GLYCAEMIC RESPONSE TO SELECTED BREAKFAST ITEMS IN DIABETICS

BY

LATHA VIJAYAN
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ANDHRA PRADESH AGRICULTURAL UNIVERSITY
RAJENDRANAGAR, HYDERABAD-500 030.

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CERTIFICATE

Ms.LATHA VIJAYAN has satisfactorily prosecuted the course of research and that the thesis entitled **GLYCAEMIC RESPONSE TO SELECTED BREAKFAST ITEMS IN DIABETICS** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by her for a degree of any university.

S. Sumathi

Date: 28.8.'92

(Dr.(Mrs.) S.SUMATHI)
MAJOR ADVISOR

CERTIFICATE

This is to certify that the thesis entitled **GLYCAEMIC RESPONSE TO SELECTED BREAKFAST ITEMS IN DIABETICS** submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN HOME SCIENCE** of the Andhra Pradesh Agricultural University, Hyderabad is a record of the bonafide research work carried out by **Ms.LATHA VIJAYAN** under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigation have been duly acknowledged by the author of the thesis.

S. Sumathi
(Dr.(Mrs) S.SUMATHI)
Chairman of the Advisory Committee

Thesis approved by the Student Advisory Committee

Chairman : **(Dr.(Mrs) S.SUMATHI)** S. Sumathi

Member : **(Dr.(Mrs) KAMINI DEVI)** Kamini Devi

Member : **(Mrs. KUSUMA RAO)** Kusuma Rao

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(LATHA VIJAYAN)

DECLARATION

I, **LATHA VIJAYAN** hereby declare that the thesis entitled **GLYCAEMIC RESPONSE TO SELECTED BREAK-FAST ITEMS IN DIABETICS** submitted to Andhra Pradesh Agricultural University for the Degree of **MASTER OF SCIENCE IN HOME SCIENCE** is a result of original research work done by me. I also declare that my material contained in the thesis has not been published earlier.

Latha Vijayan

Date: 28.8.92

(LATHA VIJAYAN)

Name of the Author	:	**LATHA VIJAYAN**
I.D. No.	:	**HFN 90-6**
Title of the thesis	:	**GLYCAEMIC RESPONSE TO SELECTED BREAKFAST ITEMS IN DIABETICS**
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Department	:	**FOODS AND NUTRITION**
Major Advisor	:	**Dr.(Mrs.) S.SUMATHI**
University	:	**ANDHRA PRADESH AGRICULTURAL UNIVERSITY**
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ABSTRACT

Diabetes mellitus - a common metabolic disorder is the third commonest disease in the world next to cardiovascular and oncological disorders. In India, the prevalence rate of this disease is 2-4 per cent and is being treated with drugs and more recently with dietary modifications also.

Recent studies on effective dietary treatment for diabetics have led to the classification of low and high glycaemic foods based on their glycaemic response, which reflects the physiological response of food apart from just the effect of carbohydrate.

In the present study, the glycaemic response to four commonly consumed breakfast items of Kerala, namely puttu, idiappam, appam and tapioca was studied in six non-insulin-dependent diabetic Malayalee men. All the breakfast items tested were isocaloric and had almost similar nutrient contents. Each of the test breakfast items and a 75 g glucose load was given in a random order after an overnight fast to the subjects. The blood samples collected were analyzed for plasma glucose by the glucose oxidase-peroxidase method. The glycaemic response to the breakfast items as compared to that of glucose in the diabetic subjects was determined by comparing the areas under the 2-hour glucose response curves.

Results obtained indicate that the mean peak rise over fasting levels was significantly lower (P < 0.05) after only puttu consumption when compared to the oral glucose tolerance test (OGTT). However, the mean AUC was significantly lower (P<0.05) after consumption of puttu, idiappam and tapioca when compared to that of OGTT. The mean glycaemic response to puttu (0.79) was found to be the lowest of the four breakfast items served to the subjects followed by that of idiappam (0.86), appam (0.90) and Tapioca (0.93). But, no significant difference (P>0.05) was found in the glycaemic responses among the different breakfast items.

Among the breakfast items tested which are commonly consumed by Malayalees, puttu may be recommended for diabetics. Results of the present study suggest that even traditionally used cereal based food items may be identified by the lower glycaemic response and can be recommended for diabetics.

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LIST OF ABBREVIATIONS

OGTT	:	Oral glucose tolerance test
CHO	:	Carbohydrate
NIDDM	:	Non-insulin-dependent diabetes mellitus
IDDM	:	Insulin-dependent diabetes mellitus
AUC	:	Area under glucose response curve
GI	:	Glycaemic index
GR	:	Glycaemic response
VLCD	:	Very low calorie diet.

INTRODUCTION

CHAPTER 1

INTRODUCTION

Diabetes mellitus is a disease of metabolism characterized by the lessened ability or the complete inability of tissues to utilize carbohydrate, accompanied by striking changes in the metabolism of fat and protein. Excessive thirst and urination, glycosuria, weight loss and hyperglycaemia are cardinal findings.

The term Diabetes mellitus was derived from the Greek words meaning passing through and sweet as honey. Normally, the food consumed is converted within the body into glucose which is used as a source of energy by the cells (only utilisable source for the brain cells). An increase in the blood glucose levels signals the release of the hormone insulin from the Beta-cells (islets of Langerhans) of the pancreas. Insulin regulates the level of glucose in the body; and thus a deficiency of insulin leads to increase in glucose levels of blood.

The fundamental abnormality, hence, in diabetic metabolism is impaired utilisation of glucose. The result is, at the very least, danger to the one fundamental process of maintenance of life viz., the production of energy. This danger stimulates the diabetic body to compensatory measures by a number of adaptive reactions. The threat to the supply of energy is due to diminished oxidative degradation. This threat to energy supply may also be due to different etiological mechanisms. Thus, this disturbance of metabolism in diabetes is not a single independent self-contained abnormality. The defect may not always be due to a deficiency of insulin, but a majority of diabetic cases are related to the availability of insulin.

WHO study group on diabetes mellitus (1985) report that if the random plasma glucose is greater than 200 mg/dl on more than two occassions, a diagnosis of diabetes may be made. Only if the random plasma glucose values lie in the uncertain range (100 to 200 mg/dl), need an oral glucose tolerance test (OGTT) be considered to establish the diagnostic status. Diagnostic interpretation of OGTT response is shown in Table 1.

Table 1: Diagnostic values for the oral glucose tolerance test

	Glucose concentration (mg/dl)			
	Whole blood		Plasma	
	Venous	Capillary	Venous	Capillary
Diabetes mellitus				
Fasting value	≥120	≥120	≥140	≥140
2 hrs after glucose load*	≥180	≥200	≥200	≥200
Impaired glucose tolerance				
Fasting value	<120	<120	<140	<140
2 hrs after glucose load*	120-180	140-200	140-200	160-220

* for epidemiological or population screening purposes the 2-hour value after 75 g oral glucose may be used alone or with the fasting value. The fasting value alone is considered less reliable since true fasting cannot be assured and spurious diagnosis of diabetes may more readily occur

Diabetes mellitus is of several types varying in the course of the disease. The American Diabetic Association at its annual meeting (1979) classified diabetes mellitus as Type I and Type II diabetes. Type I is insulin-dependent diabetes and it can occur at any age. This type of diabetes is also known as juvenile onset diabetes. Because the pancreas produces little or no insulin, such patients become dependent on outside sources of insulin. The disease can be controlled with insulin, proper diet and exercise, and careful monitoring. Type 11 is non-insulin dependent diabetes, in which additional insulin is not usually required to sustain life. This type of diabetes also called maturity onset diabetes is much more common than type 1 and can affect both obese and non obese individuals. The insulin secretion in this case is either not enough or not produced quickly enough to influence glucose levels in blood effectively. It can be controlled by diet alone, or a combination of diet, exercise and oral medication. The other types are impaired glucose tolerance, gestational diabetes mellitus, malnutrition related diabetes mellitus (MRDM), diabetes induced by drugs or chemicals and diabetes secondary to pancreatic/endocrine disease. These types occur less frequently.

Diabetes mellitus afflicts a large numbers of people of all social conditions throughout the world. Globally, there are atleast thirty million diabetics (WHO report, 1985) and in India, the prevalence rate is 2-4 % of which 90% are non-insulin dependent diabetics (Raghuram et al., 1991). In a recent study, Ramachandran et al (1988) reported a high prevalence of diabetes (41% in the age group of 55-64 years and 20% in people over 40 years of age) in an urban population of South India.

The principal means of management of diabetes mellitus are dietary modifications, maintaining normal body weight, adequate physical activity, use of oral hypo-glycaemic agents and administration of insulin if necessary. Among the factors in the package of treatment of diabetes, diet remains the cornerstone especially for non-insulin dependent diabetes mellitus (NIDDM).

Dietary measures in diabetes are intended to help optimize blood glucose levels, to achieve weight loss in the obese, to reduce the risk of hypo-glycaemia in the insulin treated patients and to reduce the risk of long term complications. The use of carbohydrate both in terms of quantity as well as quality in a diabetic diet has always been a key therapeutic issue. The amount of total carbohydrate recommended for the diabetic diet has varied significantly over the years. However, from 1970 onwards, diabetic associations of several countries have been recommending diets with high carbohydrate and restricted fat. The American Diabetic Association (1986) in a recent report has recommended that the amount of carbohydrates should be liberalized, ideally upto 55-60% of the total calories and the amount individualized depending upon the impact on blood glucose levels and individual eating patterns.

There are many traditional beliefs regarding the type of carbohydrate in the diabetic diet which in recent years are questioned. According to traditional thought, simple sugars are rapidly digested and absorbed and therefore diabetics should restrict preparations containing simple sugars.

However, recent studies (Jenkins and Coworkers, 1981; and Crapo et al., 1977) have demonstrated that equivalent amounts of carbohydrates give a different response depending on the kind of food consumed. They have reported that various carbohydrate foods have different absorption patterns raising the blood sugar to a variable extent; and thus simple carbohydrate exchanges based on chemical analysis are not sufficient to predict the physiological response. It is now suggested that the biological equivalents (i.e., the quantity of food yielding the same effect on blood glucose) or the glycemic response of a food should also be taken into account. As a measure of glycaemic response, the use of glycaemic index (GI) to classify carbohydrate containing foods into low and high glycaemic foods has been suggested. Glycaemic index is based on blood glucose response to a food in comparison with response to an equivalent amount of glucose. Jenkins et al (1981) and Walker and Walker (1984) published glycaemic indexes of several Western and African foods. From their studies, it was evident that contrary to conventional belief, ingestion of simple sugars like fructose results in a glycaemic response that is 20-29% that of glucose intake, whereas ingestion of an equivalent amount of complex carbohydrates in carrots and potatoes resulted in a blood glucose response that is 80-90% of glucose.

But, later studies have questioned the validity of this GI, since diabetic patients very rarely eat carbohydrates in isolation (Coulston et al,1984). Thus, it is now suggested that it would be more appropriate to plan the use of high carbohydrate foods in diabetic diet in relation to their glycaemic response when included in a standard meal rather than in relation to individual GI.

The glycaemic and insulin responses to commonly consumed Indian breakfast items have been studied (Raghuram et al, 1987; Vishwanathan et al, 1988; Vimala and Easwaran, 1988). Of the preparations tested, Pongal and Pesarattu were found to be suitable for diabetics as the glycaemic responses were comparatively low. These preparations are mainly made with a combination of a cereal and a pulse. But in Kerala, the southernmost tip of India, most of the breakfast preparations are mainly cereal (rice) based; and there is a paucity of data on the glycaemic response of the breakfast preparations of this State.

Since diabetes is a condition that affects a person throughout his life, it is better to modify the diet considering the traditional eating patterns for better and longer compliance. It was therefore felt necessary to undertake this study to determine the glycaemic responses of some breakfast items commonly consumed by Keralites like puttu, idiappam, appam and boiled tapioca. The objective of this study was to assess the glycaemic response of the breakfast items in comparison with glucose in non-insulin-dependent diabetic subjects.

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REVIEW OF LITERATURE

CHAPTER 11

REVIEW OF LITERATURE

Diabetes mellitus is a metabolic disorder with a widespread prevalence throughout the world. Diabetes mellitus is mainly of two types: Insulin - Dependent Diabetes Mellitus (IDDM) or type I Diabetes mellitus and Non-Insulin - dependent Diabetes Mellitus (NIDDM) or type II Diabetes mellitus of which the latter is more prevalent in India (90 per cent of the 2-4% cases reported) [Raghuram et al, 1991]. Diet has been recognised as a cornerstone of therapy for this disorder (mainly NIDDM) since the disease was first described. Evidence is continuing to grow that good diabetic control (usually achieved only with good dietary management) is important in prevention or delay of the debilitating complications of diabetes mellitus. Yet, if one looks at the history of therapeutic dietary efforts from the early historic accounts to the present, one sees wide swings between different dietary approaches with no clear progression in scientific thought. Although current dietary measures are to some extent successful, new research suggests that there may be even more effective dietary strategies, mainly involving modifications in the various nutrients of the diet.

Foods were first considered from the point of view of their carbohydrate content in the dietetic treatment of diabetes mellitus. However, recent work has suggested that the carbohydrate exchange lists that have regulated the diet of many diabetics for over three decades may not reflect the physiological effect of foods. Such factors as food form, dietary fibre and the nature of the carbohydrate have been shown to have a marked influence on the postprandial glycaemia and allowances cannot be made for these in lists which take into account only the available carbohydrate content of foods. So, it is now suggested that the glycaemic response i.e., the biological equivalence of a food, also be taken into account (Jenkins et al, 1984). This is mainly due to experiments showing that equivalent amounts of carbohydrate gives a different response depending on the kind of food consumed (Jenkins et al, 1981; Crapo et al, 1977). As a measure of glycemic response they have suggested the use of glycemic index (GI) to classify carbohydrate containing foods into low and high glycemic substances. GI is based on blood glucose response to a food in comparison with response to an equivalent amount of standard food (glucose/bread). Thus, they have reported a high GI for root vegetables (70%), followed by cereals (65%), biscuits (60%), fruits (50%), dairy products (35%) and legumes (31%) in normal individuals. It was recommended that GI be used when designing a diabetic diet, but later studies questioned the validity of this since diabetic patients very rarely eat carbohydrates in isolation (Coulston et al, 1984).

Thus, it is now suggested that it would be more appropriate to plan the use of high carbohydrate foods in the diabetic diet in relation to their glycaemic response when included in a standard meal rather than in relation to individual glycaemic index. The literature review has thus been arranged in the following order:

(a) Role of nutrients in a diabetic diet.

(i) Carbohydrate

(ii) Proteins

(iii) Fats

(iv) Calorie allowance

(b) Glycaemic response to different foods

(c) Factors affecting glycaemic response

(d) Effect of differences in glucose tolerance

2.1 ROLE OF NUTRIENTS IN A DIABETIC DIET

Blood sugar levels in a normal individual are maintained because of a delicate balance between the processes that add and remove glucose from blood. The major nutrients of the diet such as carbohydrate, protein and fats play different roles in controlling the post prandial blood glucose levels. The effect of these nutrients is briefly presented.

2.1.1 Carbohydrates

The use of carbohydrates in the diabetic diet has always been a key therapeutic issue both as to the amount of total carbohydrate and the particular type of carbohydrate to be used.

2.1.1.1 Amount of Carbohydrate:

The amount of total carbohydrate recommended for the diabetic has varied significantly over the years. Throughout most of this century, low carbohydrate diets were widely used, but a liberalisation in the carbohydrate content of diet occurred in the early 1970s and is still being advocated. This position was supported by observations that high carbohydrate intakes led to improvement in glucose tolerance and insulin sensitivity (Reaven, 1986).

A recent recommendation by the American Diabetic Association (1986) based on information accumulated since 1979 suggests that the amount of carbohydrates should be liberalized, ideally upto 55-60% of the total calories, and individualised, with the amount dependent on the impact on blood glucose and lipid levels and individual eating patterns.

Nevertheless, the issue of how much carbohydrate should be in the diabetic diet still remains controversial.

2.1.1.2 Type of Carbohydrate (CHO):

According to traditional thought of the early 1930s, simple sugars were to be limited and dietary CHO intake was primarily to come from complex CHOs or starches. The assumption was that complex CHOs are more slowly digested and absorbed than are simple sugars and that they therefore cause a flattened blood glucose rise. All complex CHOs were considered to have similar effects on blood glucose and insulin responses. However, recent studies have demonstrated that there are significantly different blood glucose and insulin responses to different types of simple and complex CHOs.

Crapo et al (1976) demonstrated in normal subjects that glucose and sucrose elicited similar plasma glucose reponse curves, but plasma insulin response of sucrose was somewhat greater (20%). Raw starch ingestion resulted in a 44% lower glucose response and a 35-65% lower insulin response than did either glucose or sucrose ingestion.

In yet another study on complex CHOs, a comparison of glucose, potato, bread, rice and corn showed that the nature of the starch itself may be of major importance in determining the glucose and insulin response and may be part of the reason for differences in glycaemic responses seen between cereals and legumes

(Crapo et al, 1977). They reported that dextrose and potato elicited similar plasma glucose and insulin responses but greater than rice and corn in normal subjects. Similar results were reported in individuals with impaired glucose tolerance (Crapo et al., 1980; Coulston et al., 1981) and in NIDDM patients (Crapo et al., 1981; Coulston et al., 1984).

However, these results have not been very consistent. Bantle et al (1983) reported that there was no significant difference in the serum glucose and insulin response between five different meals varying only in the form of CHO (glucose, fructose, sucrose, potato starch and wheat starch) in both normal and diabetic subjects. The meal containing sucrose as test CHO produced the greatest and that containing fructose the smallest increments in plasma glucose levels, but the differences were not statistically significant. Thus, this study does not support the view that dietary sucrose when consumed as part of a meal aggravates postprandial hyperglycaemia. The variation in this study could be due to the differences in meal composition and the form of administration of the meal. Also, the extra calories contained in potato and wheat meals could have influenced the results. Similar results were reported by Nielson and Thuesen (1988) that glycaemic response did not differ significantly according to CHO source (maize and potato).

Blood glucose response varies among the various simple CHO sources also. Samantha et al (1985) studied the hyperglycaemic effect of glucose, sucrose and honey equivalent to 20 gms CHO in normal and diabetic subjects. They reported that honey produced an attenuated postprandial glycaemic response in normal and IDDM subjects (versus glucose $p < 0.005$; vs sucrose $p < 0.05$). In yet another study, Bornet et al (1985) reported that simple sugars (sucrose or honey) have no additional hyperglycaemic effect over an isoglucidic amount of bread in type II diabetic subjects, even at the critical morning period, i.e. breakfast. Thus, honey may prove to be a valuable sugar substitute for diabetics.

However, variations in the per cent of complex and simple CHOs included in a mixed food diet had variable effects on the plasma glucose and insulin response in NIDDM individuals (Hollenbeck et al, 1985). They reported that the mean day long blood glucose concentration was significantly greater for the diet that contained 20% simple and 0% of complex CHO than two other diets (50% complex and 50% simple; 20% complex and 0% simple). In contrast, the day long insulin concentrations were not significantly different for the three diets.

Among the various CHO sources, spaghetti is another CHO that elicited significantly lower glycaemic response than rice and potato in IDDM and NIDDM subjects; and this difference remained when spaghetti and potato were taken as part of a mixed meal (Rasmussen et al, 1988).

The variations in the blood glucose response to different kinds of CHO led to a new hypothesis that the glucose component of food and not the total CHO is the main determinant of glycaemic response. Hughes et al (1989) tested this hypothesis in IDDM patients. The patients were given glucose alone, fructose alone, glucose plus fructose/lactose or glucose plus protein/fat. Fructose given alone increased the blood glucose almost as much as a similar amount of glucose (78% of the glucose alone area). The same amount of fructose given with glucose produced no greater glycaemic response than did glucose alone (108%). Similarly, galactose contributed only slightly to the glycaemic response when given as lactose (122%) whereas protein and fat had no additional glycaemic effect (101%). To test this hypothesis in natural foods, they gave the patients an amount of bread (high GI) or apple (low GI) that contained 25 gms glucose. Both challenges produced glycaemic responses very similar to 25 gms purified glucose.

Similar findings were reported by Dukar <u>et al</u> (1990). They compared a cholesterol free tofu based frozen dessert (TFD) containing high fructose corn syrups with a dairy based sucrose sweetened ice-cream (IC) in NIDDM subjects. The TFD elicited a higher glycaemic response than IC in spite of a high sucrose content of IC. They reported that this unexpected response was related to the substantial amount of total glucose in this "fructose" dessert.

Thus, it is possible that a variety of CHO sources at different levels of total CHO are consistent with diabetic control, provided that the types of CHO used are those that have less of a glycaemic impact. More appropriately, diets with lower total glucose content have to be encouraged.

2.1.2 Protein

A high protein diet has a beneficial effect in the treatment of diabetes. Seino <u>et al</u> (1983) reported that the administration of a high protein diet for eight days to mild diabetic patients abated their glucose tolerance considerably, and the insulin response was augmented significantly from the measurements taken after a balanced diet period. Thus, the high protein diet produced a relative improvement in plasma insulin responses for the blood glucose levels attained following the balanced meal.

In yet another study on the blood glucose and plasma insulin responses of mild diabetics to high protein divided meals, it was suggested that the best meal for mild diabetics is a divided meal (separated by 30 minutes) with the first portion containing as much protein as practicable (Seino et al, 1983).

The nature/type of the protein incorporated in a diet also has been reported to have variable effects on the blood glucose and insulin responses (Villaume et al., 1986; Gannon et al., 1988).

Kawai et al (1987) have reported similar findings that the increases in plasma glucose and insulin were the smallest with a high protein meal when compared to an oral glucose load, a mixed meal or a high fat meal.

Thus, the role of protein content of the diet seems to blunt the rate of increase in blood glucose by augmenting the plasma insulin levels. Vishwanathan et al. (1981) and Swapna Rastogi (1989) have suggested that proteins in a diabetic diet should provide 20% of total calories.

2.1.3 Fat

The effect of co-ingestion of 50 gms fat (butter) to 50 gms CHO (potato) or 50 gms protein (low fat meal) on postprandial glucose and insulin responses was examined in 8 normal subjects (Collier and O'Dea, 1983). They reported that the addition of fat to a CHO meal reduced postprandial glucose response and this could have been due to a delayed glucose absorption, secondary to a fat induced inhibition of gastric emptying. But, despite the lower blood glucose levels, the insulin response was not reduced suggesting a potentiation of insulin secretion in the presence of fat. Thus, they concluded that despite the apparent improvement in glucose tolerance when CHO is ingested together with fat, the accompanying potentiation of insulin secretion could form the basis of long term changes in insulin sensitivity which accompanies alteration in dietary fat intake.

The effect of fish oil supplementation on glucose metabolism was studied in ten NIDDM subjects (Dorkman et al, 1989). The subjects were fed a standard diabetic diet along with (1) no supplementation (baseline), (2) ten gms fish oil concentrate (30% omega-3 fatty acids) daily and (3) ten gms safflower oil daily over separate three week periods. They reported that dietary fish oils supplementation adversely affected glycaemic control in NIDDM patients. Also, the effect of safflower oil supplementation was not significantly different from fish oil, suggesting that the negative effects on glucose metabolism may be related to the extra energy from fat intake.

Thus, a low fat, high CHO, high fibre diet has been recommended as ideal for diabetics as the most significant metabolic control was obtained with such a diet (O'Dea et al., 1989). A reduction of fats in the diabetic ration to 30-35 per cent of the total caloric intake is recommended.

However, the effect of addition of protein and fat to isolated sources of CHO may be quite different from the interactions of protein, fat and CHO in an intact food. Nevertheless, it should be recognised that not only CHO but also protein and perhaps in some situations fat can also affect the blood glucose response to a food.

2.1.4 Calorie allowance

The fundamental principle in the dietary therapy of diabetes is to give the individual the minimum food necessary for the body's daily requirement. The total calories in the diabetic diet is therefore restricted, keeping in mind individual variations according to age, sex, physical activity so that the modified diet would ensure patient's cooperation and compliance (Padmalayam and Vishwanathan, 1989).

The recommended calorie requirement of a person with normal body weight is 25 to 30 Kcal/kg ideal body weight (IBW). For an overweight (underweight) diabetic, 5 Kcal/kg IBW is decreased (increased), and if he/she is a sedentary (heavy) worker, 10 Kcal/kg IBW is decreased (increased) [Khosla, 1989].

Weight reduction is one of the most effective therapies for obese NIDDM patients. The development of very low calorie diets (VLCD) over the last two decades has provided an alternative to the treatment of obese NIDDM. VLCDs provide 400 Kcal/day of carbohydrate and high quality protein fortified with vitamins, minerals and trace elements. Several workers have reported that VLCD in NIDDM patients leads to an improvement in beta-cell function and peripheral insulin resistance (Henry and Cumbiner, 1991). Fukuda et al, (1989) have also reported that VLCD improved glucose tolerance and insulin response to a glucose load in diabetics. Numerous controversies surround VLCD therapy, the most critical of which is its safety. Thus, such diets should only be used for short periods of upto four weeks (Padmalayam and Vishwanathan, 1989).

2.2 GLYCAEMIC RESPONSE TO DIFFERENT FOODS (EFFECT OF FOOD COMPOSITION)

Glycaemic response or the biological equivalence of a food has been suggested to be more appropriate to plan the use of high CHO foods in a diabetic diet as it reflects the physiological effects of food, apart from just the effect of CHO content.

Thus, food is more than a sum of its major nutrients as concluded by Sud et al (1980) from their study on comparison of glycaemic response of natural foods to the meal equivalents of these foods in terms of CHO, protein, fat and fibre content. They reported that natural foods gave a significantly different glycaemic and insulin response compared to the meal equivalents to these foods.

Several poorly understood factors may contribute to the glycaemic response of a food. In addition to the quantity of nutrients, the response may be a result of specific types of nutrients, non-nutrient chemicals and anti-nutrients composing the food, and their unique physical arrangement within the food. Also, the process of digestion, absorption and subsequent metabolic responses are more complicated than perhaps previously appreciated; and thus recent studies have begun to elucidate which factors are most critical in determining the glycaemic response to ingested food.

2.3 FACTORS AFFECTING GLYCAEMIC RESPONSE

2.3.1 Dietary Fibre Content

In recent years, claims have been made that dietary fibre improves or cures many clinical conditions including diabetes. Studies have demonstrated that diets containing high fibre and high CHO levels are associated with lower blood glucose levels (Anderson and Ward, 1979).

Bose (1979) has reported that the routine Bengali diet is high in dietary fibre content and the normal persons consuming this diet are less prone to hyperglycaemia and the Bengali diabetics can conveniently keep their blood sugar levels under control by sticking to this fibre rich diet. Similar results were reported by Rivellese et al (1980) that a high fibre normal CHO diet (CHO - 53%, fibre - 54 gms) elicited a significantly lower postprandial glucose level than 2 other diets that contained lesser amounts of fibre (16 gms and 20 gms).

Different sources of dietary fibre have a different effect on blood glucose levels due to the nature of fibre components. Bramaramba (1988) studied the effect of different sources of fibre (at the level of 15 g) like wheat bran (cereal source), green gram husk (legume source), amaranth (leafy vegetable source) and isabgol (commercial source), as part of a normal diet in normal subjects. Among all the diets, isabgol, green gram husk and amaranth diets showed low blood glucose values indicating that they have a better effect. Wheat bran had little effect on blood glucose levels.

Other studies have also indicated that cereal fibre content does not appear to be a major factor in determining subsequent metabolic response. O'Dea et al (1980) have demonstrated that there is no significant difference in glycaemic response between whole white and brown rice, both eliciting a similar glycaemic curve. Rasmussen et al (1991) also reported that the difference in the extraction rate of wheat in the form of white flour, and whole meal flour (high fibre) was not reflected in glycaemic responses in IDDM subjects.

Baumer et al (1982) reported that a low fibre diet in IDDM children resulted in highest blood glucose concentration after breakfast compared to the medium and high fibre diet; and that the bean diet produced the lowest mean blood glucose level. The effectiveness of beans in the dietary control of diabetes may be due to the colloidal and fibrous composition, relatively high protein and low CHO contents, which results in satiety, reduces the rate of gastric emptying and increases CHO oxidation (Azinge, 1985).

The low glycaemic response to legume meals which have high fibre content may be due to the reduced rate of gastric emptying, reduced rate of small intestinal absorption and the difference in fibre content. The legume seed fibre, guar gum appears to have the ability to not only flatten blood glucose response following a guar sucrose mixture but also result in a definite improvement in glucose tolerance when glucose is taken four hours later (Jenkins et al, 1980). Addition of guar to a meal is reported to be beneficial in both healthy and diabetic (IDDM and NIDDM) individuals (Goulder et al, 1978; Mcivor et al, 1985). Guar gum and pectin have proved to be beneficial in controlling hyperglycaemia in both short term and long term studies (Gupta et al, 1989).

Among the commonly used legumes, bengal gram dal and rajmah reduce post prandial plasma glucose (Dilwari et al, 1981). They reported that this effect was indirectly related to the concentrated fibre content in the legumes.

The effect of different proportions of rice and bengal gram in a diet on post prandial glycaemia in normal subjects was assessed and it was reported that the higher the pulse contribution in the diet, the lower was the blood glucose response (Radhika, 1986). The diets with high cereal CHO content showed higher and delayed (at 2 hours) blood glucose peaks than the diets with high pulse CHO which showed early peak (at 1 hour), but at a significantly lower level.

Vegetables containing cellulose when added to breakfast have also shown to exert a good effect upon the blood glucose level (Korotkova et al, 1983).

The effect of different levels of fibre (25 g, 50 g and 75 g) from three commonly consumed vegetables (Ponnaganni, Colocasia leaves and Bittergourd) on post prandial glycaemia in normal and NIDDM patients was assessed (Sreedevi, 1988). A negative correlation between level of fibre and blood glucose values was reported. Bittergourd was more effective in lowering post prandial glucose values than the other two vegetables tested.

The beneficial effect of bittergourd (Karela) was also reported by Upadhyaya et al (1985) where the intake of Karela (Momordica charantia) powder (2 g/24 hours) along with normal diet for a period of 11 days resulted in lowered blood glucose levels than the corresponding glucose level in glucose tolerance prior to Karela treatment.

Fenugreek, a condiment that is commonly used in Indian homes has also shown to have a beneficial effect on the blood glucose levels. Administration of 25 g of fenugreek seeds per day to normal and diabetic subjects for 21 days resulted in a lowered blood glucose concentration and increased insulin response (Sharma, 1986).

A high CHO, high fibre diet results in prolonged carbohydrate digestion/absorption and has shown to improve diabetic control and allow reduction of insulin or oral hypoglycaemic agent dosages (Barnard et al, 1983; Haqander et al., 1984) but it has been difficult to quantify the contribution of fibre to the glycaemic results. Hollenbeck et al (1986) assessed the impact of variations in the amount of fibre in high CHO diets on CHO metabolism in NIDDM patients. The amount and source of CHO and source of dietary fibre were held constant. They reported that an increase in fibre content from 11 to 27 gms / 1000 Kcal did not lead to measurable improvements in overall plasma glucose or insulin metabolisms. Thus, the amount of dietary fibre in foods required for a positive glycaemic effect is not yet clear.

Jenkins et al (1986) have reported that traditional processing of cereals, such as parboiling or the use of whole grains in bread may result in the low GI value associated with unmilled cereals. Other studies (Heinomen et al., 1985; Jenkins et al., 1988; Rasmussen et al., 1991) have reported that whole grain breads which contain a high proportion of whole cereal grains may be useful in reducing the postprandial blood glucose profile in diabetics because they are more slowly digested.

The effect of fibre on glycaemic response has been quite variable in some studies. Behall et al (1984) reported that consumption of the basal diet with addition of isolated fibre source (cellulose/carboxymethyl cellulose/karayagum or locust bean gum) did not significantly change fasting serum levels of glucose and insulin from levels observed after basal diet alone. This study is consistent with the lack of effect of cereal fibre on postprandial glucose levels; both of which may be related to the soluble and insoluble components of the fibre source.

Toma et al (1988) have reported that high soluble fibre meal produced significantly lower glucose and insulin responses than did low fibre or high insoluble fibre meals. However, water insoluble fibres may contribute to long term control of blood glucose through some mechanism other than the acute reduction of blood glucose level. Thus, fruits and vegetables which have viscous water soluble pectins and the fibre in the legume family of foods elicit exceptionally low glycaemic responses.

Thus, current evidence suggest that diets containing high fibre diets specially of the soluble type may offer some improvement in CHO metabolism, lower cholesterol and have other benefecial effects in NIDDM patients. An intake of upto 40 gms of fibre per day or 25 gms/1000 Kcal of food intake appears beneficial. In many individuals on weight reducing diets, higher levels may be unacceptable because of gastro-intestinal side-effects. The level of fibre which can elicit maximum benefit has not been determined. Fibre supplementation appears beneficial only if given with the diet comrising approximately half of the calorie as CHO (Vinik and Jenkins, 1988). It has also been reported that high fibre diets are beneficial only against a background of high CHOs (Ramani Char, 1988). Foods should be selected with moderate to high amounts of dietary fibre from a wide variety of choices to include both soluble and insoluble types of fibre. Insufficient data are available on the long term safety of high fibre supplements (Vinik & Jenkins, 1988).

Hence, fibre may be one of a number of factors that affect blood glucose as well as other aspects of health. An increased dietary fibre content may provide definite benefit in a total dietary program. The degree of fibre supplementation necessary to provide such benefit however is not well-defined.

2.3.2 Food Form

Physical form of food is of particular importance in determining the postprandial glucose and insulin responses as it is another factor which may affect the starch digestibility of CHO foods. O'Dea et al. (1980) have reported that while natural fibre content of foods had little discernible effect on the overall glucose and insulin responses (since brown rice did not elicit a significantly lower glucose or insulin response than white rice), there was a sustained and significant increase in insulin secretion in response to ground compared with unground rice. Any factor (low surface area/starch ratio in this case) that limits the access of intestinal hydrolytic enzymes to the ingested starch could have slowed down the rate of glucose absorption and thereby reduced insulin secretion.

The relative rate of starch hydrolysis was found to be highest for ground white rice followed by ground brown rice, then white rice and brown rice (O'Dea et al, 1981). The fibre in some foods may affect hydrolysis rate by forming a physical barrier to hydrolytic enzymes, but the fibre must be in its natural form to be effective.

The important role of physical form of complex CHO in determining the postprandial metabolic responses in diabetic subjects has been highlighted by Collier and O'Dea (1982). They reported that brown rice elicited significantly lower postprandial glucose, insulin and gastric inhibitary polypeptide response than ground brown rice or glucose. This data thus highlights the role of physical form of complex CHO in determining metabolic responses to it in both diabetics and normal subjects and thus provides a rationale for designing diabetic diets containing complex CHO in a form that is slowly digested and absorbed.

Another factor that affects starch absorption could be the chain length of the individual starches or the amylose versus amylopectin components of a starch. Wahlquist et al (1978) reported that the chain length of a saccharide did not have an effect on glucose absorption and metabolic response and suggested that the dietary form of starch was a critical element. However, it was observed by comparing high and low amylose containing rices that ingestion of high amylose containing rice resulted in lower and flatter glycaemic response pattern as compared to zero per cent amylose rice (Goddard et al, 1984). They suggested that differential enzymatic hydrolysis of the high amylose rice or some other factor such as lipid/starch complexes as being responsible for the delay in digestion and absorption.

Read (1986) reported that chewing of foods could increase digestibility and absorption by reducing particle size, thus enhancing salivation and hydrolysis of CHO in the mouth and stomach. Conversely, avoidance of chewing may be an alternative strategy for delaying CHO digestion and reducing blood glucose levels.

Golay et al (1986) compared the metabolic effects of white beans processed into two different physical forms - one maintained the integrity of the bean cell (undamaged bean cells, UC) and the other ruptured the bean cell (damaged bean cells, DC). They reported that both incremental glucose and insulin response areas were significantly lower after UC administration than DC in NIDDM patients. Similar effects were reported when these beans were incorporated into mixed meals. But in controlled subjects, there was no significant difference in incremental glucose response areas after ingestion of either UC or DC.

The differences in metabolic responses to two common starches (rice and potato) could be eliminated by altering the physical form of food (Crapo and Henry, 1988). The difference in the glycaemic potency of rice and potato is intrinsic to these starch containing foods as they exist in their native states. When the starch containing whole food products were blended to form a slurry, no difference in glycaemic potency could be detected in either normal or diabetic subjects. The physical process of breaking the starches into smaller particles and ingesting them as an emulsion served to eliminate whatever factors were intrinsic to the whole food that led to the different glycaemic potencies. This effect was somewhat different from that seen in legumes.

Blending of beans after cooking does not alter the blood glucose or insulin response as compared with reponses to whole legumes (Simpson et al., 1985). However, it was demostrated through in-vitro studies that grinding lentils before cooking increased starch hydrolysis rate by five-folds, whereas lentils which were mashed after cooking were hydrolysed significantly more slowly (Wong et al, 1983). This could be attributed to the fact that starch in leguminous seeds is entrapped in parenchyma cells and swells only partially during cooking. This limits alpha-amylase penetration of the gelatinised starch granules. Blending after cooking releases the partially swollen starch granules and thus digestion was not as complete as when disruption of cell wall preceded cooking (Wong et al, 1983; Wursch et al, 1986) allowing a more complete gelatinisation of starch granules and improved susceptibility for alpha-amylase digestion. Thus, Crapo & Henry (1988) suggest that differences in glycaemic potencies of different starch containing foods are not solely due to variations in the starch molecule per se but rather the way it is presented to the gastro-intestinal digestive and absorptive processes. The physical access of digestive hydrolytic enzymes to starch molecules differs among food stuffs and blending a rice product alters this difference so that all starch molecules now have equal availibilty to digestive enzymes. Blending leads to dispersion and hydration of the starch which could be an important factor in absorption.

Thus, these studies illustrate that the glycaemic potency of a particular food stuff cannot be considered to be a stable characteristic and emphasizes the importance of food form.

2.3.3 Digestibility

The rate of digestion of foods and hence of absorption is one of the major determinants of glycaemic response (Jenkins et al, 1982). In vitro digestibility studies using human digestive juices have provided a unique means of evaluating the differences between foods. The possible relationship between the rate of digestion of food and glycaemic response has been demonstrated by Jenkins et al (1982). Fourteen foods were digested with human saliva and pancreatic juice in-vitro in a dialysis system and the results compared with the blood glucose response in healthy volunteers after feeding the same fourteen foods individually as test meals. A significant relationship was found between the amount of sugars and oligo saccharides liberated at one hour and five hours and the blood glucose area of the test food expressed as a percentage of the blood glucose area for fifty gms glucose. ($r = 0.8627$ and 0.8618, $P<0.001$)

In-vitro studies with legumes have also shown that they are digested less rapidly than the other CHO foods and this corresponds with the markedly flattened glycaemic responses that they induce (Jenkins et al, 1980). In a similar study, these scientists reported a significant relationship between the rate of release of the sugars (glucose, maltose and maltotriose) from amylolytic digestion of ten foods tested in-vitro (expressed as digestibility index) and the blood glucose response to fifty gms CHO portions of the same foods eaten by diabetics (expressed as glycaemic index). [Jenkins et al,1984]

Wolever et al (1988) conducted a study to test whether the digestion rates of starchy foods in-vitro were related to their plasma insulin responses in vivo. Four different mixed meals consisting of either bread, rice, spaghetti or barley to which cheese and tomato were added were fed to normal subjects. The rates of digestion of these foods have shown to vary over a three-fold range. They reported that the glucose and insulin response areas for the meals were significantly related to the rates of digestion of the foods and to the published glycaemic index values of the foods. They concluded that glycaemic index provides a measure of the relative rates of digestion of different starchy foods which in turn are related to their insulin responses. The relationships between the rate of digestion of foods and their blood glucose and insulin responses are maintained when the foods are taken in a mixed meal containing protein and fat.

Thus, it is possible that glycaemic response can eventually be predicted from the rate at which a food is digested in-vitro, eliminating the need for invasive techniques in the study of food digestion and glycaemic potential.

2.3.4 Cooking

Cooking alone can result in alterations in the glycaemic response to a food. The effect of cooking starch on serum glucose and insulin responses was studied by Collings <u>et al</u> (1981). They reported that the response of insulin after cooked starch was less than that after glucose, suggesting that the viscosity of the meal was playing a role.

It is possible that the cell wall cellulose of raw foods are not completely disrupted in chewing, impairing access of digestive enzymes to the starch within the cell. Cooking swells the starch within the cell bursting the cell wall and potentially making the starch more available for digestion. Alternatively, some foods contain natural amylase inhibitors that may be inactivated by cooking or other aspects of food processing or preparation (Snow & O'Dea, 1981).

In-vitro studies of starch hydrolysis rates indeed indicate that uncooked starchy CHO are not as readily digestible as are their cooked counterparts. Thus, for example cooked rolled oats were approximately 69 per cent hydrolyzed after thirty minutes while raw rolled oats were 19 per cent hydrolyzed by that time (Snow & O'Dea, 1981). In feeding studies also, Jenkins et al (1982) have reported that legumes that are boiled, blended and dried for 12 hours produced larger increases in blood glucose than do legumes that are only boiled for twenty minutes, boiled twenty minutes and blended, or boiled for one hour. Thus, if maximal benefit (lowest blood glucose level) is to be realised from low glycaemic foods, attention must be paid to the amount of dry heat (particularly in the case of lentils) used in the preparation.

Similar results were reported by Janette et al (1985) in their study to compare the in-vitro starch digestibility and postprandial blood glucose response of conventionally cooked versus factory-processed foods. They reported that the proportion of starch digested was significantly higher ($P < 0.05$) for the factory-processed form of rice, corn and potato compared with the respective conventionally cooked foods. The glycaemic response of these foods in six healthy volunteers correlated very closely to the proportion of starch digested.

Susan et al (1987) also reported differences in the glycaemic and insulin responses to seven processed wheat products in normal subjects. This difference may be explained in part by the extent of processing and the degree of gelatinisation achieved. In this study also, the glycaemic index correlated positively with the degree of starch gelatinisation and with the percentage of starch digested in-vitro ($p < 0.05$).

This correlation was also reported in Thai cooked rice and moong bean noodles (Juliano et al, 1989). The glycaemic index was however negatively correlated to the amylose content of the food. They reported that glutinous (waxy) rice elicited the highest glycaemic index values and moong bean noodles the lowest.

Rasmussen et al (1989) reported that short-term cooking of rolled oats has no deleterious effect on blood glucose and insulin responses compared to raw oats.

The effect of processing native starches on the insulin and glycaemic responses was studied in healthy subjects by Bornet et al (1989). Native starches from wheat, manihot, smooth peas or moong beans were tested either raw, as starch gels (boiled and cooled) or cooked and cooled after a preliminary industrial processing. They reported that raw manihot starch produced the lowest ($p < 0.05$) metabolic response and cooking significantly ($p < 0.01$) increased plasma responses. However, cooked moong bean noodles gave metabolic responses similar to those of raw products. Close correlations were found between the per cent of in-vitro starch hydrolysis at thirty minutes and mean areas under the glycaemic curves and the insulinemic curves ($r = 0.95$, $p < 0.01$).

Akanji et al (1990) measured the plasma glucose responses to different mixed cassava meals in non-diabetic Nigerians. They reported that postprandial glycaemia after cassava meals depended on the mode of preparation of the meal and that lafun (one of the preparations) showed the least glycaemic response of the three cassava meals tested (the other two were qari and parboiled cassava flakes).

The influence of pasta cooking time on starch digestion and plasma glucose and insulin responses was studied in twelve healthy subjects (Bornet et al, 1990). No significant differences in plasma responses were found between the three pasta meals cooked for 11, 16.5 and 22 minutes. Thus, these results point to a lack of influence of cooking time on nutritional characteristics of pasta.

However, atleast one study points out that cooking does not always increase digestibility, as the postprandial glycaemic responses after ingestion of raw and cooked carrots were not significantly different whereas the responses to raw and cooked potato were different (Valer et al, 1984). However, the CHO in carrots are mainly sugars and there are no starch granules and thus, their CHO is readily available.

Cooking thus, most likely affects the glycaemic impact of a starchy food by increasing the availability of starch for enzymatic digestion.

2.3.5 Antinutritional Factors

The antinutritional factors like enzyme inhibitors, lectins, polyphenols and phytic acids are known to reduce the glycaemic response due to the reduced starch digestibilty and absorption. These antinutritional factors either form complexes with CHOs and prevent them from enzymatic attack or inhibit the activity of enzymes thereby reducing the rate of hydrolysis of starch to maltose. This lowers the rate of maltose transport and glucose absorption and smoothens the glycaemic curve. Though certain enzyme inhibitors can be destroyed by heat treatment, the starch digestibility of cooked foods is affected by antinutrients that can survive the cooking process. (Thorne et al, 1983)

The effect of polyphenolics present in the legumes on the digestive enzymes which in turn influence the glycaemic index was studied by Griffiths et al (1980). They reported that the activity of both trypsin and amylases were significantly reduced in rats consuming diets containing testa from coloured variety of field bean than in rats receiving the diet containing testa from white variety (tannin free) of field bean. It was concluded that the original reduction in digestive enzymes activity was due to the presence of field bean polyphenolics which are known to be present in the testa of coloured variety.

Thompson et al (1984) studied the effect of polyphenolics on glycaemic response using five leguminous and five non-leguminous foods (cereals). Polyphenol concentration and intake per 50 gms of available CHOs were higher in leguminous seeds than in non-leguminous seeds. In both normal and diabetic individuals, a negative correlation was observed between the glycaemic index and concentration or total intake of polyphenols. Polyphenols, espacially the large polymeric type or condensed tannins appear to be responsible for the reduced glycaemic response of legumes compared with cereal products.

Content of phytic acid also had an effect on blood glucose response. It was suggested that phytic acid probably affects starch digestibility through interaction with amylases, proteases and/or binding salivary minerals such as calcium which is essential for amylase activity. Thus, it decreases the digestion and absorption of CHOs resulting in lowered postprandial glycaemia (Yoon et al., 1983).

In animals fed on lectins from lentils and peas, the activity of proteases and disaccharidases (which are involved in the breakdown of CHOs to monosaccharides, which are absorbed in samll intestine) are decreased due to lectins. This leads to the reduced availabilty of CHOs which in turn reduces blood glucose levels (Jindal et al, 1982).

The presence of salivary and pancreatic alpha-amylase inhibitors have been demonstrated in several root vegetables and beans (Lajola *et al*, 1984) whereas it was found that the higher the dose of inhibitor the greater and long lasting was the smoothing effect on serum glucose levels (Jaffe *et al*, 1973).

Numerous enzyme inhibitors also occur naturally in foods and to some degree, their activity may survive processing and cooking.

Thus, these studies indicate that food composition even when it is available does not predict the physiological response to a food.

2.3.6 Effect of one meal upon subsequent meals

When CHOs are given in a slowly digestible form, not only are glucose responses reduced following the meal during which the CHO is ingested, but improvement in CHO tolerance to subsequent standard meals also occurs. Thus, when guar is added to an initial glucose load, it improves the tolerance to a subsequent guar-free glucose load taken four hours later (Jenkins *et al*, 1980).

A similar effect has been reported using lentils. Breakfasts containing lentils (associated with flattened glycaemic and insulin responses) are followed by signicantly flatter glycaemic responses to a standard lunch as compared to breakfasts containing identical amounts of CHO in the form of bread (Jenkins et al, 1982).

Grill et al (1985) have suggested that a previous intake of glucose improves subsequent glucose tolerance in normal man (the Staub Trauqott effect). They reported that in overt type 11 diabetics, a small amount of glucose before breakfast fails to ameliorate their postprandial hyperglycaemia.

2.3.7 Rate of meal ingestion

When high glycaemic CHO-containing foods are ingested slowly, the postprandial glucose excursion is blunted, mimicking the pattern seen when low glycaemic CHO foods is given. Thus, glucose when sipped over a four hour period resulted in a blood glucose pattern similar to that of glucose given in a short period of time along with guar (Jenkins et al, 1980).

Similar effects were seen when bread was fed continuosly at an even rate (small divided portions given over four hours) as when lentils were fed in a 15-20 minute period of time (Jenkins et al, 1982).

Heine et al (1983) also reported that when the glucose load during an oral glucose tolerance test was given fast (1 minute) or slow (10 minutes), the more rapid ingestion resulted in an earlier rise in blood glucose, insulin and C-peptide levels. During the later time points (at 90-135 minutes) the blood glucose concentrations were higher after the slow intake.

Thus, rate of intake of a meal may have a role in the control of subsequent metabolic responses.

2.4 EFFECT OF DIFFERENCES IN GLUCOSE TOLERANCE (between Diabetics and Non-Diabetics)

The relative glycaemic response to different foods in diabetic patients is qualitatively similar to those in normals, although the magnitude of the response is obviously much greater in the diabetic individual. Thus, small differences between foods ingested by non-diabetic individuals may be magnified in diabetic individuals due to differences in their glucose tolerance.

Plasma responses to different CHOs were studied by Crapo et al (1977) and they concluded that there is a wide range of plasma glucose and insulin response to different complex CHO, with rice and corn producing the lowest response curves. But subjects with the higher plasma glucose responses to dextrose (most glucose intolerant) have greater differences in their glucose and insulin responses to oral starch load than the subjects with the lower glucose responses.

The relative glycaemic and hormonal responses to protein, fat and CHO alone and together in normal, NIDDM and IDDM subjects were studied. Fat and protein were found to reduce the glycaemic response to oral CHO in non-diabetics. In NIDDM, the presence of protein and fat had no significant effect on the glycaemic response. While fat had no effect, protein enhanced the glycaemic response in IDDM subjects. The insulin and gastric inhibitory poly-peptide (GIP) responses to the macro-nutrients together and individually were markedly similar in all the groups. This was attributed to protein which stimulated insulin secretion in normal and NIDDM subjects while fat acted as GIP secretogogue in both the diabetic groups. Thus, the same diet had different effects on non-diabetics and diabetics (Simpson et al, 1985).

In yet another study on the effect of food physical factors on glycaemic response, Simpson et al (1985) reported that cooked blended beans gave a greater plasma glucose response than a cooked flummery (containing maize starch, protein and fat) in non-diabetics, but in NIDDM and IDDM the reverse applied. Also, the cooked flummery gave a lower glycaemic response at some time points than did uncooked flummery in non-diabetics; the opposite occurred in NIDDM.

However, in certain studies when the total meal is assessed, glycaemic differences between foods may be dampened to such a degree that clinically significant effects cannot be seen between the diabetics and non-diabetics.

These studies indicate that the glycaemic response of a food are affected by factors such as food composition, physical form of food and the method of processing. Thus, the expected biologic response to a food, viz., the glycaemic index of a food, that takes into account all these factors must be given due consideration while planning an effective diabetic diet.

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MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The study was designed to assess the glycaemic response to certain breakfast items in diabetic subjects.

3.1 SELECTION OF SUBJECTS

The study was conducted at BHEL Township, Hyderabad. Six non-insulin dependent diabetics were selected for the study. The criteria followed for selection were :

(a) Only men in the age range of 40-51 years were selected.

(b) Only Malayalee diabetic subjects were selected, as the test breakfast items are typically eaten only by Keralites, thus eliminating body's adaptation to a food as a variable.

(c) An oral glucose tolerance test (OGTT) using a glucometer and 75 g glucose load was done to assess their diabetic condition. Only those subjects with a fasting blood sugar level greater than 140 mg/dl of capillary blood and a level greater than 200 mg/dl after two hours of glucose ingestion, were selected.

(d) The subjects on oral drugs only were selected. They were healthy and free from any other major complications.

3.2 EXPERIMENTAL DIETS

The experimental diets selected for the study are four breakfast items commonly consumed in Kerala. They are : (1) puttu (2) idiappam (3) appam (4) boiled tapioca. The first three breakfast items are rice-based with a difference only in the method of preparation and fourth one is a root vegetable. The ingredients used in each breakfast item is presented in Table 2. The methods of preparation of these breakfast items are given in the Appendix A.

Table 2 : Composition of Breakfast items

Breakfasts	Ingredients	Amounts
Puttu	Rice Flour	75 g
	Tender Coconut	25 g
Idiappam	Rice Flour	75 g
	Tender Coconut	25 g
Appam	Rice	73 g
	Tender Coconut	25 g
Curry(*)	Bengal gram(whole)	20 g
	Onions	10 g
	Oil	5 ml
Boiled Tapioca	Tapioca	190 g
	Oil (for seasoning)	10 ml
Tea	Skim milk	50 ml
	Tea	50 ml

(*) served with each rice-based item

A - 'KOLA' USED FOR PREPARATION OF PUTTU

B - RAW PUTTU MIX

C - PUTTU WITH CURRY

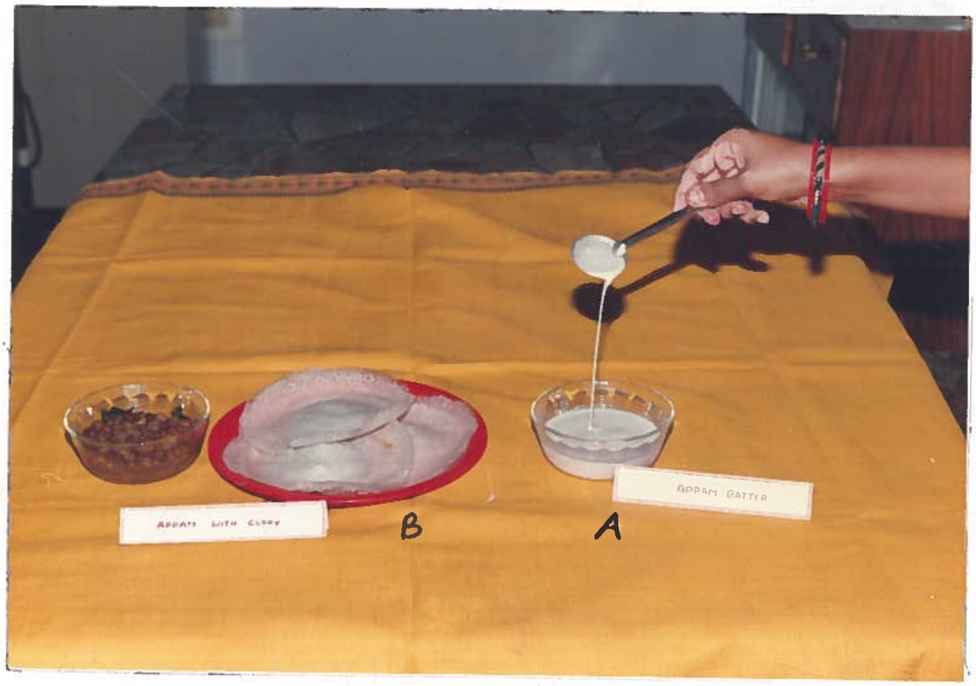
PLATE NO. 1 : PUTTU - RAW AND COOKED FORM

A - IDIAPPAM DOUGH

B - EXTRUSION OF DOUGH

C - IDIAPPAM WITH CURRY

PLATE NO. 2 : IDIAPPAM - RAW AND COOKED FORM



A - APPAM BATTER

B - APPAM WITH CURRY

PLATE NO. 3 : APPAM - RAW AND COOKED FORM

It is customary to take the first three preparations (1-3) with a curry; in the present study, all the three breakfast items were served along with Bengal gram curry. A cup of tea was served along with the breakfast items.

The break fast items were planned to be isocaloric (390 K.cal) and also to contain about 75 g. equivalent of carbohydrate load (as glycaemic response was determined in comparison with 75 g glucose load).

Nutrient composition of the breakfast items computed on the basis of Nutritive Value of Indian Foods (ICMR, 1991) is presented in Table 3.

3.3 DETERMINATION OF GLYCAEMIC RESPONSE TO BREAKFAST ITEMS

Glycaemic response to breakfast items was studied in comparison with the response to an equivalent amount of glucose.

The subjects were requested to report at a private pathological lab after an overnight fast. They were also requested to avoid taking drugs 24 hrs prior to the test. An interval of atleast two days was given between the successive breakfasts. The breakfasts were prepared independently for each subject after accurately weighing the required ingredients (Table 2).

Table 3 : Nutritive value of Breakfast Items

Breakfast items	Energy (K.cal)	CHO (g)	Protein (g)	Fat (g)	Fibre (g)
Puttu	269.0	60.23	5.33	0.725	0.15
Curry	122.0	13.30	3.42	6.10	0.84
	391.0	73.53	8.75	6.825	0.99
Idiappam	269.0	60.23	5.33	0.725	0.15
Curry	122.0	13.30	3.42	6.10	0.84
	391.0	73.53	8.75	0.825	0.99
Appam	267.85	58.93	5.19	0.715	0.15
Curry	122.0	13.30	3.42	6.10	0.84
	389.85	72.24	8.61	6.815	0.99
Boiled Tapioca (seasoned)	388.3	72.2	1.33	10.38	1.14
	388.3	72.2	1.33	10.38	1.14
Tea*	15	2.3	1.2	-	-

* Served with each breakfast

3.3.1 Administration of Glucose/Breakfast item

Fasting blood was drawn intravenously from the subjects before giving a glucose load and each of the breakfast items. A glucose load of 75 g (as per recommendations of WHO expert committee) dissolved in 200 ml of water was administered. The time taken for consumption of the entire breakfast item was 10 min.

The post prandial blood samples were drawn at 1/2 hr, 1 hr, 1 1/2 hr and 2 hr intervals after consumption of glucose/breakfast item. The blood samples (to which a pinch of NaF was added) were centrifuged immediately for the separation of plasma and stored at 4°C. Plasma glucose was estimated by the glucose oxidase-peroxidase method (Boehringer Mannheim kit). The method is detailed in the Appendix-B.

The area under the 2 hour glucose stimulation curve (AUC) was calculated for each subject, by summing up the four glucose values obtained after stimulation and similarly for each test meal also. The AUC of glucose was taken as the index value of one and the ratio of each breakfast in relation to AUC was calculated. Glycaemic response (GR) of each breakfast was calculated using the formula

$$GR = \frac{\text{AUC of breakfast item}}{\text{AUC of glucose}}$$

3.4 STATISTICAL ANALYSIS

The results of the study were subjected to ANOVA to compare the glycaemic responses among the different breakfast items, and the means were tested for significance by critical difference (Ronald A. Fischer, 1920). To compare the glycaemic response of each breakfast item with that of glucose, the data was subjected to paired t-test.

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RESULTS

CHAPTER IV

RESULTS

Glycaemic responses to selected breakfast items that are commonly consumed in Kerala were assessed in six non-insulin dependent Malayalee diabetic men.

Prior to the actual experiment, an oral glucose tolerance test (OGTT) was conducted for all the subjects to assess their metabolic response to glucose load and for comparison with the glycaemic responses to breakfast items.

4.1 GLUCOSE TOLERANCE TEST

The plasma glucose values of the subjects on OGTT are presented in Table 4.

Table 4 : Plasma glucose values of subjects on OGTT

Subjects	Plasma glucose values in mgs. per cent				
	Fasting	1/2 hr.	1 hr.	1 1/2 hr.	2hrs.
1.	144.3	197.0	220.6	241.4	220.1
2.	158.3	341.6	383.3	320.8	312.5
3.	233.3	475.0	502.6	524.3	364.6
4.	170.5	325.0	356.8	379.5	361.4
5.	229.8	315.6	393.5	502.6	440.3
6.	182.4	263.5	291.9	348.6	332.4
Mean	186.43	319.62	358.12	386.2	338.55
S.D.	37.18	92.58	95.97	108.92	72.52

The fasting glucose levels ranged from 144.3 to 233.3 mgs. per cent. The peak glucose value was observed at 1 1/2 hour for five subjects and at 1 hour for the sixth subject. By 2 hours although the glucose levels started falling in all the six subjects, they were not close to the fasting levels.

4.2 EFFECT OF BREAKFAST ITEMS ON PLASMA GLUCOSE RESPONSE

4.2.1 Puttu

The plasma glucose values of the subjects at four different intervals after consumption of puttu are given in Table 5. There was an average increase of 70 mg% in the plasma glucose from fasting level at 1/2 hour after breakfast. At 1 hr, when the peak was observed, there was an average increase of 95 mg% from the 1/2 hr value. Thereafter there was a gradual fall in the plasma glucose value, with an average decrease of 25 mg% at 1 1/2 hr and 40 mg% at the end of 2 hrs. However, the values did not reach the fasting level even by 2 hrs. The difference between the fasting and peak values for individual subjects ranged from 102.6 mg to 216.6 mg and on an average the peak rise over fasting levels was 164.2 $\pm$ 47.7 mg%.

The comparative change in mean plasma glucose concentration after administration of puttu and glucose

Table 5 : Plasma glucose values of subjects after Puttu consumption

Subjects	Plasma glucose values in mgs. per cent					Peak rise over fasting levels (mg%)
	Fasting	1/2 hr.	1 hr.	1 1/2 hr.	2hrs.	
1.	99.9	113.7	202.5	160.9	110.9	102.6
2.	145.0	223.0	304.0	260.0	200.0	159.0
3.	175.0	250.0	391.6	366.6	266.7	216.6
4.	154.5	263.3	327.2	327.2	318.2	172.7
5.	229.5	312.2	445.4	422.7	400.0	215.9
6.	175.6	234.8	294.0	274.3	266.3	118.4
Mean	163.25	232.83	327.45	301.95	260.35	164.2
S.D.	42.67	66.05	84.03	91.45	98.89	47.77

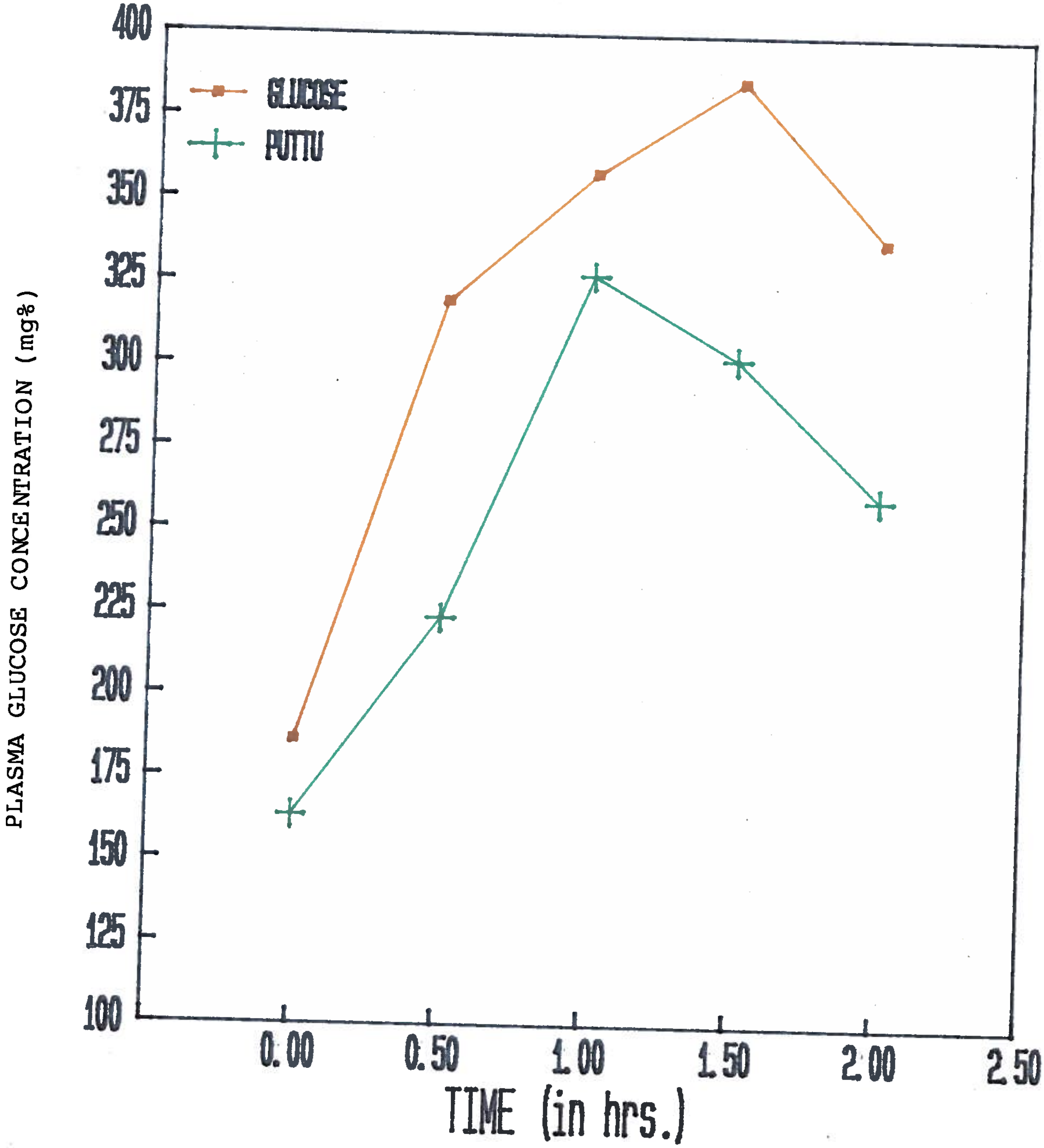

Fig.1: COMPARATIVE CHANGE IN MEAN PLASMA GLUCOSE CONCENTRATION AFTER GLUCOSE AND PUTTU ADMINISTRATION

is represented in Fig.1. The mean plasma glucose values at each time point following the intake of breakfast item is lower, though not significantly (P>0.05), than that after glucose administration.

4.2.2 Idiappam

The plasma glucose values of the subjects at four half hourly intervals after consumption of idiappam are presented in Table 6. There was an increase of 80 mg% on a average from the fasting value at 1/2 hr. But in the next 30 min, when the peak was observed, there was an average increase of 94 mg% from the 1/2 hr point. After 1 hr there was a fall in the level of glucose with an average decrease of 35 mg%. However, even by the end of 2 hrs the values did not reach the fasting levels. The difference between the fasting and peak glucose values on an average was 174.53 ± 75.95 mg%, although individual values ranged from 92-280 mg%.

The comparative change in the mean plasma glucose concentrations after administration of idiappam and glucose is represented in Fig. 2 . The mean plasma glucose values at all time points except at 1hr (where peak was observed) after the breakfast item is lower, though not significantly (P>0.05) than that after OGTT.

Table 6 : Plasma glucose values of subjects after Idiappam consumption

Subjects	Plasma glucose values in mgs. per cent					Peak rise over fasting levels (mg%)
	Fasting	1/2 hr.	1 hr.	1 1/2 hr.	2hrs.	
1.	110.4	176.1	202.4	189.3	184.0	92.0
2.	169.7	211.2	266.4	250.6	234.8	96.7
3.	213.1	351.0	493.1	461.6	430.0	280.0
4.	144.2	284.4	362.3	284.4	198.7	218.1
5.	276.6	307.7	494.8	448.1	377.9	218.2
6.	179.2	243.5	321.4	309.7	282.5	142.2
Mean	182.20	262.32	356.73	323.95	284.65	174.53
S.D.	57.67	64.52	119.09	109.21	99.83	75.95

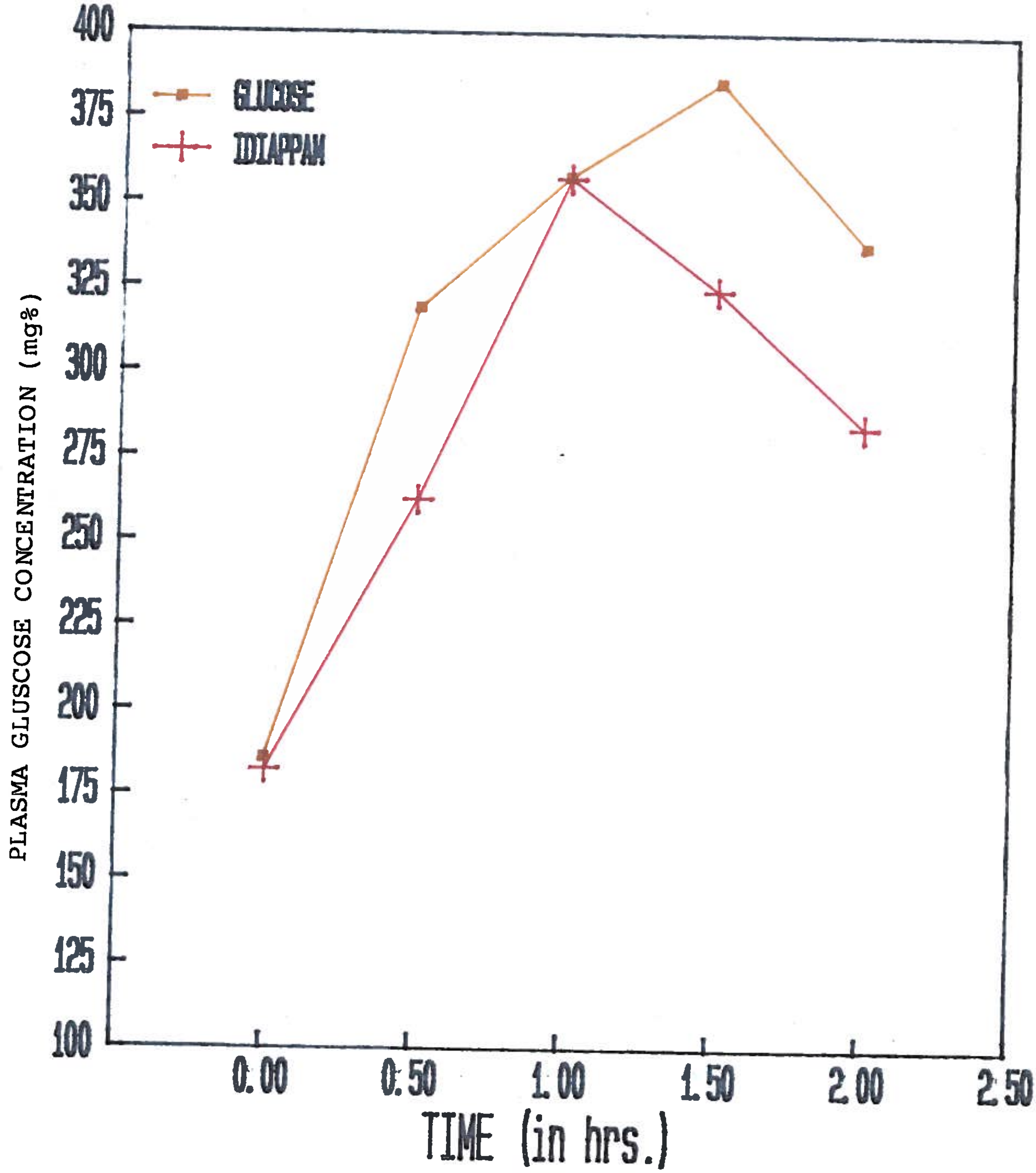

Fig.2: COMPARATIVE CHANGE IN MEAN PLASMA GLUCOSE CONCENTRATION AFTER GLUCOSE AND IDIAPPAM ADMINISTRATION

4.2.3 Appam

The plasma glucose values of the subjects at four half-hourly intervals after consumption of appam are presented in Table 7. There was an average increase of 63 mg% from the fasting levels at 1/2 hr. In the next half-hourly interval, i.e. at 1 hr, when the average peak value was observed, there was a rapid increase accounting on an average to 110 mg%. The peak level of glucose was observed at 1 hr with three subjects (3, 4, 5) in the other three at 1 1/2 hr. So, the average decrease observed at 1 1/2 hr. was only 25 mg% and nearly the same rate of decrease was seen at 2 hrs. At the end of 2 hrs, though there was a fall in the plasma glucose values, they were not close to the fasting levels. The difference between the fasting and peak values for individual subjects ranged from 137.5 to 272.6 mg% and on an average, the peak rise over fasting levels was 191.7 $\pm$ 56.10 mg%.

The comparative change in the mean plasma glucose concentration after administration of appam and glucose is represented in Fig. 3. The mean plasma glucose values at all time points except at 1 hr. (when the peak was observed) after the consumption of breakfast item is lower, though not significantly (P>0.05) than that after OGTT.

Table 7 : Plasma glucose values of subjects after Appam consumption

Subjects	Plasma glucose values in mgs. per cent					Peak rise over fasting levels (mg%)
	Fasting	1/2 hr.	1 hr.	1 1/2 hr.	2hrs.	
1.	118.1	159.6	203.7	255.6	250.4	137.5
2.	220.1	286.4	344.8	364.3	348.7	144.2
3.	233.8	268.8	455.8	377.9	331.2	222.0
4.	144.2	222.1	370.1	268.8	237.6	225.9
5.	222.2	307.8	494.8	409.1	377.9	272.6
6.	196.8	266.3	301.9	344.8	305.8	148.0
Mean	189.2	251.83	361.85	336.75	308.60	191.7
S.D.	47.27	53.32	105.32	61.57	55.42	56.10

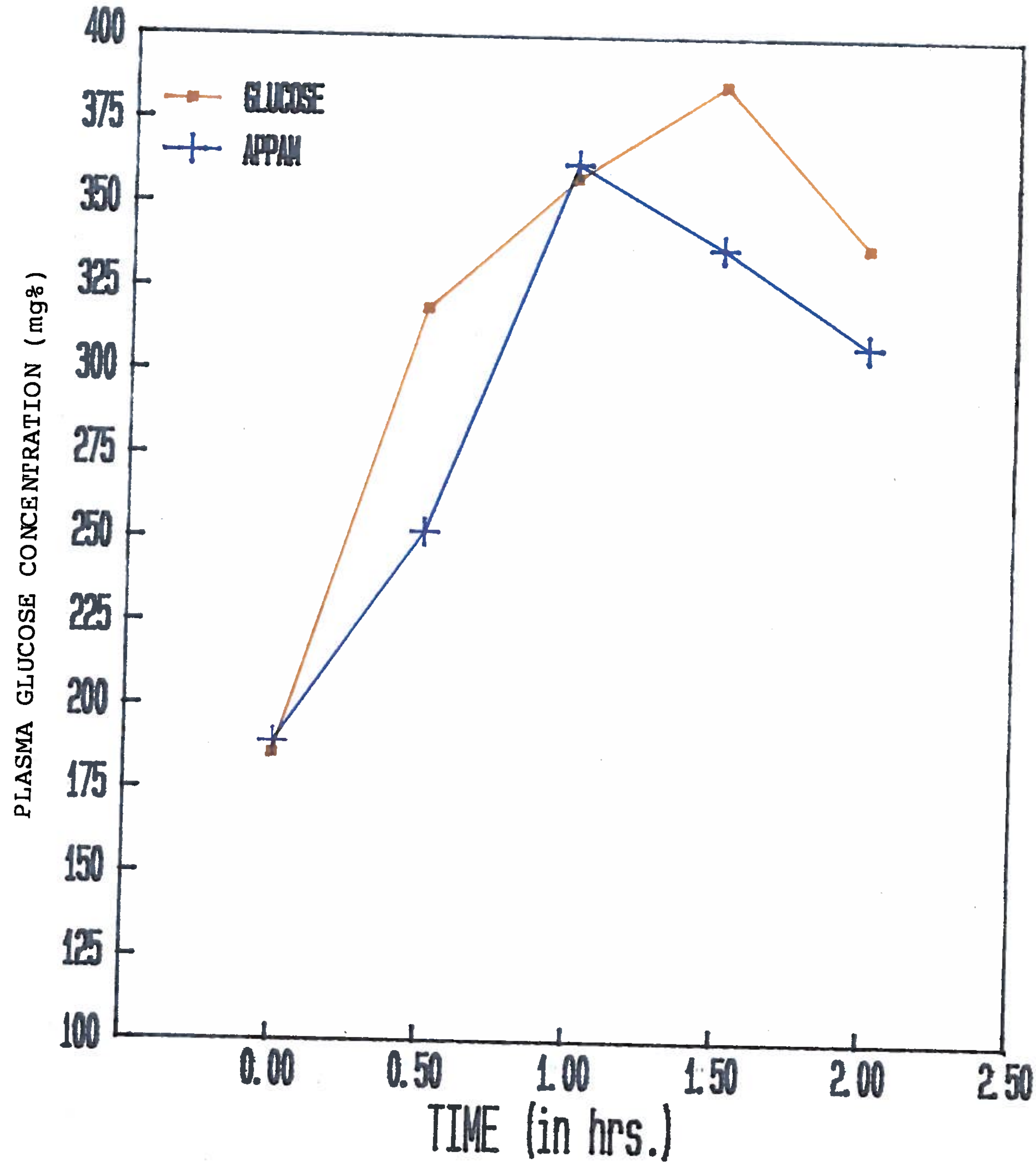

Fig.3 : COMPARATIVE CHANGE IN MEAN PLASMA GLUCOSE CONCENTRATION AFTER GLUCOSE AND APPAM ADMINISTRATION

4.2.4 Tapioca

The plasma glucose values of the subjects at four half-hourly intervals after consumption of tapioca are presented in Table 8. The increase in plasma glucose from fasting to 1/2 hr was 84 mg% on an average and from 1/2 hr to 1 hr it was 100 mg%. The peak levels were noticed at 1 hr for all the subjects. At the end of 2 hrs, there was a fall in the plasma glucose values, but they were not close to the fasting levels. The difference between the fasting and peak values for individual subjects ranged from 121.1 to 255.5 mg% on an average, the peak rise over fasting levels was 183.57 ± 52.96 mg%.

The comparative change in the mean plasma glucose concentration after administration of tapioca and glucose is represented in Fig. 4. The mean plasma glucose values at all time points except at 1 hr (when the peak was observed) after the breakfast item is lower, though not significantly ($P>0.05$) than that after OGTT.

Table 8: Plasma glucose values of subjects after tapioca consumption

Subjects	Plasma glucose values in mgs. per cent					Peak rise over fasting levels (mg%)
	Fasting	1/2 hr.	1 hr.	1 1/2 hr.	2hrs.	
1.	126.1	179.8	247.2	233.8	206.8	121.1
2.	206.8	279.2	340.5	320.2	310.1	133.7
3.	283.8	364.9	478.3	429.7	413.5	194.5
4.	162.5	258.3	391.7	316.7	308.3	229.2
5.	206.8	320.3	462.4	421.3	401.3	255.5
6.	175.5	261.8	342.9	315.9	288.9	167.4
Mean	193.58	277.38	377.17	339.6	321.48	183.57
S.D.	53.54	62.66	86.15	74.09	76.62	52.96

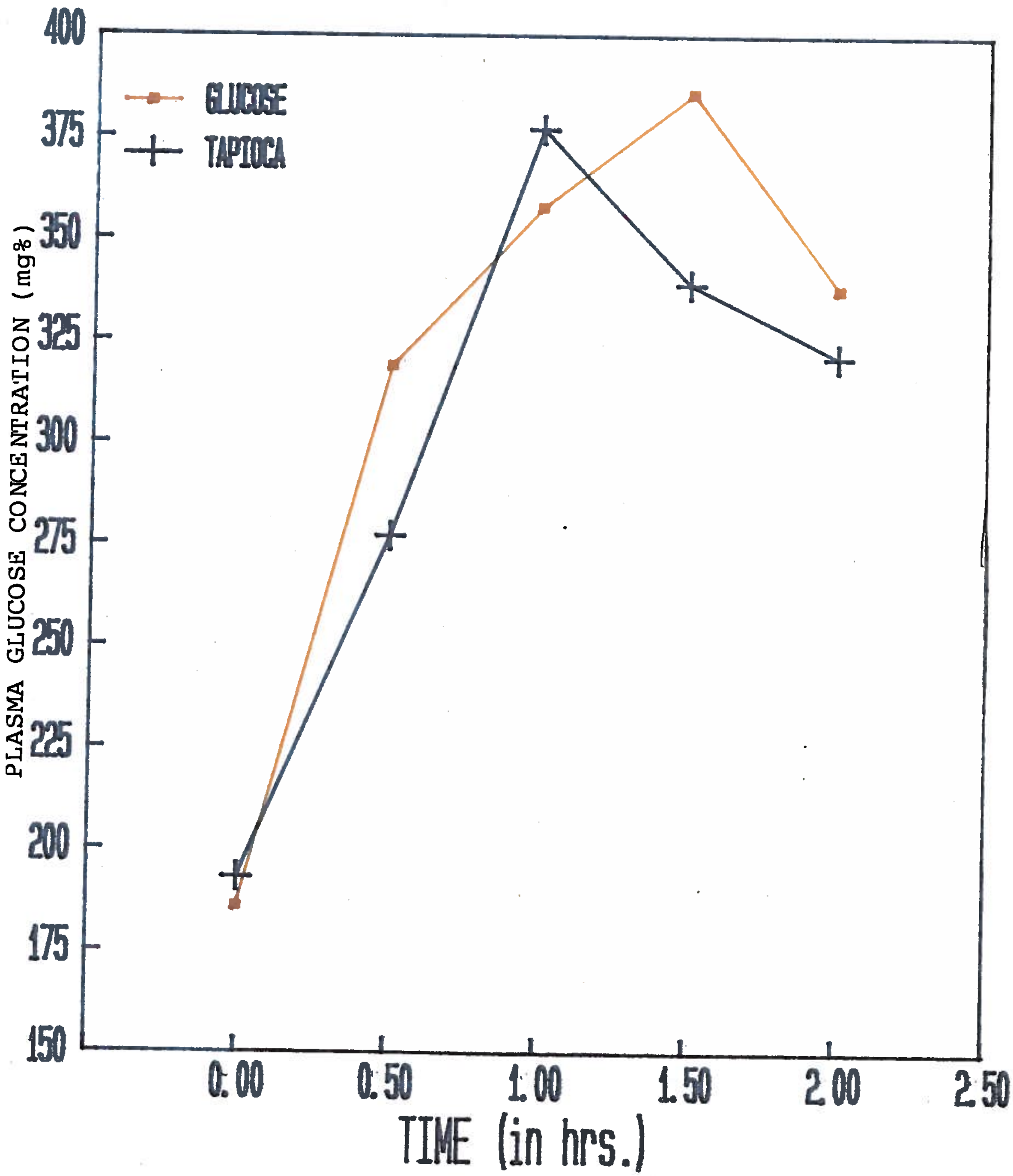

Fig.4: COMPARATIVE CHANGE IN MEAN PLASMA GLUCOSE CONCENTRATION AFTER GLUCOSE AND TAPIOCA ADMINISTRATION

4.2.5 Mean Peak rise over Fasting levels after administration of glucose and breakfast items

Table 9:

Breakfast item	Mean peakrise over fasting blood glucose levels (mg per cent)
Glucose	210.18 [a] ± 71.27
Puttu	164.2 [b] + 47.77
Idiappam	174.53 [a] ± 75.95
Appam	191.7 [a] ± 56.1
Tapioca	183.57 [a] ± 52.96

Values with different superscripts are significantly different ($P<0.05$). All values are compared with glucose

The data in Table 6 shows that the mean peak rise over the fasting blood glucose values after consumption of appam is comparitively high. The mean difference between the fasting and peak values is significantly lower ($P<0.05$) after administration of puttu when compared to that after glucose. The values obtained after consumption of the other breakfast items are however not significantly lower ($P>0.05$) from that of glucose.

The mean plasma glucose responses of the subjects fed with different breakfast items are presented in Table 10, & is illustrated in Fig.5.

Table 10: Plasma glucose values of the subjects to the different breakfast items

Items tested		Plasma glucose (mg%)				
		Fasting	1/2 hr.	1 hr.	1 1/2 hr.	2 hrs.
Glucose	Mean	186	319	358	386	338
(n = 6)	± S.D.	37	92	96	109	72
Puttu	Mean	163	233	327	302	260
(n = 6)	± S.D.	42	66	84	91	99
Idiappam	Mean	182	262	357	324	284
(n = 6)	± S.D.	57	64	119	109	99
Appam	Mean	189	252	362	337	308
(n = 6)	± S.D.	47	53	105	61	55
Tapioca	Mean	193	277	377	339	321
(n = 6)	± S.D.	53	62	86	74	76

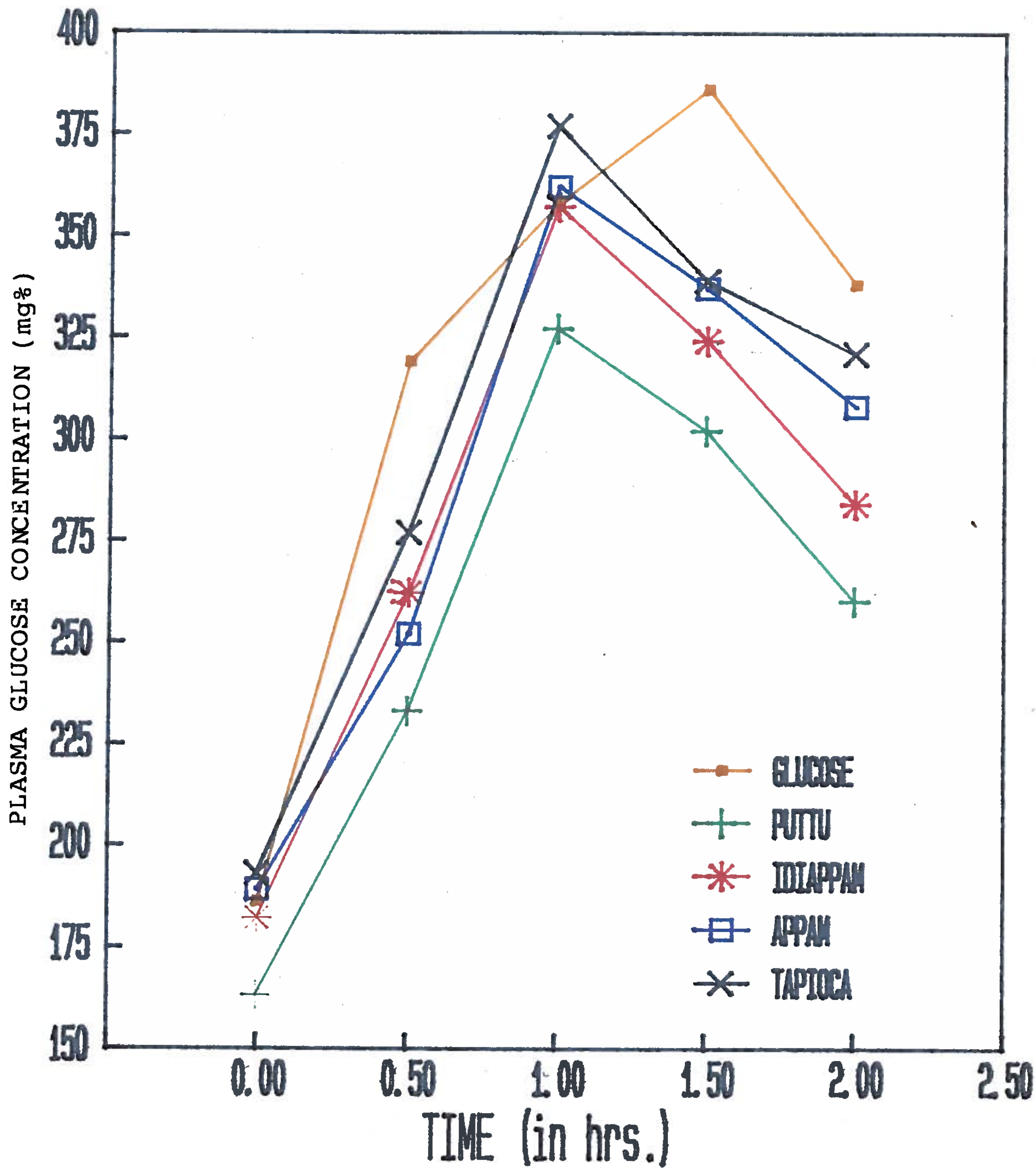

Fig.5: PLASMA GLUCOSE CONCENTRATION OF THE SUBJECTS TO DIFFERENT BREAKFAST ITEMS

The mean plasma glucose values at each time point following the intake of puttu was lower though not significantly (P>0.05) compared tothat of glucose. However, for the other breakfast items, the values at almost all time points except at 1 hr (when the peak was observed) was lower but not significantly (P>0.05) than that after glucose stimulation.

4.3 DETERMINATION OF GLYCAEMIC RESPONSE

The glycaemic responses of the breakfast items were calculated by comparing the area under the 2 hr response curve (AUC) of the breakfast item to that of glucose. The mean total areas under the plasma glucose response curve (AUC) for the four breakfast items and glucose are given in Table 11.

Table 11: Mean AUC of the food items

Breakfast item	Mean total AUC (mg%)
Glucose	1402.48 ± 341.01 [a]
Puttu	1122.58 ± 332.42 [b]
Idiappam	1227.65 ± 382.05 [b]
Appam	1259.03 ± 255.45 [a]
Tapioca	1315.63 ± 296.42 [b]

Values with different supercripts are significantly different (P<0.05). All values were compared with glucose.

The mean total AUC or the overall glycaemic stimulus is significantly lower ($P<0.05$) compared to glucose, following the stimulation of only puttu, idiappam and tapioca but not appam. The overall glycaemic response after the consumption of tapioca was found to be the highest of the four items tested. Individual values of AUC are given in Appendix C.

The comparative area under glucose response curve (AUC) values of the food items are represented in Fig.6.

The glycaemic responses of the test preparations was calculated using the formula

$$\text{Glycaemic response} = \frac{\text{Area under the 2 hour glucose stimulation curve of breakfast item}}{\text{Area under the 2 hour glucose stimulation curve of glucose}}$$

The mean glycaemic responses of the food items is presented in Table 12. The individual glycaemic responses of the subjects are given in Appendix D.

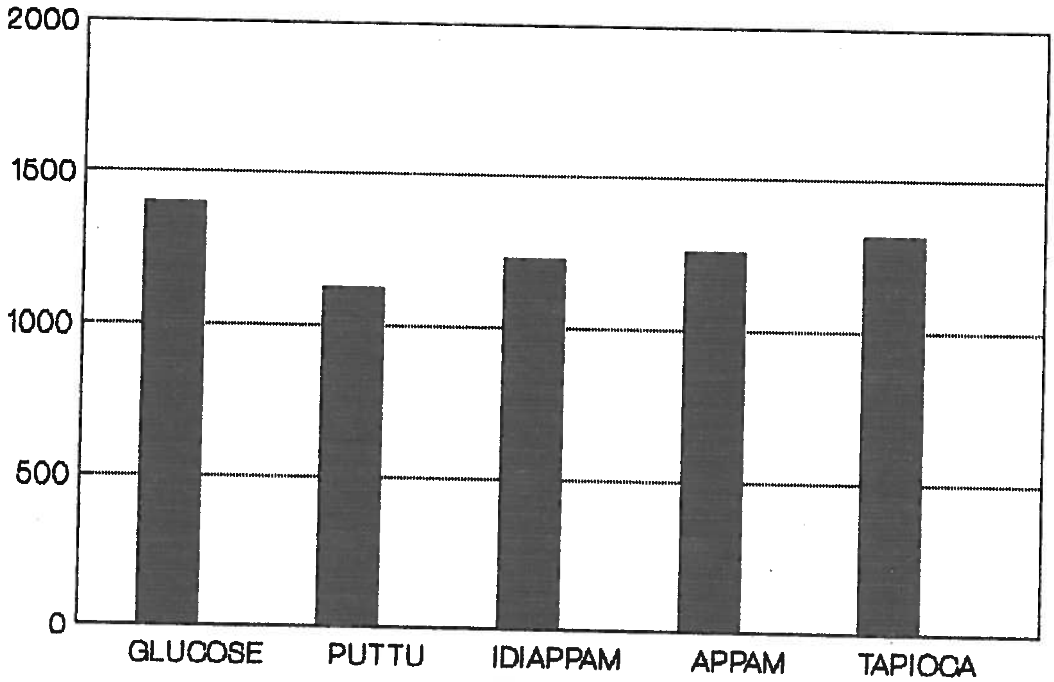

Fig. 6: COMPARATIVE AUC VALUES OF THE FOOD ITEMS

Table 12 : Mean Glycaemic responses of food items

Food item	Glycaemic response
Glucose	1.00
Puttu	0.79 ± 0.11
Idiappam	0.86 ± 0.10
Appam	0.90 ± 0.11
Tapioca	0.93 ± 0.04

The glycaemic response of puttu is the lowest (0.79 ±0.11) of the four breakfast items tested, followed by idiappam (0.86 ± 0.10). The GR of appam and tapioca were found to be the highest and almost similar to that of glucose. Though there is a difference in the glycaemic responses of these four breakfast items, the difference is not statistically significant ($P>0.05$).

4.4 RELATIONSHIP BETWEEN GLYCEMIC RESPONSE AND PEAK PLASMA CONCENTRATION

The relationship between the peak plasma concentration (C max) and glycaemic response is shown in Fig. 7. There is a significant correlation between C max and glycaemic response of the breakfast items ($r=0.96$; $P<0.05$). The regression coefficient (b) is found to be 390 which implies that for every unit

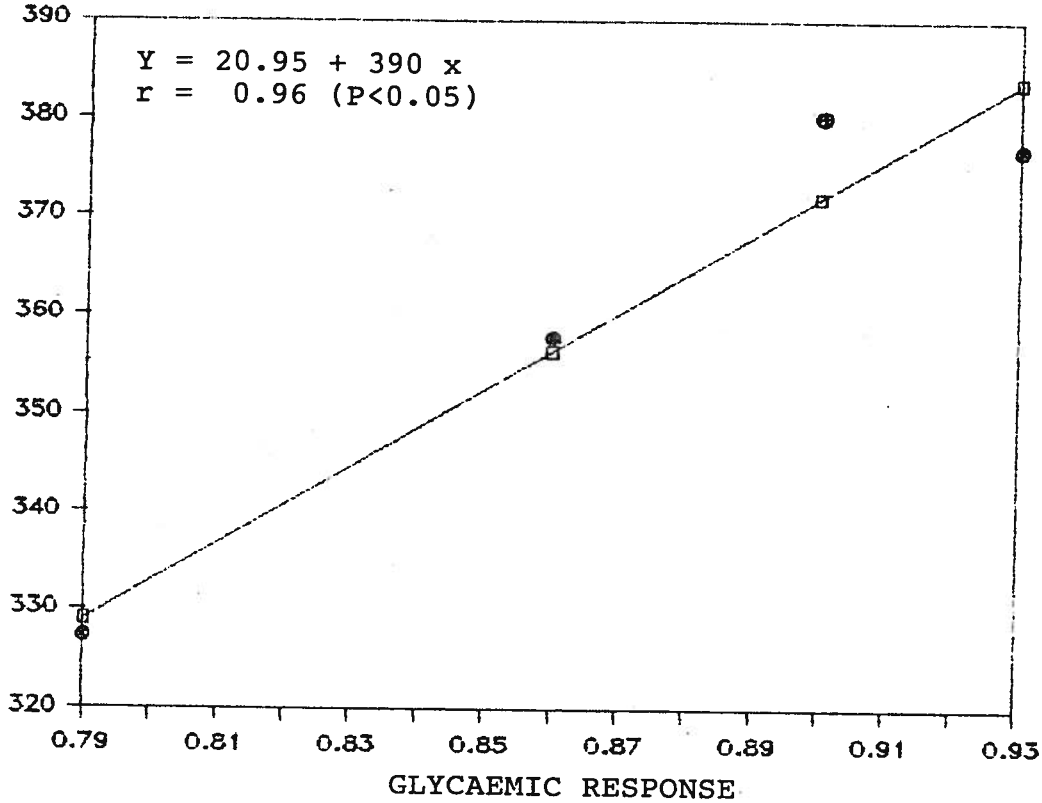

Fig.7: RELATIONSHIP BETWEEN PEAK PLASMA CONCENTRATION (C_{max}) AND GLYCAEMIC RESPONSE

increase in glycemic response, the C_{max} would increase 390 times. But since glycemic response values are less than 1.00, it could be interpreted that for every increase of 0.10 in the glycemic response the C_{max} would increase 3.9 times.

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DISCUSSION

CHAPTER V

DISCUSSION

Diabetes mellitus - a complex metabolic disorder is the third commonest disease in the world next to the cardiovascular and oncological disorders. Every fifth person in the world suffers directly or indirectly from diabetes. In our country also, diabetes is a common disease affecting 2-4 per cent of the Indian population, and a majority of them (90%) are diagnosed as non-insulin dependent diabetics. In the management of non-insulin dependent diabetic mellitus (NIDDM), diet has been recognized as a cornerstone of therapy. During the past few decades, dietary modification in the treatment of diabetes mellitus have advanced from alterations in nutrient constituents (mainly CHO) of a meal to alteration in the whole meal itself. Recent studies (Jenkins et al., 1981; 1983; 1984; Coulston et al., 1984) have suggested that not just the CHOs ingested but the biological equivalents (i.e. quantities of food yielding the same effect on blood glucose) or the glycaemic response of a food should be considered, while planning a diet for diabetics.

For an effective dietary management of diabetes, it is better to modify the diet appropriate to the individuals's life-style considering the traditional eating patterns. The glycaemic response of most of the commonly consumed Indian breakfast items have been studied (Vishwanathan et al., 1988; Raghuram et al., 1988), but there is a paucity of data on the glycaemic responses of the typical cereal (rice) based preparations of Kerala.

In this study, six non-insulin dependent diabetic Malayalee men in the age range of 40-51 years were selected. They were served separately the test breakfast items namely puttu, idiappam, appam and tapioca and a 75 g glucose load in a random order after an overnight fast. The fasting and postprandial blood samples were collected and the plasma glucose levels estimated. The glycaemic responses to the four breakfast items as compared to that obtained with glucose in the diabetic subjects was determined by comparing the areas under the 2-hour glucose response curves (AUC). The diets used in this study have been planned on an isocaloric basis so as to obtain the glycaemic response to the food consumed as a whole rather than to the CHO content of food consumed.

The mean plasma glucose values at each time point following the consumption of breakfast item was lower compared to glucose administration, though not significantly ($P>0.05$). The mean peak rise over fasting plasma glucose levels was found to be significantly lower ($P<0.05$) only after puttu consumption when compared to oral glucose tolerance test (OGTT). However, mean AUC was significantly lower ($P<0.05$) only after the consumption of puttu, idiappam and tapioca when compared to that of OGTT. The mean glycaemic response (GR) to puttu in the subjects has been found to be the lowest of the four breakfast items tested. This response has been found to be similar to that of pongal which has been recommended to be a suitable breakfast item for diabetic patients (Vishwanathan *et al*., 1988; Raghuram *et al*., 1988). The GR of tapioca was found to be highest of the breakfast items tested. But, no significant difference ($P>0.05$) has been found in the glycaemic responses among the different breakfast items. Collier *et al*. (1986) have also reported that in a group of six individuals a significant difference in glycaemic response is unlikely between meals that vary in GI by less than 21.

The breakfast items puttu, idiappam and appam are rice-based and tapioca that elicited the highest GR is a root-vegetable. The rice based breakfast items differed only in the physical form of food and method of cooking. All the four food preparations tested were isocaloric (390 K Cal) and had similar CHO content. Thus the small differences in GRs could arise mainly due to the type and form of CHO available from each food item and to the presence of non-CHO constituents, i.e. fats, proteins and unavailable CHOs. Tapioca had a slightly lower CHO content (72 g) than the other breakfast items (73.5 g), yet it showed a higher GR. This could probably be related to the nature of CHO in tapioca. Among the rice-based breakfast items, appam, made from ground and fermented rice batter, elicited a higher GR, highlighting the importance of physical form in determining the physiological responses to a food. The breakfast items tested had relatively low protein contents (less than 10 g) and thus its impact on GR is inconclusive as proteins at levels greater than 25 g seem to blunt the rate of increase in blood glucose (Seino et al., 1983). The fat content of the breakfast items was also very low and could not have had any influence on GR as tapioca with higher fat content (10 g) showed a higher GR. The fibre content also seems to have had little effect on the rate of food digestion and absorption and hence on the GR as all the breakfast items elicited mean peak glucose levels at the same time point. Thus, the small differences observed in the glycaemic responses of the subjects to the breakfast items could be attributed to the nature and physical form of the CHO in the breakfast items.

The glycaemic responses to the breakfast items in NIDDM subjects are presented in Table 12. There is a significant correlation between the glycaemic response and the peak plasma glucose concentrations (Cmax) for all the breakfast items ($r=0.96$; $P<0.05$). This implies that the preparation with high GR tends to raise Cmax to a greater extent as compared to a food preparation with low GR. Similar results were reported by Raghuram et al. (1988). The glycaemic responses of the breakfast items tested varied only slightly and were not significantly different from each other.

The rice-based breakfast items differed only in the mode of preparation with the ingredients being almost the same (Rice flour, coconut and bengalgram curry). Puttu that elicited the lowest GR among the breakfast items tested, is prepared by only moistening the coarse rice flour and steaming in a 'kola' (aluminium tube) over boiling water. Idiappam is prepared with finer rice flour made into a soft dough and steaming the extruded dough. Appam that elicited a higher GR is prepared by pan-frying a batter of ground rice, coconut milk and toddy. The main difference in these three breakfast items is the variation in the particle size of rice flour. The larger particle size of the moistened rice flour of puttu could have affected the degree of gelatinization of starch while cooking, thus affecting digestion and contributing to the lower GR as compared to idiappam made from a soft dough of fine flour. Susan et al. (1987) have also reported that the glycaemic index correlates positively with the degree of gelatinization and with the per cent of starch digested. The effect of particle size on GR was demonstrated by O'Donnell et al. (1989). They reported that bread made from coarse flour resulted in lower plasma glucose insulin concentration than that made from fine flour.

The relatively higher GR of appam could be attributed to the wet grinding and fermentation of rice prior to cooking leading to complete gelatinization of starch and enhanced rate of starch digestion of the product. Fermentation of pearl millet sprouts, green gram and sorghum has been reported to significantly increase protein and starch digestibility (Chavan et al., 1988; Khetarpaul and Chauhan, 1990). Various other studies have also demonstrated that the relative rate of starch hydrolysis and postprandial glucose response of brown rice was significantly lower than ground brown rice and glucose, but there was no significant difference in the metabolic responses to ground brown rice (complex CHO) and glucose (simple CHO) in either diabetics or normal subjects (O'Dea et al., 1981; Collier and O'Dea, 1982). In the present study also the mean peak rise over fasting levels and mean AUC of appam was not significantly different from that of glucose (P>0.05). This data thus provides a rationale for designing diabetic diets containing complex CHO in a form which is slowly digested and absorbed.

Tapioca (root vegetable) and appam (rice product) in fact elicited almost similar GRs. The physical process of breaking the rice starch into smaller particles and ingesting them seems to have eliminated the factors intrinsic to the whole food that would have led to different glycaemic potencies in these two different sources of CHOs. Similar findings have been reported by Crapo and Henry (1988) that differences in metabolic responses to two common starches (rice and potato) could be eliminated by altering the physical form (blended to form a slurry). They suggested that differences in glycaemic potencies of different starch containing foods are not due to variations in the starch molecule per se but rather the way it is presented to the gastro-intestinal digestive and absorptive processes. The physical access of digestive enzymes to starch molecules of native food stuffs differs and blending food alters this difference so that all starch molecules now have equal availability to digestive enzymes. Blending also leads to dispersion and hydration of starch which could be an important factor in absorption and hence determination of GR. Thus, the particle size of food, when presented to the gastro-intestinal tract, is a major factor that affects its digestion and absorption and hence its GR.

The processing methods involved in the preparation of the breakfast items may have also influenced the level of blood glucose by affecting the rate of digestion of food items. Jenkins et al. (1982) have reported that if maximal benefit (lowest blood glucose level) is to be realized from low glycaemic foods, attention must be paid to the amount of heat used in the preparation as it affects digestibility and hence GR to a food. Boiling of tapioca must have resulted in complete gelatinization of starches, thereby increasing the digestibility and eliciting a higher GR. In the other rice based breakfast items, the effect of exposure of starch to heat varied with the physical form of food in which the item was cooked.

Steaming of puttu, (prepared from moistened flour of larger particle size) must have resulted in an incomplete gelatinization of starch compared to the steaming of idiappam where a more complete gelatinization of starch must have occurred (finer grain size of flour) thus increasing the rate of digestion and absorption and hence an increased GR. Idiappam is a preparation that is comparable to spaghetti as they undergo similar processing. Jenkins et al. (1983) have reported that flour in the form of spaghetti raised blood glucose levels much less than when the same amount of CHO was eaten as bread. Chitra and Bhaskaran (1989) have also reported that idiappam elicited lower GRs compared to cooked rice in diabetics. Thus, it can be assumed that idiappam, like spaghetti lowers the GR due to the effect of processing that it undergoes.

In the preparation of appam, rice was subjected to wet-grinding before cooking which would have led to the dispersion and hydration of starch (which is an important factor in absorption). Even though the starch was exposed to dry heat (pan frying) after wet grinding only for a short time, complete gelatinization must have occurred in the product leading to an increased GR. Similar results were reported with lentils through in vitro studies by Wong et al. (1983). They demonstrated that grinding lentils before cooking increased the rate of starch hydrolysis by five folds. Thus, the method of preparation of a breakfast item may also affect the rate of digestibility of the food and hence GR.

The breakfast items elicited mean peak plasma glucose values at 1 hour as compared to 1 1/2 hour after OGTT. The reasons for this variation are not clear. Jenkins et al. (1984) have reported that the higher tonicity of glucose solution may result in a delayed gastric emptying. So it is possible that the 75 g glucose load could have led to a delayed gastric emptying and a delayed peak at 1 1/2 hour when compared to the peak at 1 hour after consumption of the breakfast items.

Thus, the small differences observed in the glycaemic responses to different breakfast items in NIDDM subjects in the present study may be due to differences in nature of CHO, physical form of the food and also method of processing. The results of the study lend support to the current concept that only with chemical analysis of food for its CHO content, it is not possible to predict the physiological response to a food. Among the breakfast items tested, puttu has a comparitively lower GR as compared to the other breakfast items and is found to be suitable for diabetic patients. Thus, these results suggest that even traditionally used cereal based food items may be identified by their lower GR and can be recommended for diabetics.

However, there is a need to conduct these studies on more subjects and extend to other food preparations and also to the various mixed meals consumed in a day in normals and diabetics to elucidate the factors affecting the GR to a food.

These traditional breakfast items that are rice-based can be prepared by substituting rice with millets. The acceptability and glycaemic response to these products may be investigated. This information would be useful in planning diets for diabetics as millets have shown to lower blood glucose levels (Kamini, 1975).

Similar studies can also be carried out by substituting rice by millets like jowar, bajra and ragi in the commonly consumed South Indian breakfast items like idli, dosa, upuma, pongal etc.

The effect of addition of hypoglycaemic agents like fenugreek and other condiments to these breakfast items needs to be investigated.

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SUMMARY

CHAPTER VI

SUMMARY

Diabetes mellitus is a metabolic disorder with a widespread prevalence in India (2-4%) and is being treated with drugs and more recently with dietary modifications. Foods have now been classified into high and low glycaemic foods based on their glycaemic response (Jenkins et al., 1981). Glycaemic response reflects the physiological response of food apart from just the effect of carbohydrate and thus helps in planning a good diabetic diet.

In the present study, the glycaemic response to four breakfast items commonly consumed in Kerala, namely puttu, idiappam, appam and tapioca was studied in six non-insulin-dependent diabetic Malayalee men. The diets were planned to be isocaloric (290 K cal) and contained almost similar amounts of carbohydrate, protein and fat. Each of the breakfast items and glucose load (75 g) were given to the subjects in a randam order after an overnight fast. A gap of atleast two days was given between the breakfast items.

The fasting and postprandial blood samples at four half hourly intervals were collected and plasma glucose levels estimated by the glucose oxidase-peroxidase (GOD-POD) method using the Boehringer

Mannheim kit. The glycaemic responses to the four breakfast items as compared to that obtained with glucose, in the diabetic subjects, were determined by comparing the areas under the 2-hour glucose response curves (AUC).

Results obtained indicated that the mean peak rise over fasting plasma glucose levels was significantly lower ($P< 0.05$) only after puttu consumption when compared to the oral glucose tolerance test (OGTT). However, the mean AUC was significantly lower ($P<0.05$) after the consumption of puttu, idiappam and tapioca when compared to that of OGTT. The mean glycaemic response to puttu (0.79) in the subjects have been found to be the lowest of the four breakfast items tested followed by that of idiappam (0.86). Appam (0.90) and Tapioca (0.93) elicited a higher glycaemic response. But, no significant difference ($P > 0.05$)has been found in the glycaemic responses among the different breakfast items.

Among the breakfast items tested, puttu that elicited a comparitively lower glycaemic response as compared to the other breakfast items may be recommended for diabetics. Thus, these results suggest that even traditionally used cereal based food items may be identified by their lower glycaemic response and can be recommended for diabetics.

All the four breakfast items tested were isocaloric and had similar carbohydrate content. The protein, fat and fibre contents of the breakfast items were low and hence their impact on glycaemic response is inconclusive. Thus, the small differences in glycaemic responses could be mainly due to differences in nature of CHO, the physical form of food (particle size) and the method of processing.

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LITERATURE CITED

LITERATURE CITED

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APPENDICES

APPENDIX - A

RECIPES OF THE BREAKFAST ITEMS PER SERVING

1. PUTTU

ingredients

Rice flour	75 g
Coconut (grated)	25 g
Salt	a pinch

Procedure

Rice flour was dry roasted lightly. The flour was mixed with salt and moistened by sprinkling a little water. The moistened flour was filled into a 'Kola' (a tubular vessel) alternating with grated coconut and steamed over boiling water (as in a double boiler) for about 3 minutes. The cooked puttu which takes the shape of the kola was taken out and served with a curry.

2. IDIAPPAM

Ingredients

Rice flour	75 g
Coconut (grated)	25 g
Salt	a pinch
Hot water	as required

Procedure

Rice flour was roasted till dry and crisp. Salt was added to the flour and a soft dough was made with hot (boiling) water. The prepared dough was extruded through a "Savainazhi" (muruku press) on to idli moulds. The extruded dough was topped with grated coconut and steamed in a pressure cooker for about 3 min. The prepared idiappam was served with a curry.

3. APPAM

Ingredients

Rice	73 g
Coconut	25 g
Fresh toddy	15 ml

Procedure

Rice was soaked in water for two hours and then ground into a smooth paste along with fresh toddy. The mixture was left overnight to ferment. In the morning, it was mixed with coconut milk to make a thin batter. An appam pan (a deep vessel or karai) was smeared with oil and a little of the paste was spread on it. The vessel was covered and cooked for about 3 min. on slow heat, till done. Appam was served along with a curry.

4. BOILED TAPIOCA

Ingredients

Tapioca	190 gm
Salt	to taste
For seasonings.	
Oil	10 g
Dry red chillies	2 Nos.
mustard	1/8 tsp.

Procedure

Tapioca was peeled, washed and cut into 2" x 1" pieces. The diced pieces were cooked in boiling water till done and drained. Oil was heated in a karai and the seasonings were added. The cooked tapioca pieces were added and tossed along with a little salt. The seasoned tapioca was served along with a green chilli-onion chutney.

5. BENGAL GRAM CURRY

Ingredients

Whole bengal gram (desi variety)	20 g
Onions	10 g
Oil	5 g
Coriander powder	a pinch
Salt	to taste

Procedure

Whole bengal gram was soaked in water overnight and then cooked in a pressure cooker. Oil was heated in a karai and onions (cut into small pieces) were sauted. The boiled bengal gram, coriander powder and salt were added. The stock was added and the curry cooked till a gravy of required consistency was obtained.

APPENDIX - B

PLASMA GLUCOSE ESTIMATION (USING BOEHRINGER MANNHEIM KIT)

Enzymatic colorimetirc method (Trinder P, 1969)

Principle

Glucose is oxidised by glucose oxidase (GOD) to give gluconic acid and hydrogen peroxide. The hydrogen peroxide formed is broken down by peroxidase (POD) to water and oxygen. The latter oxidise phenol which combines with 4-aminophenazone to give a red coloured complex. The intensity of the red coloured complex is proportional to the concentration of glucose in the specimen under test. The intensity of the coloured complex is measured colorimetrically at 510nm. Reactions involved are:

(i) glucose + O_2 + H_2O $\xrightarrow{GOD}$ gluconate + H_2O_2

(ii) 2 H_2O_2 + g-aminophenazone + phenol $\xrightarrow{POD}$ 4-(P-benzoquinone-mono-imino) phenazone + 4 H_2O

Reagents

1. Buffer/Enzymes/4-Aminophenazone
2. Phenol
3. Standard glucose - 100 mg/100 ml.

The contents of one bottle of Reagent 2 was dissolved in 200 ml of double-distilled water, and to this was added one bottle of reagent 2 (phenol). The reagent mixture was stored in a dark bottle at $4^{o}C$. The mixture is stable for four weeks at $+2^{o}C$ to $+ 80^{o}C$.

The standard glucose solution was used undiluted.

<u>Sample preparation</u>

Blood samples to which a pinch of NaF was added was centrifuged immediately to separate plasma from the cells. The plasma samples were stored at $4^{o}C$ and estimated for plasma glucose the next day.

The plasma sample can be stored upto 24 hours at +15 to $+25^{o}C$ after addition of glycolysis inhibitor (NaF,KF), or upto seven days in a closed vessel at $+4^{o}C$ (Boehringer Mannheim Instruction Manual).

<u>Procedure</u>

0.03 ml of the sample was pipetted into a test tube and for the standard, 0.03 ml of the standard glucose solution (reagent 3) was taken. To each of these test tubes and also for blank, 3.00 ml of the reagent mixture was added and mixed well. The test tubes were incubated at $37^{o}C$ for 30 min. The colour developed was read against a blank at 510 nm.

Calculation

$$\text{Plasma glucose concentration (mg/dl)} = \frac{\text{Reading of the sample}}{\text{Reading of the standard}} \times 100$$

Normal values*

in blood	70 - 100 mg/dl
in serum/plasma	76 - 100 mg/dl

(* Boehringer Mannheim Instruction Manual)

APPENDIX - C

Total area under the plasma glucose response curve (AUC) for the breakfast items and glucose.

Breakfast Item / Subjects	Glucose	Puttu	Idiappam	Appam	Tapioca
1.	879.1	588.0	751.8	869.3	867.6
2.	1358.2	987.0	963.0	1344.2	1250.0
3.	1866.5	1274.9	1735.7	1433.7	1686.4
4.	1422.7	1235.9	1129.8	1098.6	1275.0
5.	1652.0	1580.3	1628.5	1589.6	1605.3
6.	1236.4	1069.4	1157.1	1218.8	1209.5
Mean	1402.48	1122.58	1227.65	1259.03	1315.63
S.D.	341.01	332.42	382.05	255.45	296.42

APPENDIX - D

Glycaemic response to breakfast items in diabetic subjects.

Breakfast items / subjects	Puttu	Idiappam	Appam	Tapioca
1.	0.67	0.85	0.98	0.98
2.	0.73	0.71	0.98	0.92
3.	0.68	0.93	0.76	0.90
4.	0.87	0.79	0.77	0.89
5.	0.95	0.98	0.96	0.97
6.	0.86	0.93	0.98	0.97
Mean	0.79	0.86	0.90	0.93
S.D.	0.11	0.10	0.11	0.04