENDICES	244
	APPENDIX I – Publications and communications	244
	APPENDIX II – Letters of ethical clearance	248
	APPENDIX III – Consent forms given to healthy individuals and type 2 diabetic patients	251

APPENDIX IV	–	Fasting serum glucose concentrations and IAUC values of healthy individuals on different days when standard (white sliced bread) was given	253
APPENDIX V	-	Glycaemic responses to foods with healthy individuals	254
APPENDIX VI	–	Proximate data of wheat flour, rice flour, snake gourd (raw), chickpea and <i>atta roti</i>	255
APPENDIX VII	-	Correlations between IAUC with RDS and SAG/RAG ratio	256
APPENDIX VIII	–	Glycaemic and insulinaemic responses to breakfast and lunch meals with type 2 diabetic patients	257

LIST OF TABLES

Table 2.1	Calculation of GI of meals from individual components	19
Table 2.2	GI and GL of commonly consumed foods	25
Table 2.3	Diagnostic criteria of diabetes	45
Table 3.1	Ingredients of <i>roti</i> and <i>pittu</i> preparations	69
Table 3.2	Foods given to healthy individuals for determination of GI	80
Table 3.3	Volume (V) and concentration (C) values for the different analytes	92
Table 3.4	Amounts (g) of <i>gotukola</i> , <i>kohila</i> and snake gourd included in meals	99
Table 4.1	Moisture, ash, fat and protein contents of processed foods (g/100 g fresh weight)	105
Table 4.2	Digestible starch, undigestible starch, IDF and SDF contents of processed foods (g/100 g fresh weight)	108
Table 4.3	Chemical compositions of bananas (g/100 g fresh weight)	110
Table 4.4	Proximate compositions of meal accompaniments (g/100 g fresh weight)	111
Table 4.5	Portion sizes, IAUC, GI values against bread with enzymatic kit method, glucometer, GL values, categorization values of GI, CV of GI values	114
Table 4.6	Average serum glucose concentrations of foods determined	

	using enzymatic kit	117
Table 4.7	GI values of foods against glucose with enzymatic kit method, glucometer and conversion factors (inter-convertible ratio) of the standard	120
Table 4.8	Amylose, amylopectin, WAI and WSI of processed foods and raw flour	126
Table 4.9	Nutrient contents (g) in 50 g available carbohydrate portions of foods	134
Table 4.10	RAG, SAG, RDS and SDS fractions of basic foods (g/100 g fresh weight)	138
Table 4.11	RAG, SAG, RDS and SDS fractions of mixed meals containing two carbohydrate sources (g/50 g available carbohydrate portion)	139
Table 4.12	Portion sizes and HI (n=6) of basic foods and mixed meals	145
Table 4.13	IDF, SDF, TDF contents, incremental peak serum glucose values, IAUC and GI values of rice meals.	150
Table 4.14	Proximate compositions (g) of foods in 25 g available carbohydrate portions of breakfast meals and lunch	154
Table 4.15	Glycaemic and insulinaemic responses of breakfast meals with type 2 diabetic patients	155
Table 4.16	Glycaemic and insulinaemic responses of lunch meal following the breakfast meals in type 2 diabetic patients	157

LIST OF FIGURES

Figure 4.1	Standard curve of glucose (with enzymatic kit method)	106
Figure 4.2	Standard curve of glucose (with glucometer readings)	116
Figure 4.3	Glycaemic responses to wholemeal bread, wholemeal bread & lentil curry meal and standards (white sliced bread and glucose)	121
Figure 4.4	Glycaemic responses to red rice (AT 353) meals and standards (white sliced bread and glucose)	121
Figure 4.5	Glycaemic responses to manioc, jackfruit, banana (<i>kolikuttu</i>) and standard (white sliced bread)	122
Figure 4.6	Standard curve of amylose	125
Figure 4.7	Correlation between GI values and amylose content of 50 g available carbohydrate portions	127
Figure 4.8	Correlation between GI and IDF content	135
Figure 4.9	Correlation between GI and SDF content	135
Figure 4.10	Correlation between GI and TDF content	136
Figure 4.11	Correlations between glucose or starch fractions with GI or IAUC	140
Figure 4.12	Standard curve of maltose	143
Figure 4.13	Rate of hydrolysis of starch in basic foods and standard (white sliced bread)	146
Figure 4.14	Rate of hydrolysis of starch of mixed meals	147
Figure 4.15	Correlation between <i>in vivo</i> GI and <i>in vitro</i> HI values	147

Figure 4.16	Incremental serum glucose values of rice meals	151
Figure 4.17	Glycaemic responses to (a) breakfast meals and (b) lunch meals following the breakfast meals and standard	156
Figure 4.18	Insulinaemic responses to (a) breakfast meals and (b) lunch meals following the breakfast meals and standard	158

LIST OF PLATES

Plate 3.1	Bread varieties given to healthy individuals	82
Plate 3.2	Mixed meals given to healthy individuals	85
Plate 3.3	<i>In vitro</i> hydrolysis of starch	97
Plate 3.4	Breakfast meals given to type 2 diabetic patients	101
Plate 4.1	Starch granules of raw and processed wheat based foods (10x10)	128
Plate 4.2	Starch granules of raw and processed rice based foods (10x10)	129
Plate 4.3	Starch granules of raw and boiled manioc (10x10)	132
Plate 4.4	Starch granules of raw and boiled jackfruit flesh (10x10)	132
Plate 4.5	Starch granules of raw and boiled jackfruit seeds (10x10)	133
Plate 4.6	Starch granules of raw and cooked lentils (10x10)	133

ABBREVIATIONS

AUC	Area under curve
BMI	Body Mass Index
CV	Coefficient of variation
CHD	Coronary heart disease
CVD	Coronary vascular disease
DM	Diabetes mellitus
FAO	Food and Agricultural Organization
FFA	Free fatty acids
FSG	Free sugar glucose
GER	Gastric emptying rate
GDM	Gestational diabetes mellitus
GLP-1	Glucagons-like peptide 1
GIP	Glucose dependent insulintrophic peptide
GI	Glycaemic index
GL	Glycaemic load
HDL	High density lipoprotein
HI	Hydrolysis index
IGT	Impaired glucose tolerance
IAUC	Incremental area under curve
IDF	Insoluble dietary fibre

IDDM	Insulin dependent diabetes mellitus
IGF-1	Insulin like growth factor-1
IR	Insulin resistance
II	Insulinaemic index
LDL	Low density lipoprotein
NIDDM	Non insulin dependent diabetes mellitus
RAG	Rapidly available glucose
RDS	Rapidly digestible starch
RS	Resistant starch
SCFA	Short chain fatty acids
SAG	Slowly available glucose
SD	Standard deviation
SDS	Slowly digestible starch
SDF	Soluble dietary fibre
SEM	Standard error of mean
TDF	Total dietary fibre
WAI	Water absorption index
WSI	Water solubility index
WHO	World Health Organization

ACKNOWLEDGEMENTS

I am deeply indebted to my supervisor Dr. Sagarika Ekanayake, Department of Biochemistry, Faculty of Medical Sciences; University of Sri Jayewardenepura for her continuous support, guidance and advice given throughout my Ph.D. programme. She was a great source of strength to me during carrying out experimental work, solving practical problems, and writing up processes. I am very grateful for her patience, enthusiasm and motivation during supervision as well as all other times.

My greatest gratitude to my supervisor, Prof. Jayantha Welihinda, Department of Biochemistry and Molecular Biology, University of Colombo for his support, guidance, advice and motivation given during my postgraduate degree programme.

I wish to express my gratitude to everyone who volunteered to participate in this study for devoting their time and being patient throughout the period. Without their selfless contribution this achievement would not have been possible.

I wish to acknowledge the financial assistance given by IFS E3941/1 grant, Sweden, NSF RG/2005/AG/10 grant, NRC 05-03 grant and IPICS Sri-07 grant.

I wish to express my gratitude to Emeritus Professor E.R. Jansz for the encouragement and all the advice given especially at the initial stages of this project.

I wish to thank Prof. Hemantha Peiris, Head/Department of Biochemistry for arranging for study leave to complete my PhD study programme and all academic and non academic staff of Department of Biochemistry for the support given at needed times.

I wish to extend my gratitude to Dr. W.M.A.D.B. Wickramasinghe (Rice Research Institute, Batalagoda) for providing me with the rice samples.

I wish to thank Prof. Renu Wickramasinghe, Head, Department of Parasitology, FMS, USJP for giving permission to use the Parasitology laboratory and facilities and Mr. W.D.I Thilakarathna for the assistance given when using the microscope.

I wish to acknowledge Prof. M.S.A Perera, Department of Family Medicine, FMS, USJP for the assisting given in enrolling type 2 diabetic patients and allowing me to use Family Practice Centre for the study. I would like thank Dr. Malkanthi Galhena, Mrs. L.K.D.T. Dassanayake, Mrs. Amitha Jayawardena and other non academic staff members of Family Practice Centre, FMS, USJP for the kind cooperation given during my study at Family Practice Centre.

Also I wish to acknowledge the consultant medical officer and the staff of Diabetes Clinic, Colombo South Teaching Hospital for their assistance given in enrolling type 2 diabetic patients for the study.

I wish to acknowledge Mr. Samanatha, National Research Council for the assistance given in developing the web site.

I wish to sincerely thank all my research colleagues at the Research Lab, Department of Biochemistry, FMS for their support and sharing their valuable time at critical stages.

Finally I would like to thank my parents and my husband for their unconditional support, encouragement given throughout the study. I wish to especially thank my little son for tolerating me through this difficult period, when he was not getting enough attention from his mother.

I dedicate this thesis to my family.

U.P.K. Hettiaratchi

June, 2009.

ABSTRACT

EFFECTS OF MACRONUTRIENTS AND PHYSICOCHEMICAL PROPERTIES OF CARBOHYDRATES ON GLYCAEMIC INDICES (GI) OF SOME SRI LANKAN FOODS

U.P.K. Hettiaratchi

The glycaemic index (GI) concept ranks basic foods and mixed meals according to the blood glucose response following ingestion of foods. Low GI foods with slow and prolonged glycaemic responses are reported to be beneficial for diabetic patients and in general for non-diabetic individuals. The recent reports imply a markedly high prevalence of diabetes mellitus (DM) in Sri Lanka among both urban (16.4%) and rural populations (8.7%) with one in five adults having either diabetes or pre-diabetes.

Currently, GI values of only basic foods are available with little or no information regarding frequently consumed Sri Lankan mixed meals. The availability of such data will be of value for clinicians and dieticians in planning meals for diabetic patients. The present study was therefore designed to determine the GI values of frequently consumed Sri Lankan foods and mixed meals with healthy individuals. Further, the physicochemical properties (factors) contributing to the differences in GI of foods and the effect of edible portion of fibre on GI were studied. An *in vitro* method was also used to predict the glycaemic responses of mixed meals. The present study further determined the glycaemic and insulinaemic responses to selected foods with type 2 diabetic patients and the second

meal effect of breakfast meals on a subsequent lunch meal as the data regarding glucose and insulin responses to Sri Lankan foods with diabetic patients are not available.

GI values of foods were determined according to Brouns *et al.*, (2005), FAO/WHO, (1998), physicochemical factors by AOAC, standard methods and rapidly and slowly available glucose and starch fractions using a modified method of Englyst *et al.*, (2000). *In vitro* starch hydrolysis was carried out according to Granfeldt *et al.*, (1992).

GI of foods with healthy individuals were as follows: bread varieties [wholemeal bread (103 ± 11), ordinary bakery bread (114 ± 9)], mixed meals [wholemeal bread & lentil curry meal (87 ± 6), red rice & *kiri hodi* meal (99 ± 10), red rice mixed meal (60 ± 5), string hopper meal (wheat flour) (104 ± 7), string hopper meal (red rice flour) (103 ± 11), manioc meal (120 ± 9), jackfruit meal (75 ± 11)], and bananas [*kolikuttu* (61 ± 5), *embul* (61 ± 5), *anamalu* (67 ± 7), *seeni kesel* (69 ± 9)]. The red rice mixed meal, jackfruit meal and bananas can be categorized as low GI, wholemeal bread & lentil curry meal as medium GI and all other foods as high GI foods. The rice mixed meal yielded the lowest GI among the foods analyzed.

The GI values obtained using a bread of Sri Lankan origin as the standard can be converted to GI values expected against glucose by a conversion factor of 1.34. This enables reporting GI data with respect to glucose for comparison with the internationally reported values.

The GI values determined with the conventional enzymatic kit method were not significantly different ($p > 0.05$) to that of the GI values calculated using a glucometer

(Accu-Check Active, Roche Diagnostics GmbH, Germany) thus indicating the potential to use this particular glucometer when determining GI values.

Significant negative correlations ($p < 0.05$) were observed with GI & insoluble dietary fibre (IDF) ($p = 0.032$), soluble dietary fibre (SDF) ($p = 0.010$) and total dietary fibre (TDF) ($p = 0.038$) contents of 50 g available carbohydrate portions of basic foods and mixed meals.

Protein and amylose contents of portions given for determination of GI indicated non significant negative relationships ($p = 0.165$ and $p = 0.054$ respectively) with GI values.

The wet heat processed foods analyzed in this study that elicited high GI values had disintegrated starch granules compared with the raw flour. The observed effect on the starch granules of the foods studied in this thesis was due to the gelatinization of starch granules during wet processing highlighting the impact of processing methods on GI for the foods concerned.

When the rapidly available glucose (RAG), slowly available glucose (SAG), rapidly digestible starch (RDS) and slowly digestible starch (SDS) contents of portions given for determination of GI in basic foods and mixed meals were correlated with GI values, significant positive correlations ($p < 0.05$) were observed with RAG ($p = 0.023$), RDS ($p = 0.011$) fractions and significant negative correlation with SAG/RAG ($p = 0.036$) ratio. This indicates that the rapidly available carbohydrates of a food/meal could be taken as a food related determinant of GI.

As a novel approach a standard *in vitro* method was used to predict GI values of mixed meals by estimating the hydrolysis indices (HI) of composite meals. The *in vitro* HI values

indicated a significant positive correlation ($p=0.0001$) with *in vivo* GI values of both basic foods and mixed meals.

The GI of a rice meal declined by 9% with an increase of 7.2% TDF content as meal accompaniments of a part of a rice meal.

Three breakfast meals (chickpea, red rice meal, *atta roti*) were given to type 2 diabetics. GI values of three meals were 40 ± 7 (low GI), 64 ± 11 (low GI), 88 ± 9 (medium GI) and the insulinaemic indices (II) were 76 ± 13 , 90 ± 20 and 115 ± 28 respectively. The glycaemic responses of the meals analyzed indicated a positive linear relationship ($r=0.9838$) with the corresponding insulinaemic responses. The GI values of the meals with diabetic patients were not significantly different ($p>0.05$) from healthy individuals but slightly higher than the values reported with healthy individuals. The peak serum glucose levels of chickpea, rice and *roti* declined by 27%, 13%, 4% respectively compared with the standard (bread).

The effects of above breakfast meals on the glycaemic and insulinaemic responses of a standard rice lunch meal (second meal effect) were analyzed. According to the results obtained none of the breakfast meals elicited an effect on the subsequent lunch.