DEVELOPMENT AND EVALUATION OF MILLET BASED COMPOSITE FOOD FOR DIABETICS

SUNANDA K. ITAGI

DEPARTMENT OF FOODS AND NUTRITION
COLLEGE OF RURAL HOME SCIENCE,
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005

FEBRUARY, 2003

DEVELOPMENT AND EVALUATION OF MILLET BASED COMPOSITE FOOD FOR DIABETICS

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfillment of the requirements for the
Degree of

Doctor of Philosophy

In

FOODS AND NUTRITION

By

SUNANDA K. ITAGI

DEPARTMENT OF FOODS AND NUTRITION
COLLEGE OF RURAL HOME SCIENCE,
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005

FEBRUARY, 2003

DEPARTMENT OF FOODS AND NUTRITION

COLLEGE OF RURAL HOME SCIENCE

UNIVERSITY OF AGRICULTURAL SCIENCES, DHARWAD

CERTIFICATE

*This is to certify that the thesis entitled " **DEVELOPMENT AND EVALUATION OF MILLET BASED COMPOSITE FOOD FOR DIABETICS**" submitted by **Mrs Sunanda K. Itagi** for the degree of **Doctor of Philosophy** in Foods and Nutrition of the University of Agricultural Sciences, Dharwad, is a record of research done by her during the period of her study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

DHARWAD
February, 2003

(RAMA K.NAIK)
MAJOR ADVISOR

Approved by:

CHAIRMAN: ________
(RAMA K.NAIK)

MEMBERS:

1. ________
(V.GAONKAR)

2. ________
(NIRMALA YENAGI)

3. ________
(PUSHPA BHARATI)

4. ________
(G.SHANTKUMAR)

AFFECTIONATELY DEDICATED

TO

DIABETICS

ACKNOWLEDGEMENT

*I wish to express my sincere appreciation and heart felt gratitude to **Dr. (Mrs.) Rama K. Naik**, Professor and Head, Department of Foods and Nutrition, College of Rural Home Science, Dharwad and chairman of my Advisory Committee, for her inspiring and incessant encouragement shown during the course of this investigation.*

*I avail this opportunity to express my heartfelt thank and deep sense of gratitude to the members of my Advisory Committee, **Dr. (Mrs.) V. Gaonkar**, Professor and Head, Department of Human Development, **Dr. (Mrs.) Nirmala Yenagi**, Associate Professor, Department of Foods and Nutrition, **Dr. (Mrs.) Pushpa Bharati**, Associate Professor, Department of Foods and Nutrition and **Dr. G. Shantkumar**, Assistant Professor, Agricultural Research Station, Hanumanamatti, University of Agricultural Sciences, Dharwad for their co-operation valuable suggestions and times review of my work in making this investigation more meaningful.*

I extended my thanks to Director of Instructions (PGs) for providing me an opportunity to carry out my Doctoral Research. My sincere feeling of indebtedness to the staff of Foods and Nutrition and Human Development Department for their help and encouragement during the course of my research. I also thank Mrs. Ashalatha, Statistician, AICRP (CD) for her sincere help and guidance during the analysis.

I like to express my sincere gratitude to diabetic and non-diabetic volunteers of Hubli-Dharwad for their co-operation during the research *work of the study. I owe all my success to my family members whose unfailing love and affection has been a source of inspiration to me.*

Lastly I thank Mr. Sundar S. Potdar, who have neatly typed this thesis for printing the manuscript neatly.

Dharwad

February, 2003

S.K. Itagi

(Mrs. Sunanda K. Itagi)

CONTENTS

Contd…

LIST OF TABLES

Contd...

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Contd…

Introduction

I INTRODUCTION

Diabetes Mellitus is the most common metabolic disorder affecting humankind and creating health hazards. Indian physicians Charaka and Sushrutha gave the earliest description of diabetes during 6^{th} century AD and who recommended physical exercise and proper diet for the control of diabetes. Later, Arab physician Avicena (960-1037) prescribed a mixture of lupin, fenugreek and *zedoary* seeds, which exhibited hypoglycemic response and helped in curing diabetes. A new era began in 1921, with the discovery of Insulin by Banting and Best, which saved thousands of lives. At present, anti-diabetic medicines *viz.*, 'Sulfonamide, Biguamide, Acarbose play a vital role in the control of the diabetes, hence it is a disorder which cannot be cured but kept under control through proper management strategies.

Diabetes exists in all population sectors, with variations in prevalence between different ethnic groups and geographical areas. A multi centre study of Indian Council of Medical Research (ICMR), revealed an incidence of diabetes upto three per cent in urban and 1.8 per cent in rural India (Ahuja, 1979). Whereas current scenario pointed out a prevalence upto 11.6 per cent in urban and 2.4 per cent in rural areas of South India (Ramachandran, 2002). At present 11 per cent of Chennai and 7-10 per cent of Bangalore population found to be diabetic (Krishnaswamy 2002), thus diabetes is increasing at an alarming rate in the country. Though diabetes is associated with aging the recent hike can be attributed to change in life styles, poor dietary habits and stressful events affecting the younger generations of 25-40 years leading to premature deaths and disabling complications.

The worldwide two large study groups, namely Diabetes Control and Complication Trial of United States of America and the United Kingdom Prospective Diabetes Study confirmed that optimal glycemic control reduced the risk of vascular complications by 60 per cent. Hence early diagnosis and intervention reduces the economic burden and morbidity and mortality rates among diabetic population (Anon, 1993 and 1998).

The earlier classification of diabetes mellitus given by WHO (1985) has been reclassified by the Expert Committee of American Diabetic Association (ADA) (Anon, 1997) into four board types *viz.*

Type 1 diabetes -- includes β-cell destruction or absolute insulin deficiency.

Type 2 diabetes -- range from insulin resistance to secretary defect in insulin.

Other specific types -- includes genetic defects in β-Cells function, diseases of endocrine and exocrine pancreas.

Gestational Diabetes Mellitus

Among these, type 2 diabetes constitute more than 90 per cent of diabetic population, growing constantly and leading to multiple health problems. Two primary defects impaired beta cells function and diminished tissue sensitivity in liver and muscle cells cause the type 2 diabetes. American Medical Association has designated diabetes as a 'silent disease' because in uncontrolled condition the vital organs get damaged severely without any warning symptoms (Anon, 1994).

The recent study conducted by Kapur and co-workers (2000) presented realistic scenario of diabetic complications *viz.*, loss of vision (46%), heart attacks (24%), kidney failure (17%), limb amputations (7%) and impotency (3%) among Indian diabetic population. Hence, appropriate treatment modalities should be envisaged in diabetic management with individualized care.

Recently, American Diabetic Association has recommended standard for Glycosylated haemoglobin (HbA) less than 7%, blood glucose, 90-130 mg / dl before meals and 110-150 mg / dl at bed time with personalized dietary regime for good monitoring of the diabetes (Anon, 2000). For better quality of life, early detection and use of modern therapy in diabetes control is essential.

Dietary regulation is a major component of the diabetes monitoring to avoid further complications. Dietary prescription should be individualized considering the dietary pattern, habitual diet and regional availability of the foods to achieve better meal adherence. At present the recommended diabetic diet is high carbohydrate, high fibre and low fat because it helps in minimizing the rise in post prandial hyperglycaemia and serum cholesterol. Hence, the diabetic diet should provide 60-65 per cent calories from carbohydrates, 15-25 per cent from fat and 15-20 per cent from protein foods to achieve closeness to the normal diet (Raghuram, 1996). The total calorie requirement of the diabetic depends on age, gender, weight, height, physical activity and physiological needs of the individual

Cereals and millets, the staple foods in an Indian diet, supply carbohydrates that constitute major caloric requirement even in diabetic diet. Several studies have shown that generous supply of carbohydrates along with high fibre (25g/1000 calories) has beneficial effect in improving glucose tolerance and insulin sensitivity (Vishwanath *et al.*,1981, Wolever, 1990b and Anderson *et al.*,1991). Studies have also demonstrated that the diet rich in complex carbohydrates delays gastric emptying and slows down glucose absorption which is advantageous for diabetics.

Food habit surveys conducted in India revealed that the major cereals used are rice and wheat and commonly supplemented with millets and pulses. The minor millets like sorghum, pearl, finger, foxtail, little, barnyard and kodo are familiar staple foods among the people of lower socio-economic groups, tribes and hilly regions of India. The millets being disease resistant, adaptive and tolerant to adverse environmental conditions, grown with minimum input costs from grower's side. These are used for various purposes *viz.*, food, feed, fodder, green manure and medicines.

Recent studies indicate that minor millets are nutritionally superior to conventional food grains and exhibit hypoglycemic effect due to presence of higher proportion of unavailable complex carbohydrate, resistant starch and release sugars slowly (Malleshi, 1993, Mani *et al.*, 1993 and Krishnakumari and Thayumanavan, 1997).

In addition, millets contain water-soluble gum β-glucans which improve glucose metabolism. Therefore, the millets are suitable in diabetic diet to improve metabolic control of glucose.

The flavor and difficulty in processing of millets are the limitations for their use in the routine diets. Hence, combination of millets, pulses and spices with suitable processing protocol may be emerged to develop composite foods / mixes which will cater the needs of the diabetics and overcome the problem of aroma with improvement in functional quality of the products.

It has been reported that addition of pulses in composite food / mix improved acceptability of the products along with lowering of glyco-lipemic response in diabetic volunteers (Mani *et al.*, 1992a). Studies have indicated that addition of spices *viz.*, fenugreek, cumin seeds, turmeric, garlic and coriander seeds in composite foods serve as an effective supportive therapy in lowering the glucose levels of diabetic subjects (Sharma and Raghuram, 1990 and Srinivasan, 1997). It has been also suggested that glucose and insulin response in diabetics depends on type of starch, processing method, physical form of food, starch digestibility and mixed meal pattern (Crapo *et al.*, 1988, Comi *et al.*, 1995 and Lintas *et al.*, 1995). Hence, mixed meal or composite food with blend of millets, pulses and spices having natural source of dietary fibre can be advised as diabetic food for long-term efficiency and good compliance.

A few studies have pointed out that millets like foxtail, little and pearl millets are traditionally accepted good sources of dietary fibre with slow digestible carbohydrates and possess hypoglycemic properties which is beneficial in diabetic diet (Geeta and Eshwaran, 1990, Hadimani and Malleshi, 1993 and Torangatti, 1995). The milled millets (bran removed) have quick hydration and softening property, which is advantageous in preparation of quick cooking cereal products. The milled and pearled millets possess better nutritive value, blend easily with pulses and spices and culturally accepted by the local people. Thus the characteristic nature of small millet carbohydrates combined with dietary fibre render their suitability for development of diabetic food and give scope to popularize the nutritional benefits of the minor millets. Hence, the present study has been conducted to exploit nutraceutical benefits of millets through development of millet based diabetic composite food / mix and encourage their utilization in daily diet of diabetics.

The present study has been focussed on type 2 diabetics, due to their high prevalence and type 1 diabetics deleted to avoid intra and inter individual differences. The study is an attempt in this direction with the following objectives.

1. To develop ready to use millet based diabetic composite food / mix.
2. To evaluate the nutritional quality of the developed diabetic composite food.
3. To standardize acceptable products from the mix to suit Indian palate.
4. To assess glycemic index of the diabetic composite food.
5. To test clinical efficacy in terms of glyco-lipemic responses in long term feeding among non-diabetic and diabetic human volunteers.
6. To popularize and commercialize the developed diabetic composite food / mix.

Review of Literature

II REVIEW OF LITERATURE

Diabetes is now one of most common global metabolic disorders. It is the fifth leading cause of death in many countries. Complications from diabetes – coronary artery and peripheral vascular disease, stroke, diabetic neuropathy, amputations, renal failure and blindness – are resulting in increasing disability, reduced life expecting and enormous health cost for virtually every society. The policy makers and public health planners are still unaware of the current magnitude and serious consequences of diabetes on the population. Therefore, an effective preventive and control protocol for insulin dependent diabetes mellitus (Type 1) and non- insulin dependent diabetes mellitus (Type 2) are inevitable in the present context of management. The studies related to diabetes and management protocol are reviewed is the following text.

2.1 Magnitude of diabetes

Diabetes mellitus can now be found in almost every population of the world and epidemiological evidence suggest that, without effective curative, preventive and control protocols, it will continue to increase globally.

2.1.1 Global scenario

Orchard (1999) projected that the world's diabetic population will probably have doubled from an estimated 110 million in 1994 to 221 million in 2010. In the similar line, several attempts have been made to estimate the global burden of diabetes. The World Health Organization (WHO) report (1997) on epidemiological information indicated that the global burden of 135 million diabetics in 1995 will increase to 229 million by the year 2025.

Joshi (1998) reported that 124 million people suffered form diabetes and 3.5 million were IDDM out of the diabetic population in the world. Continental distribution viewed by the report is as follows.

Continent	Prevalence (in millions)
Asia	66
Europe	22
North America	13
Latin America	13
Africa	8
Occania	1

The regions with higher potential increase are Asia and Africa, where diabetes may spurt 2 to 3 times more than existing situation. The Asian countries will harbor 61 per cent of the total global projected number of diabetes by 2010 (Anon, 1997).

Castaneda and Odilia (1999) reported that 25 million diabetic population in America accounts for 25 per cent of world population and estimated to increase upto 45 per cent by the year 2010. These projections pointed out drastic increase in Central American 'transplanted population' such as Africans in America. Thus diabetes prevalence has increased among populations of the developing countries especially in migrant and minority communities. According to review report of Viswanathan *et al.* (1988) the of diabetes among migrant Indians is as follows (Table 1).

Table 1. Prevalence of diabetes among migrant Indians

Place	Source	Age group (yr)	Prevalence (%)
Fiji	Cassidy (1967)	>20	5.7
Trinidad	Zimmet *et al.* (1985)	>40	13.0
South Africa	Poon-king (1968)	all age	2.4
Singapore	Jackson (1978)	>10	6.0
London	Cheah and Tan (1980)	>15	6.1
Mauritius	Mather and Keen (1985)	>20	2.2
	Ohlson *et al.* (1985)	>40	8.9

2.1.2 Prevalence of diabetes in India

Diabetes is not only spreading fast in India but hitting even the young population. Currently 30 million people are suffering from diabetes in India and it may increase to 60 million by 2025 (Kapur, 2000).

According to Kaul (2000) the recurrent exposure of Indians to fasting and feasting might have created fat cells which are insulin resistant leading to central obesity, one of the major causes of the diabetes mellitus.

The increasing trend of diabetic population is projected in Table 2.

Table 2. Prevalence of diabetes in India

Study Area	Diabetic	Population	Source
	Urban (%)	Rural (%)	
ICMR Multi Centre	2.3--3.0	1.5–1.8(>15yr)	Ahuja (1979)
New Delhi	9.0 (>40 yr)	--	Verma *et al.* (1986)
Kudremukh	5.0 (>20yr)	--	Ramachandran *et al.*
		---	(1988)
Elura	--	6.1 (>40yr)	Yagnik (1995a)
Madras	8.2 (>20yr)	2.4 (>20yr)	Ramachandran (1995)
Pune	--	4.0 (>20yr)	Yagnik (1995b)
Dharwad	--	2.8 (>50yr)	Naik (2000)

2.2 Significance of the diet in diabetic management

A carefully planned diet is one of the ways of the management of diabetes. The dietary recommendations for diabetes seems to vary from time to time along with research insight, social changes and individual life style (Ghoshal, 1999).

Raghavan and Mohan (1999) lay down specific goals of nutritional management of diabetes as follows.

- Maintaining normoglycemia.
- Achieving optimum serum lipid levels.
- Maintaining ideal body weight and over all health.
- Providing normal diet and adherence to the diet plan.
- Treating nutrition related risk factors to prevent complications.

Prior to the discovery of insulin, the treatment of diabetes included intermittent fasting, under nutrition and carbohydrate restriction. With the advent of insulin and oral hypoglycemic drugs, there is an intentional shift to liberal diets providing prime importance to calorie restriction. In recent diabetic diet the recommendation for carbohydrate is 60 to 70, fat 15 to 25 and protein 15 to 20 per cent accounting to 1000 calories for obese, 1400 calories for overweight, 1800 calories for normal weight and 2200 calories for young, active and pregnant diabetics (Ghoshal, 1999).

Viswanathan (1990) experimented diabetic diets with combinations of energy yielding nutrients, such as high carbohydrate, high carbohydrate + high protein and high carbohydrate with high fiber in the hospitals for the period of 10 years. The high carbohydrate with high fiber diet (1800 calories) showed good results in maintaining normoglycemia and adherence to the diet plan among the diabetics.

2.2.1 Effect of diet on the indices of diabetic control

The recent studies related to the type of staples used as main course in the diabetic diet are reviewed in the following section.

2.2.1.1. Efficacy of carbohydrate in diabetic management

The five isocaloric breakfast meals containing identical amounts of protein, fat and carbohydrate (glucose, fructose, sucrose, potato and wheat starch) given to 12 Type I and 10 Type II diabetic subjects. It exhibited greatest glycemic response to glucose and least to fructose and no apparent differences between potato, wheat starch and sucrose, thus highlighting the view that dietary sucrose, when consumed as a part of meal did not aggravate post prandial hyperglycemia (Bantle *et al.*, 1983).

According to Crapo and Henry (1988) the post prandial metabolic responses vary with the physical form of food. The 50g of carbohydrate given in the from of cooked whole rice, potatoes and slurries of rice and potato, to 6 Type 2 and 12 normal volunteers, lowered the glycemic and insulin responses. The whole rice and potato elicited better response compared to slurries.

Indian breakfast foods such as rice and wheat *upma*, *chapathi* and *dosa* supplying 50g carbohydrate when tested on 18 Type II diabetics, revealed no significant differences among these foods (Winnie and Easwaran, 1988).

The lower glycemic response was observed after feeding the isocaloric test breakfasts (*idli*, *pongal* and *upma*) as compared to the bread. The study indicated that the mode of cooking and processing, the from of food, digestion, absorption and metabolism influence the glycemic and insulin response in NIDDM subjects (Viswanathan *et al.*, 1988).

The glycemic and triglyceride responses of five conventional carbohydrate foods such on *dal-iya*, *rava upma* and *dhokla*, *rava* and black gram *dal dhokla* and rava and green gram *dal dhokla* was determined in 36 NIDDM subjects. The lower glycemic and triglyceride responses were observed after consumption of *rava* and black gram *dal dhoklas*, *dal-iya*, *rava* and green gram *dal dhoklas* as compared to *rava upma* and *dhoklas*, indicating that glycol-lipidemic response depends on physical form and processing of the food (Pradhan, 1989).

Chitra and Bhaskaran (1989) demonstrated that food form, dietary fibre and the nature of the carbohydrate have a marked influence on post prandial glycemia. Different glycemic responses were observed when 50g of carbohydrate given in the form of parboiled rice, rice flour (*idiappam*), broken wheat (*upma*), wheat flour (*chapathi*) and *ragi* flour (*mudde*) in 3 IDDM, 3 NIDDM and 3 nondiabetic subjects. It was interesting to note lower glycemic response to *idiappam* than cooked rice among IDDM and healthy volunteers and elevated glycemic response to wheat flour and *ragi* flour as compared to broken wheat in all three groups.

Prabhu (1990) reported the lower glycemic response to *bajra, kodri* + green gram, *kodri* and *jowar* while intermediate GI response to *kodri* in combination with green gram *dal* and equal response of *ragi* to glucose, when tested in 36 NIDDM subjects.

The glycemic response was determined in 36 Type II diabetics providing 50g carbohydrate in the from of six Indian conventional foods including rice, a rice – legume combination (bengal gram, peas, and green gram) and rice – *dal* combination (green gram and red gram). A lower glycemic response was obtained in all combinations except rice and rice with peas and found no significant difference to triglyceride response (Mani, *et al.*, 1990).

Patel (1991) demonstrated that wheat *bhakri* stuffed with fenugreek leaves was most suitable in terms of glycemic and lipemic response followed by puffed rice, wheat *bhakri* stuffed with spinach leaves, rice flakes and wheat *bhakri* given in the form of 50 g carbohydrates foods to 27 NIDDM subjects.

Reducing the glycemic index of the diet (15%) without change in dietary fibre result in modest but significant reductions in blood glucose concentrations in 16 NIDDM as measured by glycosylated hemoglobin. Hence the quality of dietary carbohydrate which influence the metabolic response rather than high carbohydrate diets (Brand, 1991).

Shukla *et al.* (1991) determined the glycemic response of maize, *bajra* and barley in 14 Type II diabetes and 18 healthy volunteers. The glycemic response to barley was significantly lower in both groups of the subject while glycemic response to *bajra* was lower only in diabetic subjects and maize showed no difference in glycemic response in both groups when compared to glucose load.

Agarwal *et al.* (1992) studied the post prandial glycemic response of some commonly eaten foods in 12 NIDDM and 20 normal subjects and concluded that the inclusion of various foods should be based on physiological response (GI) rather than crude isocaloric carbohydrate exchanges.

The glycemic and triglyceride response were studied in 36 Type II diabetics providing 50 g carbohydrate in the form of six different recipes based on cereal-millet like *jowar* (*Sorghum vulgare*), *ragi* (*Eleusine coracana*), *bajra* (*Pennisetum typhoideum*), *varagu* (*Paspalum scrobiculatum*) and *varagu* – pulse combinations (green gram and green gram *dal*). A higher glycemic response was obtained for *ragi*, intermediate to *varagu* + *dal* , *jowar* and *varagu* and lower responses to *varagu* + gram and *bajra*. The triglyceride response did not correlate with glycemic response. The high content of phytin phosphorus, lecithins, saponins and tannins of the millets contributed to the low glycemic response (Mani *et al.*, 1993).

Kavita and Prema (1995) estimated the post prandial glucose response of 75g carbohydrate given as rice, wheat, *ragi* and tapioca in isocaloric meals. The lower glycemic response was observed by wheat followed by *ragi*, rice and tapioca. The least glycemic response of wheat can be attributed to high content of amylose and protein while absence of anti nutrients (phytic acid) in tapioca elicited highest glycemic response.

The glycemic and triglyceride responses were determined by Torangatti (1995) in 6 NIDDM and 6 healthy subjects providing 50 g of carbohydrate in the form of six cereal-millet test foods such as *jowar* with green gram (Phaseolus aurous roxb), rice with red gram *dal* , *chapathi* with green leafy vegetable, *ragi mudde* with *dal* curry, *navane* (*Sateria italica*) with curds and *bajra* with *brinjal bhaji*. In normal subjects, a lowest glycemic and triglyceride response was observed to *navane* and *bajra* meals and highest to rice followed by wheat, *ragi* and *jowar* diets and in diabetics lowest glycemic response to *bajra* and *navane* followed by *jowar*, *ragi*, wheat and rice diets.

Lintas *et al.* (1995) noticed that the test meals given in the form of pasta and cereals (fibre enriched and barley) to 10 NIDDM subjects showed lower glycemic responses than rice and plain pastas, indicating that physiological effects of cereal based meals depend on the inter-relationship between chemical and physiological properties of dietary fibre and other fibre components.

The lower glycemic response was observed in 6 NIDDM subjects after consumption of three traditional recipes (*missi roti*, *upma* and *dhokla*) prepared from whole sorghum as compared to the recipes from dehulled sorghum and wheat (Lakshmi and Vimala, 1996).

Studies of the populations from Mediterranean and Asian countries revealed that traditional diets consisting of plant foods contributed to less prevalence of degenerative diseases like diabetes and coronary disorders. The mediterrian diet generally composed of fat (25-35% of energy) from dairy products and monosaturated olive oil, whole wheat bread (50-60% of energy) and very low intake of meat. In a same way, Asian diets composed of grains (rice, wheat, millets), legumes, fruits and vegetables, nut seeds and low fat (15%) along with plant based beverages (tea, coffee) contributed to longevity and good health conditions (Macdonald, 1996).

Chaturvedi *et al.* (1997) reported that the lower glycemic response observed after feeding wheat, amaranth + wheat flour (25:75), rice and amaranth + wheat flour (50:50) meals as compared to popped amaranth in milk which equaled to glucose load. Hence, composite flour mixture improved glucose tolerance in NIDDM subjects, indicating that method of processing (popping); mixture of flours and type of carbohydrate of foods influence glycemic response.

2.2.1.2 Long term feeding of carbohydrate diet in diabetic management

The test meal experiments demonstrated beneficial effect of various types of carbohydrate foods depending upon their characteristics on the glucose tolerance of type II and I diabetics. Many long term feeding intervention studies have been conducted to understand the sustainability of different carbohydrate meals in hypoglycemic control of diabetics.

Simpson *et al.* (1979) reported that 40 and 60 per cent carbohydrate diets with fibre from cereal and tubers given for the duration of six weeks revealed no difference in post prandial glucose and insulin levels in 14 Type II diabetics. However, highlighting the fact that high fibre content of the two diets causes reduction in basal blood glucose but no improvement after meals.

Rivellese *et al.* (1980) compared the effects three diets viz., low carbohydrate and fibre , high carbohydrate + fibre and high carbohydrate and low fibre in four IDDM and three NIDDM subjects for the duration of 10 days. The fasting and post prandial glucose levels found to be significantly lowered after consumption of high carbohydrate and fibre diet as compared to the other two diets (low carbohydrate and fibre, high carbohydrate with low fibre).

In another study, Simpson *et al.* (1982) compared two normal diets, of low carbohydrate and high carbohydrate (35 and 60 per cent of total calories) with low fibre content in NIDDM subjects for the period of four weeks. The post prandial glucose increment was significantly higher after the consumption of high carbohydrate intake but no difference in natural glucose levels between two diets.

Viswanthan and Mohan (1991) reported that High Carbohydrate and High Fibre (HCHF) diets appear to enhance tissue sensitivity to insulin (receptor and intra cellular level) compared to High Carbohydrate (HC) diet in 250 NIDDM subjects after a week feeding trial. The HCHF diet provided 67 per cent of total calories from carbohydrates (whole grain cereals), 19 per cent from protein, 14 per cent from fat and 52 g fibre (green leafy vegetables and legumes) while HC diet 60 per cent calories from carbohydrate, 10 per cent from protein and 30 per cent from fat of the total energy throughout the feeding period.

The glycemic control was improved on the low glycemic index (GI) diet containing porridge and pastas compared with high GI diet containing processed cereals and potatoes in 10 NIDDM subjects after feeding for one week. The glycosylated haemoglobin was lowered by 11 per cent but no apparent changes in lipemic parameters (Brand *et al.*, 1991).

The serum fructosamine (as an index of blood glucose) and cholesterol level was lowered by 8 per cent after consumption of low GI diet (GI=58) as compared to high GI diet (GI=86) among six NIDDM subjects after feeding intervention of six weeks (Wolever *et al.*, 1992).

Fontvieille *et al.* (1992) reported lowered levels of fructosamine, glucose and triglycerides after feeding low GI diet (GI=38) containing pasta, rice and legumes as compared to high GI diet (GI=64) containing bread and potato for five weeks duration among 12 IDDM and 6 NIDDM subjects.

Yenagi *et al.* (2001) proposed that inclusion of diccocum wheat in daily diet benefits the diabetics as compared to bread wheat. The lowered glycemic, cholesterolemic and triglyceride levels were observed in diabetics after consumption of diccocum *chapathis* (200 g flour) every day for the period of 45 days as compared to bread wheat *chapathis* eating diabetic group.

Thus several studies on carbohydrate in diabetic diet concluded that the variation in glycemic response to carbohydrate is influenced by various factors such as consistency of foods, form of carbohydrate, method of cooking and processing involved, duration of consumption, presence of anti nutrients and enzyme inhibitors and composition of foods. Hence, dietary modifications of diabetics are individualized and depend on the dietary pattern and food habits.

2.2.2 Effect of fat in diabetic diet

The concept of restriction of the carbohydrates in diabetic diet resulted in increased consumption of fat and provoked secondary complications hence quality and quantity of fat consumed is important and should be individualized with consideration given to eating habits and other life style factors.

Anderson *et al.* (1984) reported that the diabetics (Type II) who consumed rice diet for a long duration had lower serum levels of very low-density lipoproteins (VLDL) than those consuming potato rich diet.

Koppikar (1988) opines that the total amount of fat should be restricted to 20 per cent of the total calories in diabetic diet. Inclusion of fish oil as a substitute to vegetable oil improved lipid profile due to increase in omega 3 fatty acid content and there by decreased the tendency for blood clot and lowered the blood pressure in diabetics.

According to Wolever (1990a) the addition of large amounts of oil or fat (>25g / day) to 25 and 50g carbohydrate meal reduce glycemic response but enhance post prandial insulin and lipemic responses leading to other complications.

Bonanome *et al.* (1991) pointed out that the glycemic and lipemic response in NIDDM subjects did not alter considerably after consumption of low fat (25% with monounsaturated fatty acid) and 60 per cent carbohydrate diet and high fat (40%) + carbohydrate (45%) diet.

Anderson *et al.* (1991) demonstrated that high complex carbohydrate (low glycemic foods) and fibre with low fat (< 25%) diet reduced insulin requirement, increased insulin sensitivity, lowered serum triglycerides and cholesterol concentrations in Type I and II diabetics.

Garg *et al.* (1992) reported that under isoenergetic conditions a high fat diet (50 % of total energy) enriched in monounsaturated (33 % of energy) fatty acids with 10 per cent of energy from saturated fatty acids lowered blood glucose and insulin concentrations with improvement in serum lipoprotein of NIDDM subjects as compared to high carbohydrate diet .

Shah and Garg (1996) reported the moderate increase in monounsaturated fats reduced intake of carbohydrates in diabetics whose high carbohydrate diets deteriorate glycemic and lipoprotein levels. Thus concluded that moderate monounsaturated fat diet control glycemic and lipoprotein levels in diabetics and not cause loss in body weight but maintains, provided the energy intake is carefully controlled.

According to American Diabetic Association average recommendation of fat should be less than 30 per cent of the total calories with less than 10 per cent in saturated form in daily diet of non-obese diabetic without hyper lipidemias. In hyper cholesterolemic diabetic diet saturated fat content should be less than 7 per cent of total calories and cholesterol below 200 mg/day (Anon, 2000).

2.2.3 Effect of protein in diabetic diet

Karlstrom *et al.* (1987) reported that the diet with 20 per cent calories from protein, 33-34 per cent calories from fat with 37g fibre per day improved glucose control in 15 uncontrolled NIDDM subjects after three weeks of intervention period. The post prandial glucose concentration was lowered after consumption of leguminous (peas and beans) diet as compared to regular bread diet of hospital with 24g fibre per day.

Kurup and Krishnamurthy (1992) demonstrated that lipemic index for rice, tapioca and millets were 121,57 and 55, respectively compared to 100 isocaloric wheat supplemented in background meal of 400 calories.

In another study, Kurup and Krishnamurthy (1993) reported that 75g carbohydrate given in form of pulses such as black gram (*Phascolus vulgaris*), bengal gram (*Ceier arietium*), horse gram and green gram (*Phaseolus areus Roxb*) with the replacement of wheat during dinner to four groups of non diabetic volunteers varying from 22 to 41g in quantity, appeared to be beneficial in reducing lipemic changes and not glycemic levels. Black gram and bengal gram found to be more effective in reducing triglyceride levels by 8 per cent and increasing HDL cholesterol by 20 per cent as compared to horse gram and green gram meal. Hence, the inclusion of legumes approximately $1/5^{th}$ of calorie requirement would prevent coronary complications in diabetics.

Diabetic nephropathic subjects may be benefited by 40g protein allowance per day with slower rate of loss of kidney functions. It is estimated that usually kidney failure may develop in 30 per cent of Type I and 10-20 per cent of Type II uncontrolled diabetics. Therefore the protein intake should be restricted to 0.6-0.8g / kg ideal body weight / day (Locatelli *et al.*, 1991).

The glycemic response to chick pea (*Cicer arietinum linn*) and white bean (*Phaseolus vubgris linn*) was significantly lower than black bean (*Phascolus vulgaris*), pigeon pea (*Cajanus cajan linn huth*) and moth bean (*Phaseolus areas Roxb*). The blood glucose response to all legumes was significantly lower compared to bread among healthy volunteers. The differences in the glycemic responses among the legumes could be due to amount and kind of dietary fibre, amylose content and the presence of antinutritents, therefore inclusion of legumes in diabetic diet found to be beneficial (Panlasigui *et al.* , 1995).

Raghavan and Mohan (1999) mentioned that diabetic nephropathy subjects intake must be restricted to 0.6 g protein /kg ideal body weight per day but addition of 2 to 6g high quality protein would make the daily diet more palatable.

According to ADA, the minimal requirement of protein for good nutrition is 0.9g/kg body weight / day and the acceptable range recommended 1 to 1.5g /kg body weight /day. The low protein diets (0.8g /kg body weight) may slower the progression of nephorpathy and other micro level complications in diabetes (Anon, 2000).

2.2.4 Effect of dietary fibre in diabetic diet.

Dietary fibre was defined as that portion of food derived from plant cells, resistant to hydrolysis / digestion by the human alimentary enzymes consisting of hemicelluloses, celluloses, lignins, oligosacharides, pectin, gum and waxes. (Trowell, 1974). Dietary fibre is a complex mixture of chemical entities and its concentration and composition in different sources are neither constant nor uniform. The term total dietary fibre (TDF) includes soluble dietary fibre (SDF) present in plant gums, pectins, mucilages and galactomanose and insoluble dietary fibre (IDF) present in lignins, cellulose and hemicelluloses, categorized depending on their solubility in water. The plant foods contribute to dietary fibre requirements in the diet but individual intake is influenced by the nature of source, maturity moisture, proportion in the diet and mode of processing and preparation of the foods.

In 1971 ADA introduced dietary fibre in diabetic diet as a calorie restriction tool for overweight, for maintenance of weight in Type II diabetics and as regular food in consumption pattern with variety for Type I diabetics. The studies over the past 20 years related to dietary fibre summarized in the following text enlighten that fibre has a positive role in prevention and treatment of the chronic diseases associated with lipids and enzymes.

The longest term studies using guar gum (14-26g) as fibre supplement in daily diet of eight type I and three Type II diabetics for six months revealed consistent improvement in post prardial glucose but no change in the fasting glucose control (Jenkins *et al.*, 1980a).

The blood glucose response of the normal volunteers to a variety of carbohydrate (50g) foods such as eight varieties of dried legumes, grains, bread, pasta, tubers and biscuits tested, revealed that smaller rise in post prandial glucose level after consumption of legume than the other foods. Thus, the study concluded that all types of dietary fibre have some effect on post prandial glycemia but the greatest reduction occur with leguminous fibres because of their high viscosity. (Jenskins *et al.* , 1980b)

Vaaler *et al.* (1980) reported the lowest post prandial rise in blood glucose level after feeding 105g carbohydrate breakfast with pectin jam (15%) compared to fibre from barley (85%) and 15 per cent citrus (*Dumovital*) in eight NIDDM subjects, indicating that specific type of fibre helps in retardation of glucose.

The lowered glucose, cholesterol and triglyceride levels were observed in 54 lean and 20 obese NIDDM subjects after consumption of high carbohydrate (60%) and high fibre (50g) diet in three year follow up study conducted by Viswanathan *et al.* (1981).

Patel (1985) reported that addition of wheat bran (11g) in the form of biscuits for 30 days in 14 NIDDM diet, lowered fasting and post prandial glucose levels but observed no change in glycosylated haemoglobin and amino acid levels.

Osilesi *et al.* (1985) reported that 12g addition of xanthium gum in NIDDM diet improves fasting and post prandial glucose levels and better lipidemic profile.

The normalized carbohydrate tolerance without serious consequences has been observed by providing 30g guar gum in NIDDM diet (Mclvor *et al.* , 1985).

The guar gum (10g) supplemented in IDDM and NIDDM diet lowered the glycosylated hemoglobin level by 10 per cent and reduced the medicine intake in both groups (Jones *et al.*, 1985).

Fuessl *et al.* (1987) reported that 15g addition of guar gum in the regular diet reduced fasting glucose levels by 10 per cent and improvement in lipid profile of NIDDM subjects.

Paganus *et al.*(1987) observed that replacement of 5 per cent carbohydrate by guar gum in IDDM children diet improved glycosylated hemoglobin level, glycosides and glycosuria.

Inclusion of 25g of fenugreek seeds as fibre supplement in diabetic diet for 21 days reduced 20-30% glucose levels and showed better control of diabetic symptoms such an polyphagia, polydipsia and polyuria. (Sharma, 1987).

The consumption of guar bread (8.3 g in granulated form) by NIDDM subjects showed fall of glycosylated hemoglobin level by 8 per cent during six months feeding intervention (Peterson *et al.* , 1987).

Ceruti *et al.* (1987) reported that inclusion of 66g vegetable as form of dietary fibre in adolescent's diabetic diet reduced glycosylated hemoglobin and insulin requirement.

The glycemic response was significantly reduced by cereal, leguminous and mixed (vegetable and fruit) dietary fibre diet than control meal (bread) in 13 diabetic subjects but observed no change in 12 healthy volunteers. The lower insulin responses were observed after all the high fibre diets as compared to control diet in both diabetic and non diabetic subjects highlighting the fact that the fibre and different content of digestible carbohydrates influence the metabolic responses (Karlstrom *et al.*, 1988).

The lower glucose and insulin responses observed after feeding high soluble fibre diet (vegetable soup) as compared to low fibre meal (plain pasta and white bread) and high insoluble fibre meal (fibre enriched pasta and whole wheat bread) in 10 NIDDM subjects. The study enlighted the efficacy of soluble dietary fibre of naturally occurring foods in modulations of glycemic responses (Toma *et al.*, 1988).

Ellis *et al.* (1988) demonstrated that guar biscuits supplemented at 2.9, 6.0 and 9.1 g produced smaller insulin rises than the control (without guar) biscuits in all post pradial tests of eight NIDDM subjects. Significant insulin – sparing effect was achieved using less than 3g guar flour in biscuit at palatable level in diabetics.

Wolever (1990b) reported that in purified form soluble fibres have great reducing effect on glycemic response than insoluble fibres and the cellulose and uronic acid concentrations. Efficacy of individual food with regard to glycemic index depends on nature and composition of dietary fibre, which has been correlated in 25 foods such as cereals, legumes, vegetables and fruits.

Sharma *et al.*(1990) demonstrated that in long term trial addition of 100g fenugreek seeds in diabetic meals of IDDM and NIDDM subjects, reduced fasting glucose level by 54%, twenty four hours urinary glucose output, serum cholesterol and triglyceride levels.

Iyer and Mani (1990) reported that supplementation of 12g curry leaves powder (2.5 g fibre) in 30 NIDDM diets for the period of 30 days lowered glucose response but no appreciable changes in lipid profile.

Easwaran *et al.* (1991) reported that the reduction of fasting glucose (3%) and post prandial glucose (17%) in six diabetic subjects after consumption of Globe artichoke (*Cynara scolymus*), a herbaceous perennial plant (75g) in the form of *poriyal* for 15 days as compared to diabetic control group.

Consumption of High Carbohydrate (70%) and High Fibre (70g) (HCHF) diet for the period of 4 weeks, reduced basal insulin requirement, enhanced peripheral glucose disposal and lowered cholesterol levels without altering glucose and triglyceride levels as compared to Low Carbohydrate (39%) and Low Fibre (10g) (LCLF) diet in 10 IDDM subjects (Anderson *et al.*, 1987).

The glycolipemic profile of NIDDM subjects was improved by consumption of 7.5 g psyllium fibre concentrate, twice a day along with meals (Chatterjee *et al.*, 1992)

Easwaran *et al.* (1992) demonstrated that 50 g of tree lettuce (Pisonia alba) consumed in the form of poriyal for 30 days reduced fasting and post prandial glucose levels by 17 per cent in six NIDDM subjects. It also exhibited antihypertensive effect in six hypertensive subjects enlightening the fact that inclusion of high fibre green leafy vegetables in daily diet beneficial to diabetic and hypertensive subjects.

Singamsetti *et al.*(1992) demonstrated that a high dense fibre supplement (*Logadanya*) prepared from vegetable sources taken along with the meals in 40-60 g/day, reduced the dependence on insulin and oral hypoglycemic drug in 5560 diabetic subjects and helped in maintaining normoglycemia and normolipidemia.

The post prandial glucose levels were lowered after consumption of bitter gourd (*Momordica charantia*) as vegetable (100g), drumstick leaves (*Moringa oleifera*) as *bhaji* (50g) and dried curry leaves (*Murrya koiengio*) powder (3g) as compared to standard meal (without vegetable) in 21 NIDDM subjects. The vegetables exhibited hypoglycemic response by 12 per cent due to presence of inhibitors in the bitter gourd, a potent adrenegic neurone blocking substance in drumstick leaves and glycopeptides in curry leaves by interfering glucose absorption (William *et al.* , 1993).

Premkumari *et al.* (1993) reported that consumption of amla (*Embilica officinale*), turmeric (*Circuma longa*) or combination of both (50:50) in juice or paste form (15g) before breakfast and dinner reduced fasting glucose by 10 per cent and post prandial glucose by 8 per cent in 36 NIDDM subjects after three months of experimental period.

Vessby (1994) opined that the concept of 'common diet' benefits diabetic people which includes 55 per cent of total energy from carbohydrate sources, 30 per cent energy from fat and dietary fibre 3 g /MJ (soluble fibre) and other low glycemic foods.

The consumption of sucrose at 0, 44 and 80 per cent levels along with rice meal by 12 healthy individuals indicated lower glucose response to the meals containing higher sucrose levels than without sucrose meal. Thus highlighting the concept that the sucrose which replaces fully gelatinized starch (rice) reduce metabolic responses resulting in lower levels of glucose (Miller, 1994).

Comi *et al.*(1995) reported that hypocaloric (1400 calories) diet with high carbohydrate (56%) and high fibre (42g) significantly improved glycolipid metabolism and reduced body weight in 46 obese NIDDM subjects after 30 days of intervention.

The consumption of sprouted fenugreek seeds (30g) per day in diabetic diet for the period of 60 days showed reduction in fasting and post prandial glucose level as compared to control group (Chandra and Aruna, 1997). The hypoglycemic action of fenugreek is due to presence of mucilaginous fibre (20%) and total fibre (50%) content.

Several dietary surveys carried out in India indicated that the daily total dietary fibre intake varies from region to region ranging from 22 g in Kerala to 42 g in Karnataka state. On an average estimated intake of dietary fibre among Indians found to be 38g /day as compared to 15-25g /day in western countries (Rao and Ramulu, 1998).

The potent hypoglyemic response was observed after consumption of the root and seeds (20g) of the fenugreek (*Trigonella Foenum graecum*) in 10 NIDDM subjects as compared to 20g leaf and stalk portion. The low glycemic index of root and seeds may be due to the presence of high amount of dietary fibre, antinutrients such as tannin, phytates, polyphenols and protein content (Nair and Kapoor, 1999).

The experimental diet with vegetables and fruits (50g fibre) reduced the blood sugar levels by 10 per cent in 13 Type II diabetics as compared to ADA diet (25g fibre) for a period of six weeks intervention and observed no change in the drug therapy (Garg, 2000).

Anuradha and Vidhya (2001) reported that four gram supplementation of Spirulina (micro algae) for the period of 60 days in 10 NIDDM subjects significantly reduced fasting glucose by 14 per cent and post prandial glucose level by 8 per cent as compared to control group.

Potty (1996) reviewed that commercial or purified fibre concentrates (methyl cellulose, tialose, alpha cellulose, oat and barley fibre) used in fibre enriched products causes gastrointestinal distress (bloating, belching), abdominal discomfort, flatulence and interference with absorption of vitamins and minerals. Therefore naturally available high fibre foods (whole grains, fruits and vegetables) should be recommended to the diabetics. These foods possess low caloric value, complex carbohydrate exhibiting low glycemic index and providing proteins, minerals and vitamins as compared to synthetic fibre concentrates. The beneficial effect of dietary fibre has been summarized in the following table 3.

Table 3. Benefits of dietary fibre

I	**Type**	Water insoluble (Cellulose, hemicelluloses)	Water soluble (gums, pectins, mucilages, galactomansoes)
II	**Benefits**	Bulk of stool ↑ Satiety value Regulation of bowel movement.	Viscosity of foods ↑ Tissue insulin sensitivity ↑ Insulin receptor number ↑ Satiety value ↑ Absorption of nutrients ↓ Post prandial plasma glucose ↓ Fasting and post prandial serum triglycierides ↓ Serum cholesterol ↓
III	**Sources**	Whole cereals and millets and brans, cabbage.	Legumes, fruits, vegetables, oats, barley, ispagule, sea-weeds.

2.3 Importance of glycemic index of foods in diabetes

The glycemic index (GI) is a ranking of foods based on their glycemic impact. It has proven to be a logical and useful tool for comparing foods in situations such as diabetes where fluctuations in blood sugar levels are considered important. Jenkins *et al.* (1981b) introduced the concept of GI and classified several foods based on this concept, which suggested a system of carbohydrate exchanges for diabetic diets.

The International Diabetes Institute in Melbourne has produced educational material connected to GI of different foods and documented clinical usefulness in dietary management of IDDM, NIDDM and hyper lipidaemia through various counselling centers (Miller, 1993).

The GI of a food is usually defined as,

$$\frac{\text{Incremental area under blood glucose response curve for test food}}{\text{Corresponding area after equal portion of glucose (reference food)}} \times 100$$

Nevertheless, there has been controversial issue regarding the clinical utility of the GI of foods emphasizing the fact that the individual carbohydrate foods taken as part of a mixed meal showed no apparent difference in glycemic responses. In the same way the effect of long term feeding trials in diabetic subjects as compared to short-term feeding exhibit not apparent changes.

2.3.1 Glycemic Index (GI) of foods

In the last 20 years nearly 300-400 separate foods and mixed meals have been subjected to GI testing in both normal and diabetic individuals all around the world. Methodological differences created confusion regarding clinical interpretation of GI of foods, hence the results of different studies have not been directly comparable (Wolever *et al.*, 1991).

2.3.1.1 Glycemic index of the individual foods

About 62 commonly eaten foods and sugars were fed individually to groups of 5-10 healthy volunteers to test GI of the foods by Jenkins *et al.*, (1981b). The highest GI values reported for root vegetables (72 ± 6) followed by vegetables (65 ± 14), breakfast cereals (65 ± 5), creals and biscuits (60 ± 3), fruit (50 ± 5), dairy products (35 ± 1) and dried legumes (31 ± 5) excluding sugars.

Dilwari and co-workers (1987) obtained a significant lower GI for legumes (*rajmah*, 29.59, green gram, 48.12 and *channa*, 48.89) as compared to cereals (wheat, 87.86 and rice, 89.67).

Winnie and Easwaran (1988) reported no significant difference between GI of four breakfast foods given to 18 NIDDM subjects (56g carbohydrate). The cereals based breakfast foods indicated GI values between 74-84, while rice *upma*, 84.83, wheat *upma*, 74.08, wheat *chapathi*, 78.02 and wheat *dosa* 77.67.

Singh Verma *et al.* (1989) demonstrated the GI of five common foods and four fruits on 21 NIDDM subjects. The GI ranged widely for rice flour (76.2 ± 4.1), *dhalia* (71.6 ± 3.2), *chapathis* (66.42), rice (65.4 ± 1.5) and milk (52.3 ± 1.9) and those of papaya, orange, orange juice, apple, apple juice and banana were 55.9 ± 2.8, 61.3 ± 3.3, 73.9 ± 3, 65 ± 3.8, 74.5 ± 0.9 and 77.4 ± 1.9 respectively

Wolever (1990a) tested 11 foods in at least three different centres using different groups of diabetics. The GI values of the foods tested ranged widely viz., whole meal bread, 100 ± 5, potato, 98 ± 26, oat meal, 89 ± 10, banana, 84 ± 14, corn, 80 ± 11, corn flakes, 121 ± 13, white rice, 77 ± 12, white spaghetti, 67 ± 16, orange, 59 ± 14, apple, 52 ± 5 and kidney beans, 38 ± 9 in diabetcs.

Shukla *et al.* (1991) demonstrated that 50g of carbohydrate in the form of barley (with GI 68.7 in healthy and 53.4 in NIDDM) reduced glucose response and improved insulinaemic index in 14 NIDDM subjects and aided in better mobilization of insulin, thus indicating suitability of barley as diabetic food.

Raghuram *et al.* (1993) categorized the glycemic index values for 36 Indian foods into different groups like high glycemic index group ranging from 65-75 includes cereals (wheat and rice), millets and root and tuber vegetables (sweet potato, yam, beet root), intermediate group with 45-55 GI (fruits) and low GI group (30-40) consisting dried beans, peas and legumes.

The glycemic index of chick pea (13.87±4) was significantly lower than that of black bean (27.91±4), pigeon pea (30.99±4) and mung bean (44.38 ± 4.9) when cooked and given to healthy volunteers in Philippines by Panlasigui *et al.* (1995).

Kavita and Prema (1995) reported that the glycemic index was comparatively low in wheat (84) followed by *ragi* (89.8), rice (99) and tapioca (102.6), which was more than glucose when, tested in 20 NIDDM subjects.

Rema *et al.* (1998) reported that glycemic index value 46.9 in non-diabetic and 28.9 in diabetics for green gram (*Vigna radiata*) and for bengal gram (*Ceier arietium*) 115.5 and 36.3 respectively. The significant difference between two meals observed in non-diabetics but not in diabetic subjects. In general pulses exhibited lower glycemic response.

Nair and Kapoor (2000) estimated lower glycemic index values for fenugreek root (37.7) and seed (40.7) as compared to fenugreek stalk (45.8) and leaves (52), when supplemented (209) with glucose to a groups of 10 NIDDM subjects emphasizing the ant diabetic property of the different parts of fenugreek plant.

2.3.1.2 Glycemic index of the mixes and mixed meals

Different foods raise the blood sugar to variable extent and exhibit different glycemic responses. However when the individual food is used in mixed meal or in mixture of certain foods, it exhibits glycemic response in different way, similarly long term feeding trials with particular food or mixes also exhibit varied results.

Mani *et al.* (1990) reported highest GI value for rice with peas (80) followed by rice (74). The combination of rice – legume (bengal gram and green gram) and rice –*dal* combinations (green gram *dal* and red gram *dal*) elicited GI ranged between 54-59 emphasizing that combinations of foods especially with legume and *dal* reduce the glycemic index of foods.

Prabhu (1990) reported that the low GI for *bajra* (54) and 10-15 per cent increase in GI values for *kodri* in combination with green gram, *jowar* and green gram *dal* , where as *ragi* showed high GI equal to glucose in NIDDM subjects.

In corporation of defatted soy flour (1 part) to other foods (4 parts) found to be beneficial for NIDDM subjects (Subbulakshmi and Bolaki, 1991). The glycemic index of flour selected defatted soy-cereal mixes in the preparations such as *ragi ball, chapathi, rava iddli* and *upma* were determined in diabetic and non-diabetic subjects. The lower glycemic indices elicited ranging from 40-50 in diabetics as compared to 57-83 in non-diabetics.

Fourteen common recipes each containing 75g carbohydrate and 12.5g fenugreek seeds were formulated and tested for glycemic index by Raghuram *et al.* (1992). All preparations with fenugreek seeds had a low glycemic index < 50 and lower than that of preparation without fenugreek. Incorporation of any two recipes in diabetic diet reduced the glycemic response and controlled blood sugar level.

Mani *et al.* (1992a) determined the glycemic index of the diabetic mix formulated from a variety of cereals and pulses in 15 NIDDM subjects. The GI of the cereal pulse mix found to be 38.25 ± 11.02 after consumption of 90g mix in the form of *kichadi*.

Mukherjee (1992) reported that supplementation of 80g cereal- pulse mix significantly lowered blood glucose, uronic acid and amino acid levels in 10 NIDDM subjects during long term study. Thus highlighting the fact that cereal –pulse mix had beneficial effect on glucose as well as glycosamino-glucan metabolism causing improvement of carbohydrate metabolism and preventing degenerative complications.

Two different iso-carbohydrate meals (50g) were used by Chandalis *et al.* (1992) for testing GI against white bread, whole wheat flour and bengal gram flour *chapathi* in ratio of 2:1 and only bengal gram *chapathi*. The lowest GI value of elicited from gram flour *chapathi* (48.3) and wheat and gram mixture (66.4), indicated the fact that mixed meals of different carbohydrate exhibit intermediate GI as compared to individual foods.

Bijlani *et al.* (1993) demonstrated that the substitution of 100 g cereal pulse mix (wheat, barley and bengal gram *dal* flour in equal proportions) with carbohydrate exchange in 5 healthy and 4 NIDDM diet for a period of four weeks lowered post prandial glycemic and insulinaemic response, noting GI for mix 68.6 in healthy and 64.9 in NIDDM subjects. The hypoglycemic effect was attributed to the high total dietary fibre content, viscous fibre content (B-glucans) present in barley and higher protein content (15%) of the mix.

Mani *et al.* (1993) reported lowest GI value for *bajra* (55±13), *varagu* in combination with green gram (57±6), intermediate GI values for *varagu* (68±8), jowar (77±8) and *varagu* + green gram *dal* (78±12) and highest for *ragi* flour (104±13). The study indicated that dietary fibre of millets and cereals lowers glycemic response but representing unsuitability of *ragi* as diabetic food.

In a similar study, Mani *et al.* (1994) elicited 42.72 GI value for diabetic mix (prepared by Desikarchar) consisting wheat grits (52%), soybean (20%), green gram and red gram *dal* and lentil (4.41 each), black gram *dal* and guar seeds (3.25% each), fenugreek seeds (1.6%) when given in the form of *kichadi* prepared from 90g mix to 20 NIDDM subjects.

Potdar *et al.* (1994) reported that mixed diet (defatted soy flour, wheat bran and roasted barley flour) reduced blood sugar level by 19 per cent in 27 obese diabetics as compared to 24 diabetics who consumed customary iso-caloric diet (less fibre and without mix) for the period of 10 weeks.

Torangatti (1995) demonstrated that the glycemic value for mixed meals ranged from 55-63 in normal and 60-65 in diabetic subjects. The lowest glycemic value obtained for *navane* rice with curds (55.01± 10.74) in healthy and *bajra roti* with *brinjal bhaji* (60.11 ± 3.2) in diabetic subjects while highest value observed for rice and red gram *dal curry* (62.61 ± 1.91 and 65.83 ± 9.57) in healthy and diabetic subjects, respectively.

Chaturvedi *et al.* (1997) reported a low glycemic index for 25.75 amaranth-wheat composite flour (65.6), wheat (65.7) and rice (69.2) diets, medium GI for 50:50 grain amaranth + wheat composite (75.5) diet while high GI value for popped amaranth in milk (97.3), when 50g of carbohydrate equivalent foods given to diabetic subjects.

Pathak and Srivastana (1998) observed a reduction in blood glucose level in normal and diabetic subjects, after consumption of *dhokla*, *upma* and *laddu* prepared from millet mix based on foxtail millet, fenugreek seeds and legume. The glycemic index noticed for *upma*, 17.6, *dhokla*, 35 and *laddu* 23.5 when tested against 25g carbohydrate load in normal subjects.

Sai Priya and Megeshwari (1998) reported that supplementation of the therapeutic premix (30g) based on legumes as a drink to 12 NIDDM subjects for a period of one month reduced fasting and post prandial glucose levels. The premix was prepared from sprouted bengal gram (10g), dry peas (5g) horse gram (5g), green gram (5g). The mix was dried, roasted and powdered then mixed with rice flour (g) in order to increase dietary fibre content without much alteration in their regular diet.

2.3.2 Factors affecting the glycemic index

The difference observed in GI are attributed to several factors such as food portion size, choice of standard food, methodology of testing foods, subject's characteristics, treatment and degree of control, nature and source of starch, physical from of food, method of processing and cooking, starch- nutrient interaction, dietary fibre and anti nutrients. There is a need for screening more foods for their glycemic response on individual and part of mixed meal and suitability for diabetic diet leading to meal adherence.

Borent *et al.* (1987) demonstrated that different glycemic index was obtained in six iso-caloric meals containing different amount of fibre in 18 NIDDM subjects as compared to six starch foods taken alone. The least glycemic index was obtained for bans and lentils followed by rice, spaghetti, potato and bread exhibiting different kind of glycemic response in a mixed meal.

Wolever *et al.* (1987) observed that the GI of canned beans providing 50 g carbohydrate was significantly lower than bread but higher than that of five varieties of cooked beans in groups of diabetics, thus enlightening the fact that processing of the food also affect glycemic index.

Heaton *et al.* (1988) explained that oat based meals cooked smaller glucose and insulin responses than wheat and maize based meals. In normal individuals the iso caloric wheat based meals increased insulin response stepwise; whole grains followed by cracked grains, coarse flour, fine flour. Thus indicating the fact that particle size influence digestion rate and metabolic responses.

Hollenbeck *et al.* (1988) reported that the total integrated glucose response during day time lowered by seven per cent after ingestion of low glycernic meal as compared to the intermediate and high glyernic meals. It was interesting to note the identical plasma glucose response after consumption of low, intermediate and high glycemic breakfast and dinner meals but reduction in plasma glucose after low glycernic lunch was thus apparent. Thus highlighting the fact that the same meal may exhibit different glucose response in mixed meal pattern during the day.

The fibre which are viscous, water soluble such as guar gum and pectin are most useful in supplementation and reducing the GI of foods as compared to water insoluble and non viscous fibre such as cereal fibre (Siddu *et al.*, 1989).

Wolever (1990b) observed a significant correlation between the amount of total dietary fibre per 50 g carbohydrate portion of food and GI. The author also emphasized that cellulose proved to be best predictor of glycemic response even better than total dietary fibre content and composition of 25 foods to the glycemic index.

Gregersen *et al.* (1990) carried out a study to understand the effect of volume of water and the duration of eating time influence on the glycenic responses in 10 NIDDM subjects. The glycemic responses to is caloric meals (bread with butter and tomatoes) along with large 600 ml) and small (90 ml) amount of water consumption were similar and in the same way eating time from 10-30 minutes did not affect the values.

Anderson *et al.* (1991) demonstrated that consumption of high carbohydrate (70%) and high fibre (70g) diet by 10 IDDM subjects for a period of one week showed identical glycemic control as compared to low carbohydrate (39%) and low fibre (10g) diet. It was interesting to note that high carbohydrate and high fibre diet significantly decreases of basal insulin requirements and increase peripheral glucose disposal in Type I diabetic subjects. Hence, high fibre diet found to be beneficial in decreasing peripheral insulin sensitivity.

Paul and Vijayalakshmi (1992) reported that millet soy mix (foxtail and samai) in different proportions such as 1:1 and 2:1 exhibit lower values of net protein utilization (NPU) as compared to skim milk mix, due to presence of fibre and making them suitable as diabetic health foods.

Brand *et al.* (1992) determined GI of 12 rice products. The high amylose rice exhibited lower GI than the normal amylose and waxy rice varieties. The rice products and converted rice, produced a high GI in range of 64-93. Usually rice varieties contain 20 per cent amylose but varieties with high amylose content (>28%) have shown shower rate of digestion producing hypoglycemic effect.

Westrate and Amelsvoort (1993) experimented on 22 healthy male volunteers to see the impact of the amylose content of breakfast and lunch on post prandial variables.

There was no systemic effect of amylose content on appetite and fullness but affected post prandial responses, which depend on meal size or composition.

Milk produced low GI due to its fat content (8%) as compared to rice (1%) and wheat (1.5%). Fat is known to show down gastric mobility and emptying resulting in low GI. Oilseeds and nuts such as groundnuts, cashew nuts also exhibit similar low glycemic index but are calorie dense foods hence stimulate secondary complications (Raghuram *et al.*, 1993).

William *et al.* (1993) demonstrated that the blood glucose responses of meals containing bitter ground, curry leaves and drumstick leaves were 72 , 60 and 56 respectively as compared to 75 g glucose and to the standard meals without these vegetables 88, 97 and 79 respectively. Thus indicating the fact that some vegetables lower the post prandial glucose level to greater extant than mixed meal without vegetable, proving their suitability to the diabetic diet for long term meal adherence. The presence of inhibitors present in bitter gourd, glycopetide from curry leaves showed hypoglycemic action in diabetics. Along with this presence of small amounts of minerals like calcium, magnesium and phosphorus from vegetables triggered the hypoglycemic effect.

The GI of different 44 foods such as tropical fruits from 51 (mango) to 72 (water melon), in the cookies from 55-79, in the breakfast cereals from 43-90 in healthy subjects (Miller, 1994). There was no difference between the GI of breakfast cereals with or without sucrose or fibre enriched. The GIs of muffins and banana cake made with sugar and without sugar where almost identical. However, dairy products such as low fat milk and yogurt with added sugar had a higher GI than without sugar. The GI of many starchy foods and cereals found to be 73 which produced rapid rise and fall in blood glucose levels, highlighting the fact that sucrose produces glycemic responses equal to starchy foods. Thus amount of glucose in the diet, its distribution through out the day and rate of absorption influences glycemic rather than type of carbohydrate.

The physical form of food changes the post pradial effect as white bread exhibit higher glycemic index than pasta and rice flour than rice. In a same way high index foods after the glycemic response when combined with other foods or taken as a part of mixed meal (Jenkins *et al.* , 1994)

Slavin and Dwyer (1994) suggested to increase consumption of whole grain cereals (including millets) due to beneficial physiological effects of fibre and resistant starch, whole grains contain 3-20 per cent of starch resistant to digestion, which can be fermented in the colon. The resistant starch hinders absorption of glucose and reduces the pH of colon thereby reducing the effect of carcinogens.

Lakshmi and Vimala (1996) reported the GI values for the recipes (*upma, missi roti* and *dhokla*) ranged from 75 to 84 as compared to high GI values (>95) for dehulled sorghum recipes and wheat. The study pinpoints the fact that processing and method of cooking canes variation in the GI values.

The addition of fenugreek seeds significantly reduces the glycemic index of the preparation by 10 to 20 per cent. It may be advised to consume in powdered form (15g) by Madar *et al.* (1988) or 25g seeds incorporated in different recipes by Raghuram *et al.* (1993) or in sprouted form (30g) by Chandra and Aruna (1996) for reduction in blood sugar and less excretion of sugar in urine with improvement in glucose tolerance by the diabetics. This hypoglycemic property of fenugreek seeds is attributed to its mucilaginous fibre (20%) and total dietary fibre (50%) content. It contains ***trigonelline***- an alkaloid, which reduces blood sugar level. The 50% of soluble dietary fibre content of the fenugreek seeds forms colloidal suspension when hydrated and decrease rate of gastric emptying and slows carbohydrate digestion (Rao and Ramulu , 1998).

Rema *et al.*(1998) reported that addition of 40g of bitter gourd (*Momordica charantia*) pulp for 30 days lowered post prandial glucose level lowered by 27 per cent in non-diabetic and 36 per cent in diabetic subjects without definite change in fasting glucose and plasma lipid parameters.

From the above studies it can be concluded that the GI of the foods are affected by a number of factors such as nature or source of starch, physical form of food, method of processing or cooking, dietary fibre content, antinutrients starch –nutrient interactions and combination of mixed meals.

2.4 Shelf-life study of the mixes or ready to use foods

The consistency in quality of ready to use mixes is assessed by its, storage stability, resistance to rancidity, off flavor, odour, appearance and microbial spoilage. The type of the storage, packaging materials, quality of raw foods, pre-processing techniques, composition of food and extent of heat application may cause changes during the storage period. A brief review regarding shelf -life of eat composite foods has been presented below.

Tripathi and Date (1975) reported that breads prepared from composite flour having 15 per cent substitution of wheat flour by millet flour (10% maize and 5% sorghum) and 30 per cent from pulse flour such as bengal gram 15 per cent, lentil 10 per cent and peas 5 per cent, exhibited better shelf life of 4-5 days as compared to conventional wheat bread at 27^{o} c room temperature.

Gopaldas *et al.* (1992) formulated malted and roasted ready to eat mixes for young children using different cereal, pulse and oil seeds (wheat, *ragi*, bengal gram, green gram and ground nuts) combinations and per 100 g of mix providing 12-15g protein and 300 -380 calories. The roasted mixed packed in sealed polyethylene bags stored in good condition at room temperature for 28 days as compared to 14 days for malted mixes.

Lina and Reddy (1984) prepared low cost indigenous food mixes for pre schoolers from wheat, *ragi*, horse gram, plantain or tapioca and with without fish powder, per 100g mix providing 13-14 per cent protein and 325 calories. These mixes stored well for 4 weeks by traditional method (tin containers and polyethylene bags) at room temperature without deterioration in taste and aroma.

Prasannappa and Jagannath (1985) prepared blends from roasted wheat, bengal gram *dal* , maize, *jowar* and *jaggery* providing 11-13g protein and 371 calories (100 g mix), used for supplementary feeding programme. These blends were acceptable upto 4 weeks without organoleptic variations when stored in 250 gauge polyethylene bags at 37^0C temperature.

The malted and roasted ready to use formulations for babies developed from wheat and bengal gram with or without oilseed (groundnut or gingelly) and per 100g mixture providing 12 per cent protein and 350-380 calories, stored well in air tight polyethylene bags covered in glass bottles for a period of six weeks. The stored products exhibited the quality parameters within the limits of Indian Standard Institute (ISI) with regard to alcoholic acidity, peroxide value and bacterial count (Solanki, 1986).

The *upma* mix stored in paper-aluminum foil polyethylene laminate and polythene pouches at room temperature without noticeable changes in peroxide value, free fatty acid and methyl aldehyde were acceptable for the period of 10 and 3 months respectively (Premavalli *et al.* , 1987).

Gopaldas *et al.* (1988) demonstrated that roasted wheat Amylase Rich Food (ARF) stored better (30 days) than sundried ARF (10 days) at room temperature.

Chandrashekhar *et al.* (1988) reported that the weaning mix (malted ragi and horse gram and groundnut) stored well for 45 days in household containers like plastic tin, bottles and polyethylene bags within limits of ISI specifications for moisture and bacterial count.

Dastur and Prakash (1988) developed the health food snack containing wheat bran, which provided 11.3g protein, 18.94g fibre, 5g fat, 40g carbohydrate and 300 calories per 100 g product. The snack food stored at room temperature for 16 weeks when packed in polypropylene pouches without any deterioration in quality.

Vaijayanthi (1988) developed RTE mixes of *masala roti*, biscuits, cookies and crackers using rice, *dal* , bean, bran and wheat germ (20%) with spices, green leafy vegetables and nuts that contributed 10-19g protein and 350-450 calories from 100g product. The ready mixes for *masala roti* and cookies stored well in polyethylene covers at room temperature upto two months and biscuit and cracker mixes for three months as per with the ISI specifications for peroxide and free fatty acid value.

Reddy *et al.* (1990) formulated four types of weaning mixes based on cereal and millets (wheat, rice, *jowar*, *bajra* and foxtail millet), pulse (green gram, moth bean and bengal gram), grain amaranth, potato and spinach in combinations, providing 10-17.4 per cent protein and 325-352 calories (100g mix). The roasted, malted, puffed and fermented mixes, in air tight containers at zero and 26°C temperature stored upto 4 weeks with no changes in organoleptic parameters.

The modified, roasted *sattu* (wheat and bengal gram mix) elicited no physical changes when stored in sealed polyethylene bags at room temperature for a period of three months (Devi *et al.* , 1990).

Gupta (1991a) reported that 100g of weaning food mixture (wheat, rice, *bajara*, dehusked barley, grain amaranth and green gram) providing 9-12 g protein and 400 calories, stored well in polyethylene bags at room temperature upto 30 days without qualitative changes.

Lakshmi (1991) developed dietetic baked foods by incorporating defatted soy flour (5-51%), wheat bran (12%) green leafy vegetable (15-25%) and egg white (20%) contributing 14-19g protein, 0.4-5 g fibre, 14.5-19.4g fat and 251-382 calories from 100g product. The biscuits and cookies from the mix had shelf life of 9 and 7 days respectively while cakes and breads stored well for four days at room temperature.

Rathod and Udipi (1991) revered that 24 weaning mixes (grain amaranth, rice products and green leafy vegetables) stored in good conditions, with no sign of spoilage in terms of rancidity, off flavour, off colour, bowing and caking in polyethylene bags for the period of two months.

Goyle and Gujral (1993) carried out shelf life study of malted and raw wheat, Bengal gram and green leafy vegetable mixes for a period of 28 days. The mixes were acceptable at room temperature (25-34^{0}C and 46-41% RH) and under accelerated conditions (37^0 C and 90% RH) throughout the storage period.

Rathna and Neelakanthan (1995) demonstrated that substitution of 20 per cent wheat flour with puffed bengal gram flour in bread making increased protein (25%) and lysine (175%) and shelf life upto four days when packed in polyethylene bags.

The instant *rava idli* mix had shelf life of eight months at room temperature and six months at 30^{0}C when packed in PEP pouches and eight months at room temperature and four months at 37^{0}C when packed in PP pouches. The increase in free fatty acid and titrable acidity during storage increased hardness of *idlis* and decreased acceptability scores (Madhura *et al.* , 1998).

The low cost malted and roasted weaning mixes developed using Italian millet and grain amaranth (7:3) proportion stored well for 28 days and 49 days respectively at 29^{0}C room temperature (Suma, 1998).

Uma (1998) developed five cereal pulse blends for elderly using *jowar*, wheat, roasted bengal gram *dal* , grain amaranth, soybean, rice flakes, green gram, groundnut oil and spices, providing 14-19g protein and 354-392 calories from 100 g product. The porridge mixes and *aralu* mix were acceptable for the period of 90 days when stored in polyethylene bags except *upma* and *semian* (vermicelli) mix showed bacterial counts beyond ISI specifications after 75 days of storage.

Pathak and Srivastava (1998) developed foxtail millet mixes by incorporating fenugreek seeds and legume for *dhokla*, *upma* and *laddu*, providing 4-9g protein, 3-8g fat, 3-6 g fibre, 20-63g carbohydrate and 131-325 kcalories /100g product. There was no significant difference in overall acceptability of the products prepared from the mixes packed in polyethylene bags for one month at room temperature as compared to control.

Neeta (1999) reported that *madeli* a sweet prepared from diccocum wheat and bengal gram flour (4:1) stored well in aluminum box upto 35 days and in polyethylene bags upto 21 days at room temperature as compared to *madeli* from other wheat varieties.

Annapurna (2000) reported that diccocum wheat *upma* mix was acceptable upto 10 weeks when stored at room temperature as compared to durum wheat mix.

The nutri bun prepared from composite flour of dicoccum wheat, refined wheat flour and black gram *dal* flour (4:2:2) enriched with carrot (20%) and ginger (4%) stored well upto 3 days at room temperature (Shridevi, 2000).

On the whole it can be concluded that food mixes which are nutrient dense, ready to use, convenient, therapeutic value and low cost can be stored for a larger period in polyethylene bags or traditional method without affecting organtoleptic qualities of the products.

Material and Methods

III MATERIAL AND METHODS

Diabetes is increasing at an alarming rate in India, especially in urban pockets. It has become a major health problem even among developing countries. The genetic predisposition combined with adoption of faulty life style, which makes obese Indians, inactive and stress prone and hence susceptible to non-communicable disorders like diabetes and cardiac menace even at younger ages. Though exercise, antidiabetic drugs and education are important in management of diabetes, the diet plays a key role in blood glucose control, besides preventing complications. A diabetic food formulated based on hypoglycemic ingredients is the need of the day. Hence, a study on formulation of diabetic mix based on millets suited for Indian population was under taken during 1998-2001.

This chapter deals with material and methods used in the formulation, standardization of millet based diabetic mix as well as standard analytical procedures used in various phases of experimentation. The entire experiment was divided into three phases (Fig 1).

The phase I includes formulation, standardization, nutrient analysis and storability of the millet based diabetic mix. The phase II deals with nutritional evaluation of the developed mix in human volunteers by estimation of glycemic and lipemic responses. While phase III deals with popularization and commercialization of the developed diabetic mix through different outlets.

The Phase I is described under the following heads.

3.1 Preparatory methods

3.2 Analytical methods

3.3 Shelf life studies

3.4 Cost analysis

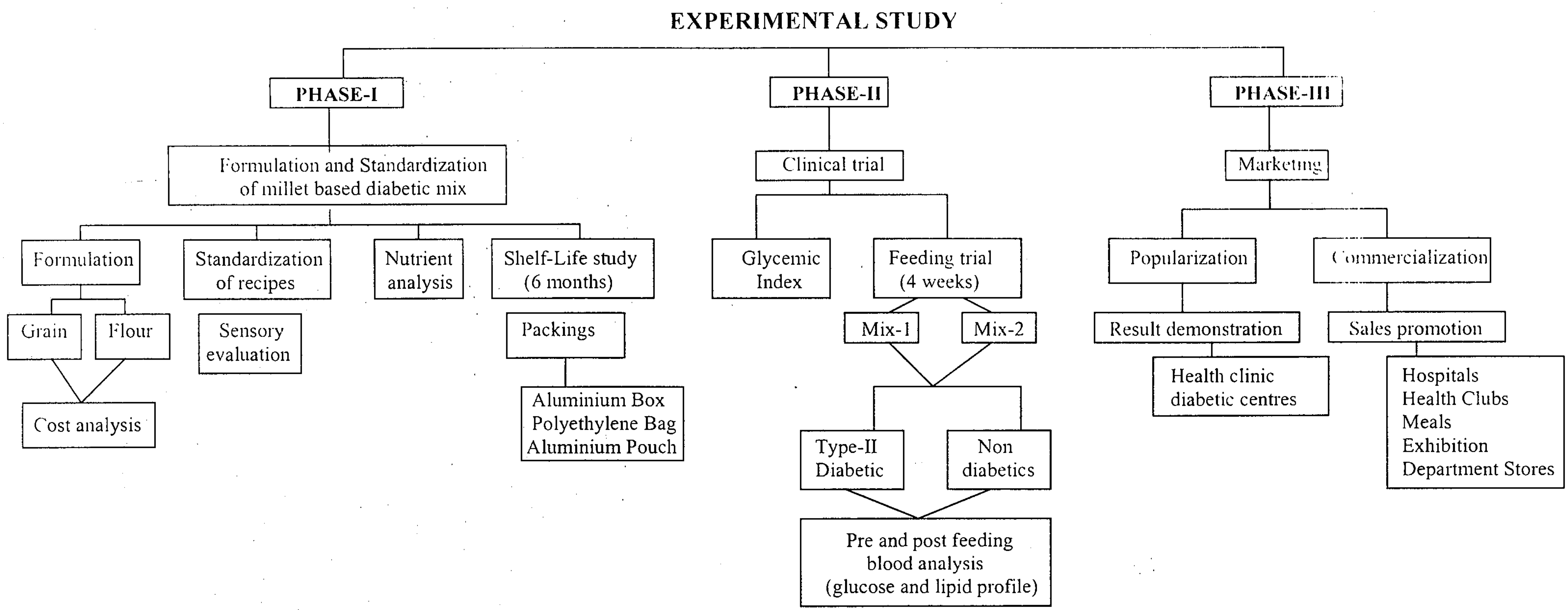


Figure 1. Experimental design of the study

3.1 Preparatory Methods

Under the preparatory methods are detailed the criteria for formulation of the mix, processing protocols and standardization of raw materials.

3.1.1 Criteria in formulation of the mix / food

Following criteria was used in formulating the composite mix.

- Ingredients availability and cultural acceptability.
- Rich in dietary fibre.
- Major ingredients should possess complex carbohydrates.
- Should possess hypoglycemic property.
- Should be cost effective.
- Better shelf life.

3.1.2. Processing protocols

The mix was prepared in two forms (grain and flour) to break the monotony in the taste of the diet, with low cost and effective technologies viz., cleaning, sedimentation, drying, roasting, milling and packaging.

3.1.3 Procurement and selection of raw material for standardization of mix

The raw materials used for the formulation of mix preparation are detailed below.

3.1.3.1 Millets

Milled millets viz., foxtail and little millets were procured from Agricultural Research Station, Hanumanmatti, University of Agricultural Sciences, Dharwad. The millets were cleaned by sedimentation technique, dried, roasted and milled and mixed at 50 to 80 per cent levels in the blends.

3.1.3.2 Other ingredients

The blends were formulated by mixing wheat-based products like semolina and flour and split pulses. Wheat products and split pulses were procured from the local market, cleaned, roasted and mixed at 10 to 40 per cent levels in the blend forms.

3.1.3.3 Spices

Different combinations of spices were tested. Spices *viz.*, fenugreek seeds (*Trigonella foenumgraecum*), coriander seeds (*Coriandrum sativum*), cumin seeds (*Cuminum cyminum*), black pepper (*Piper nigrum*) and turmeric powder (*Curcuma domestica*). The spices were procured from local market, cleaned, roasted and powdered. Fenugreek seeds were soaked in water for 10-12 hours, dried, roasted and powdered. Fenugreek, coriander and cumin seeds, black pepper were mixed in various proportions in the millet mixes and mixed at 6, 8, 10 and 12 per cent levels in the selected recipes such as rice and pancakes.

3.2 Analytical Methods

The analytical methods are enumerated under the three heads *viz.*, sensory, physical and chemical methods.

3.2.1 Sensory methods

Under the sensory methods are discussed the selection of judges, development of score card, method of sample presentation and evaluation and data analysis.

3.2.1.1 Selection of the judges

The experienced ten panel members, trained in quality testing of the foods were selected from Foods Science and Nutrition Department, U.A.S. Dharwad. The members of the panel were selected on the basis of their performance in the threshold and replicate tests. The training involved the presentation of the products to be used over a period until the subject's response satisfied the performance criteria suggested by Campbell *et al.* (1979) and consistency in evaluating sensory parameters *viz.*, appearance, aroma, texture, taste and overall acceptability of the recipes.

3.2.1.2 Development of score card

The score card with four point scale was developed for organoleptic evaluation of the recipes prepared from diabetic mixes (Appendix 1). The recipes prepared from the mix were evaluated in triplicates for acceptability.

3.2.1.3 Presentation of the products

The products were coded and placed in a random manner. The recipes were presented in clean and well-ventilated area of the laboratory, with a glass of water to rinse the mouth. The panelists were instructed to evaluate each sample as per regulations given in score card. Detailed methodology of the preparation of the recipes from grain mix and composite flour is given in Appendix 2.

3.2.2 Physical methods

Under the physical methods are discussed visual observation, thousand kernel weight, volume, bulk density, swelling and hydration capacity, swelling power, per cent solubility, cooking time and water absorption of millets. Particulars of these methods are detailed below.

3.2.2.1 Visual observation

Color, shape and tactile characteristics of whole and milled millets were observed and recorded.

3.2.2.2 Physical characteristics

The physical characteristics of whole and milled millets included thousand kernel weight, volume of raw and cooked grains, bulk density, swelling and hydration capacity.

Hydration capacity of grains was recorded as the difference in weight of thousand kernels before and after soaking for 24 hours and expressed as weight per gram (Dhingra *et al.,* 1992).

3.2.2.3 Swelling power and per cent solubility

Swelling power and per cent solubility of millets and mixes was determined according to the method used by Schoch (1964).

About 500mg (W_1) of grain or flour weighed and added to a centrifuge tube, weight of centrifuge tube and test sample was noted (W_2). After addition of 20ml (V_E) distilled water, the centrifuge tube was placed in the water bath at 100 °C for 20-30 min, till the contents were cooked. Then it was centrifuged at 5000 rpm for 10 min.

The supernatant was transferred to a test tube and inner sides of the centrifuge tube dried well and weighed (W_3). The swelling of grain per gram was calculated using the formula.

$$\text{Swelling power/g/g} = \frac{W_3 - W_2}{W_1} \times 100$$

For per cent solubility of grain or flour, weight of dried moisture dish was noted (W_4) and after pouring 10ml of aliquot (V_A) in a dish, dried at 110°C for 4-5 hours. The moisture dish was cooled and weighed (W_5). Per cent solubility was calculated as

$$\text{Per cent solubility} = \frac{(W_5 - W_4)V_E}{V_A} \times \frac{100}{W_1}$$

3.2.2.4 Cooking time

Cooking time of milled millet grains were tested by dropping known quantity of raw grains in boiling water. Doneness of the cooked grains was tested by pressing the cooked grain between glass slides. The disappearance of chalky spot of cooked grain was considered as end point and time taken was noted.

3.2.2.5 Particle size of flour

The millet based composite mixes were milled into flour in a commercial electrical flourmill and studied for flour characteristics related to cooking. The millet and composite flours were sifted in different size sieves 150, 180 and 250 microns to grade them as coarse, medium and fine particles respectively.

3.2.2.6 Water absorption

Weigh 20 grams of flour and prepare a dough with measured quantity of water. The water required to form soft dough was calculated as per cent absorption of the water by flour. Further, the dough was covered with muslin cloth and rested for 30 min, at ambient temperature. The stickiness, elasticity and puffing of the dough was studied and recorded as per the method suggested by Austin and Ram (1971).

3.2.3 Chemical analysis

The analysis of millet and mixes for proximate principles *viz.*, moisture, protein, fat, ash and crude fiber using standard AOAC procedures are discussed below. Carbohydrate and energy values were computed. The fiber profile of the mixes was analyzed by estimating soluble, insoluble and total dietary fibre and protein quality by amino acid scoring.

3.2.3.1 Moisture

Known quantity of powdered samples were taken in previously weighed moisture boxes and oven dried at 90 to 110^{0}C until two consecutive weights were noted (Anon, 1990).

3.2.3.2 Protein

Total nitrogen of moisture free samples were estimated by micro-kjeldhal method (Anon, 1990). Crude protein of millets was calculated by multiplying total nitrogen by the factor 5.83 (Swaminathan, 1985).

3.2.3.3. Ash

The moisture free sample was weighed in dried crucible, charred for 30 min, ignited in muffle furnace for 4 to 5 hours at 600^{0}C. The sample was cooled in desicator and weight was recorded. The difference in the weight of crucible with and without ignited sample was as weight of total ash (Anon, 1990).

3.2.3.4 Fat

Crude fat was estimated in moisture free samples using solvent extraction method by refluxing with petroleum ether for 12 hours (Anon,1990).

3.2.3.5 Crude fiber

Crude fiber was estimated from the moisture and fat free samples. The residue obtained after digestion with acid and alkali was dried in a crucible and weighed. The difference in weight of the crucible before and after ashing of the digested residue was taken as weight of the crude fiber (Jacobs, 1979).

3.2.3.6 Total carbohydrates

The content of total carbohydrates was calculated by difference method after subtracting the sum of the values for moisture, protein, fat, ash and crude fiber from 100.

3.2.3.7 Dietary fiber

Soluble, insoluble and total dietary fiber fractions of grains and mixes were analyzed by rapid enzymatic method proposed by Asp et al. (1983). Moisture and fat free samples were digested with amylo-glucosidase and protease to remove starch and protein. Collecting the filtrate and treating with 78 per cent ethanol precipitated soluble fiber and insoluble fiber was separated by filtration. The residue obtained after filtration was washed with ethanol and acetone then oven dried, weighed and ignited to ash. The soluble, insoluble and total dietary fiber content was calculated by the formula.

$$\text{Soluble / Insoluble / Total Dietary fiber} = \frac{\text{Wt. of residue} - \text{Wt. of ash}}{\text{Wt. of the sample}} \times 100$$

3.2.3.8 Protein quality

Protein quality of the formulated diabetic mixes was assessed by amino acid scoring method suggested by Pellet and Young (1980). The quantity of each essential amino acid in the protein was computed from food composition tables given by Gopalan *et al.* (2000). The amino acid score that shows the lowest proportion was defined as the limiting amino acid. This was compared with FAO / WHO reference pattern of the amino acids.

3.3 Shelf life studies

3.3.1 Storage of diabetic mix

The diabetic mixes were stored for a period of six months in different packaging materials at ambient temperature. The grain and flour mixes were divided into 160g portions, packed in high-density polyethylene bag and aluminium laminated pouches, heat sealed and stored in wooden cupboard. Besides, another set of grain mix and composite flour was stored in tight aluminium boxes as traditional way of storage at household level. The stored samples were analyzed for moisture, peroxide content and sensory qualities initially and fortnightly during six months of storage.

3.3.2 Evaluation of stored diabetic mix

3.3.2.1 Moisture

The procedure is given in 3.2.3.1

3.3.2.2 Peroxide value

Peroxide value is a measure of development of rancidity in foods containing fat and expressed in millie equivalents per kilogram of fat (meq / kg). The peroxide value of the stored mixes was determined periodically, after extraction of oil by Folche reagent and titrating iodiometrically (Sadhashivam and Manickam, 1992). The procedure is mentioned in Appendix 3.

3.3.2.3 Sensory evaluation

Acceptability of the developed mixes was carried out through sensory evaluation by the taste panel at 15 days interval throughout the storage period of six months. Cooked rice and pancake were prepared respectively from grain and flour mixes and presented to ten well-trained judges for organoleptic evaluation using four-point hedonic scale (Appendix 4).

3.4 Cost analysis of developed diabetic mix / food

The cost of the product includes the purchase and economic feasibility of production and sales. The cost of the mix varies with price fluctuations of raw materials in the local market. The cost of the mix per kilogram was calculated considering the cost of raw materials and cost involved in processing, packaging and depreciation value of fixed cost materials.

In Phase II, the determination of glucose response and feeding trials were carried out in non diabetic and diabetic volunteers under the following heads.

3.5 Nutritional efficacy of the developed diabetic mix

3.5.1 Glycemic index

The glycemic index indicates the extent of rise in blood sugar in response to a test food in comparison with the response to an equivalent dose of glucose. The concept of glycemic index (GI) of the foods is considered as physiological basis for ranking carbohydrate foods, which are useful in planning diabetic diets (Jenkins *et al.*, 1981b). Hence a scientific approach was planned to determine glycemic response of the developed mix in non diabetic volunteers through meal tolerance test.

3.5.1.1 Meal tolerance test

The study was conducted on six non diabetic healthy volunteers. Age, gender and anthropometric measurements of the selected volunteers were noted. Each subject underwent Meal Tolerance Test (MTT) with one-week interval period. On first occasion, 50g glucose powder (as reference food) and on second occasion, 50g carbohydrate tests food either in the form of *upma* from grain mix or pancakes from flour mix was given to the volunteers in random order. The volunteers were asked to come for blood glucose test after overnight fast. The volunteers were asked to consume test food with 200ml drinking water within 10 min and the blood samples were drawn at 1 and 2 hours interval for the post prandial glucose level. Each time the capillary blood glucose level was estimated using Glucometer (Precision, I.Q.D.). The blood glucose response curves were plotted for both the oral Glucose Tolerance Test (GTT) and the test carbohydrate meal. The glycemic index was calculated using the formula given by Wolever and Jenkins (1986).

$$\text{Glycemic Index (GI)} = \frac{\Delta \text{ Area under glucose curve of test meal}}{\Delta \text{ Area under glucose curve of reference meal}} \times 100$$

3.5.2 Feeding Trial

The long term feeding study was conducted on six non diabetic and nine type 2 diabetic volunteers. The age, gender and physical characteristics of the volunteers were recorded. The diabetic mixes were used in feeding study of four weeks, each with one month washout period between them. In pre-trial period, the volunteers consumed the diet to which they are normally accustomed. The normal dietary pattern of the volunteers was recorded and asked to replace part of the daily cereal intake by diabetic mix /composite food. Each subject consumed 87g of mix (80g mix + 7g spice mix) per day as breakfast, lunch and /or dinner food. The portion size of diabetic mix given in the clinical feeding trial was based on daily recommendation of dietary fiber content. The mix was supplied to the volunteers in the polyethylene bags with clear instructions to use one packet per day. A record card was given to all volunteers to note down name of the recipe consumed, mealtime and any discomforts felt after eating the mix.

The venous blood samples were collected for estimation of fasting glucose, triglycerides, total cholesterol and HDL cholesterol values at the initial and end of each feeding period of four weeks. Plasma glucose was measured by GOD/POD method enzymatic kit (Coral Clinical systems, Goa, India). Triglycerides, total cholesterol and HDL cholesterol were measured by rapid enzymatic method using commercial kits (Span Diagnostics Ltd., Surat, India.). Low density lipoprotein (LDL) cholesterol was estimated by using the formula mentioned by Friedewald *et al.* (1972).

$$\text{Serum LDL Cholesterol} = \text{Serum total Cholesterol} - \left\{ \text{HDL Cholesterol} - \frac{\text{Triglycerides}}{5} \right\}$$

The values of the variables obtained at the initial of each dietary period (4 weeks) were compared with those at the end of corresponding value to assess efficacy in terms of biochemical evaluation.

In Phase III, popularization and commercialization of the developed and standardized diabetic mix is discussed under the following heads.

3.6 Popularization of the diabetic mix / food

Popularization in a way is market – testing of the product. It helps to obtain accurate information on the product's sale potential. The diabetic mix was popularized through diabetic clinics and health clubs of Hubli- Dharwad, Belguam, Dandeli, Sirsi, Bijapur by method demonstration and exhibitions. During demonstration, the mix was introduced to the target population, emphasizing its importance and method of preparation in daily diet. The efficiency and clinical benefits of the mix were discussed and test samples were distributed to the volunteers. Personal interviews and family group discussions elicited acceptability and willingness to purchase the mix. Guidelines for the usage of the mix were printed in the regional language for its easy and wide publicity.

3.7 Commercialization of the diabetic mix

Commercialization is the final step in the product development to draw the attention of beneficiaries or consumers. Proper advertisement, market testing, consumer acceptability and introduction of developed health food in market place, is an essential step in commercialization process (Baker *et al.*, 1988). Sales promotion of the developed mix was carried by contacting target groups at different occasions through diabetic centers, workshops, personal and group counselings, diabetic *melas*, hospitals, exhibitions, *krishi melas*, Probo's club and *Mahila Mandals*.

For commercial sales, the mix was packed in half and one kg packages in polyethylene bags and heat-sealed. The attractive colored label was inserted in each packet indicating the name of ingredients, date of manufacture, instruction sheet, nutrient composition and unit cost.

3.8 Statistical Analysis

The results were quantified, classified, tabulated and expressed in frequencies, means, standard deviation and percentages (Gupta, 1991b). The percentages have been calculated with the totals of respective columns in the tables. The following statistical tools were used in the analysis and interpretation of data. The results of chemical parameters and sensory scores of stored diabetic mixes were analyzed using factorial CRD. With 4 different types diabetic mixes as a factor having its 5 levels and duration of storage as another factor having its 14 levels as zero, 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165 and 180 days. Critical difference (CD) was used for comparison of means.

Correlation coefficient (r) was calculated to know the relation between different chemical parameters and sensory attributes of diabetic mixes during storage.

$$r = \frac{\Sigma XY - \dfrac{(\Sigma X \Sigma Y)}{n}}{\sqrt{\Sigma X^2 - \dfrac{(\Sigma X)^2}{n} \quad \Sigma Y^2 - \dfrac{(\Sigma Y)^2}{n}}}$$

where r = Correlation coefficient

X = Independent variable

Y = Dependent variable

n = Number of observations in each group

Coefficient 'r' was tested using the formula,

$$t = \frac{r / X / \sqrt{n-2}}{\sqrt{1-r^2}}$$

with ∽ t distributed with n-2 degrees of freedom

The significant difference in chemical and nutrient composition of diabetic composite mixes was tested using student's 't' test. The following formula was used to find out the 't' value.

$$t = \frac{/ \; d \; /}{\sqrt{\sigma^2 / n}}$$

with (n-1) degrees of freedom

Where d = Mean difference before and after feeding period

σ = Standard deviation of the diffrential values

n = Number of observations

In a similar manner the significant difference in plasma glucose and lipemic response before and after feeding of diabetic composite food in human volunteers was tested using 't' test.

Experimental Results

IV EXPERIMENTAL RESULTS

The results of the investigation conducted from 1999-2001 on 'development and evaluation of millet based composite food for diabetics' are presented in this chapter. The results pertaining to selection, formulation and standardization of the diabetic composite food / mix with physical and chemical characteristics are included in the first part of the chapter. The shelf life study and acceptability of the recipes are presented in the second part, while third part deals with glycemic and lipemic responses of diabetic mix and effect of long term feeding trials on non diabetic and diabetic volunteers. The last part covers popularization and commercialization of the mix / food to the beneficiaries.

4.1 Development of the diabetic composite mix

Foxtail (*Navane*) and little (*Save*) millets were selected for the development of diabetic mix based on cultural acceptability and availability among the local population. As per the traditional practice, majority of the people is known to consume *navane* and *save* in milled (debraned) form during fasting and festival period and few take it as a substitute for the rice in diabetic condition.

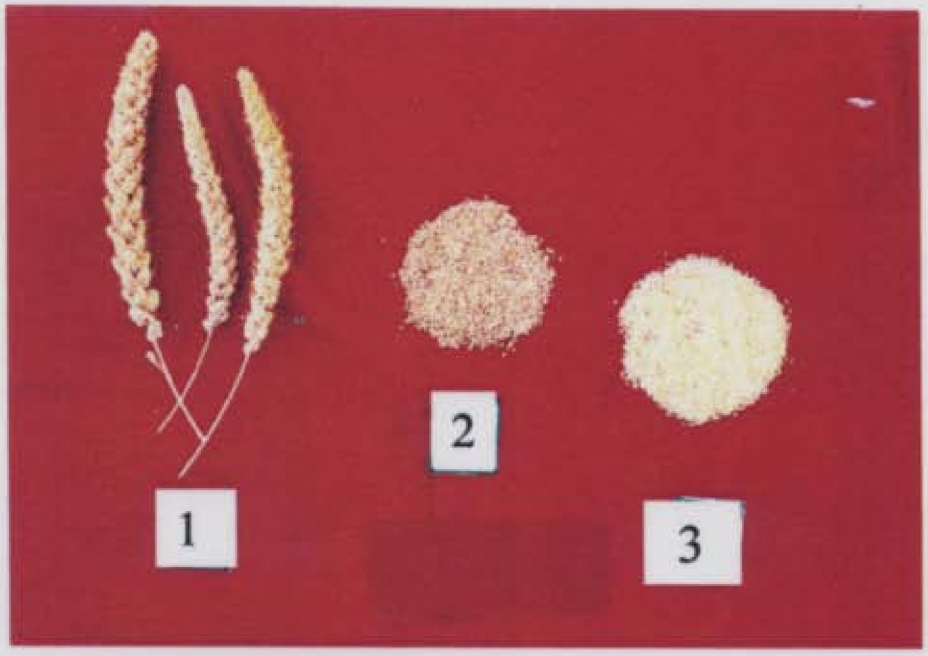
4.1.1 Physico-chemical characteristics of the millets

The foxtail and little millets were cleaned by sedimentation technique, air dried for 8-10 hours and dried in hot air oven at 60-70°c for 4-5 hours for further analysis. The results pertaining to physico- chemical characteristics of the millets are presented in Table 4.

Debraned (milled) raw foxtail millet grains were oval in shape and dark yellow in colour while those of little millet were round and bright white in colour compared to roasted grains. Millets with husk were shiny with dark coloured seed coat and elongated in shape and coarse in texture compared to raw milled and roasted grains (Plate 1).

Table 4. Physico- chemical characterstics of the millets

Parameters	Foxtail Millet			Little Millet		
	Whole	Debraned / milled		Whole	Debraned / milled	
		Raw	Roasted		Raw	Roasted
Colour	Brown	Bright yellow	Light Yellow	Blackish Brown	White	Creamish White
Shape	Elongated	Oval	Oval	Elongated	round	round
1000 Kernel :						
Weight (g)	3.05	2.27	2.12	2.67	2.22	2.14
Volume (ml)	2.80	1.70	1.60	2.20	1.60	1.50
Bulk Density (g/ml)	1.09	1.34	1.32	1.21	1.39	1.45
Swelling :						
Capacity (%)	1.00	0.40	0.55	0.64	0.42	0.50
Index	35.17	23.53	34.38	29.09	26.25	33.33
Hydration :						
Capacity (%)	0.76	0.38	0.56	0.55	0.35	0.46
Index	24.91	16.74	26.42	20.60	15.77	21.50



Foxtail Millet

1. Earheads 2. Whole grains 3. Milled grains

Little Millet

Plate 1. Foxtail Millet and Little Millet

The thousand kernel weight (whole, debraned raw and roasted) ranged from 2.12 to 3.05g in foxtail millet and 2.14 to 2.67g in little millet. The volume of foxtail and little millet ranged from 1.60 to 2.80ml and 1.50 to 2.20ml respectively, while the densities varied from 1.09 to 1.45g /ml in both the millets. The density of milled raw and roasted millets was increased by 20-21 per cent compared to whole grains. The swelling capacity was ranged between 0.4 to 1.00 per cent in foxtail millet while index ranged from 23.53 to 35.71. In a similar manner the swelling capacity in little millet was ranged between 0.42 to 0.64 per cent while index ranged from 26.25 to 33.33. The swelling capacity and index were observed to be high in whole grains compared to raw and roasted millets. The hydration capacity of both millets ranged from 0.35 to 0.76 per cent and index from 15.77 to 26.42. Though high hydration capacity was noted in whole grains (0.55 and 0.76 per cent, little and foxtail millet respectively), but index was increased in roasted grains of little and foxtail millets (21.50 and 26.42 respectively).

Generally millets are consumed in milled and roasted form hence, the nutrient composition of millets was analyzed and mean values are given in Table 5.

The moisture content of the foxtail and little millets was varied from 9.75 to 14.8 and 10.65 to 14.55 per cent respectively. The fat content was ranged from 2.45 to 2.96 and 3.24 to 3.79 per cent in little and foxtail millets respectively. The ash content in both the millets was ranged from 1.27 to 1.45 per cent. The crude fibre was estimated 1.20 per cent in little millet while 1.36 to1.39 per cent in foxtail millet. The analyzed protein values ranged from 9.8 to 10.2 per cent in little millet while 12.0 to12.2 per cent in foxtail millet. There is an increase in fat and ash of roasted grains compared to respective debraned raw grains. The protein content of little millet (9.8 g) was found lower than foxtail millet (12.2 g). The carbohydrate content of both millets ranged from 67.09 to 74.06 per cent and energy values 344 to 369 kcalories. The roasted millets exhibited higher values for carbohydrate and energy compared to respective milled raw

Table 5. Nutrient composition of the millets (% *dwb*)

Millets	Moisture	Protein	Fat	Crude Fibre	Ash	Carbohydrate	Energy(kcal)
Foxtail							
Raw	14.80	12.20	3.24	1.39	1.28	67.09	346
Roasted	9.75	12.00	3.79	1.36	1.45	71.65	369
Little							
Raw	14.55	10.20	2.45	1.20	1.27	70.33	344
Roasted	10.65	9.80	2.96	1.20	1.33	74.06	362

dwb = dry weight basis

grains. However the difference between the nutrient composition of milled raw and roasted millets was found statistically not significant except for fat and carbohydrate content. The difference between the nutrient composition of little and foxtail millets was found statistically not significant except for fat content (Appendix 5).

The cooking quality parameters of millet grains are summarized in the Table 6. The cooking time for boiling of little and foxtail millets ranged from 5.5 to 6.0 and 6.00 to 6.50 minutes respectively. Little millet gets cooked faster than foxtail millet. The increase in cooked weight of milled raw and roasted foxtail millet was varied from 352 to 371 per cent while volume increased by 3.8 to 4 times respectively. In a similar manner the cooked weight of milled raw and roasted little millet was increased to 332 to 342 per cent while volume increased by 3.7 to 3.8 times respectively. Thus weight and volume of roasted millets were slightly higher than respective raw grains (Plate 2).

4.1.2 Preparation of diabetic mix

The diabetic composite mixes were prepared from foxtail and little millet in grain and flour form. The formulations of the composite mixes were tried out with addition of wheat in the form of semolina or flour and black gram *dal* in different proportions to the millets. The initial proportions of the mix were selected on the basis of acceptability of the recipes and recommended total dietary fibre content. The spice mixture was added to improve glycemic response and taste of the recipes. The detailed information regarding preparation of the diabetic mixes is presented in Figure 2.

The initial trials of different proportions of the grain mix by preparing rice with the spice mixture at six, eight, ten and 12 per cent levels were tried. The sensory qualities of the product as reported by expert panels accepted the spice mixture at eight per cent level. Hence, addition of spice mixture /powder at eight per cent was fixed for the trial of subsequent recipes such as pancakes and *chapathis*. The dietary fibre content along with acceptability attributes of different recipes in three proportions has been screened in Table 7.

Table 6. Cooking quality of the millets

Millets	Cooking time (min)	Increase	
		Weight (%)	Volume (R : C)*
Foxtail			
Raw	6.00	352	1:3.8
Roasted	6.50	371	1:4.0
Little			
Raw	5.50	332	1:3.7
Roasted	6.00	342	1:3.8

Note: *R - Raw grains
C - Cooked grains.

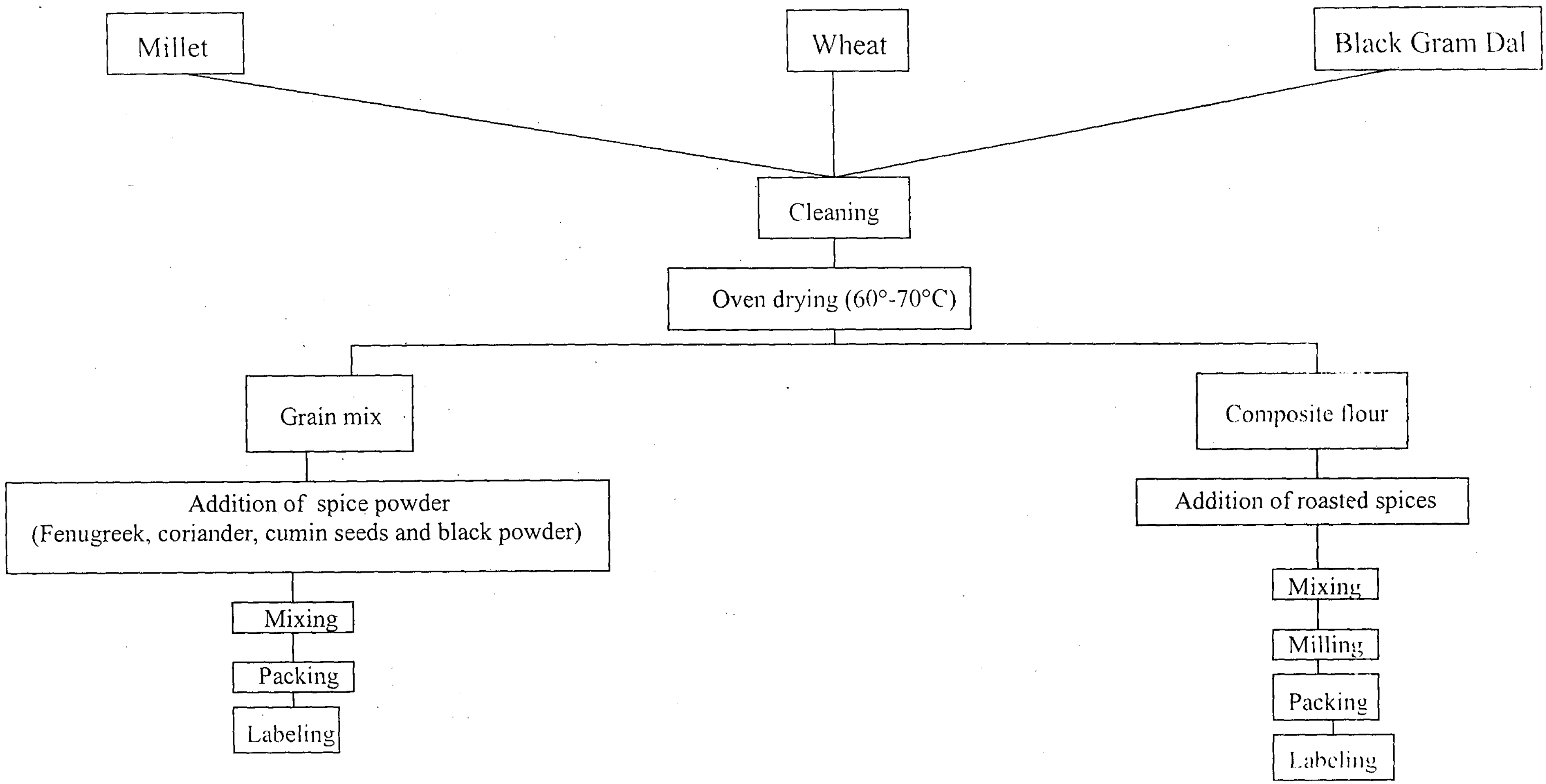


Figure 2. Flow chart of diabetic mix preparation

Foxtail Millet

1. Raw 2.Cooked

Little Millet

Plate 2. Expansion of Millets after cooking

Table 7. Initial trials for development of diabetic composite mix

Variables	Proportions (Millet : Wheat : Black gram *dal*)					
	Foxtail Millet			Little Millet		
	6:3:1	7:2:1	8:1:1	6:3:1	7:2:1	8:1:1
Acceptability						
Rice	+	+	+	+	+	+
Pancake	+	+	+	+	+	+
Chapathi	+	+	+	+	+	+
Remarks:	soft	-	crisp	soft	-	slightly hard
Total Dietary Fiber (%)	13.20	13.33	13.42	12.76	12.77	12.78

Note: + Acceptable

The dietary fibre content of the diabetic composite mix increased with an increase in the proportion of millet from12.76 to 13.42g. The recipes (rice, pancakes and *chapathi*) prepared from different proportions *viz.*, 6:3:1, 7:2:1 and 8:1:1 (millet: wheat: black gram *dal*) were acceptable with spice mixture at eight per cent. Hence, the composite mixes with 8:1:1 proportion of millet: wheat: black gram *dal* with high content of dietary fibre (12.78 and 13.42g in little and foxtail millet respectively) were selected for further experiment (Plate 3).

4.1.2.1 Physical characteristics of diabetic composite flour mix

The diabetic composite mix was prepared in the flour form to add variety in the diabetic diet. The particle size of millet and composite flours were estimated using different size test sieves and data related to this aspect is summarized in the Table 8.

The fine flour, which passed through the test sieve mesh 250 microns, was 93-94 per cent and six to seven per cent of coarse particles in both millet and composite flours. The coarse flour which was unable to pass through test sieve mesh 180 and 150 microns ranged from 17-21 and 28-35 per cent respectively in foxtail and little millet flours and respective composite flours. The fine flour yield was decreased with a decrease in test sieve mesh microns. There was not noticeable change in coarse and fine flour yield of millet and composite flours, since the particle size of flour depends on the size of mesh used in the flourmills.

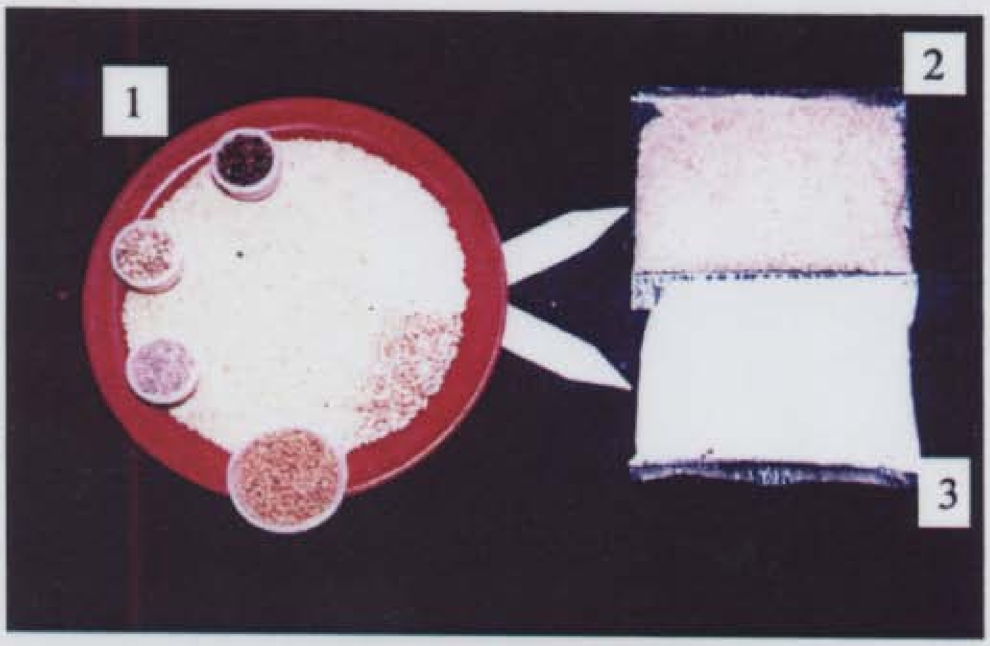
The swelling power of foxtail and little millet grains was ranged from 7.70 to 7.74 and 7.7 to 7.86g /g while flour from 8.70 to 8.79 and 8.7 to 8.84g /g respectively (Table 9). The solubility of the foxtail millet grains varied from 4.00 to 6.00 per cent and the flour from 4.70 to 6.20 per cent. While solubility of the little millet grains was varied from 4.00 to 6.30 per cent and the flour from 4.80 to 6.60 per cent. Both swelling power and solubility were increased in flour form compared to respective grains with marked difference observed in the solubility of both millet flours (plain) compared to respective composite flours.

Table 8. Particle size of the flour (%)

Mesh size	Particle size	Foxtail Millet		Little Millet	
		Flour	Composite flour	Flour	Composite flour
60 (250 micron)					
	Fine	94	94	94	93
	Coarse	6	6	6	7
85 (180 micron)					
	Fine	83	83	79	82
	Coarse	17	17	21	18
100 (150 micron)					
	Fine	67	72	65	71
	Coarse	33	28	35	29

Table 9. Swelling power and solubility of millet grains and flours

Millets	Swelling power g/g	Increase %	Solubility %	Increase %
Foxtail				
Grains	7.70	-	4.00	-
Flour	8.70	13.00	4.70	0.70
Grain mix	7.74	-	6.00	-
Composite flour	8.79	13.60	6.20	0.20
Little				
Grains	7.70	-	4.00	-
Flour	8.70	13.00	4.80	0.80
Grain mix	7.86	-	6.30	-
Composite flour	8.84	12.50	6.60	0.30



Foxtail Millet

1. Raw Ingredients 2. Grain Mix
3. Composite Flour

Little Millet

Plate 3. Developed Diabetic Composite Foods / Mixes

The rheological properties of foxtail and little millet dough have been summarized in Table 10. The water absorption of millet and composite flours of both millets varied from 68 to 73 per cent. However, the composite flours of both millets absorbed less water compared to plain flours of respective millet. The kneading and formation of dough was easy in composite flours than plain flours of both millets. The dough from both composite flours showed slightly sticky texture compared to dough from respective millet flours. The foxtail millet dough was light yellow in colour than composite flour while little millet dough was white in colour than composite flour. The dough from composite flours expanded and puffed evenly and rolled easily as compared to respective plain flours. The dough from the composite flours revealed few cracks at the edges after rolling compared to respective millet flours. The foxtail millet flour formed hard dough while, slight hard dough was obtained from foxtail composite flour and soft textured dough was obtained from little millet (plain and composite flour).

4.1.2.2 Nutrient composition of diabetic composite mixes

The diabetic mixes were prepared using foxtail and little millet in major proportion along with wheat and black gram *dal* and selected spices. The mixes were analyzed for their nutrient composition, dietary fibre profile and amino acid scores. The results pertaining to the nutrient composition of diabetic mixes are presented in Table 11.

The moisture content of foxtail and little composite mixes ranged from 6.12 to 6.31 and 4.67 to 5.15 per cent respectively. The protein content ranged from 10.21 to 10.71 and 12.91 to 13.42 per cent in little and foxtail millet composite mix respectively. The maximum fat content was estimated in foxtail millet composite flour (4.24 %) followed by little millet composite flour (3.71 %), foxtail millet grain mix (3.47 %) and little millet grain mix (3.30 %). The crude fibre content was 1.57 and 1.55 per cent in little and foxtail millet composite flours respectively while 1.46 and 1.42 per cent in respective grain mix. While ash content was varied from 1.72 to 1.81 and 1.86 to 2.12

Table 10. Rheological characterstics of the millet doughs

Characterstics	Foxtail millet		Little millet	
	Flour	Composite flour	Flour	Composite flour
Water absorption (%)	73.00	68.00	70.00	68.50
Kneading (mixing behaviour)	not easy	easy	not easy	easy
Formation of dough	not easy	easy	not easy	easy
Handling behaviour (stickiness)	non sticky	slighty sticky	non sticky	slightly sticky
Colour of dough	light yellow	dark yellow	white	creamish white
Rolling	not easy	easy	not easy	easy
Expanding (spreading behaviour)	uneven expanding	easy and even expanding	uneven expanding	easy and even expanding
Edges after rolling	cracks easily at edges	few cracks at edges	cracks easily at edges	no cracks at edges
Puffing	uneven puffing	even and easy puffing	uneven puffing	easy and even puffing
Texture	hard	slightly hard	slightly hard	soft

Table 11. Nutrient composition of diabetic composite mixes (% *dwb*)

Millets	Moisture	Protein	Fat	Crude Fibre	Ash	Carbohydrate	Energy (kcal)
Foxtail							
Grain mix	6.12	12.91	3.47	1.42	1.86	74.04	379
Composite flour	6.31	13.42	4.24	1.55	2.12	72.36	381
Little							
Grain mix	4.67	10.21	3.30	1.46	1.72	78.64	385
Composite flour	5.15	10.71	3.71	1.57	1.81	76.59	387

dwb = dry weight basis

per cent in little and foxtail millet composite mix respectively. The carbohydrate content of both grain mixes varied from 74.04 to 78.64 per cent and in composite flours from 72.36 to 76.59 per cent. The difference between the nutrients of both millets mixes was statistically not significant except mineral content (Appendix 5).

The mean total solids (exclusion of moisture) of the composite mixes ranged between 93.69 to 95.33 per cent and high total solid values for little millet grain mix was found to be 95.33 and foxtail grain mix 93.88 per cent as compared to respective composite flours. The estimated energy values from analyzed nutrients of the mixes were ranged from 379 to 381 and 385 to 387 kcalories in foxtail and little millet composite mix respectively. The nutrients of both the mixes were within the limits of ISI (BIS) specifications except protein and crude fibre content, for processed cereal weaning food.

The dietary fibre profile of millets and composite mixes is summarized in Table 12. The total dietary fibre content of little and foxtail millets was ranged from 20.60 to 22.10 and 22.5 to 23.4 per cent in composite mixes while 18.10 and 19.80 per cent in plain millet grains respectively. The soluble and insoluble dietary fibre content of foxtail millet was 2.80 and 17.00 per cent respectively and in little millet 3.15 and 14.95 per cent respectively. While the soluble and insoluble dietary fibre content of both composite mixes was slightly higher than respective grains. The soluble dietary fibre content was ranged from 12 to 14 and insoluble dietary fibre from 86 to 88 per cent of total dietary fibre in foxtail millet. In a similar way, the soluble dietary fibre content was ranged from 17 to 19 and insoluble dietary fibre from 81 to 83 per cent of total dietary fibre in little millet. The soluble fibre was noticed in higher amounts in little millet compared to foxtail millet. But the total dietary fibre increased by 2.5 and 4.1 per cent in little millet composite mixes compared to their respective plain grains. In the similar manner, the total dietary fibre content was increased by 2.7 and 3.6 per cent in foxtail millet composite mixes compared to plain grains. However the difference between the total dietary fibre content of foxtail and little millet was found significant ($P < 0.01$)

Table12. Dietary fibre profile of millets and mixes (%)

Millets / Mixes	Soluble Fibre	Insoluble Fibre	Total Dietary Fibre	Increase
Foxtail				
Grains	2.80 (14)	17.00 (86)	19.80	-
Grain Mix	2.90 (12)	20.50 (88)	23.40	3.60
Composite flour	2.95 (13)	19.55 (87)	22.50	2.70
Combined	2.89 (13)	19.01 (87)	21.90	2.10
Little				
Grains	3.15 (18)	14.95 (82)	18.10	-
Grain Mix	3.50 (17)	17.10 (83)	20.60	2.50
Composite flour	4.10 (19)	18.00 (81)	22.10	4.10
Combined	3.58 (18)	16.68 (82)	20.26	2.16
't' value between				
Grains	0.0002**	0.0002**	0.0004**	-
Grain Mix	0.003**	0.004**	0.008**	-
Composite flour	0.001**	0.054NS	0.43NS	-
Combined	0.00005**	0.001**	0.028*	-

Note: Figures in the parenthesis indicate percentages of total dietary fibre.

** - Significant @ 1%

* - Significant @ 5%

NS - Not Significant

except for the composite flour. There was a significant difference between the millets in dietary profile including soluble, insoluble and total dietary fibre content.

The protein quality of millets and mixes were calculated by computing amino acid scores, considering FAO/ WHO reference scoring pattern as standard. The results concerned with this aspect are given in Table 13. The amino acid scores for foxtail and little millet was almost similar for tryptophan, methionine and threonine but lower scores observed for lysine, phenylalanine, isoleueine, leucine and valine in little millet compared to foxtail millet. The amino acid scores among the composite mixes were almost equal except wide variation for isoleucine, leucine and valine. The lysine was observed to be the first limiting amino acid in little millet (0.36), foxtail millet (0.41) and in composite mixes (0.56 each). The second limiting amino acid was threonine in millets and mixes (0.76 – 0.79) while phenylalanine was found to be third limiting amino acid only in little millet (0.87). It was apparent to note that the scores for limiting amino acids increased in diabetic composite mixes compared to millet grains. The lysine content was increased in the mixes by 15-24 per cent, threonine by 2-3 per cent and phenylalanine by 13 percent than respective millet grains.

4.2 Standardization of recipes from diabetic composite mixes

A variety of recipes were attempted from grain mix and composite flour of foxtail and little millet. Initially 'rice, *upma* and *idli*' were prepared from grain mix and '*chapathi*, pancake, *mudde*, *masala roti*, *thalipatti*' and bun were tried from composite flour of both the millets. Each recipe was tried in triplicates for standardization. Among the trial products, *idli* and bun from composite flour were not acceptable due to very hard texture without proper fermentation and leavening, as tested by investigator. Hence, these recipes were deleted from subsequent sensory evaluation. The recipes viz., rice and *upma* from the composite grain mix and *chapathi*, *mudde*, pancake, *masala roti* and *thalipatti* from composite flour prepared and subjected to sensory evaluation in triplicate (Plate 4).

Table 13. Amino acid scores in millets and mixes

Millets / Mixes	# Essential Amino Acids							
	Lysine *	Tryptophan	Phenylalanine	Methionine	Threonine**	Iso leucine	Leucine	Valine
Foxtail								
Grains	0.41	1.00	1.10	1.27	0.76	1.92	2.36	1.39
Mix	0.56	1.05	1.13	1.16	0.78	1.71	2.02	1.27
Little								
Grains	0.36	1.00	0.87***	1.23	0.76	1.46	1.72	1.13
Mix	0.56	1.07	1.00	1.10	0.79	1.38	1.49	1.07
Reference protein mg of amino acids / g (FAO / WHO,1973)	340	60	380	220	250	250	440	310

Note: * / ** / *** First / Second / Third limiting amino acid

Calculated values from composition tables (Gopalan *et al*., 2000)

Foxtail Millet

1. Rice	2. Upma	3. Thalipatti
4. Chapathi	5a Pancake	5b Masala roti

Little Millet

Plate 4. Recipes prepared from Diabetic Composite Mix

4.2.1 Nutrient composition of standardized recipes

The estimated nutrient composition of recipes per serving size, for diabetic mixes of both millets has been summarized in Table 14.

The energy values were ranged from 151-202 and 154 to 206 kcalories for different recipes prepared from foxtail and little millet composite mix respectively. The addition of cooking oil (5g) in the preparation increased caloric value (10-25%) in all recipes except *rice* (151- 154 kcals). The protein content of the recipes were ranged from 4.08 to 5.28 and 5.16 to 6.07 g and total dietary fibre from 8.24 to 8.94 and 9.10 to 9.46 g per serving size (40g mix) in little and foxtail millet respectively. The protein content of the recipes from composite flour increased by 2.28 to 3.25 per cent than the recipes from the grain mix. Whereas the total dietary fibre content was higher by 1.15 and 2.00 per cent in recipes of foxtail millet than little millet mix. In both the mixes, the cooked weight of rice and *upma* (195-210 g) increased upto five times as compared to raw weight. However, *mudde* from composite flour exhibited four times expansion while other recipes (*chapathi*, pancake, *thalipatti* and *masala roti*) showed two times increase in cooked weight.

4.2.2 Sensory evaluation of the recipes from diabetic mixes

The sensory scores obtained for appearance, texture, aroma, taste and Over All Acceptability (OAA) of all standardized recipes from foxtail and little millet composite mix has been presented in Table 15.

All the recipes from foxtail millet composite mix were acceptable and mean OAA scores ranged between 2.79 to 3.29 out of 4.00. The recipes from foxtail millet mix *viz,* pancake, *upma* and *mudde* scored >3 out of 4 points indicated good acceptability while *chapathi, masala roti, thalipatti* and rice scored <3 indicated only acceptable range of OAA scores. The recipes from little millet mix *viz*, rice, pancake and *thalipatti* scored >3 out of 4 points indicated good acceptability while *upma, chapathi, masala roti* and *mudde* scored <3 indicated only acceptable range of OAA scores. The lowest mean score

Table 14. Composition (per serving size*) of diabetic mix recipes

Recipes	Energy# (kcal)	Protein# (g)	Total Dietary Fibre# (g)	Cooked Weight (g)
Foxtail Millet				
Rice	151	5.16	9.36	195-200
Upma	201	5.47	9.46	205-210
Chapathi	173	5.37	9.00	65-68
Pancake	200	5.97	9.00	75-80
Mudde	202	5.97	9.10	150-155
Masala Roti	197	6.07	9.20	70-75
Thalipatti	201	5.97	9.10	72-75
Little Millet				
Rice	154	4.08	8.24	195-200
Upma	205	4.38	8.34	205-210
Chapathi	177	4.68	8.84	65-68
Pancake	204	5.28	8.84	75-80
Mudde	206	5.28	8.94	150-155
Masala Roti	201	5.38	9.04	70-75
Thalipatti	205	5.28	8.94	72-75

Note: * - Serving size = 40g

- Estimated values

Table 15. Sensory scores of diabetic mix recipes

Recipes	Appearance	Texture	Aroma	Taste	Mean total score	Overall Acceptability
Foxtail Millet						
Rice	3.25±0.53	3.00±0.51	2.79±0.69	3.04±0.69	3.02	2.92±0.72
Upma	3.13±0.61	3.25±-0.61	3.29±0.69	3.21±0.72	3.22	3.25±0.68
Chapathi	2.54±0.72	2.50±0.66	2.67±0.56	2.71±0.69	2.61	2.79±0.66
Pancake	3.17±0.64	3.33±0.64	3.29±0.69	3.29±0.55	3.27	3.13±0.54
Mudde	3.13±0.54	2.88±0.45	2.92±0.50	3.00±0.59	2.98	3.29±0.69
Masala Roti	3.08±0.72	2.79±0.59	3.25±0.53	2.71±0.55	2.96	2.79±0.51
Thalipatti	2.54±0.66	2.63±0.71	2.92±0.78	2.92±0.50	2.75	2.96±0.62
Little Millet						
Rice	3.29±0.55	3.21±0.66	3.08±0.58	3.31±0.68	3.18	3.21±0.59
Upma	3.88±0.58	2.96±0.46	2.88±0.45	2.88±0.54	3.03	2.96±0.46
Chapathi	2.67±0.64	2.42±0.78	2.71±0.62	2.42±0.83	2.56	2.63±0.71
Pancake	3.17±0.48	3.28±0.53	3.13±0.45	3.29±0.46	3.21	3.33±0.56
Mudde	3.04±0.55	2.75±0.61	2.58±0.72	2.58±0.78	2.74	2.92±0.72
Masala Roti	2.67±0.64	2.63±0.71	2.83±0.56	2.58±0.58	2.68	2.92±0.65
Thalipatti	3.04±0.46	3.04±0.46	2.96±0.55	2.96±0.55	3.00	3.13±0.45

Note: Mean ± SD (4 point scale)

was noted for *chapathi* (2.61) and highest for *upma* (3.22) excluding OAA scores in foxtail millet mix preparations. While the lowest mean score was noted for *chapathi* (2.56) and highest for pancake (3.21) excluding OAA scores in little millet mix preparations.

It is evident from the Table 15, that the lowest mean scores obtained for the aroma in rice (2.79), appearance in *upma* (3.13), pancake (3.17) and *thalipatti* (2.54), texture in *chapathi* (2.50) and *mudde* (2.88), taste in *masala roti* (2.71) mainly influenced the OAA of the respective foxtail millet mix products. In a similar manner, the lowest mean scores obtained for the aroma in rice (3.08) and pancake (3.13), aroma and taste in *upma* (2.88), texture and taste in *chapathi* (2.42), aroma and taste in *mudde* (2.58) and *thalipatti* (2.96), taste in *masala roti* (2.58) mainly influenced the OAA of the respective little millet mix products. On the basis of sensory evaluation *upma* from foxtail millet mix and pancake from little millet mix were found more acceptable than other respective preparations.

4.3 Shelf – life studies

The different diabetic mixes with one set stored in aluminium box and other sets were packed and sealed in polyethylene bag and aluminium pouch and kept in the wooden cupboard at an ambient room temperature (30 ± 2°C). These stored composite mixes were analyzed fortnightly for various chemical parameters. Further, the mixes were used in the preparation of rice from grain mix and pancake from composite flour and evaluated periodically for sensory attributes during six months of storage. The results pertaining to this aspect is presented in this section (Plate 5).

4.3.1 Chemical analysis of the diabetic mixes

The moisture and peroxide content of stored diabetic mixes in different packages were analyzed at regular interval. The moisture content of diabetic composite mixes (grain and flour form) of both millets stored in three packages presented graphically in Figure 3 and detailed data is given in Appendices 6 and 7.

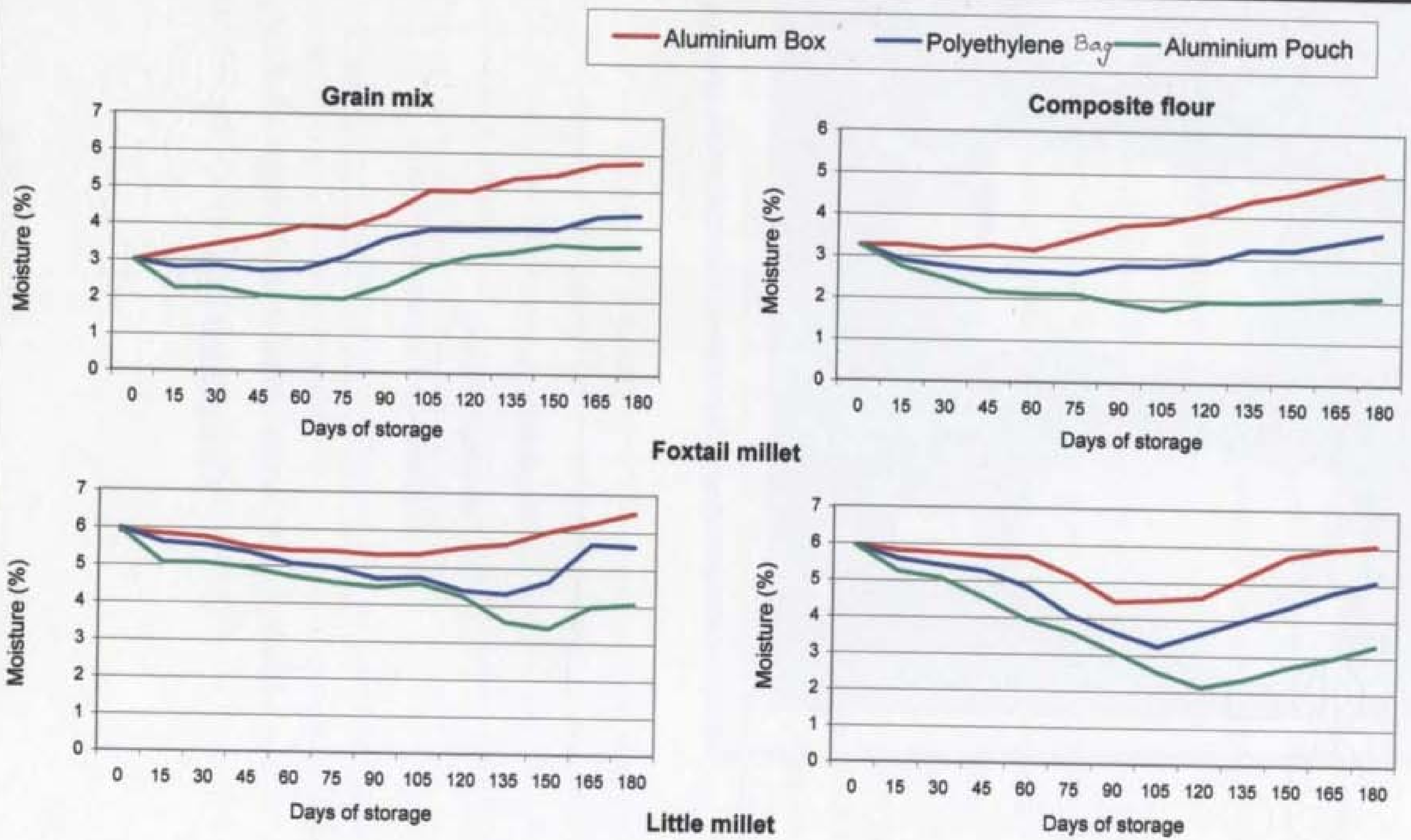


Fig. 3. Impact of storage on moisture content (%) of diabetic composite food/mix

1. Aluminium Box
2. Polyethylene Bag
3. Aluminium Laminated Pouch

Plate 5. Packages used for storage of Diabetic Composite Mix

4..3.1.1 Moisture

The initial moisture of foxtail and little millet grain mix was 2.99 to 3.00 and 5.96 to 5.97 per cent respectively. The moisture content of foxtail millet mix, stored in aluminium box increased significantly (P ≤0.05) throughout the storage. Whereas the moisture content of the mix stored in sealed in polyethylene bag and aluminium pouch reduced significantly (P ≤0.05) upto 45 and 75 days of storage respectively but increased later throughout the storage period.

On the contrary, the moisture of little millet grain mix stored in aluminium box was reduced significantly upto 90 days of storage and increased significantly (P ≤0.05) after 105 days of storage. However, the moisture of little millet grain mix, stored in sealed polyethylene bag and aluminium pouch was also reduced significantly (P ≤ 0.01) upto 135 days of storage and later increased till the at end of storage period (180 days). It is clearly noted that the mean moisture content in comparison with initial moisture of the foxtail millet mix was high when stored in aluminium box and sealed polyethylene bag during storage period. Whereas, the mean moisture content in comparison with initial moisture of the little millet mix was low in three packages during storage period (Appendix 6).

There was a significant difference (P≤0.01) in mean moisture content of foxtail millet mix stored in aluminium pouch (2.74%), polyethylene bag (3.48%) and aluminium box (4.43%) throughout the storage period. The same trend was also noted in moisture for little millet mix, stored in aluminium pouch (4.49%), polyethylene bag (5.11%) and aluminium box (5.72%) throughout the storage period.

The initial moisture content of foxtail and little millet composite flour was 3.25 and 5.95g per cent respectively (Appendix 7). The moisture content of foxtail millet composite flour stored in aluminium box was not much changed upto 60^{th} days of storage and later increased significantly (P≤0.01) throughout the storage period. The moisture content of composite flour stored in sealed polyethylene bag decreased significantly ($P \leq 0.05$) upto 45 days of storage and later remained almost same upto 75 days of storage but increased significantly from 105 days of storage upto end of storage study. A similar trend was observed in composite flour packed in sealed aluminium pouch, exhibiting decreased moisture content upto 105 days of storage and later increased significantly ($P \leq 0.01$) throughout the storage period.

It was interesting to note that the moisture content of little millet composite flour stored in aluminium box initially reduced significantly ($P \leq 0.05$) upto 30 days of storage. But later decrease in moisture content was not significant statistically upto 60 days of storage and further it decreased significantly ($P \leq 0.01$) upto 90 days of storage and further increased significantly ($P \leq 0.01$) after 120 days storage. The moisture content of little millet composite flour stored in sealed polyethylene bag and aluminium pouch exhibited steady and significant decrease upto 105 and 120 days of storage respectively. Later the moisture content increased significantly ($P \leq 0.05$) but not more than the initial value in both the packages.

It is clearly noted that the mean moisture content in comparison with initial moisture of the foxtail millet composite flour was slightly high when stored in aluminium box and low in sealed polyethylene bag and aluminium pouch during storage period. Whereas, the mean moisture content in comparison with initial moisture of the little millet composite flour was considerably low in three packages during storage period. There was significant ($P \leq 0.01$) difference in mean moisture of foxtail millet composite flour stored in aluminium pouch (2.19%), polyethylene bag (2.97%) and aluminium box (3.84%) throughout the storage period. The similar observations were noted for mean moisture of little millet composite flour stored in aluminium pouch (3.64%), polyethylene bag (4.59%) and aluminium box (5.41%) throughout the storage.

4.3.1.2 Peroxide

The rancidity of the diabetic mixes stored in different packages was analyzed in terms of peroxide value periodically and is depicted graphically in Figure 4 and detailed data is given in Appendices 8 and 9. The initial peroxide content of foxtail and little millet grain mix was 1.77 and 1.90 meq/ kg of fat respectively. There was steady increase in peroxide content of foxtail millet grain mix stored in aluminium box (1.78 to 4.35 meq/ kg of fat) throughout the storage but the increase was significant ($P \leq 0.01$) after 30 days of storage. The mix stored in polyethylene bag and aluminium pouch exhibited reduction in peroxide content from 15 to 105 and 135 day of storage respectively, later increased significantly ($P \leq 0.05$) upto end of storage period (from 1.75 to 2.85 and 1.60 to 2.00 meq / kg of fat respectively).

On the contrary the little millet grain mix stored in aluminium box exhibited a steady decrease trend in peroxide content from 30 days of storage but started with significant increasing trend after 120 days of storage. While the mix stored in polyethylene bag and aluminum pouch also showed decreasing trend in peroxide content from the beginning upto 120th days of storage and later increased significantly ($P \leq 0.05$) upto 180 days of storage. The peroxide content was increased from initial value of 1.99 to 2.73, 1.62 and 1.58 meq / kg of fat in aluminium box, polyethylene bag and aluminium pouch respectively during storage period.

It was interesting to note that there was significant ($P \leq 0.01$) difference observed in mean peroxide of foxtail grain mix stored in aluminium pouch (1.72%), polyethylene bag (1.96%) and aluminium box (2.46%) throughout the storage. However the significant difference in mean peroxide of little millet grain mix was also found between sealed packages (polyethylene bag, 1.46% and aluminium pouch, 1.45%) and aluminium box (2.09%) during storage (Appendix 8).

The initial peroxide of both foxtail and little millet composite flours was 0.95 meq / kg of fat. The peroxide content of foxtail millet composite flour stored in

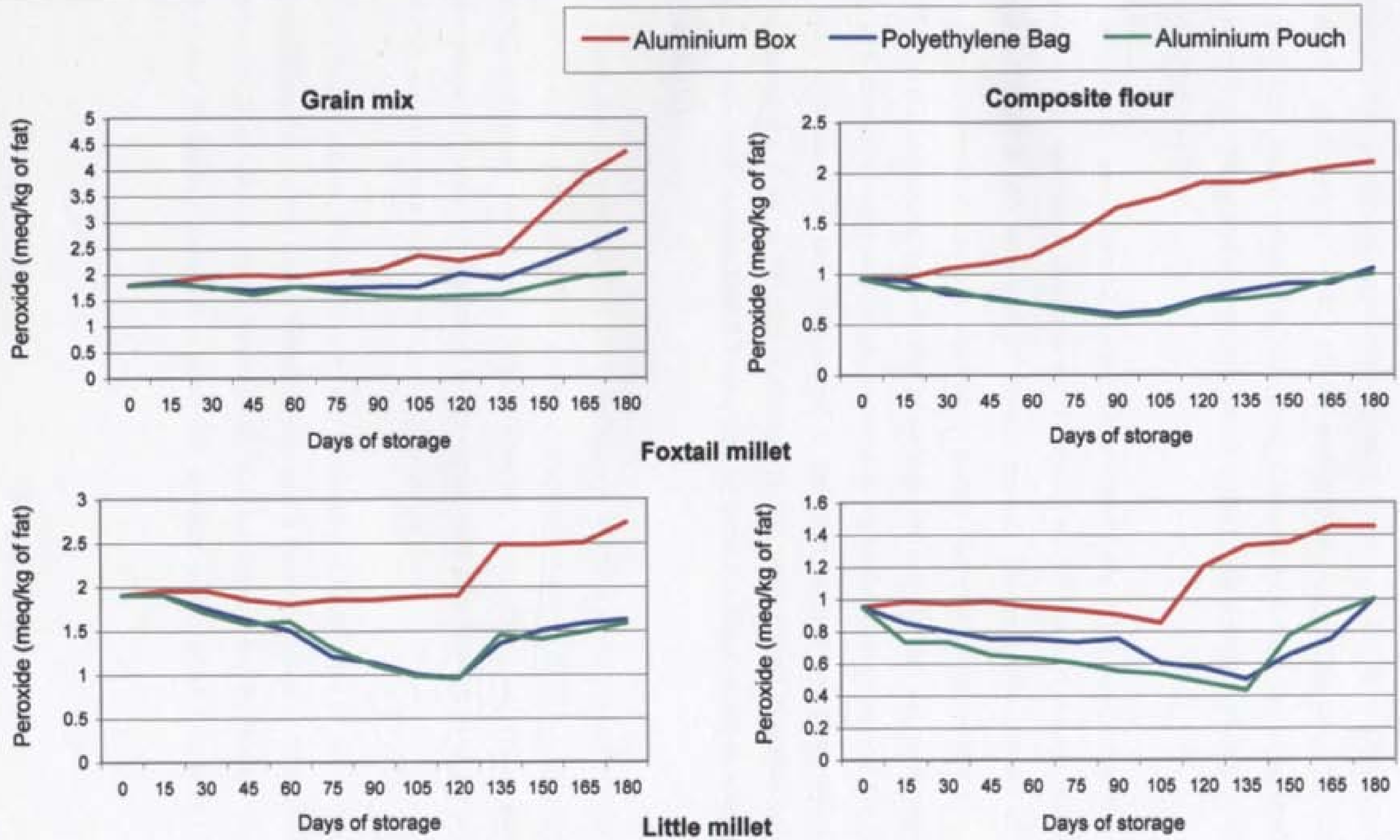


Fig. 4. Impact of storage on peroxide content (meq/kg of fat) of diabetic composite food/mix

aluminium box exhibited a significant increase ($P \leq 0.05$) after 15 days of storage throughout the storage. The peroxide content of flour stored in polyethylene bag and aluminium pouch showed significant decrease trend upto 105 days of storage and later increased significantly ($P \leq 0.05$) till the end storage period. The peroxide content was increased from initial value of 0.95 to 2.10, 1.05 and 1.00 meq / kg of fat in aluminium box, polyethylene bag and aluminium pouch respectively during storage period of foxtail millet composite flour.

It is clearly noted that the peroxide content of little millet composite flour stored in aluminium box exhibited decrease trend form 45 to 105 days of storage later increased significantly ($P \leq 0.01$) upto end of storage period. The peroxide content of the flour stored in polyethylene bag and aluminium pouch decreased significantly ($P \leq 0.05$) from the beginning upto 45 day of storage and later further decrease was observed upto 135 days of storage with slight increase at the end of storage period. On the whole, the least increase (0.05 meq / kg of fat) in peroxide content was observed in the little millet composite flour at the end of storage period when stored in sealed polyethylene bag and aluminium pouch and 0.5 meq / kg of fat in the flour stored in aluminium box (Appendix 9).

There was significant ($P \leq 0.01$) difference noted in mean peroxide value between the foxtail millet composite flour stored in aluminium pouch (0.78%), polyethylene bag (0.80%) and aluminium box (1.53%). However, a significant difference was noted in mean peroxide value of the little millet composite flour stored in aluminium pouch (0.69%), polyethylene bag (0.74%) and aluminium box (1.10%).

On the whole, irrespective of the packaging a significant ($P \leq 0.05$) increase in moisture has been observed in the grain mix and a decrease trend in moisture content of composite flour which found statistically not significant during storage period. The significant ($P \leq 0.01$) increase in peroxide content of the grain mix ($r = 0.280$) and composite flour (r = 0.260) has been observed during storage, irrespective of the packing materials.

It was observed that the mean moisture content increased in grain mix and composite flour of foxtail millet mix when stored in aluminium box and the difference found highly significant and positively correlated (r = 0.988 and 0.946 respectively) to period of storage (Table 16).In a similar manner the increase in moisture of the grain mix and composite flour of foxtail millet stored in sealed polyethylene bag indicated positive correlation to the period of storage. But the moisture content of foxtail millet composite flour showed negative correlation to the storage period when stored in sealed aluminium pouch. It was also observed that the mean moisture content increased in grain mix of little millet when stored in aluminium box found significant positively correlated (r = 0.946) to period of storage. While the composite flour mix showed negative correlation to the period of storage when stored in aluminium box. In a similar manner the increase in moisture of the grain mix and composite flour of little millet stored in sealed polyethylene bag and aluminium pouch indicated negative correlation to the period of storage.

It is interesting to note the inter relation between storage and chemical parameters (moisture and peroxide) of the grain mix and composite flour of the millets (Table 16). The foxtail millet mix exhibited highly significant and positive correlation between moisture and different packaging used during storage and similar trend has been observed between peroxide and storage period. The mean increase in moisture and peroxide of the foxtail grain mix was found statistically not significant, while increased peroxide content of the composite flour was significant ($P \leq 0.01$) irrespective of the packages used during storage. The opposite trend has been observed in little millet mix. The moisture content of the little millet mix (grain and composite flour) reduced significantly ($P \leq 0.05$) in all types of packages except aluminium box and the peroxide content of little millet grain mix correlated negatively to the storage and the composite flour positively to the storage period.

Table 16. 'r' value for the chemical parameters of diabetic composite mixes during storage

Types	Packaging material	Moisture	Peroxide
Duration of storage			
Grain Mix			
Foxtail Millet	Al.B.	0.988**	0.847**
	P.B.	0.923**	0.747**
	Al.P.	0.734**	0.236
	Mean	0.633	0.544
Little Millet	Al.B.	0.401*	0.750**
	P.B.	-0.405*	-0.416*
	Al.P.	-0.885**	-0.492*
	Mean	-0.300**	-0.028
Composite Flour			
Foxtail Millet	Al.B.	0.946**	0.969**
	P.B.	0.571**	0.162
	Al.P.	-0.715**	0.770
	Mean	0.208	0.339**
Little Millet	Al.B.	-0.117	0.763**
	P.B.	-0.517**	-0.289
	Al.P.	-0.840**	0.037
	Mean	-0.429**	0.175
Moisture			
Grain Mix			
Foxtail Millet	Al.B.	-	0.821**
	P.B.	-	0.723**
	Al.P.	-	0.343
	Mean		0.798**
Little Millet	Al.B.	-	0.771**
	P.B.	-	0.785**
	Al.P.	-	0.458*
	Mean		0.738**
Composite Flour			
Foxtail Millet	Al.B.	-	0.925**
	P.B.	-	0.772**
	Al.P.	-	0.530**
	Mean		0.829**
Little Millet	Al.B.	-	0.351
	P.B.	-	0.707**
	Al.P.	-	0.459*
	Mean		0.699**

Note: Al.B. - Aluminum Box
P.B. - Polyethylene bag
Al.P. - Aluminium Pouch
* - Significant @ 5 %
** - Significant @ 1 %

It is also noted that the diabetic mixes exhibited highly significant ($P \leq 0.01$) and positive relation between moisture and peroxide during storage, highlighting the fact that the increase in moisture also increased peroxide of the mix during storage irrespective of the packing used.

4.3.2 Sensory attributes of diabetic mixes

The rice and pancake were prepared respectively from grain mix and composite flour stored in three packages and was evaluated periodically for sensory parameters *viz.*, appearance, texture, aroma, taste and Over All Acceptability (OAA) by ten panel members. The results pertaining to this aspect is presented in the following sections.

4.3.2.1 Sensory evaluation of diabetic grain mix

The rice was prepared fortnightly from stored foxtail and little millet grain mixes and subjected to sensory evaluation by trained panel members. The mean sensory scores obtained for different sensory attributes for diabetic mixes are depicted in the Figures 5,6,7,8 and 9 and the data is given in Appendices 10,11,12 and 13.

It is evident from the figures that the scores for the sensory attributes tend to decrease with increase in storage period (180 days).The foxtail millet rice prepared from the mix stored in aluminium box obtained low scores (<2, below acceptable range) for aroma, taste and OAA, after 150 days of storage and later on indicated poor acceptability. While the sensory scores for aroma, taste and OAA of the rice prepared form the mix stored in polyethylene bag and aluminium pouch were low (<2) after 165 day of storage.

As increase in the days of storage, the decrease in sensory attributes *viz.*, appearance ($r = -0.258$), texture ($r = -0.293$), aroma ($r = -0.632$), taste ($r = -0.668$) and OAA ($r = -0.720$) were highly significant ($P \leq 0.01$) when the mix stored in aluminium box. Whereas the mix stored in polyethylene bag exhibited highly significant difference for aroma ($r = -0.530$), taste ($r = -0.681$) and OAA ($r = -0.449$) and appearance

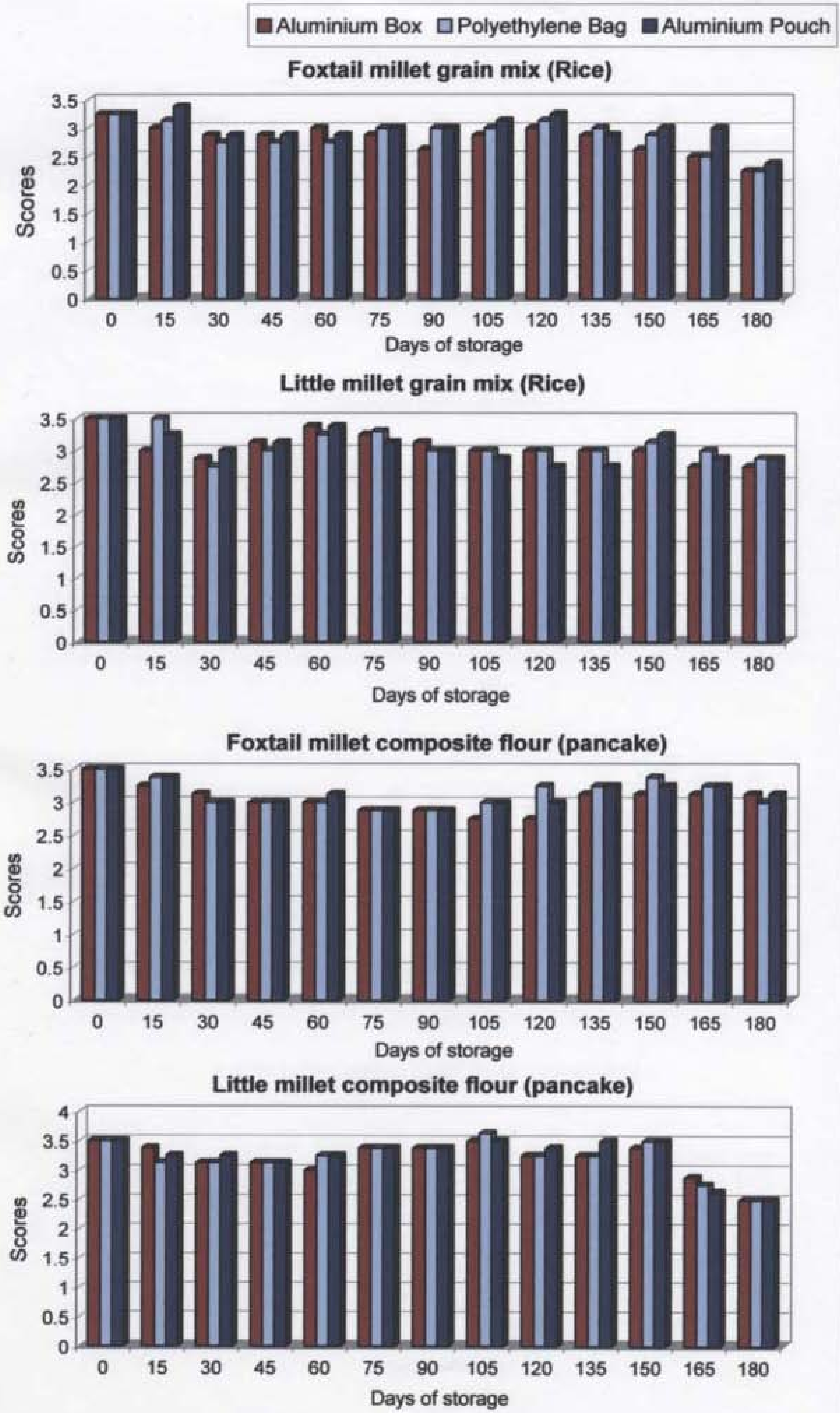


Fig. 5. Appearance scores of recipes for stored diabetic composite mixes

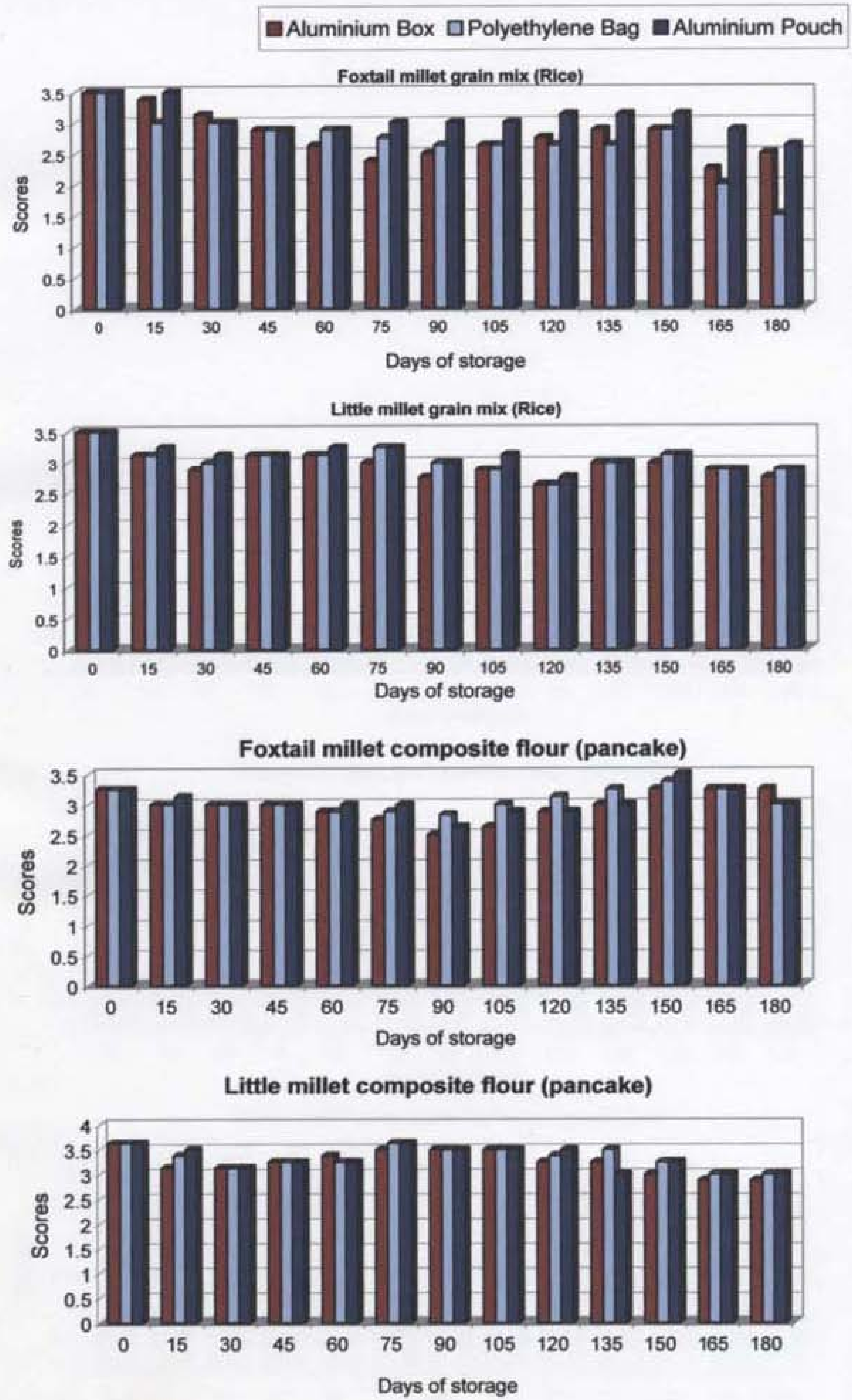


Fig. 6. Texture scores of recipes for stored diabetic composite mixes

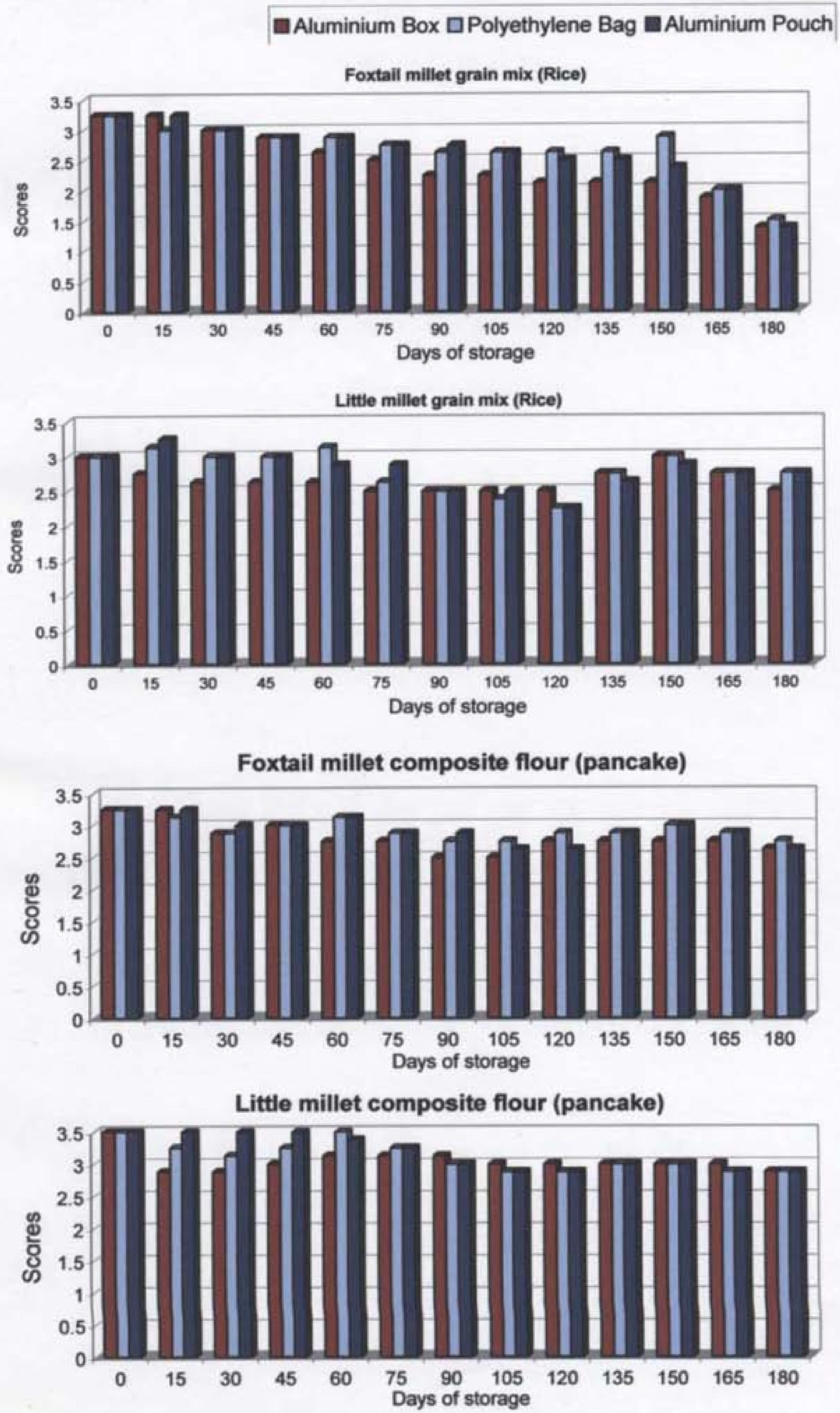


Fig. 7. Aroma scores of recipes for stored diabetic composite mixes

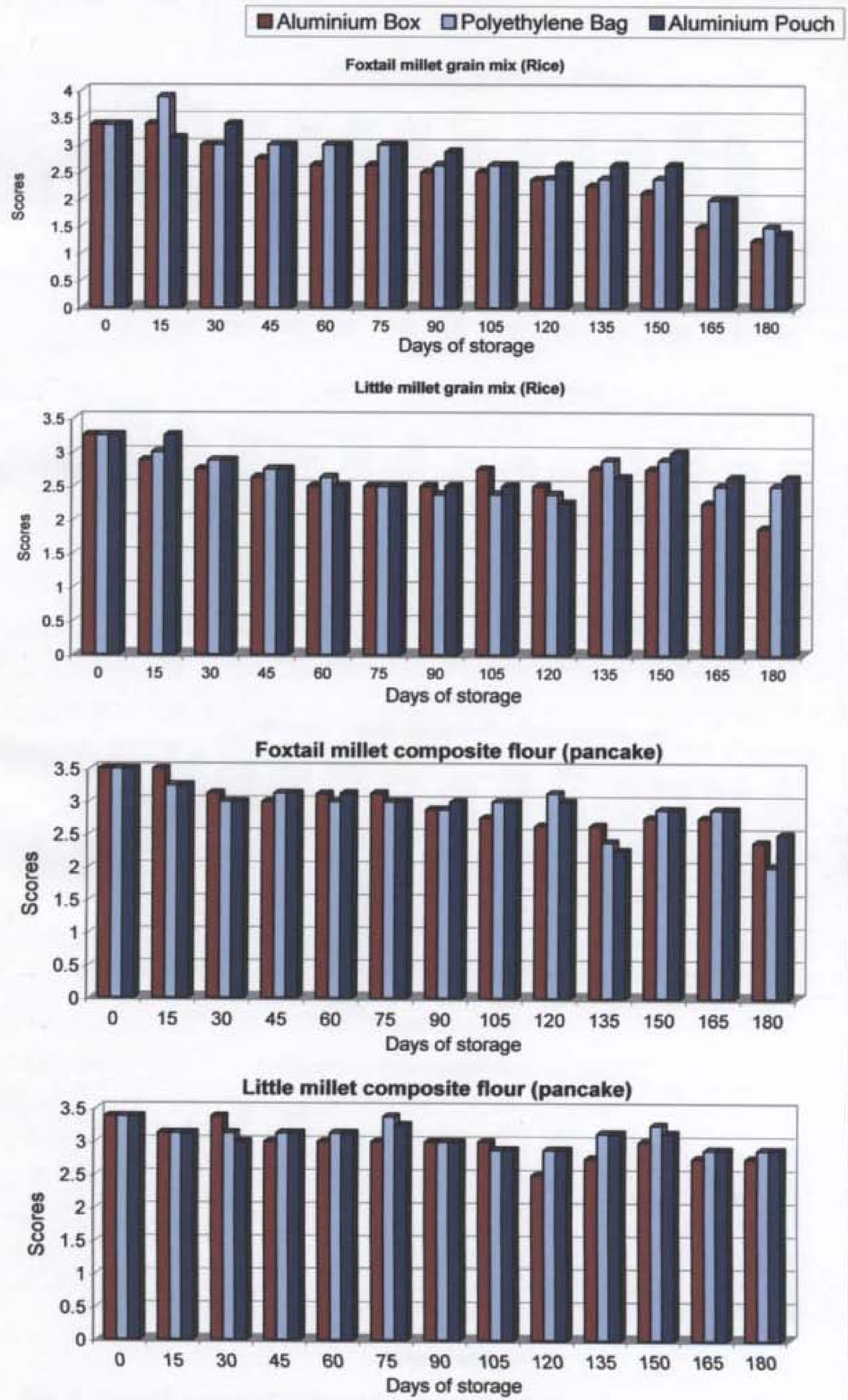


Fig. 8. Taste scores of recipes for stored diabetic composite mixes

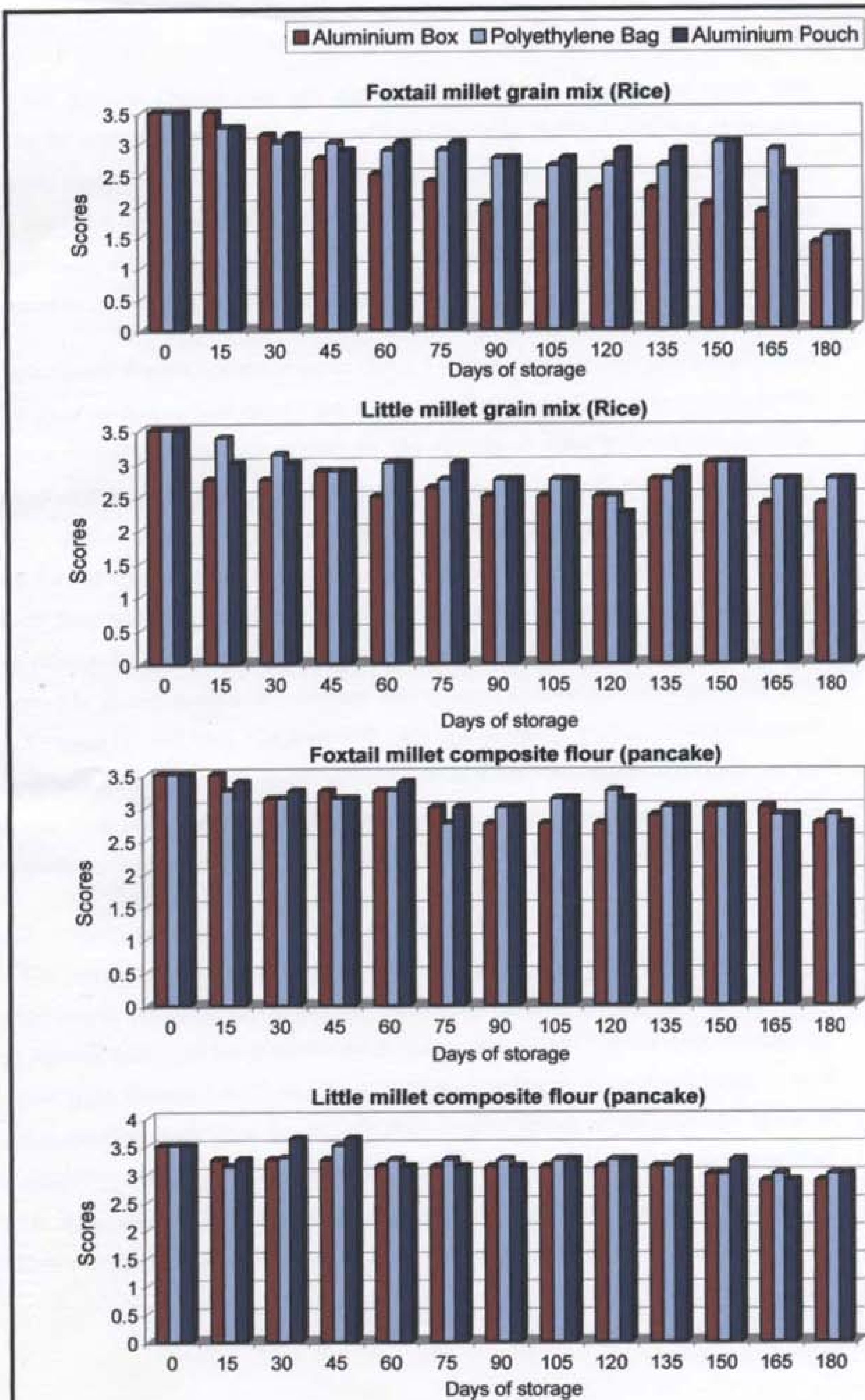


Fig. 9. Overall acceptability (OAA) scores of recipes for stored diabetic composite mixes

(r= -0.194) but textural change was not significant statistically. The similar trend was observed for sensory scores of the rice prepared from mix sealed in aluminium pouch, expressing highly significant ($P \leq 0.01$) difference for aroma (r = -0.637), taste (r = -0.564) and OAA (r = -0.480) and difference for appearance and textural attributes were not significant statistically, during storage. In general the OAA scores seems to be influenced by aroma and taste of the product.

It is clearly depicted in the Figures (5,6,7,8 and 9) that, the little grain mix stored well in three packages throughout the storage and obtained more scores (>2, above acceptable range) upto 6 months of storage. The decrease in sensory scores with increase in days of storage were found to be highly significant ($P \leq 0.01$) for aroma (r = -0.256), taste (r = -0.428) and OAA (r =- 0.356) without noticeable changes in appearance and texture for the mix stored in aluminium box. The similar trend was observed for rice prepared form millet stored in polyethylene bag except for aroma, which decreased during storage but the difference was not significant statistically. In a similar way the mix stored in aluminium pouch exhibited lower scores and were found significant ($P \leq 0.01$) for taste (r = -0.394), OAA (r = -0.321) and aroma (r = -0.256) without much changes for appearance and texture. In other words, the sensory results focussed that the grain mix stored in polyethylene bag and aluminium pouch maintained better quality throughout the six months storage period than the mix stored in aluminium box.

4.3.2.2 Sensory evaluation of diabetic composite flour

The pancake was prepared from foxtail and little millet composite flour stored in three packages and subjected to sensory evaluation by panel at periodic interval. The mean sensory scores of the pancake for different sensory attributes during storage are depicted in the Figures 5,6,7,8 and 9 and the data is given in Appendices 10,11,12 and 13. It is clearly noted from the figures that sensory scores of the pancake reduced considerably towards end of the storage period in both the mixes. The increase in days of storage with decrease in sensory scores was negatively correlated ($P \leq 0.05$) for appearance (r = -0.210), texture (r = -0.202), taste (r = -0.337) and OAA (r = -0.264)

(P <0.01) in the foxtail millet composite flour stored in aluminium box. The sensory scores were decreased significantly (P ≤ 0.01) for all attributes except appearance of pancake prepared the flour stored in polyethylene bag. Whereas all sensory attributes were significant (P ≤ 0.05) and exhibited negative correlation as increase in the days of storage for pancake prepared from composite flour stored in aluminium pouch.

A similar trend has been observed for little millet composite flour stored in three packages during storage. The sensory scores were decreased significantly (P ≤ 0.05), for all attributes and correlated negatively (r value for appearance,-0.195, texture,-0.223, aroma,-0.105, taste,-0.284 and OAA,-0.259) to the days of storage when the flour stored in aluminium box. The pancakes prepared from composite flour stored in polyethylene bag showed decrease scores for aroma, taste and OAA and not noticeable changes for appearance and texture but correlated negatively during storage period. Whereas the scores for the pancakes prepared from the flour stored in aluminium pouch were significant (P ≤ 0.01) and low for appearance, aroma and OAA and the scores for texture and taste were not significant statistically during storage.

On the whole the reduced trend of scores for all sensory attributes were observed for foxtail millet mix as compared to little mix during storage. The sensory scores were reduced more in composite flour than grain mix in three packages throughout the storage.

All the sensory attributes of foxtail millet composite grain mix were significantly low (P≤0.01) for aluminium box as compared to polyethylene bag and aluminium pouch and were negatively correlated to the respective moisture content (Table 17). The little millet composite mix exhibited positive correlation to the respective moisture content with slight changes for texture during storage. Whereas the moisture of the composite flour (foxtail and little millet) affected sensory attributes when stored in aluminium box as compared to polyethylene bag and aluminium pouch. In a similar manner, with increase in peroxide value of foxtail millet grain mix, the sensory scores were decreased

Table 17. 'r' value of chemical parameters of diabetic composite mixes for sensory attributes during storage

Types	Packaging material	Moisture Content				
		Appearance	Texture	Aroma	Taste	OAA
Grain Mix						
Foxtail Millet	Al.B.	-0.734**	-0.649*	-0.948**	-0.926**	-0.901**
	P.B.	-0.366	-0.325	-0.761*	-0.906**	-0.641*
	Al.P.	-0.164	-0.048	-0.675*	-0.673*	-0.430
Little Millet	Al.B.	0.599*	0.855**	0.190	-0.250	0.061
	P.B.	0.187	-0.031	0.428	0.224	0.236
	Al.P.	0.167	-0.120	0.543	0.807**	0.773**
Composite Flour						
Foxtail Millet	Al.B.	-0.679*	-0.517	0.023	-0.611*	-0.387
	P.B.	-0.039	-0.126	0.011	0.161	0.009
	Al.P.	0.667*	0.687**	0.669*	0.803**	0.724**
Little Millet	Al.B.	-0.489	-0.525	-0.021	0.335	-0.011
	P.B.	-0.366	-0.309	0.604*	0.400	0.230
	Al.P.	0.010	0.253	0.906**	0.597*	0.563*
		Peroxide value				
Grain Mix						
Foxtail Millet	Al.B.	-0.875**	-0.523	-0.830**	-0.919**	-0.749**
	P.B.	-0.720**	-0.637**	-0.861**	-0.858**	-0.673*
	Al.P.	-0.392	-0.196	-0.492	-0.517	-0.444
Little Millet	Al.B.	0.305	0.650*	-0.219	-0.636*	-0.337
	P.B.	0.440	0.220	0.644*	0.150	0.318
	Al.P.	0.681	0.507	0.786**	0.270	0.457
Composite Flour						
Foxtail Millet	Al.B.	-0.611*	-0.678*	-0.167	-0.611*	-0.518
	P.B.	0.203	0.128	0.465	0.537	0.414
	Al.P.	0.137	0.001	0.432	0.553*	0.292
Little Millet	Al.B.	-0.606*	-0.804**	-0.353	-0.614*	-0.704**
	P.B.	-0.464	-0.279	0.382	0.161	0.101
	Al.P.	-0.623*	-0.236	0.152	0.083	-0.115

Note: Al.B. - Aluminum Box   Al.P. - Aluminium Pouch   * - Significant @ 5 %
P.B. - Polyethylene bag   OAA - Over All Acceptability   ** - Significant @ 1 %

significantly ($P \leq 0.01$) and considerably compared to little millet mix stored in three packages. In case of composite flour, increase in peroxide content of flour negatively correlated and influenced sensory attributes of both the mixes (foxtail and little millet) stored in aluminium box compared to polyethylene bag and aluminimium pouch. It is clearly evident that all sensory attributes negatively correlated with moisture of diabetic composite grain mixes during storage in all packages. The appearance and texture of the composite flour negatively correlated and other three sensory attributes positively correlated to moisture when stored in aluminium box and polyethylene bag. The sensory attributes of the composite flour stored in aluminium pouch was significant ($P \leq 0.05$) with positive correlation to the moisture during storage . Thus increase in moisture mainly affected texture, aroma and taste of the products during storage.

In a similar manner all the sensory attributes negatively and positively correlated with peroxide content of foxtail and little millet grain mix respectively, during storage. Whereas all sensory attributes of composite flour significantly ($P \leq 0.05$) and negatively correlated with peroxide when stored in aluminium box. However the composite flour stored in polyethylene bag and aluminium pouch exhibited positive correlation with peroxide during storage. Thus increase in peroxide content of the composite mix mainly influenced appearance , texture, taste and aroma of the products during storage.

4.4 Clinical studies

The results of the clinical trial of diabetic composite mix in terms of glycemic and lipemic response in non-diabetic and type 2 diabetic subjects is presented in this section. The information pertaining to the profile of the 27subjects is documented in the first part of section, followed by glycemic response of diabetic mixes //foods and effect of feeding diabetic mixes for four weeks on glyco-lipemic parameters of the volunteers.

4.4.1 General profile of volunteers

For clinical studies, 15 type 2 diabetics and 12 non-diabetics were considered and general information collected has been tabulated in Table 18.

Table 18. Profile of the volunteers of the study

Characterstics	Diabetics (N=15)		Non-diabetics (N= 12)	
	Experimental (n = 9)	Control (n = 6)	Experimental (n = 6)	Control (n = 6)
Gender				
Male	4	2	3	4
Female	5	4	3	2
Body Mass Index (BMI)				
<18.5 (under weight)	-	-	-	-
18.5 - 25 (normal)	1	-	5	3
>25 (obese)	8	6	1	3
Duration of disease				
< 5 yrs	7	1	-	-
> 5yrs	2	5	-	-
Hypoglycemic drugs				
taken regularly	5	6	-	-
not taken regularly	4	-	-	-
Other complications				
Hypertension	4	5	-	-
Arithitis	2	1	-	-
No complications	3	-	6	6
Exercise				
Regular	3	3	-	-
Not regular	6	3	-	-
Hypoglycemic foods used				
Regular	2	-	-	-
Occasionally	3	6	-	-
Not at all	4	-	-	-
Type of diet				
Vegetarian	4	4	1	3
Eggetarian	3	-	5	2
Non vegetarian	2	2	-	1
Consumption of millets				
Regular	-	-	-	-
Very rarely	6	2	6	2
Not at all	3	4	-	4

Out of 15 type 2 diabetics (6 males and 9 females) and 12 non-diabetics (7 males and 5 females), nine diabetics and six non-diabetics volunteered for feeding study of diabetic composite mixes, hence the remaining were treated as control (6 each). It was clearly noticed (Table 18) that 14 diabetics were obese (>25 BMI) while only one had normal BMI (18.5-25) and among the non-diabetic volunteers eight belonged to normal BMI category and four were obese. The duration of diabetic disorder indicated that the eight subjects were diabetic since five years while seven were suffering from it for more than five years. Among the diabetic group, eleven were consuming hypoglycemic drugs regularly and remaining (4) were not so regular. The nine diabetics expressed that they are suffering from hypertension while three of them with arthritis and remaining three were without complications. Only six of diabetic subjects performed exercise regularly while remaining (9) not included exercise pattern in their management strategy. The two volunteers of type 2 diabetics continued the consumption of 20g fenugreek seeds regularly while nine of them consumed occasionally and four had not included any hypoglycemic foods in their diet. Eight diabetics were vegetarians, while three were eggetarians (atleast 1 egg/week) and four consumed non-vegetarian diet occasionally. In non-diabetic group, most of them vegetarians and eggetarians except one consumed non-vegetarian foods once a week. About eight diabetics and non diabetics consumed millets rarely (2-3 times in a year) during festive or fasting periods and none of them included millets regularly in daily diet.

4.4.2 Glycemic index of diabetic composite mixes

The Glycemic Index (GI) of two millet based diabetic composite mixes were estimated in the present study, on six non-diabetic (3 males and 3 females) volunteers. The blood glucose curves for the reference meal (50g glucose) as compared to that for test meals (65g millets / diabetic mixes) in six healthy individuals are shown in the Figure 10 and the data enclosed in Appendix 14.

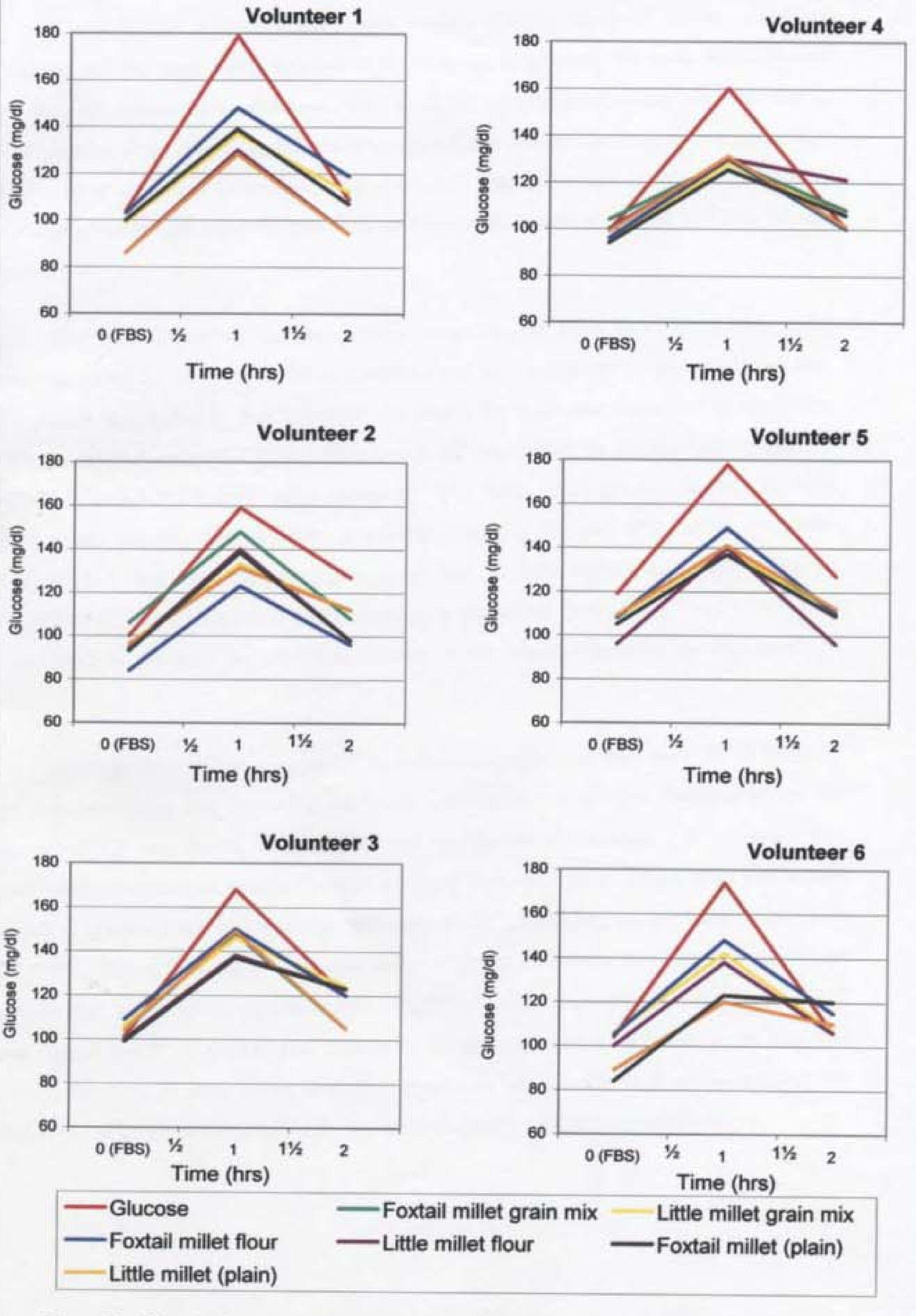


Fig. 10. Blood glucose response to test foods as compared to glucose in non-diabetic volunteers

A steady rise in blood glucose was evident after ingestion of reference and six test meals and the peak being reached at 60 minutes. In general, the peak values for all test meals were lower than reference meal in all the non-diabetic volunteers. The rise in blood glucose after one hour of consumption of the millets and respective composite mixes were much lower to glucose. The estimated glycemic index values for millets and the diabetic composite mixes in non diabetic subjects has been presented in Table 19 and Figure 11.

The mean GI values for the diabetic mixes ranged from 54.39 for foxtail millet grain mix to 64.51 for little millet composite flour with reference to glucose being 100. At a glance, it is apparent that lower GI was found for grain mix compared to respective millet grains and composite flours. The lowest GI was noted for foxtail millet grain mix (54.39) followed by foxtail millet grains (57.91), little millet grain mix (58.75), little millet grains (61.98), foxtail millet composite flour (63.07) and little millet composite flour (64.51). The diabetic composite grain mix of both millets exhibited lower GI (54.39 and 58.75) as compared to the respective composite flours (63.07 and 64.51) thus it increased by 10 to16 per cent with change in the physical form of the mix (grain to flour).

It is clearly noted that mean GI of individual subjects ranged from 58.13 to 61.53 per cent exhibiting less individual variations among the volunteers. Irrespective of the mix mean GI was found to be 60.04 and coefficient of variance 7.8 per cent. The coefficient of variations among the mixes ranged from 6.27 to 11.26 per cent and lowest variation observed for foxtail millet grain mix (6.27%) and highest for little millet grain (11.26%). The difference in glycemic index of grain and grain mix was not significant statistically, where as the glycemic index of foxtail millet grain mix and composite flour was significant ($P \leq 0.01$). The difference in glycemic index of grain, grain mix and composite flour of little millet were not significant statistically. In a similar manner the difference in glycemic index of both the millets was not significant statistically.

Table 19. Glycemic index of diabetic composite mixes in non diabetics

Volunteers	Foxtail millet			Little millet			Mean
	Grain Rice	Grain Mix Rice	Composite flour *Pancake*	Grain Rice	Grain Mix Rice	Composite flour *Pancake*	
1	58.57	49.39	60.34	62.85	57.14	69.44	59.62
2	51.81	55.71	62.85	67.46	54.21	65.14	59.53
3	64.51	51.21	67.46	66.66	59.67	59.67	61.53
4	53.66	58.06	66.66	68.29	53.65	68.25	61.43
5	58.57	57.14	56.62	54.28	64.35	57.83	58.13
6	60.32	54.85	64.51	52.38	63.49	64.51	60.01
Mean±Sd	57.91±4.59	54.39±3.41	63.07±4.08	61.98±6.98	58.75±4.56	64.51±4.60	60.04±1.28
CV (%)	7.93	6.27	6.47	11.26	7.76	7.13	7.80
t' value	0.28	0.005**	0.07	0.51	0.18	0.47	—
't' value(between mixes)	0.34	0.12	0.65	—	—	—	—

Note: ** - Significant @ 1 %
CV - Coefficient of variation

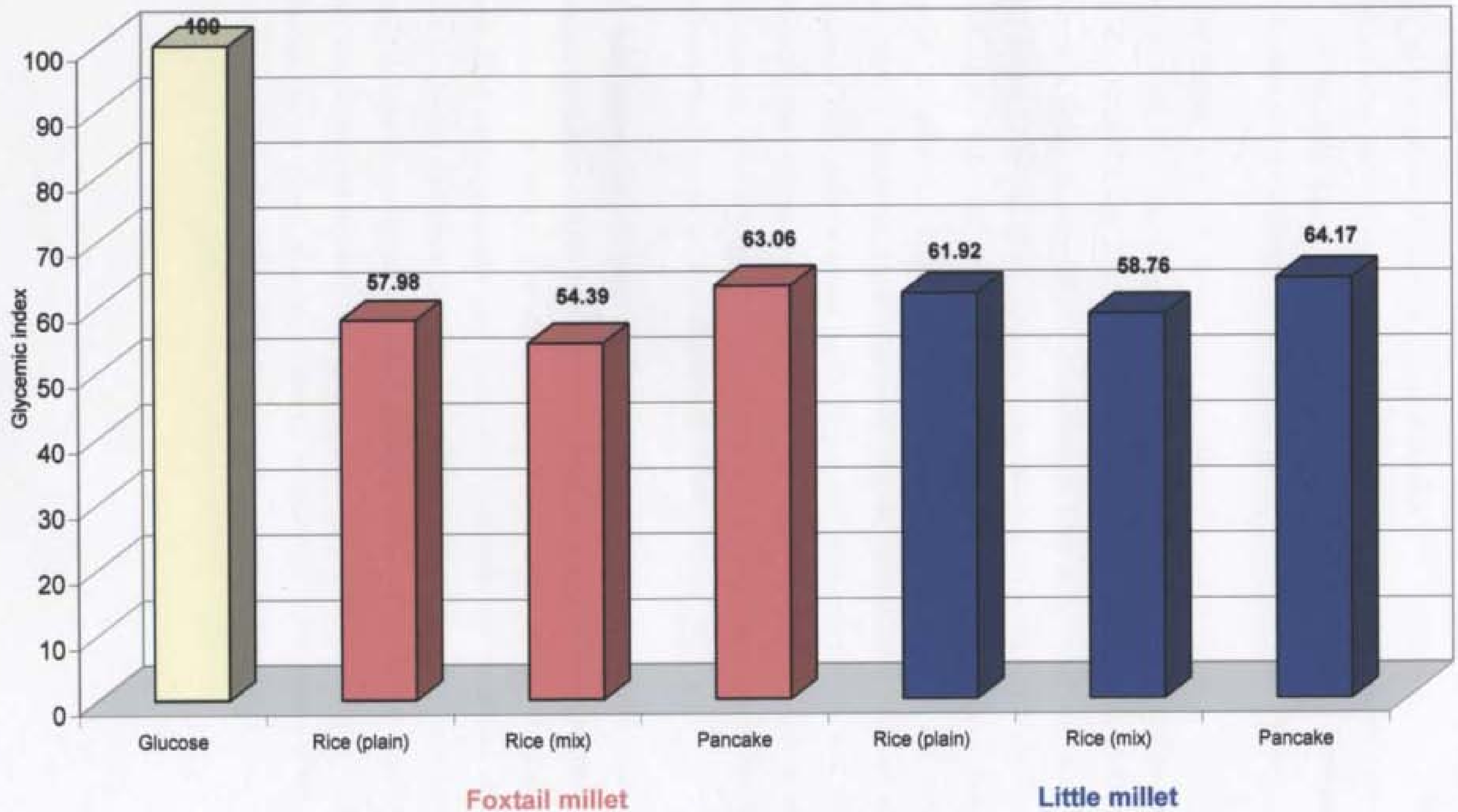


Fig. 11. Mean glycemic index of diabetic composite food/mix in non-diabetics

4.4.3 Glycemic response of diabetic mix in diabetics

The glucose response of capillary blood to the consumption of diabetic composite mixes in diabetic subjects (3 females and 1 male) were estimated and compared to glucose response of the customary breakfast (*upma*, *idli*, rice and *masala roti*).

The fasting and two hours post prandial blood glucose were analyzed and presented in Table 20. The fasting capillary whole blood glucose of diabetic subjects ranged from 109 to 152 mg/ dl and two hours post prandial between 155 to 219 mg/dl. The increase in blood glucose after consumption of both grain mixes was found to be lower (32.38 and 37.84 %) than respective composite flours (42.82 and 45.33 %). It was apparent from the Table 20, that per cent increase in blood glucose was a lower after consumption of diabetic composite mixes (18.32 to 64.57%) than the customary breakfast (52.94 to 89.91%). Hence the lower glucose response was obtained after the consumption of both diabetic mixes by 23.91 per cent (composite flour) and 33.05 per cent (grain mix) than cereals (wheat and *rice*) based breakfast, (68.061%). In general, the glycemic response was reduced by 28.5 per cent in diabetics after consumption of millet based diabetic mixes compared to customary breakfast.

It was interesting to note that the increase in fasting blood glucose after consumption of diabetic mixes was very low (9.34%) in non-diabetics as compared to diabetic subjects (39.59%). The difference in the increase of blood glucose after consumption of both grain mix and composite flour was not significant statistically compared to glucose (reference meal) in non-diabetics. The difference in the increase of blood glucose after consumption of foxtail and little millet grain mix was significant at 1 and 5 per cent compared to customary food in diabetic subjects respectively. In a similar way, the increase in blood glucose difference in diabetics after consumption of both diabetic mixes was significant ($P < 0.05$) compared to customary food.

Table 20. Glucose response # of diabetic composite food in diabetics

Type	Volunteers	Blood Glucose mg (%)			
		Fasting	2hr Post Prandial	% Increase	t' value
Grain Mix					
Foxtail Millet	1	136	169	24.26	
	2	134	200	49.25	
	3	131	155	18.32	
	4	138	190	37.68	
	Mean	134.75	178.50	32.38	
	Sd	2.99	20.31	13.86	0.0008**
Little Millet	1	142	200	40.80	
	2	150	204	36.00	
	3	131	201	53.44	
	4	142	170	21.13	
	Mean	141.25	193.75	37.84	
	Sd	7.80	15.92	13.35	0.03*
Composite Flour					
Foxtail Millet	1	135	190	40.74	
	2	152	219	44.08	
	3	127	209	64.57	
	4	128	156	21.87	
	Mean	135.50	193.50	42.82	
	Sd	11.56	27.74	17.49	0.08NS
Little Millet	1	146	206	41.09	
	2	150	197	31.33	
	3	129	205	58.91	
	4	130	195	50.00	
	Mean	138.75	200.75	45.3325	
	Sd	10.81	5.56	11.84	0.07NS
Customary Food (Wheat *upma* / Rice *roti)*	1	136	208	52.94	
	2	132	219	73.48	
	3	109	207	89.91	
	4	127	198	55.91	
	Mean	126.00	208.00	68.06	
	Sd	11.92	8.60	17.16	0.03*

Note: # - Capillary blood glucose values

* - Significant @ 5 %

** - Significant @ 1 %

4.4.4 Interrelation between nutrients and glycemic index of diabetic composite mixes

It is evident from the Table 21 that the glycemic index of grain mix (foxtail and little millet) was negatively and significantly correlated to the fat while positively but not significantly correlated to the protein. The GI of foxtail millet grain mix negatively correlated to the total dietary fibre content but was not significant statistically. Whereas the glycemic index of the foxtail millet composite flour negatively correlated to the fat and protein while the GI of little millet composite flour positively correlated to the fat and protein. The little millet composite flour exhibited negative correlation between the dietary fibre content and glycemic index. On the whole, the relation between glycemic index and fat ($r= -0.587$) and total dietary fibre ($r= -0.755$) were negatively but significantly ($P \leq 0.05$) correlated except protein ($r=0.563$) content of the foxtail millet composite food. The glycemic index of the little millet composite food indicated negative correlation only to the fat content and positive correlation to protein and total dietary fibre, though none of them were found significant statistically.

4.4.5 Feeding Trial of Diabetic Composite Foods

The millet based diabetic composite foods (grain mix and composite flour) were given to nine confirmed type 2 diabetic and six non-diabetic volunteers for the period of four weeks each. All the subjects were asked to consume the composite food / mix (80g) with regular diet, either in breakfast, lunch and /or dinner convenient to their work schedule, Most of them consumed the composite food as pancake, *upma* and *thalipatti* in breakfast or rice in lunch or dinner session. There was a 'wash out' period of four weeks between the consumption of foxtail and little millet composite mix. The blood analysis for glucose, total cholesterol, triglycerides and HDL- cholesterols of all the subject (27) were noted before and after each feeding study.

Table 21. 'r' value between nutritional composition and glycemic index of diabetic composite food

Foods	r' value		
	Fat	Protein	Total Dietary Fibre
Foxtail Millet			
Grain Mix	-0.675*	0.641	-0.571
Composite Flour	-0.351	-0.039	0.084
Combined	-0.587*	0.563	-0.755**
Little Millet			
Grain Mix	-0.917**	0.037	0.316
Composite Flour	0.608	0.295	-0.307
Combined	-0.497	0.257	0.096
Grain Mix	0.206	0.496	0.453
Composite Flour	-0.183	-0.114	-0.202

Note: * - Significant @ 5%
** - Significant @ 1%

4.4.5.1 Capillary blood glucose analysis

The fasting blood glucose (capillary) of the subjects involved in the clinical trial, before and after feeding of foxtail and little millet composite mix are presented in Table 22 and 23.

It is clearly noted from the Table 22 that in the experimental group (diabetic and non diabetic), there was a marked decrease in fasting blood glucose level to15.93 and 4.23 per cent respectively compared to control group where, there was a marked increase of 5.66 and 0.84 per cent respectively, after consumption of foxtail millet composite food. The diabetic group exhibited 11 per cent higher decrease in glucose levels than non-diabetic experimental group. While 22 and five per cent difference was noticed in glucose values between experimental and control group of diabetic and non-diabetics, respectively after completion of feeding study of four weeks with foxtail millet mix. There was an increase in fasting blood glucose level upto5.66 and 0.84 per cent in both control groups (6 each) after the period of four weeks.

A similar trend was noticeable after consumption of little millet composite food in diabetic and non-diabetic volunteers. It is clearly noted from the Table 23 that the decrease in the fasting blood glucose of diabetics (9.25%) was four per cent higher than the non-diabetic (5.73%) volunteers after four weeks study period. The increase trend in glucose level was noted in both control groups (0.63 and 6.31% in non diabetic and diabetic respectively) after four weeks period. The experimental diabetic and non diabetic group exhibited 15 and six per cent decrease in glucose levels to their counter part control group respectively. Between the mixes, the consumption of foxtail millet composite mix reduced fasting blood glucose (final) levels higher (6.7%) than little millet composite mix in diabetics while in non-diabetics, little millet composite mix exhibited higher decrease in blood glucose (final) levels by 1.5 per cent compared to the group which taken foxtail millet composite mix.

Table. 22 Effect of feeding foxtail millet composite foods on fasting blood glucose (4 weeks)

Volunteers	Diabetics (N=15) Blood glucose (mg/ dl)			Non-diabetics (N=12) Blood glucose (mg/ dl)		
	Initial	Final	Difference (%)	Initial	Final	Difference (%)
A) Experimental						
1	123	103	-16.36	98	96	-2.04
2	109	106	-2.75	96	95	-1.04
3	127	98	-22.83	100	95	-5.00
4	127	119	-6.30	97	89	-8.23
5	143	102	-28.67	100	97	-3.00
6	95	86	-9.47	99	93	-6.06
7	132	99	-25.00	-	-	-
8	149	129	-13.42	-	-	-
9	118	96	-18.64	-	-	-
Mean	124.78	104.22	-15.93	98.33	94.17	-4.23
Sd±	±16.45	±12.78	±8.76	±1.63	±2.86	±2.69
B) Control						
1	127	134	+5.51	89	91	+2.25
2	132	139	+5.30	92	92	0.00
3	135	145	+7.41	87	85	-2.30
4	116	126	+8.62	69	71	+2.10
5	126	132	+4.76	92	98	-1.01
6	126	129	+2.38	82	96	+3.23
Mean	127	134.17	+5.66	88.17	88.83	+0.84
Sd±	±6.51	±6.91	±2.17	±10.25	±9.83	±2.28

Note: Capillary blood glucose values

Table.23 Effect of feeding little millet composite food on fasting blood glucose (4 weeks)

Volunteers	Diabetics (N=15) Blood glucose (mg/ dl)			Non-diabetics (N=12) Blood glucose (mg/ dl)		
	Initial	Final	Difference (%)	Initial	Final	Difference (%)
A) Experimental						
1	105	103	-1.90	104	99	-4.81
2	123	119	-3.25	108	104	-3.7
3	110	104	-5.45	101	97	-3.96
4	135	117	-13.33	85	77	-9.41
5	129	102	-20.93	87	83	-4.6
6	96	84	-12.50	101	93	-7.92
7	129	105	-18.60	-	-	-
8	142	139	-2.11	-	-	-
9	115	109	-5.22	-	-	-
Mean	120.44	109.11	-9.25	97.67	92.17	-5.73
Sd±	±15.02	±15.06	±7.26	±9.42	±10.24	±2.35
B) Control						
1	120	132	+10.00	90	91	+1.11
2	137	141	+2.92	94	93	-1.06
3	133	145	+9.02	84	85	+1.19
4	115	127	+10.44	99	98	-1.01
5	126	129	+2.38	93	95	+2.15
6	128	132	+3.13	72	73	+1.39
Mean	126.5	134.33	+6.31	88.67	89.17	+0.63
Sd±	±8.12	±7.09	±3.87	±9.54	±9.04	±1.34

Note: Capillary blood glucose values

It was noted that the difference in fasting blood glucose was found significant ($P \leq 0.01$) in experimental (diabetic and non-diabetic) and diabetic (experimental and control) groups after consumption of foxtail millet composite food. But after consumption of the little millet composite mix, a significant ($P < 0.05$) difference in fasting blood glucose was found only in diabetic and non-diabetic group and not in experimental group (Appendix 15). It was interesting to note that between the composite mixes during feeding trial the difference in capillary blood glucose level was not significant statistically in experimental, control and non-diabetic groups except a significant ($P \leq 0.05$) difference was observed in diabetic (experimental and control) volunteers.

4.4.5.2 Plasma analysis of glucose and lipids parameters

The fasting blood glucose, triglycerides, total cholesterol and HDL- cholesterol before and after feeding study of foxtail and little millet composite food, were analyzed and tabulated in Table 24 and 25.

It is evident from Table 24 that the noticeable reduction in plasma glucose (19 %) and triglcerides (2-5%) and increase in HDL – cholesterol (6%) were observed in experimental diabetic group. While total cholesterol level reduced upto 4 per cent among diabetics compared to control diabetics (3% increase) after consumption of foxtail millet composite mix. The plasma glucose increased by three per cent and HDL-cholesterol decreased by three per cent among control group.

It is clearly noted from Table 25 that marked reduction in plasma glucose (17 %) and triglcerides (6%) and increase in HDL – cholesterol (6%) were observed in experimental non diabetic group. While total cholesterol level increased upto six per cent among non diabetic both groups (experimental and control) after consumption of foxtail millet composite mix. There was no apparent change observed in plasma glucose but slight reduction in HDL-cholesterol (2%) levels of control non diabetic group after four weeks period.

Table 24. Effect of feeding foxtail millet composite food (4 weeks) on plasma glucose and lipid profile of diabetics

	Fasting glucose (mg %)			Triglycerides (mg %)			Total Cholesterol (mg %)			HDL Cholesterol (mg %)		
Volunteers	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change
A. Experimental												
1	96	94	-2.08	250	242	-3.20	265	268	+1.13	37	46	+24.32
2	114	90	-21.05	157	101	-35.67	197	218	+10.66	38	43	+13.16
3	120	100	-11.67	139	121	-12.95	200	192	-4.00	46	44	-4.35
4	129	114	-11.63	96	82	-14.58	170	185	+8.82	37	41	+10.81
5	115	87	-24.35	106	142	+33.96	146	176	+20.55	29	32	+10.34
6	137	116	-15.30	137	165	+20.44	223	172	-22.87	48	43	-10.41
7	146	100	-31.51	143	149	+4.20	293	229	-21.84	44	40	-9.09
8	99	67	-32.32	110	103	-6.36	182	179	-1.65	36	36	+0.00
9	100	82	-18.00	100	96	-4.00	240	185	-22.92	38	43	+13.16
Mean ± Sd	117.33±17.54	95.11±15.78	-18.66	137.56±47.36	133.44±49.08	-2.02	212.89±46.97	200.44±31.82	-3.57	39.22±5.85	40.89±4.37	+5.33
B. Control												
1	96	106	+10.42	215	219	+1.86	247	257	+4.05	32	32	+0.00
2	106	116	+9.43	206	210	+1.94	245	269	+9.80	35	33	-5.71
3	145	139	-4.14	144	113	-21.53	249	266	+6.83	33	27	-18.18
4	119	123	3.36	162	160	-1.25	195	200	+2.56	39	40	+2.56
5	127	122	-3.94	172	168	-2.27	175	170	-2.86	37	38	+2.70
6	126	132	+4.76	242	252	+4.13	217	205	-5.53	42	42	+0.00
Mean ± Sd	119.83±17.22	123.00±11.63	+3.32	190.17±36.90	187.00±49.69	-2.85	221.33±31.12	227.83±41.58	2.47	36.33±3.78	35.33±5.65	-3.10

Table 25. Effect of feeding foxtail millet composite food (4 weeks) on plasma glucose and lipid profile of non-diabetics

Volunteers	Fasting glucose (mg %)			Triglycerides (mg %)			Total Cholesterol (mg %)			HDL Cholesterol (mg %)		
	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change
A. Experimental												
1	89	69	-22.47	72	67	-6.94	230	147	-36.09	51	49	-3.92
2	110	90	-18.18	130	122	-6.15	208	207	-0.48	30	39	+30.00
3	91	80	+2.09	107	70	-34.58	106	156	+47.17	38	48	+0.00
4	93	80	13.97	164	152	-7.32	150	199	+32.67	44	38	-13.64
5	90	77	-14.44	148	160	+8.11	196	180	-8.16	50	60	+20.00
6	92	76	-17.39	179	200	+11.73	205	205	+0.00	57	58	+1.75
Mean ± Sd	94.17±7.88	78.67±6.86	-16.43	133.33±39.26	128.50±52.73	-5.86	182.50±45.83	182.33±25.87	+5.85	45.00±9.80	48.67±9.20	+5.70
B. Control												
1	68	63	-7.35	160	176	+10.00	166	170	+2.41	48	40	-16.67
2	110	112	+7.82	169	139	-17.75	188	215	+14.36	41	43	+4.88
3	85	86	+1.18	137	130	-5.11	184	170	-7.61	24	26	+8.33
4	99	96	-3.03	130	135	+3.85	185	190	+2.70	29	30	+3.45
5	97	100	+3.09	191	196	+2.62	230	241	+17.83	40	38	-5.00
6	93	98	+5.37	159	159	+0.00	229	242	+5.68	35	33	-5.71
Mean ± Sd	92.00±14.31	92.50±16.68	+0.18	157.67±22.09	155.83±26.13	-1.07	197.00±26.34	204.67±32.98	+5.89	36.17±8.70	35.00±6.45	-1.79

In a similar way, the marked reduction in plasma glucose (16%) and increase in HDL cholesterol (2%) was noted in experimental diabetic group after consumption of little millet composite food for four weeks (Table 26). There was no apparent change observed in triglyceride and total cholesterol level of diabetic experimental group after completion of feeding study. The plasma glucose increased by three per cent and HDL-cholesterol decreased by three per cent among diabetic control group with marked increase in total cholesterol (8%) levels after four weeks.

A noticeable reduction in plasma glucose upto 9 per cent, triglyceride and total cholesterol level upto 19 and 5 per cent respectively, were noted in non diabetics after assumption of little millet composite food (Table 27). There was an increase in HDL – cholesterol upto 9 per cent in experimental non diabetic group without much changes in control group after four weeks period. The plasma glucose was increased by three per cent, total cholesterol by four per cent and triglycerides by three per cent among non diabetic control group after four weeks.

However, the plasma glucose was reduced two times more in non-diabetics after consumption of foxtail millet composite mix compared to the subjects, who consumed little millet composite mix. But difference in decreased value of triglycerides and increased level of HDL – cholesterol were more apparent by three times in non-diabetic subjects after consumption of little millet composite mix compared to consumption of foxtail millet composite mix.

The difference in the plasma glucose, triglyceride, total cholesterol and HDL cholesterol were not significant statistically in experimental (diabetic and non diabetics) and conrol groups after feeding study of foxtail millet composite mix. But the significant ($P \leq 0.01$) difference in plasma glucose was observed in the diabetic and non diabetic (experimental and control) groups after the consumption of foxtail millet composite mix (Appendix 16). It was evident that there was significant ($P \leq 0.01$) decrease in the plasma glucose of diabetic and non-diabetic (experimental and control) groups after

Table 26.Effect of feeding little millet composite food (4 weeks) on plasma glucose and lipid profile of diabetics

Volunteers	Fasting glucose (mg/dl)			Trighycerides (mg/dl)			Total Cholesterol (mg/dl)			HDL Cholesterol (mg/dl)		
	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change
A. Experimental												
1	125	117	-6.40	240	189	-21.25	258	212	-17.83	39	35	+10.26
2	106	83	-21.70	118	165	39.83	220	183	-16.81	42	32	-23.81
3	129	124	-3.88	150	145	-3.33	193	203	+5.18	43	40	-6.98
4	131	100	-23.66	183	177	-3.27	213	200	-6.10	43	48	+11.63
5	137	109	-20.44	137	142	+3.65	223	198	-11.21	48	46	-4.17
6	127	96	-24.41	181	187	+3.31	173	232	+34.40	31	36	+16.13
7	159	134	-15.72	127	130	+2.36	287	292	+1.74	42	43	+9.52
8	120	93	-22.50	120	105	-12.50	147	194	+31.97	40	41	+2.50
9	109	100	-8.27	118	108	-8.47	250	232	-7.20	36	38	+5.56
Mean ± Sd	127±15.66	106.22±16.23	-16.33	152.67±41.43	149.78±31.86	+0.04	218.22±43.49	216.22±32.84	+1.54	40.44±4.82	39.88±5.23	+2.29
B.Control												
1	98	109	+11.22	217	220	+1.38	250	260	+4.00	33	32	+0.30
2	108	119	+10.19	247	212	-14.17	248	269	+8.47	35	33	-5.71
3	147	141	-4.08	253	115	+15.02	250	267	+6.80	34	30	-11.76
4	123	125	+1.63	200	165	-17.50	199	202	+1.51	39	40	+2.56
5	130	125	-3.85	178	170	-4.49	178	185	+3.93	37	36	-2.70
6	129	133	+3.10	245	250	+2.04	215	270	+25.58	42	41	-2.38
Mean ± Sd	122.50±17.38	125.33±11.06	+3.03	223.33±30.16	188.67±48.21	-2.95	223.33±30.81	242.17±38.24	+8.38	36.67±3.39	35.33±4.46	-3.28

Table 27. Effect of feeding little millet composite food (4 weeks) on plasma glucose and lipid profile of non-diabetics

Volunteers	Fasting glucose (mg %)			Triglycerides (mg %)			Total Cholesterol (mg %)			HDL Cholesterol (mg %)		
	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change	Initial	Final	% Change
A. Experimental												
1	76	66	-13.16	148	73	-50.68	138	171	+23.91	49	40	-18.37
2	96	85	-11.46	151	120	-20.52	225	194	-13.77	46	44	-4.35
3	89	77	-13.48	89	75	-15.73	149	106	-28.85	38	50	+31.58
4	85	82	-3.53	165	152	-7.88	182	189	+3.85	37	39	+5.41
5	100	91	-9.00	200	226	+13.00	217	202	-6.91	41	54	+31.71
6	84	84	+0.00	184	120	-34.78	182	169	-7.14	41	43	+4.88
Mean ± Sd	88.33±8.69	80.83±8.57	-8.44	156.17±38.42	127.67±56.81	-19.43	182.17±34.92	171.83±34.75	-4.82	42.00±4.65	45.00±5.87	+8.47
B. Control												
1	98	100	+2.04	98	100	+2.04	234	233	-0.43	32	31	-3.13
2	66	63	-4.55	150	176	+17.33	166	170	+1.81	45	42	-6.67
3	102	112	+9.80	159	139	-12.57	190	200	+5.26	41	40	-2.44
4	83	88	+6.02	130	130	+0.00	174	179	+2.87	26	30	+15.38
5	95	96	+1.05	120	135	+12.50	175	195	+11.43	29	30	+3.49
6	93	96	+3.23	149	150	+0.67	220	231	+5.00	35	32	-8.57
Mean ± Sd	89.50±13.16	92.50±16.44	+2.93	134.33±58.49	138.33±24.92	+3.33	197.17±27.69	201.33±26.10	+4.32	34.67±7.23	34.17±5.38	-0.33

consumption of foxtail as well as little millet mix. The triglycerides reduced significantly ($P \leq 0.05$) only in the non-diabetics on consumption of little millet composite mix otherwise there were no apparent differences in lipid profiles of experimental and control subjects. Between the foxtail and little millet mixes a significant ($P \leq 0.05$) difference was observed in the experimental and non diabetic subjects only in plasma glucose level and the differences in lipid profiles were not significant statistically after four weeks period.

It is clearly depicted in the Figure 12 that the ratios of Total cholesterol to HDL – cholesterol (TC:HDL) and LDL- cholesterol to HDL cholesterol (LDL:HDL) decreased markedly after consumption of foxtail millet diabetic mix in diabetic subjects compared to non-diabetics and control group. In non-diabetics not much change was observed in TC:HDL ratio (<5:1 risk range) after feeding study while LDL:HDL ratio (<3.5:1 risk range) decreased markedly as compared to their counterpart control subjects.

It was surprising to note that there was not much changes in TC:HDL and LDL:HDL ratios of diabetic and non-diabetic subjects after consumption of little millet composite mix (Figure 13). But the TC:HDL and LDL:HDL ratios were reduced by 10 and 24 percent respectively in diabetics compared to their respective control group. While in non-diabetics the ratios were reduced only 2 and 5 per cent, respectively compared to their counterpart control subjects after four weeks period.

It is interesting to note that consumption of foxtail millet composite mix exhibited significant ($P \leq 0.01$) reduction in LDL:HDL ratio in diabetic subjects. The difference in TC:HDL ratio was not apparent after feeding of foxtail millet composite mix in diabetic and non diabetic group (Appendix 17). The difference in LDL:HDL ratio in diabetic subjects was significant ($P \leq 0.05$) after feeding of little millet composite mix. The difference in TC:HDL and LDL:HDL ratios before and after consumption of foxtail and little millet mix in experimental and control subjects were not significant statistically. It

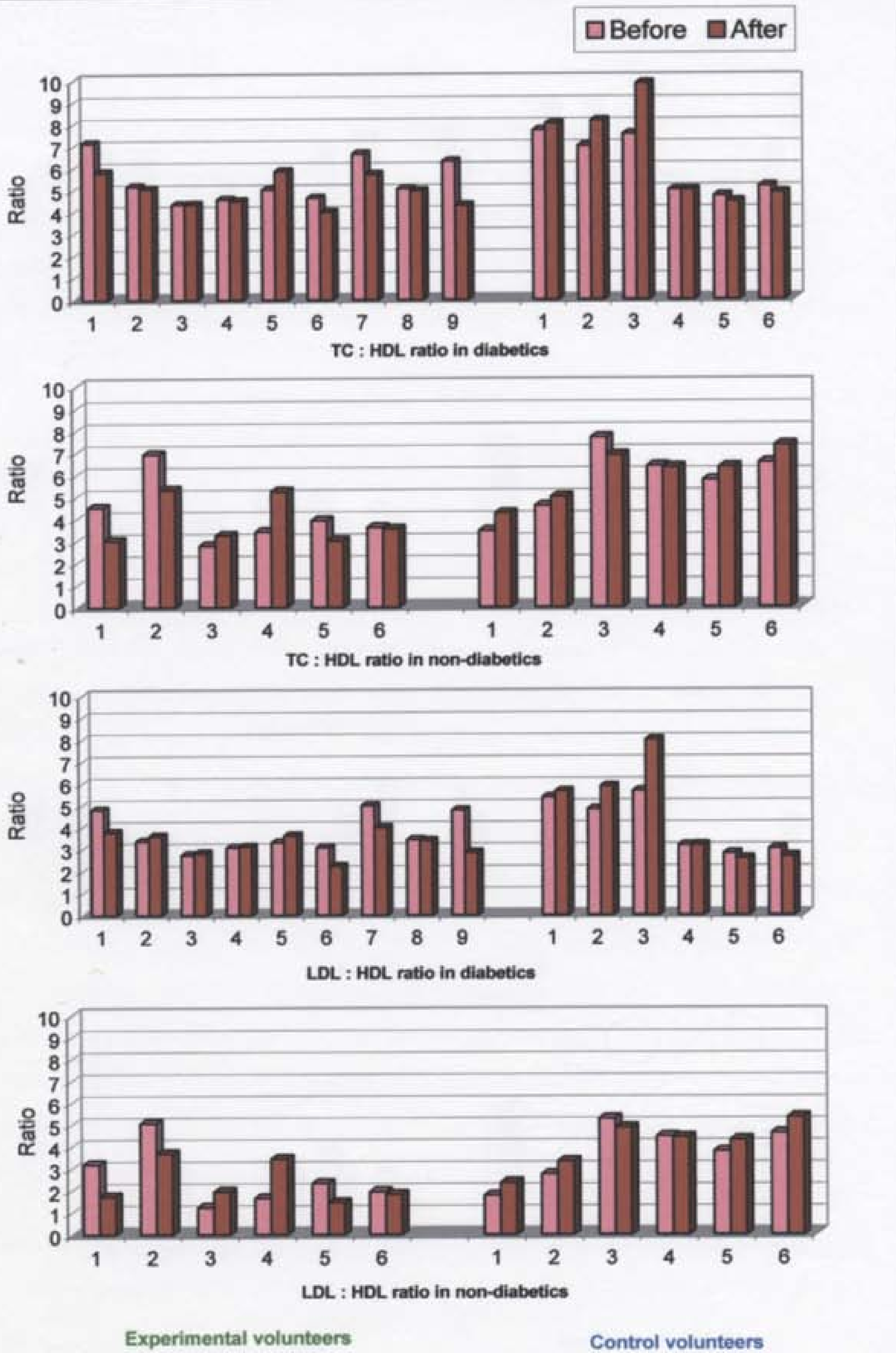


Fig. 12. Effect of foxtail millet composite food/mix on lipid ratios in human volunteers after feeding (4 weeks)

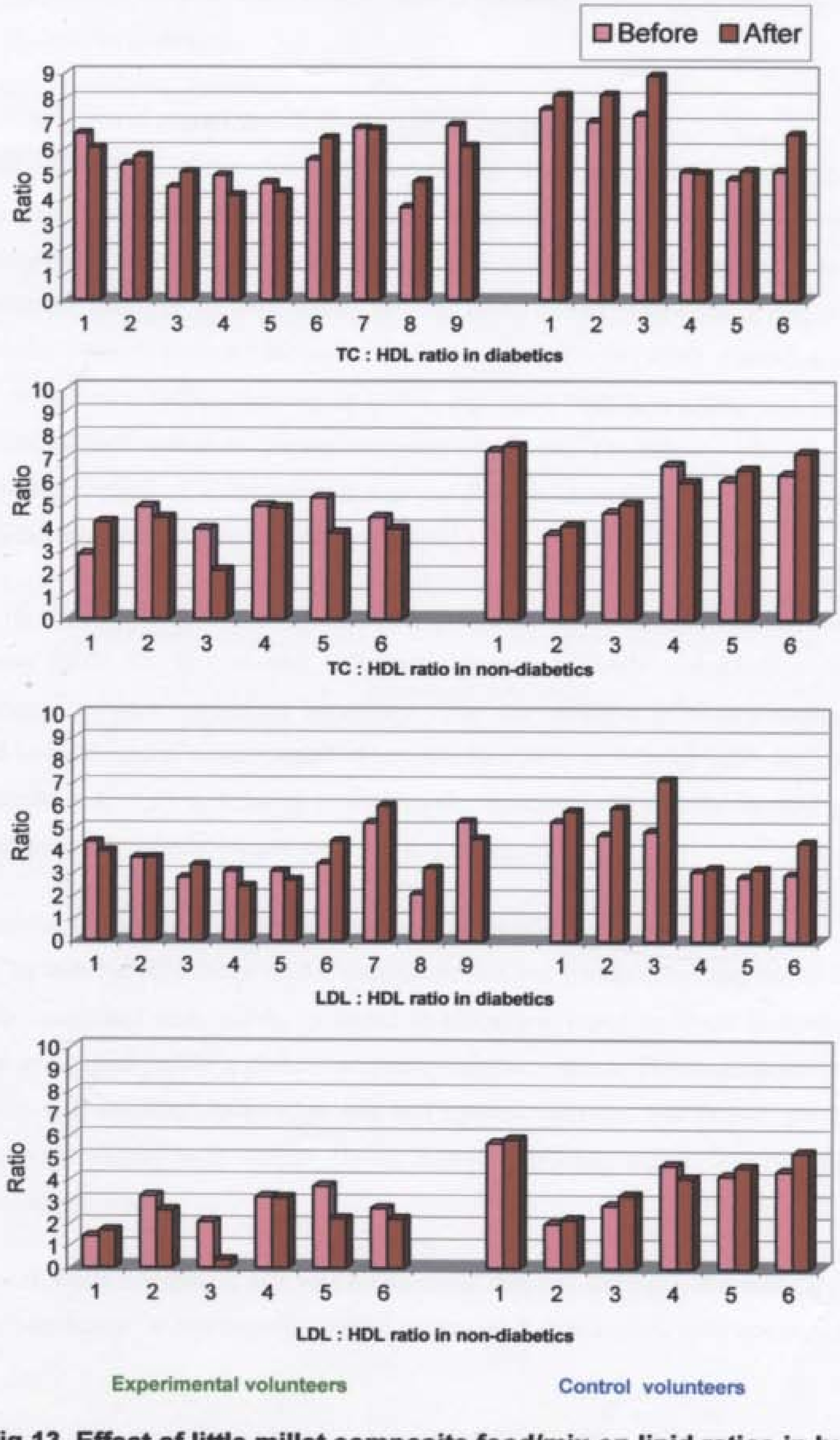


Fig.13. Effect of little millet composite food/mix on lipid ratios in human volunteers after feeding (4 weeks)

is also noticed that between the mixes the difference in both lipid ratios were significant ($P \leq 0.05$) only in diabetics.

4.4.5.3 Compliance report and body weight changes of subjects

The 15 subjects of experiment were asked to produce self compliance report of feeding and discomforts experienced during consumption of foxtail and little millet composite food. Nearly 99 per cent of diabetic and non-diabetic subjects has consumed the composite food for 28 days during feeding study period. The various discomforts noted by the subjects included feeling of fullness and heaviness (60%), distention of gas (47%), constipation (40%), burping up (27%), increased body heat (20%) and diarrhea (6%) within first few days of the feeding study (Table 28). The subjects also expressed that the consumption of millet based composite food produced satiety and reduced the craving for other eatables during feeding period.

It is clearly noted from the Table 29 that after consumption of both diabetic composite foods for four weeks indicated decrease in body weight (0.7-2%) of experimental subjects compared to control. The consumption of foxtail millet mix reduced body weight of experimental volunteers from 0.07 to 1.60 kg while little millet mix reduced only 0.11 to 0.50 kg in four weeks duration where as the control group indicated increase in body weight from 0.5 to 1.08 kg.

4.5 Popularization and commercialization of diabetic composite mix

The result of the clinical trial of two developed and standardized composite mixes based on foxtail and little millets indicated its efficacy in lowering blood glucose level and improving lipid profile in diabetic and non-diabetic subjects. However, foxtail millet composite mix exhibited better glycemic and lipemic response and further proved its efficacy in decreasing body weight. Hence, foxtail millet mix was further selected for popularization purpose.

The diabetic composite mix was popularized through different channels targeting diabetic population. In this regard, several registered diabetologists were contacted and

Table 28.Discomforts noted during feeding among volunteers

Discomforts	N=15	%
Distention (Gas trouble)	7	47
Constpation	6	40
Burping up	4	27
Feeling of Fullness (Heaviness)	9	60
Increased body heat	3	20
Diarrhoea	2	13

* - Nearly 99 per cent of the subject consumed completely serving of food for 28 days period of experiment (80g /day).

Table 29. Change in body weight of volunteers after consumption of diabetic composite food (4 weeks)

Type	Volunteers	Difference in body weight (kg)		Control
		Diabetic	Non-diabetic	
A.Foxtail Millet Mix	1	-2.00	-2.50	0.00
	2	-2.00	-1.00	+0.50
	3	0.00	0.00	+1.00
	4	-1.00	-1.50	+1.00
	5	-2.50	0.00	+0.50
	6	0.00	-1.00	0.00
	7	-2.00	--	--
	8	-2.00	--	--
	9	-2.00	--	--
	Mean	-1.60	-0.67	+0.50
B.Little Millet Mix	1	+1.00	0.00	+2.00
	2	0.00	0.00	+1.00
	3	0.00	-1.00	0.00
	4	1.00	-1.00	0.00
	5	-1.00	0.00	+1.00
	6	-1.00	-1.00	0.00
	7	0.00	--	--
	8	-1.00	--	--
	9	-1.00	--	--
	Mean	-0.11	-0.50	+1.08

the food was introduced to diabetics through method demonstration in selected health centers and diabetic clubs of Hubli – Dharwad. In collaboration with diabetologists and local service organizations like Rotary and Indian Medical Association (IMA), several counselling sessions and diabetic *meals* were organized with definite objectives, in six talukas surrounding the host institution. The detailed information regarding this aspect is depicted in the Table 30.

The informative lectures, informal talks, method and result demonstrations of the developed diabetic composite mix, self explanatory charts, films, books on diabetes and group discussions with subjects and experts were included in each session to have effective popularization of the product (Plates 6 and7).

The foxtail millet mix was commercialized through proper packaging, sealing, labeling and feasibility at different centers of the town. For commercialization of the diabetic mix the interactions were organized with hotel owners, retail shop keepers and *Bazar*, *expo* organizers, providing free sample packets for display. The diabetic mix was packed in ½ kg quantity with printed label covering list of ingredients, instructions for use, date of manufacture, contact address and retail sale price. A plastic measuring cup of 40g capacity was packed in each packet to benefit the customer to know the quantity of mix to be consumed per day (Plate 8).

For commercialization, the foxtail and little millet diabetic composite mix were produced upto 400 kg and 60 kg respectively. Along with this, advertising of the diabetic mix was triggered through publishing newspaper articles, handouts and seminars. The individual counselling was performed in the host institution and mix was supplied to the needy subjects. The little millet mix was prepared on demand of the diabetic subjects, since the cost per unit was higher than foxtail millet mix.

Table 30. Popularization of diabetic composite food

Demostration Centres	Place	No. of beneficiares	Sale of mix (kg)
Diabetic Centres	Hubli	20--25	22
	Dharwad	"	18
Health Clubs	Hubli	10--15	19
	Dharwad	"	21
Melas /Exhibitions	Hubli	110--135	25
	Dharwad	80--100	45
	Dandeli	150--165	18
	Sirsi	70--80	18
	Belgaum	180--200	20
	Bagalkot	250--260	15
	Bangalore	800--850	20
	Bijapur	125--140	25
Bazars	Hubli	140-150	18
	Dharwad	60-75	34
Counseling centres	Hubli	70-80	25
	Dharwad	110-120	57
			400

Table 31. Cost analysis for commercial production of diabetic mix

Particulars	Quantity (kg)	Amount (Rs)
Fixed Cost :		
Building (10 x 12)	--	90,000
Major equipments		
Flour mill	--	10,000
Destoning machine	--	15,000
Roaster	--	8,000
Sealing machine	--	2,000
Minor equipments	--	5,000
Total		1,30,000
Variable Cost:		
Millets (Foxtail / Little)	22	330/ 555
Black gram dal	3	90
Wheat Semolina	3	45
Spice Mix	2	155
Labour charges	--	60
Packaging materials	0.5	50
Labels	--	50
Electricity	--	50
Miscellaneous	--	20
Total		850 /1025

Depriciation cost on building, equipment @ 10% = Rs.13,000 p.a.
Production rate: ...25/ kg Mix / Day
Production cost per unit: Rs.34 or 41 / kg. (Foxtail / Little millet)

Method Demonstration

Display of Foods in Exhibition

Plate 6. Popularization of Diabetic Composite Mix / Food

Giving instructions to the patient

Tasting the prepared product

Plate 7. Demonstration of Diabetic Composite Food

1. Sealed packet
2. Measuring cup
3. Instruction sheet
4. Masala mixture

Plate 8. Sealed packet of diabetic composite mix for sales

4.6 Cost analysis of diabetic composite mix

It is clearly noted from the Table 31 that the cost analysis of the diabetic mix included fixed and variable cost components. Building and major equipment which costing rupees one lakh thirty thousand (1,30,000) with present rate of the commodities sumed up the fixed cost. The variable cost included *viz.*, raw ingredients, labour and electricity charges, packaging materials. For calculation of production cost the expenses incurred for daily production of 25 kg composite mix was considered. The unit cost for one kilogram of diabetic mix was calculated. The estimated unit cost without margin the profit sumed up Rs 34.00 and 41.00 for foxtail millet and little millet composite mix respectively. The sales of diabetic composite mix with 10-20 per cent profit provided net gain of Rs 488 – 513 per day. On the whole the sales price of the diabetic food was found to be within the budget of moderate income group and it opens good venture for entrepreneur to capture the health conscious populations customers.

Discussion

V DISCUSSION

The genetic factors clubbed with 'cola culture', urbanization, altered life styles and Information Technology (IT) revolution seems to have aggravated the prevalence of degenerative disorders even in small towns of India. The present day health scenario highlights that by the year 2025, diabetes in India would increase by 59 per cent compared to 41 per cent in other Asian countries (Kaul, 2000). The National Nutrition Monitoring Bureau's (NNMB) 25 years of Dietary Survey (1972-97) report (Kamala Krishnamurthy *et al.*, 1997) indicated that the higher consumption of refined foods such as fat, sugar and sweets, processed and preserved foods and lower consumption of protective vegetables and fruits indirectly triggered the type 2 diabetic population in the country. There is a demand for the foods, which are nutrient dense, low cost, locally available, culturally accepted and suitable to individual's health status and effective in management of normal blood sugar. The globalization increased the need for development of health foods that satisfy the consumer in terms of convenience, acceptability and maximum shelf-life along with nutritional benefits.

The major objective of dietary treatment in diabetics is to maintain near normoglycemia with ultimate goal of leading normal span of life in health and comfort. The dietary concepts in the treatment of diabetes have undergone profound changes because of several factors, which include better understanding of the pathophysiology of the disease like recognition of atherosclerosis and vascular complications as the major causes of morbidity and mortality.

The Indian traditional meal which has a combination of whole grain and /or coarse cereals, pulses, vegetables and fruits contain high quantity of dietary fibre with complex and slow digestible carbohydrates. The coarse cereals form staple food for a large segment of population can replace rice and wheat in the Indian dietaries. The value of the millets though not comparable with respect to major nutrients, are superior to cereals because of high levels of protective nutrients *viz.*, minerals, vitamins, dietary fibre and phyto- chemicals. These characteristics highly qualify and favor in formulation of millet based health foods.

The millets, which include finger millet (*Elecusine coracana*), pearl millet (*Pennisetum americanum*), foxtail millet (*Setaria italica*), kodo millet (*Papalum scrobiculatum*), barnyard millet (*Echinochloa colona*), little millet (*Panicum miliare*), proso millet (*Panicum miliaceum*), teff (*Eragrostis tef*) and others are small sized grains containing large proportion of husk and bran. The millets require debraning prior to the consumption. The hard seed coat of the millets permits them to store for years without any infestation in normal household conditions.

The production and availability of the millets has increased upto 40 million tons in 2001 from 27 million tons of 1980 in the country (Anon, 2001b). The millets being adoptive to a wide ecological conditions including severe drought, produce appreciable yields. The non-availability of clean, refined and processed millets in ready to use form has restricted their wider use and acceptability, thus confined mainly to traditional consumers and the people of low economic strata. The processing of the millets *viz.*, washing, cleaning, debraning and roasting constitute 20 and 32 per cent inevitable loss. Nevertheless milling, flaking, popping and malting processes enhance their use in value added products, besides improving nutrient value and digestibility.

5.1 Development of diabetic composite food / mix

The present investigation was focused on foxtail and little millets due to availability in local market at nominal cost and traditionally accepted. For better utilization of millets different processing techniques were used *viz.*, dry heat roasting, milling in development of diabetic composite mix. The heat application during processing resulting in dextrinization reduces the transparency of the millet grains. The moisture content of the roasted millet grains (foxtail and little millet) was reduced by 4 to 5 per cent compared to raw milled grains without much change in chemical parameters (Table 5). The dry heat roasting improved the hydration capacity by 18 and 11 per cent in foxtail and little millets respectively (Table 4). The roasted grains required half a minute more time for cooking than raw milled grains. Better grain structure and yield was noticed (cooked weight and volume) in the products prepared with roasted grains than raw (Table 6). The milling of the millets into flour increased solubility and swelling power by 13 per cent (Table 9), indicating the fact that change in physical form (grain to flour) increases feasibility of the millets in the regular diet. Though lack of gluten in the millet limits their use in bakery and fermented products so can be liberally utilized in composite mixture as supplements.

The cereal-pulse composite mix was found to be a beneficial combination (Bijlani *et al.*, 1993 and Mani *et al.*, 1992a) when utilized in the form of meal rather than individual food increased long term dietary adherence. Generally, the composite mixes are rich in protein, total dietary fibre and minerals but low in fat. Therefore millet, cereal and pulse combinations were used for formulating the diabetic composite food in the present study.

Recently several authors have been reported that a moderate increase in soluble fibre and complex starchy foods in the natural dietary form act as anti risk factors for ischaemic heart disease (IHD) and diabetes. (Austin, 1989, Anderson *et al.*, 1991 and Kurup and Krishnamurthy, 1992). The millets predominant in polysaccharides, lignin and substances associated with low lipemic index were selected for formulation of diabetic composite food. The increase in the proportion of millet in the composite mix increased total dietary fibre content (Table 7). The soluble dietary fibre content in the millet mixes ranged from 12-19 per cent and insoluble dietary fibre from 81-83 per cent of the total dietary fibre, which reduced glycemic peaks after the meals (Table 12).

The selected hypoglycemic spices *viz.*, fenugreek, coriander, cumin seeds and black pepper were blended in various proportions and used in diabetic composite food exploit their neutraceutical properties. The fenugreek seeds are known to have hypoglycemic and hypocholesterolemic activity and serve as a good supplement to millet because of its high protein (25%), lysine (5.78/16gN), minerals, antioxidants and dietary fibre (48%) contents (Saibaba and Raghuram, 1997). The other spices used in the mix are rich source of phthalides, which have anti carcinogenic potential and known for gastric stimulation and reduce flatulence, indigestion and intestinal disorders (Polasa, 1993). Hence, the spice mixture having therapeutic benefits also improved flavor and taste of the developed composite mix. The nutrient composition of foxtail and little millet mixes (grain and flour) were found within the BIS (ISI) specifications, for processed cereal supplementary food except for the crude fibre (Anon, 1969). Higher level of crude fibre having soluble and insoluble dietary fibre was intentionally increased for the maintenance of glucose levels in type 2 diabetic subjects.

It was found that lysine and threonine were the limiting amino acids of the diabetic composite food (Table 13). The addition of pulse and spice mixture improved amino acid score of the developed mix. The composite diabetic mix was used in the preparation of several traditional foods routinely consumed by the local population. The cooked weight of grain mix products (*upma* and rice) increased by five times than initial. While the composite flour preparations *viz., chapathi, masala roti* and *thalipatti* increased by two times and dumpling (*mudde*) four times in weight after cooking (Table 14). The increase in weight of the products after cooking was due to higher water binding capacity and gelatinization temperature of the millet starches (Hulse *et al.*, 1980).

The preparations using the little millet composite mix were more acceptable than the foxtail millet composite mix as shown by the sensory scores of the products (Table 15). The pale creamish color of the little millet might have helped in better appearance than foxtail millet. The *chapathis* prepared from composite flour obtained lower scores for sensory characteristics due to cracks at the edges and hard texture.

This type of characteristic texture and appearance is attributed to lack of gluten in the millet flour. Addition of sour buttermilk, tomato, green leafy vegetables and lemon in pancake, *masala roti, mudde* and *upma* respectively helped to produce better aroma, taste and texture of the products.

The diabetic composite food / mix when stored in three types of packages for a period of six months an increase in the moisture and peroxide contents was observed. Though the increased values were within the limits of BIS specifications (<10% moisture and 10 meq /kg fat). The increase in moisture and peroxide values was significantly higher in composite mix stored in aluminium box than those stored in sealed packages (polyethylene bag and aluminium laminated pouch). The higher values might be due to easy exchanges of gases in aluminium boxes. The increase in moisture content significantly increased the peroxide content of the composite mix which effected sensory scores of taste, aroma and overall acceptability for the products after 165 days of storage (Appendices 10,11,12 and 13).

Though the storage results of the developed diabetic composite food /mix stored in aluminium laminated pouch was better from chemical and sensory points of view, the cost per package was found to be much higher than the polyethylene bag and aluminium box. To achieve better sensory attributes, the polyethylene bag with 150 microns at nominal cost (Rs 0.40 / bag) was found feasible for prolonged shelf-life during storage. Thus, the polyethylene packaging provides easy handling and good appeal for commercial production.

5.2 Clinical efficacy of the developed diabetic composite food

The composition of the diabetic composite food /mix was found to be nutritionally and functionally satisfactory but it is necessary to test the clinical efficacy in human volunteers and understand the long term feeding effect on glyco-lipemic parameters. Hence, the feeding study was conducted for four weeks on six non-diabetic and nine diabetic volunteers. Initially the glycemic index of the diabetic mixes were determined by the incremental glycemic response of the developed composite mix compared to reference meal (glucose) only in non-diabetic volunteers as the increased glycemic effect after consumption glucose causes prolonged uneasiness and discomforts in known diabetics (Miller, 1994).

Lowest glycemic index was noted for developed foxtail millet composite mix (54.4) followed by foxtail millet grains (56.8) and the composite flour (63.1). A similar trend was also observed for little millet composite mix. It is noted that the composite grain mix of foxtail and little millet exhibited lower GI than their respective composite flour, since the physical and particle size of the food influence the GI. (Crapo and Henry, 1988 and Heaton *et al.*, 1988). The composite mix (grain) exhibited lower GI than their respective plain grains along with improvement in cooking and acceptability of the prepared products. It is clearly established fact that GI for millets (foxtail and little) was found to be lower than other cereals *viz.*, rice (Wolever, 1990a), wheat (Walker and Walker, 1984), dicoccum wheat (Bhuvaneshwari, 1999) and sorghum (Lakshmi and Vimala, 1996).

The developed millet based diabetic composite food /mix had several other advantages. The processing of millet in developed composite food altered physical properties and molecular arrangement of the dietary fibre, which helped in non-availability of starches for enzymatic digestion thus reducing glucose response. Lindsay et al. (1984) reported similar observations. The foxtail and little millet composite food /mix contributed 80 per cent increase in dietary fibre content of the meal (Table 12). There is a negative and significant correlation has been observed between dietary fibre and GI of the developed mix (Table 21). The dietary fibre content of developed composite mix /food helped to decrease the post prandial glycemic response in diabetic volunteers by 22-23 per cent compared to rice and wheat products (Table 20). Many studies have indicated lower GI for millet based mix /food than cereal based mixes (Geeta and Easwaran, 1990,Wolever, 1990b and Mani *et al.*, 1994).

The diabetic composite food /mix included 10 per cent pulse (black gram *dal*) and eight per cent spice mixture, which were beneficial to maintain normoglycemia in diabetic volunteers besides adding variation to the regular meal. Black gram *dal* and spices such as fenugreek seeds and coriander seeds exhibit hypoglycemic and hypocholesterolemic effect when included in diabetic diet as reported by Mani *et al.* (1992b) and Srinivasan (1997). The wheat semolina added at 10 per cent in the developed composite food increased amylose and gluten content and thus enabling the mix /food to be utilized in many preparations *viz., thalipatti, masala roti, kadak roti,* pancake. Increase in amylose and protein further helped in providing hypoglycemic effect and improving the amino acid scores respectively (Kurup and Krishnamurthy, 1993 and Westrate and Amelscoort, 1993).

The developed diabetic composite flour conveniently substituted staple cereals *viz.*, rice and wheat flour in preparations like *chapathi, roti, pancake, mudde* (dumpling) and *thalipatti*. The easy availability and familiarity of the millets helped to exploit the natural and nutritional component of the food and provided clinical benefits to the diabetics in a economic way. Inclusion of millet based composite mix / food in regular diet for a period of four weeks exhibited several neutraceutical benefits in experimental volunteers.

The feeding of developed diabetic composite food /mix resulted in improving carbohydrate tolerance among experimental volunteers, as shown by reduction in fasting plasma glucose after four weeks. The assay of plasma lipid fractions highlighted the effect of diabetic composite food on lipemic control also among the volunteers. The decrease in triglycerides by 19 per cent and an increase in HDL-cholesterol upto eight per cent were noted in both the groups. It has been reported that the controlled diabetics with lower level of plasma glucose aids in alteration of metabolism of low-density lipoproteins, triglycerides and total cholesterol bringing beneficial change in the lipid profile. In other words, the uncontrolled diabetics depict not only higher level of plasma glucose levels but also higher levels of lipids fractions leading to other complications (Miller, 1994). The change in the total cholesterol level was not apparent after feeding the developed diabetic mix among experimental group, but TC: HDL and LDL: HDL ratios were improved, more so in diabetic volunteers. This improvement in lipid profile will reduce the risk of coronary diseases and other micro level complications in diabetics. Many studies have proved that decrease in total cholesterol by one per cent reduces the risk of coronary heart diseases by two per cent and helps to avoid vascular complications in diabetics (Rifkind, 1990).

The control of plasma lipid constituents within the limits of National Cholesterol Education Program (NCEP) guidelines {triglycerides (<150 mg/dl), LDL cholesterol (< 100 mg/dl), total cholesterol (< 200 mg/dl) and HDL-cholesterol (>40 mg/dl)} helps to lead comfortable and healthy life without further complications (Anon, 2001a). About 65 per cent of experimental volunteers were found within these limits after feeding study of diabetic composite food / mix.

The compliance of the volunteers in terms of consuming diabetic composite food was normal and there was reduction in craving for other eatables and giving feeling of fullness (Table 28). Nevertheless, 60 per cent of the volunteers reduced 1-2 kg of body weight after four weeks of feeding study without any changes in daily physical activities. In spite of short duration of the experimental period (4 weeks) considerable changes were observed in positive direction with plasma glyco-lipemic parameters and weight control. It was also noticed that the diabetic volunteers who continued the consumption of the composite mix upto 6 to 8 months showed better glyco-lipemic control without any side effects.

After testing the efficacy, storability (6 months) and feasibility of the diabetic composite food /mix in the daily diet of diabetics, the mix was popularized through different channels. Many diabetic clinics, health clubs, Non-Government Organization (NGOs), *Mahila Mandals* and local Diabetologists joined hands to reach target population and to accept the mix as routine food. The local and community organizations play pivotal role in control of diabetes as it involves the family members and effective way of convincing the beneficiaries. For successful popularization and commercialization advertisement through local newspapers, market testing and consumer acceptability of developed diabetic composite food /mix was adopted. The method demonstration of developed composite mix in health centres, exhibitions, group counseling and sales at several *melas* promoted effective popularization within short period. It was estimated that a diabetic person has to spend approximately Rs.100 per month for diabetic composite food / mix, which is beneficial in glyco-lipemic control without changing the normal pattern of the dietary habits.

In conclusion, the developed diabetic composite food is an inexpensive, readily available food with acceptable cooking and organoleptic properties. It is a suitable diabetic food for maintaining normoglycemia and aids in preventing coronary complications. At present the demand for diabetic composite food is increased in host institution's counseling center and opened challengeable avenue to start production of such health food / mix at commercial scale to benefit innumerable diabetic population and enthusiastic entrepreneurs.

Future line of work

- There is a need to develop economic and feasible processing techniques, which improve storage and functional qualities of milled millet in ready to use foods.
- Exploitation of locally available millets in preparation of therapeutic foods.
- Effect of long term feeding on glyco-lipemic response in normal and diabetics need to be estimated.
- Many more preparations from ready to use mix and novel foods from the developed composite mix should be standardized.
- Anti-nutritional factors (phytophenols) and microbiological quality of the millet-based foods may be estimated to exploit the nutritional benefits.

Summary

VI SUMMARY

An investigation on the development and evaluation of millet based diabetic composite mix / food for a type 2 diabetic was undertaken during 1999-2001 in Hubli-Dharwad area. The main objective was to exploit nutritional and clinical efficacy of the millet based diabetic composite food among local people and popularizes the product. The physico-chemical parameters of composite food were estimated using standard procedures. The developed foxtail and little millet diabetic composite mixes /foods were analyzed for chemical composition, dietary fibre profile and protein quality along with shelf life study for six months. The glycemic and lipemic responses in plasma were assayed after feeding diabetic composite food in diabetic and non-diabetic subjects for a period of four weeks. The product was popularized through effective result demonstrations to reach maximum beneficiaries in several diabetic centres. The salient findings of the present study are summarized below.

- The thousand-kernel weight and volume of milled millet grains ranged from 2.12 to 3.05 g and 1.50 to 2.80 ml respectively.
- The density of the milled and roasted millet grains increased by about 20 per cent compared to whole grains.
- The hydration capacity was high in whole little and foxtail millets (0.55 and 0.76%, respectively) while hydration index was high in milled and roasted grains of little and foxtail millets (21.50 and 26.42, respectively).
- The protein content of little millet (9.8g) and foxtail millet (12.2g) was found to be higher than in other minor millets.
- The difference between the nutrient composition of milled raw and roasted millets was not significant statistically except for fat content.
- The increase in weight of cooked roasted millets ranged from 332 to 371 per cent and volume by 3.7 to 4 times which was found to be slightly higher than cooked weight and volume of raw grains of both millets.

- The dough of the composite flour expanded evenly with a few cracks at the edges compared to dough of millet flour when rolled into round shaped chapathis.
- The total dietary fibre content was increased by 2.5 to 4.0 per cent in little and foxtail millet composite mix / food compared to respective plain grains.
- The nutrient composition of diabetic food was within the limits specified by BIS specifications for the processed cereal based weaning food except for crude fibre, which was higher but beneficial to diabetics.
- Lysine and threonine were observed to be first and second limiting amino acids, respectively in the diabetic composite mix.
- The swelling power and solubility increased in diabetic composite grain mix and composite flour obtained after processing and helped to prepare a variety of traditional / routine products with acceptable sensory attributes
- The expert panel accepted all the products prepared out of millet, wheat and black gram *dal* in 8:1:1 proportion with addition of eight per cent spice powder.
- The products prepared from the diabetic composite food *viz*., rice, *upma*, *mudde*, pancake and *masala roti* provided 302 to 412 kcalories, 8.16 to 12.14 g protein and 16.48 to 18.92 g dietary fibre per 80g mix.
- Irrespective of the packages (aluminium box, polyethylene bag and aluminium pouch) a significant ($P \leq 0.05$) increase in moisture was observed in the diabetic grain mix and a decrease in the diabetic composite flour the during storage period of six months.
- A significant increase in peroxide value of foxtail and little millet composite food were noted during storage in all the three types of packages.
- The diabetic composite foods stored in sealed packages (polyethylene bag and aluminium pouch) exhibited highly significant and positive relation to moisture and peroxide during storage and were best suited for storage.
- The chemical parameters and sensory scores obtained by the products prepared from stored diabetic composite food (foxtail and little millet) were acceptable throughout the storage period of six months.

- The lowest Glycemic Index (GI) was noted for foxtail millet grain mix (54.39) followed by little millet grain mix (58.75), foxtail and little millet composite flour (63.75 and 64.51, respectively) in non-diabetic volunteers.
- The GI of the foxtail millet diabetic mix (grain and flour) exhibited significant negative correlation (r= -0.587) with nutrients (fat and total dietary fibre) and little millet diabetic mix showed negative correlation only with fat and positive correlation with protein and total dietary fibre content.
- The increase in post prandial glycemic response after consumption of the diabetic composite food was significantly lower compared to the customary breakfast foods among the diabetic volunteers.
- There was a significant ($P \leq 0.01$) reduction in fasting blood glucose levels among the diabetic (15.94%) and non-diabetic volunteers (4.23%) after consumption of diabetic composite food for four weeks.
- There was a significant ($P \leq 0.01$) reduction in triglyceride levels only in the non-diabetics after consumption of little millet composite food.
- The apparent changes were not observed in Total Cholesterol (TC) and HDL Cholesterol values among the diabetic and non diabetic volunteers after consumption of diabetic mixes for four weeks.
- A significant ($P \leq 0.05$) reduction in TC:HDL and LDL:HDL ratios (10 and 24%, respectively) was observed in diabetic group compared to control after feeding trial of diabetic mixes for four weeks.
- Both the lipid ratios shifted towards normal, among the 60 per cent of the experimental volunteers after consumption of diabetic composite food for four weeks.
- Total improvement in lipid profile (reduction in triglycerides and cholesterol and increment in HDL cholesterol) along with average weight loss upto 1.65 kg was observed only in diabetic experimental group after consumption of diabetic composite food / mix (80g /day) for the period of four weeks.
- On the whole consumption of foxtail millet diabetic mix /food indicated improvement in glyco-lipemic responses than the little millet mix among the experimental volunteers.

- The foxtail millet composite food was effectively popularized through several diabetic centres, health clinics and diabetic clubs.
- About five quintals of diabetic composite food /mix was produced during popularization span of one-year span and sold in organized *melas*, exhibitions, displays and seminars at different places.
- For commercialization the diabetic composite food /mix was packed in ½ and 1 kg attractive polyethylene sachets and heat sealed with insertion of label, instruction sheet and the household measure equivalent to 40g grains.
- The cost analysis of the composite food indicated that the production of diabetic mix at commercial level might be a feasible and remunerative enterprise apart from popularizing the nutritional benefits of the millets both for the farmers and consumers.

References

VII REFERENCES

AGARWAL, N., ARORA, R.C., ARORA, S. AND DINESHKUMAR, 1992, Glycemic index of some commonly eaten foods. *Journal of Diabetic Association of India*, **32**(3).55-59.

AHUJA, M.M.S., 1979 Epidemiological studies on diabetes mellitus in India. In: *Epidemiology of Diabetes in Developing Countries* , Interprint,New Delhi, p. 29-38.

ANDERSON, J.W., GUSTAFSON, N.J., BRYANT, C.A., AND TIETYEN, C.J., 1987, Dietary fibre and diabetes: a comprehensive review and practical application. *Journal of American Dietetic Association*, **87**: 1189-1197.

ANDERSON, J.W., STORY, L., SIELING, B . AND CHEN W.J.L., 1984, Effect of a rice-rich versus potato-rich diet on glucose lipo protein and cholesterol metabolism in non-insulin dependent diabetics. *American Journal of Clinical Nutrition*, **39**:598-606.

*ANDERSON, J.W., ZEIGLER, J.A.,DEAKINS, D.A.,FLOORES, T.L., DILLION, D.W., WOOD C.L.,OCLTGEN, P.R. AND WHITLR.J., 1991 Metabolic effects of high carbohydrate, high fibre diets for insulin dependent diabetic individuals. *American Journal of Clinical Nutrition*, **54**:936-943.

ANNAPURNA K., 2000, Comparative study on protein and storage quality of supplemented *Uppuma* of Dicoccum and Durum wheat. *M.H.Sc. Thesis* ,University of Agricultural Sciences, Dharwad.

ANONYMOUS, 1969 Specifications for processed Cereal Weaning Foods, IS:1656, *Indian Standard Institute* (BIS), New Delhi, p.42.

ANONYMOUS, 1990, Official methods of analysis of the Association of Official Analytical Chemistry, Washington, p.579-580.

• ANONYMOUS, 1993, Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long term complication in insulin-dependent diabetes mellitus. *New England Journal of Medicine*, **329**:977-986.

ANONYMOUS, 1994, Prevention of Diabetes, *World Health Organization, Technical Report Series*, No.884, Geneva, p.120-126.

ANONYMOUS, 1997, Report of the expert committee on the Diagnosis and Classification of Diabetes Mellitus, *Diabetic Care*, **20**:1183-1197.

ANONYMOUS, 1998, UK Prospective Diabetes Study Group. Intensive blood glucose control and risk complications in type 2 diabetes (UKPDS-33), *Lancet*, **352**: 837-853.

ANONYMOUS, 2000, Clinical practice recommendations. *Nutrition Recommendations and Principles for people with diabetes.* American Diabetes Association, Washington, p. 1-20.

ANONYMOUS, 2001a, Cholesterol Guidelines 2001- A call for more aggressive lipid lowering. *Current Medical Science*, **16**(3): 1-8.

ANONYMOUS, 2001b, Millets,*Indian Farming*, p.16-20.

ANURADHA V. AND VIDHYA D., 2001, Impact of administration of spirulina on the blood glucose level of selected diabetic patients. *The Indian Journal of Nutrition and Dietetics*, **38**:40-44.

ASP, N.G., JOHANSON, C.G., HALMER, H. AND SILJESTORM,M., 1983, Rapid enzymatic assay of insoluble dietary fibre. *Journal of Agriculture and Food Chemistry*, **31**:476-482.

AUSTIN,A., 1989, Plasma triglyceride as a risk factors for coronary heart diseases. *American Journal of Epidemology*, **129**:249-259

AUSTIN, A. AND RAM, A., 1971, *Studies on chapathi making quality of wheat.* ICAR *Bulletin* 31, NewDelhi, p.10-19.

BAKER, R.C. PATRICIA, W.H. AND KELLY R.ROBBINS, 1988, *Fundamentals of new food product development.* Sciences Publishers, Elsevier, Amsterdam, p.34-36

*BANTLE, J.P., LAINE, D.C., CASTLE, G.W., THOMAS, J.W., HOOGWERF, B.J. AND GOETZ, F.C., 1983, Post prandial glucose and insulin responses to meals containing different carbohydrates in normal and diabetic subjects. *New England Journal of Medicine*, **309**:7-12.

BHUVANESHWARI,G.,1999, Nutritional and processing qualities of dicoccum (Triticum, dicoccum, schrank, suhulb) wheat varities. *Ph.D. Thesis*, University of Agricultural Sciences, Dharwad.

BIJLANI, R.L., NARAIN, J.P., SHUKLA ,K., KOCHHAR, K.P., PURI, P., KARMARKAR, S.G., AND BALA, S., 1993, Glycemic and metabolic responses to a traditional cereal legume Mixture. *International Journal of Food Sciences and Nutrition*, **44**:243-251.

*BONANOME, A., VISONA, A., LUSIAN, L., BELTRAMELLO, G., CONFORTIN,L., BIFFANTI, S., SARGATO,F., COSTA, F. AND PAGNAN, A., 1991, Carbohydrate and lipid metabolism in patients with NIDDM. *American Journal of Clinical Nutrition,* **54**(3):586-590.

BORNET, F.R., COSTAGLIOLA, D., RIZKALLA, S.W., BLAYO, A., FONTVEILLE, A.M., HAARDT, M.J., LETANOUX, M., TCHOBROUTSKY, G. AND SLAMA, G., 1987, Insulinemic and glycemic indexes of six starch-rich foods taken alone and in a mixed meal by type2 diabetics. *American Journal of Clinical Nutrition,* **45**(3):588-595.

BRAND, J.C., COLAGIURI, S., CROSSMAN, S., ALLEN, A., ROBERTS, D.C. AND TRUSWELL, A.S., 1991, Low glycemic index foods improve long term glycemic control in NIDDM. *Diabetes Care,* **14**(2):95-101.

BRAND, J.C., PANG, E. AND BRAMALL, L., 1992, Rice: a high or low glycemic index food? *American Journal of Clinical Nutrition,* **56**:1034-1036.

CAMPBELL, A.M., PENFIELD, M.P. AND GRISWOLD, M.R., 1979, *The experimental study of food*, Houghton Muffin Company, Boston, p.372-374.

CASTANEDA , C. AND ODILIA, I. B., 1999, The diabetes epidemics in the Americans. Greater risks for older persons, *SCN News*, **19**:41-44.

*CERUTTI, F., VIGO, A. AND GUIDONI, C., 1987, Usefulness and side effects of a high fibre diet in a group of adolescents affected by insulin dependent diabetes mellitus. *Helv.Paediatrician Acta*, **42**:281-288.

CHANDALIS, H., NEOGI, M.R., AND MEHTA, S., 1992, Mechanism of low glycemic index of pulse and pulse incorporated cereal foods. *International Journal of Diabetes in Developing Countries*, **12**:9-11.

CHANDRA, V., AND ARUNA, K., 1997, Glycemic and cholesterolaemic effect of sprouted fenugreek on diabetic subjects. *The Indian Journal of Nutrition and Dietetics,* **34**:246-251.

CHANDRASHEKHAR, V., BHOOMA, N.N. AND REDDY, S., 1988, Evaluation of malted weaning food based on low cost locally available food. *The Indian Journal of Nutrition and Dietetics,* **25**:37-43.

CHATTERJEE, S., SEN, A., MOOKERJEE, G.C., AND MUKHERJEE, K.C., 1992, The effect of psyllium fibre supplement on lipid profile in-patients with NIDDM. *International Journal of Diabetes in Developing Countries.* **12**:5-8.

*CHATURVEDHI, A., SAROJINI, G., NIRMALA, G., NIRMALAMMA, N. AND SATYANARAYANA, D., 1997, Glycemic index of grain amaranth, wheat and rice in NIDDM subjects. *Plant Foods for Human Nutrition,* **50**(2):171-178.

CHITHRA, K.V. AND BHASKARAN, T., 1989, Glycemic response of diabetics to selected cereals administered in different forms. *The Indian Journal of Nutrition and Dietetics,* **26**:122-128.

COMI, D., BRUGNANI, M. AND GIANNO, A., 1995, Metabolic effects of hypocaloric high carbohydrate/high fibre diet in non-insulin dependent diabetic patients. *European Journal of Clinical Nutrition,* **49**(3):S242-S244.

CRAPO, P.A. AND HENRY, R.R., 1988, Post prandial metabolic responses to the influence of food form. *American Journal of Clinical Nutrition,* **48**:560-564.

DASTUR, K.S. AND PRAKASH, M., 1988, A novel food snack containing wheat bran. *The Indian Journal of Nutrition and Dietetics.* **25**: 29-33.

DEVI, R., BORALKET, M.A. AND HAMDAPURKAR, V.R., 1990, Nutritional improvement of a traditional weaning food mix (sattu). *Food and Nutrition Bulletin,* **12**:324-325.

DHINGRA, M., SRIVASTAVA, S. AND CHAVHAN, G.S., 1992, Nutrient composition and relationship between physio-chemical and sensory qualities of sorghum genotypes. *Journal of Food Science and Technology*, **29**(2):97-100.

DILWARI, J.B., AJITKUMAR, V.K., KHURANA, S., BHATNAGAR, R. AND DAGH R.L., 1987, Effect of legumes on blood sugar in diabetes mellitus. *Indian Journal of Medical Research,* **85**(2):184-187.

EASWARAN, P., KALPNA N. AND MAGESWARI, V.S., 1992, Consumption pattern of five under exploited greens and the therapeutic uses of 'tree lettuce' on selected non-insulin dependent diabetic hypertensives. *The Indian Journal of Nutrition and Dietetics,* **29**:1-6.

EASWARAN, P.P., MAGESWARI, V. AND NARAYANAN, G., 1991, Therapeutic use of Globe artichoke in non-insulin dependent diabetes mellitus and hyper cholesterolemia. *The Indian Journal of Nutrition and Dietetics,* **28**:321-327.

ELLIS, P.R. , KAMALNATHAN, T., DAWOUD, F.M., STRANGE, R.N. AND COULTATE, T.P., 1988, Evaluation of guar biscuits for use in the management of diabetes. *European Journal of Clinical Nutrition,* **42**:425-429

*FONTVIEILLE, A.M., ALZKALLA, S.W., PANFORMIS, A., ACOSTA, M., BORNET, F.R. AND SALMA, G., 1992, The use of low glycemic index foods improve metabolic control of diabetic patients over five weeks. *Diabetic Medicine*, **9**(5): 444-500.

*FRIEDEWALD, W.T., LEVY, R.I. AND FREDRICKSON, D.S., 1972, Calculation of the concentration of low density lipo protein cholesterol in plasma without use of qualitative ultra centrifuge. *Clinical Chemistry,* **18**:495-502.

*FUESSL, H.S., WILLIAM,G., ADRIAN, T.E. AND BLOOM, S.R., 1987, Guar sprinkled on food: effect of glycemic control, plasma lipids and gut hormones in non-insulin dependent diabetic patients. *Diabetic Medicine,***4**:463-468.

GARG,A., 2000, Diabetes and fibre, *New England Journal of Medicine,* **336**(11): 584-587.

GARG, A., GRUNDY, S.M. AND UNGER, R.H., 1992, Comparison of effects of high and low carbohydrate diets on plasma lipo proteins and insulin sensitivity in patients with mild NIDDM diabetes. *Plant Foods for Human Nutrition,* **41**:1278-1285.

*GEETA, G. AND EASWARAN, P.P., 1990 Hypoglycemic effect of millet incorporated breakfast items on selected non-insulin dependent diabetic patients. *The Indian Journal of Nutrition and dietetics,* **27**:316-320.

GHOSHAL, B.M., 1999, Diabetic diet, *Indian Medical Journal,* **93**(7):123-124.

GOPALAN, C., 1994, Nutrition and degenerative diseases in India, *NFI Bulletin,* **15**(1):1-4.

GOPALAN, C., SHASTRI, B.V.R. AND BALASUBRAMANIAN, S.C., 2000, *Nutritive value of Indian Foods.* National Institute of Nutrition, Indian Council of Medical Research, Hyderabad, p 45-85.

*GOPALDAS, T., DESHPANDE, S. AND JOHN, C., 1988, Studies on wheat amylase rich food. *UNO Food and Nutrition Bulletin,* **10**:55-59.

GOPALDAS, T.S, INAMDAR, F. AND PATEL, J., 1992, Malted versus roasted young child mixes; viscosity, storage and acceptability trials. In *the miracle of germinated cereal grain powders*.Daya Publishing House, New Delhi, p.68-82.

GOYLE, AND GUJRAL, S., 1993, Keeping quality of mixes and biscuits from malted and raw wheat, bengal gram with or without green leaf vegetable. *The Indian Journal of Nutrition and Dietetics*,**30**:186-191.

GREGERSEN, S., RAGMUSSEN, O., WINTHER, E.AND HERMANSEN, K., 1990, Water volume and composition time: influence on the glycemic and insulinemic responses in NIDDM subjects. *American Journal of Clinical Nutrition*,**52**(3):515-518.

*GUPTA, C., 1991a, Development and nutritional evaluation of weaning mixtures. *M.H.Sc.Thesis*, University of Agricultural Sciences,, Hissar,

GUPTA, S.P., 1991b, *Statistical Methods*, Sultan Chand and Sons, New Delhi, p.150-201.

HADIMANI, N.A. AND MALLESHI, N.G., 1993, Studies on milling, physico-chemical properties composition and dietary fibre content of millets. *Journal of Food Science and Technology*, **30**(1):17-20.

*HEATON, K.W., 1990, Dietary fibre, *British Medical Journal*, **300**:1479-1480.

HEATON, K.W., MARCUS, S.N., EMMETT, P.M. AND BOLTON, C.H., 1988, Particle size of wheat, maize and oat test meals: effects on plasma glucose and insulin responses and on the rate of starch digestion in vitro. *American Journal of Clinical Nutrition*,**47**(4):675-682.

*HOLLENBECK, C.B., COULSTON, A.M., AND REAVEN, G.M. Comparison of plasma glucose and insulin responses to mixed meals of high, intermediate and low glycemic potential. *Diabetes Care,* **11**(4):323-329.

HULSE.J.H., LAING, E.M. AND PEARSON, O.T., 1980, Minor millets, *Sorghum and the millets: Their composition and nutritive value*. Academic Press London, 444-452.

*IYER,U.M. AND MANI, U.V., 1990, Studies on the effect of curry leaves supplementation, on lipid profile, glycated proteins and amino acids in non-insulin dependent diabetic patients. *Plant Foods for Human Nutrition,* **40**(4):275-282.

JACOBS, B.M., 1979, *The chemical analysis of food and food products,* Devan Strant Co., New Jersey, p.597.

JENKINS, D.J.A., TAYLOR, R.H. AND GOFF, D.V., 1981a, Scope and specificity of a carbose in showing carbohydrate absorption in man. *American Journal of Clinical Nutrition,* **34**:951-954.

JENKINS, D.J.A., WOLEVER, T.M.S., TAYLOR, R.H., BALDWIN, J.M. AND NEWMAN, H.C.,1994, Low glycemic index: Lente carbohydrate and physiological effects of altered food frequency. *American Journal of Clinical Nutrition,* **59**(5):7065-7095.

JENKINS, D.J.A., WOLEVER, T.M.S.. TAYLOR, R.H.,BARKER, H.M. AND FIELDMAN, H., 1980b, Exceptionally low blood glucose response to dried beans; Comparison with other carbohydrates foods. *British Medical Journal,* **ii**:578.

JENKINS, D.J.A., WOLEVER, T.M.S.. TAYLOR, R.H.,BARKER, H.M., FIELDMEN, H., BALDWIN, J.M., BOWKING, A.C., NEWMAN, H.C., JENKINS, A.C. AND GOFF, D.V., 1981b, Glycemic index of foods: A physiological basis for carbohydrate exchange. *American Journal of Clinical Nutrition,* **34**:362-367..

*JENKINS, D.J.A., WOLEVER, T.M.S.. TAYLOR, R.H., REYNOLDS, D., NINEHAM, R. AND HOCKADAY, T.D.R., 1980a, Diabetic glucose control, lipids and trace element on long term feeding of guar. *British Medical Journal,* **I**:1353.

*JONES, D.B., LOUSLEY, S. AND JELFS, R., 1985, Low dose guar improves diabetic control. *Journal of Social Medicine,* **78**:546-548.

JOSHI, S.R., 1998, Rising global burden of diabetes and its complications. *The Indian Practitioner,* **51**(12):933-935.

KAMALA KRISHNAMURTHY, VIJAYARAGHAVAN, K., GOWRINATH SASTRY, J., HANUMANTHA RAO, D., BRAHMA, G.N.V., RADHAIAH, KASHINATH, K., AND VISHNUVARDHAN RAO, K., 1997,Twentyfive years of National Nutrition Monitoring Bureau, NIN, Hyderabad. p. 10,66.

KAPUR, A., 2000, 60 million Indian may be diabetic by 2025, *The Times of India, Bangalore,* 16 November, p.5.

KAPUR, A., SHISHOO, S., AHUJA, M.N.S., SEN, V. AND MANKAME, K., 2000, Role of patient perception in diabetic care, *Medical Times,* **30**:1-5.

*KARLSTROM, B., VESSBY, B. AND ASP, N.G., 1987, Effect of leguminous seeds in a mixed diet in non-insulin dependent diabetic patients. *Diabetic Research,* **5**:199-205.

KARLSTROM, B., VESSBY, B. AND ASP, N.G. AND YETTERFORS, A., 1988, Effects four meals with different kinds of dietary fibre on glucose metabolism in healthy subjects and non-insulin-dependent diabetic patients. *European Journal of Clinical Nutrition*,**42**:519-526.

KAUL, M., 2000, Diabetes- A growing health problem in India, *Health Dialogue*, **23**:8-9.

KAVITA, M.S. AND PREMA, L., 1995, Post prandial blood glucose response to meals containing different carbohydrates in diabetics. *The Indian Journal of Nutrition and Dietetics.***32**:123-127.

KOPPIKAR, M.S., 1988, Diet section:A fish story. *Journal of Diabetic Asociation of India*, ,**28**:35-37.

KRISHNAKUMARI,SAND THAYUMANVAN,B1997, Comparative study of resistant starch from minor millets on intestinal response of blood glucose, serum cholesterol and triglycerides in rats. *Journal of Sciences of Food and Agriculture*, **73**(3): 296-302.

KRISHNASWAMY, 2002, Shed diabetes fears with the cup that cheers, *Deccan Herald*, 14 November, p.2.

KURUP, P.G. AND KRISHNAMURTHY, S., 1992, Glycemic index of selected and food stuffs commonly used in South India. *International Journal of Vitamin and Nutrition Research*, **62**:266-268.

KURUP, P.G. AND KRISHNAMURTHY, S.,1993, The effect of different pulses and banana on the glycemic response and lipemic index in healthy humans. *The Indian Journal of Nutrition and Dietetics.* **30**:206-211.

LAKSHMI, 1991, Dietetic baked products for obesity, diabetes mellitus and hypertensive conditions. *MHSc.Thesis,* University of Agricultural Sciences, Bangalore.

LAKSHMI, K.B. AND VIMALA, V. 1996, Hypoglycemic effect of selected sorghum recipes. *Nutrition Research,* **16**(10):1651-1658.

LINA, S. AND REDDY, P.R., 1984, Development and evaluation of low cost indigenous food mixes for preschoolers of Trichur, Kerala. *The Indian Journal of Nutrition and Dietetics,* **21**(9):330-341.

LINDSAY, A.L., HARDY, S., JARETT, L. AND MARVIN, L.R., 1984, High carbohydrate high fibre diet in children with type I diabetes. *Biochemistry Journal,* **197**:405-412.

LINTAS, C., CAPDELLONI, M., BONMASSAR, L., CLEMENTI, A., TOMA, D.E. AND CECCARELLI, G., 1995, Dietary fibre, resistant starch and *in vitro* starch digestibility of cereal meals, glycemic and insulinaemic responses in NIDDM patients. *European Journal of Clinical Nutrition,* **49**:111-114.

LOCATELLI, F., ALBERTI, D., GRAZIANI, G. AND PONTICEUI, 1991, Prospective, randomized, multi centre trial of effect of protein restriction on progression of chronic renal insufficiency, *Lancet,* **337**:1299-1304.

MACDONALD J., 1996, Preserving the healthful dietary patterns of the traditional Mediterranean and Asian diets. *Carbohydrate Review,* **2**(1):3.

MADAR, Z., ABEL, R., SAMISH, S. AND ARAD, S., 1988, Glucose lowering effect of fenugreek in non-insulin dependant diabetics. *European Journal of Clinical Nutrition,* **42**:51-54.

MADHURA, C.V., PREMAVALLI, K.S. AND ARYA, S.S., 1998, Studies on traditional Indian foods III, Development and storage stability of *rava idli* mix. *Indian Food Packer*, **52**:33-38.

MALLESHI, N.G., 1993, Processing of coarse and minor millets for food and industrial uses. *Proceedings of International Food Convention,* Mysore, p.349-359.

*MANI, U.V., BHATT, S., MEHTA, N.C., PRADHAN, N.C., SHAH, V. AND MANI, I., 1990, Glycemic index of traditional Indian carbohydrate foods. *Journal of the American College of Nutrition,* **9**(6):573-577.

MANI, U.V.,DESIKACHAR, H.S.R., IYER, U.M., MEHTA, N.C. AND MUKHERJEE, N., 1992a, Studies on the effect of supplementation of diabetic mix on serum lipids in NIDDM patients. *National Symposium on recent trends in therapeutic and dietary management of diabetes mellitus*, Baroda, p.53.

MANI, U.V., PARULKAR, J., IYER, V., PRABHU, B., RAI,V., KURIAN, E., MUKHERJEE, N.,MANI, I., MEHTA, K.C., PATEL, K.H. AND DESIKACHAR, H.S.R., 1994, Glycemic index of a cereal pulse mix (diabetic mix) in non-insulin dependent diabetes mellitus (NIDDM) subjects. *International Journal of Food Sciences and Nutrtion,* **45**(2):141-145.

MANI,U.V., PRABHU, B.M., DARNLE, S.S. AND MANI, I., 1993, Glycemic index of some commonly consumed foods in Western India. *Asia Pacific Journal of Clinical Nutrition,* **2**(3):111-114.

MANI, U.V., PRADHAN, S.N., MEHTA, N.C., THAKUR, D.M., IYER, V. AND MANI, I., 1992b, Glycemic index of conventional carbohydrate meals. *British Journal of Nutrition*, **68**(2):445-450.

MCLVOR, M.E., CAMMINGS, C.C. AND MENDALOFF, A. 1985, Long term ingestion of guar gum is not toxic in-patients with NIDDM. *American Journal of Clinical Nutrition*,**41**:891-94.

MILLER, J.B., 1993, The glycemic index of foods. *Asia Pacific Journal of Clinical Nutrition*,**2**:107-110.

MILLER, J. B., 1994, Importance of glycemic index in diabetes. *American Journal of Clinical Nutrition*,**59**:7475-7528.

MUKHERJEE, N., 1992, Studies on the effect of long term supplementation with cereal-pulse mix on the carbohydrate, lipid and imino acid metabolism in NIDDM subjects. *National on Symposium on recent trends in therapeutic and dietary management of diabetes mellitus*, Baroda, p.12-13

NAIK, R. (2000), Impact of dietary intervention / counselling on the nutritional status of senior citizens of rural Karnataka. *Ad-hoc Project Report*, 1997-2000,p.20.

NAIR, D. AND KAPOOR, L., 2000, Comparative efficacy of different parts of fenugreek on glycemic response in diabetic subjects in Anantpur, Andhra Pradesh. *The Indian Journal of Nutrtion and Dietetics*, **37**:76-84.

NEETA, P. 1999,. Standardization and quality evaluation of traditional ready to eat *Madeli* , from selected wheat varieties. *M.H.Sc. Thesis*, University of Agricultural Sciences, Dharwad.

ORCHARD, T., 1999, Diabetes: a time for excitement and concern. *British Medical Journal*, **14**:946-947.

OSILESI, O., TRONT, D.L. AND GLOVER, E.E., 1985, Use of xanthum gum in dietary management of diabetes mellitus. *American Journal of Clinical Nutrition*,**42**:597-603.

*PAGANUS, A., MAENPPA, J. AND AKERBLOM, H.K., 1987, Beneficial effects of palatable guar and guar plus fructose diets in diabetic children. *Acta Pediatrician Journal of Scandinavia*,**76**:76-81.

PANLASIGUI, L.N., PANLILIO, L.M. AND MADRID, J.C., 1995, Glycemic response in normal subjects to five different legumes commonly used in the Philippines. *International Journal of Food Science and Nutrition*,**46**(2):155-160.

PATEL, J.J., 1985, Studies on the effect of wheat bran fibre on imino acid metabolism in non-insulin dependant diabetic patients. *National Symposium on recent trend in the therapeutic and dietary management of diabetes mellitus*, Baroda, p.8.

PATEL, K., 1991, Determination of the glycemic index of selected cereals and cereal green leafy vegetable combination in NIDDM patients. *National Symposium on recent trend in the therapeutic and dietary management of diabetes mellitus* , Baroda p.12.

PATHAK, P. AND SRIVASTAVA, S., 1998, Development and evaluation food formulation based on foxtail millet for their suitability in diabetic diet. *Proceedings of Nutrition Society of India.*NIN, p.51.

PAUL, M. AND VIJAYALAKSHMI, P., 1992, Nutritional evaluation of soy-millet mixes. *The Indian Journal of Nutrition and Dietetics*, **29**:305-311.

PELLETT, P.L. AND YOUNG, V.R., 1980, *Nutritional evaluation of protein foods.* Food and Nutrition Bulletin supplement No.4. The United Nations University, USA, p.27.

*PETERSON, D.B., ELLIS, P.R. AND BAYLIS, J.M., 1987, Low dose guar in a novel food product, improved metabolic control in non-insulin dependent diabetes. *Diabetic Medicine,* **4**:111-115.

POLASA, K., 1993, Spices in health and disease, *Nutrition News,* **14**(4):1-4.

POTDAR, K., MISRA, MISHRA, M. AND YESIKAR, 1994, A study on the effect of soybean, wheat bran and hydrodextrins on the blood sugar and lipid profile in obese diabetics. *The Indian Journal of Nutrition and Dietetics,* **31**:299-302.

POTTY, V.H., 1996, Physico-chemical aspects, physiological functions, nutritional importance and technological significance of dietary fibres. *Journal of Food Science and Technology,* **33**(1):1-18.

PRABHU, B., 1990, Glycemic responses to traditional carbohydrate foods in NIDDM patients. *National Symposium on recent trend in the therapeutic and dietary management of diabetes mellitus,* Baroda, p.11.

PRADHAN, S., 1989, Determination of glycemic index for conventionally used carbohydrate foods in NIDDM patients, *National Symposium on recent trend in the therapeutic and dietary management of diabetes mellitus* ,Baroda, p.11.

PRASANNAPPA G. AND JAGANATTH, K.S. 1985, A nutritious food supplement for feeding programme. *Nutrition Reports International,* **31**:191-196.

PREMAVALLI, K.S. VIDYASAGAR, K. AND ARYA, S.S., 1987, Studies on traditional Indian foods. II development and stability of uppuma mix. *Indian Food Packer,* **41**:23-40.

PREMKUMARI, S., PADMANATHY, C. AND PONNE, S., 1993, Therapeutic effect of herbs, turmeric and amla in the treatment of diabetes mellitus. *Research Highlights,* **3**:161-165.

RAGHAVAN, S. AND MOHAN, V., 1999, Current concepts in diet and diabetes. *The Indian Journal of Nutrition and Dietetics,* **36**:193-197.

RAGHURAM, T.C., 1996, Diet and Diabetes Mellitus, In Textbook of Human Nutrition, Ed. Bamji, M.S., Rao, N.R. and Reddy, V., Oxford and IBH Publishing Co., New Delhi, p.333-345.

RAGHURAM, T.C., PASRICHA, S. AND SHARMA, R.D., 1993, *Diet and Diabetes,* NIN, Hyderabad, p.63.

RAGHURAM, T.C., SHARMA, R.D., PASRICHA, S., MENON, K.K. AND RADHAIAH, G., 1992,. Glycemic index of fenugreek recipes and its relation to dietary fibre. *International Journal of Diabetes in Developing Countries,* **12**:1-4.

RAMCHANDRAN A., 1995, Epidemiology of NIDDM in India. *International Journal of Diabetes in Developing Countries,* **15**(2):42-44.

RAMCHANDRAN, A., 2002, Personalized treatment goals advised for diabetic patients. *Medical Times,* **32**:5.

RAMCHANDRAN, A., JALI, M.V., MOHAN, V., SNEHALATHA, C., AND VISWANTHAN, M., 1988, High prevalence of diabetes in an urban population in South India. *British Medical Journal,* **297**:587-590.

RAO, O.V. AND RAMULU, P., 1998, Dietary fibre. *Nutrition News*, **19**(2):1-4.

RATHNA AND NEELAKANTHAN, 1995, Effect of incorporation of puffed bengal gram dhal on the quality of bread. *Journal of Food Science and Technology,* **32**(2):169-171.

RATHOD, P. AND UDIPI, S.A., 1991, The nutritional quality and acceptability of weaning foods incorporating amaranth . *Food and Nutrition Bulletin,* **13**:59-64.

REDDY,N.S. WAGHMARE, S.Y. AND PANDE, V., 1990 Formulation and evaluation of home made weaning mixes based on local foods. *Food and Nutrition Bulletin,* **12**:138-140.

REMA, S., SADHANA, M. AND SALI, S.S., 1998, Glycemic index of green gram and bengal gram in NIDDM and control subjects. *Proceeding of Nutrition Society of India, NIN,* p.52.

RIFKIND, B.M., 1990,Policies for the prevention of heart disease through cholesterol lowering. *British Medical Bulletin,* **46**:1059-1074.

RIVELLESE, A., RICCARDI, G., GAICCO, A., PACCONI, D., GENOUESE, S. MATTIOLI, P.L. AND MANCINI, M., 1980, Effect of dietary fibre on glucose control and serum lipo proteins in diabetic patients, *Lancet*,**ii**:447.

SADHASHIVAM, S. AND MANICKAM, A., 1992, *Biochemical methods for Agricultural Sciences,* Wilsey Eastern Ltd., New Delhi, p.27-28.

SAIBABA, A. AND RAGHURAM, T.C., 1997, Fenugreek the wonder seed, *Nutrition*, **31**(2):21-25.

SAI PRIYA, M. AND MAGESHWARI, S., 1998, Development of an indigenous fibre rich therapeutic food and its impact of selected diabetes. *The Indian Journal of Nutrition and Dietetics*, **35**:143-148.

SCHOCH, T.J., 1964, Swelling power and solubility of granular starches. *In Carbohydrate Chemistry* Ed. Whistler, R.L., Smith, R.J., BE Miller, N.J. and Wolform, M.I., Academic Press, New York, p.106-108.

*SHAH, M. AND GARG, A., 1996, High fat and high carbohydrate diets and energy balance. *Diabetes Care*,**19**(10):1142-1152.

SHARMA, R.D.,1986, Effect of fenugreek seed and leaf on blood glucose and serum insulin responses in human subjects. *Nutrition Researh*,**6:**1354-1369.

SHARMA, R.D. 1987 Diabetes mellitus and fenugreek seeds, *Nutrition News*,**8**(3):1-4.

SHARMA, R.D. AND RAGHURAM, T.C., 1990, Hypoglycemic effect of fenugreek seeds in non insulin dependent diabetic subjects. *Nutrition Research*, **10**:731-739.

SHARMA, R.D., RAGHURAM, T.C. AND RAO, N.S., 1990, Effect of fenugreek seeds on blood glucose and serum lipid in type I diabetics. *European Journal of Nutrition*, **44**:301-306.

SHRIDEVI,B.S.,2000, Development of Dicoccum wheat based therapeutic bun. *M.H.Sc. Thesis*, University of Agricultural Sciences, Dharwad.

SHUKLA, K., NARAIN, J.P., PURI, P., GUPTA, A., BIJLANI, R.L., MAHAPATRA, S.C. AND KARMARKER, M.G., 1991, Glycemic response to maize, *bajra* and barley. *Indian Journal of Physiology and Pharmacology*, **35**(4):249-254.

SIDDHU, A., SAU, S., BIJLANI, R.L., KARMARKAR, M.G. AND-NAYAR, V., 1989, Modulation of post prandial glycemia and insulinaemia by cellulose in mixed nutrient combination. *British Journal of Nutrition*, **62**:131-137.

SIMPSON, H.C.R., CARTER, R.D., LOUSLEY, S. AND MANN, J.I., 1982, Digestible carbohydrate- An independent effect on diabetic control in type 2 diabetic patients, *Diabetologia*,**23**:235.

SIMPSON, H.C.R. AND MANN, I,M 1985, The dietary management of diabetes. *Advances in Nutrition Research*,**7**:39-69.

*SIMP(SON, R.W., MANN, J.I., EATON, J.AND HOCKANDAY, T.D.R., 1979,High carbohydrate diets and insulin dependent diabetics *British Medical Journal*,**ii:523.**

SINGAMSETTI, P., KURUP, P.G. AND KRISHNAMURTHY, S., 1992, Glucose dialysis retardation index of common vegetables, pulses and cereals. *Nutritional Symposium on recent trend in the therapeutic and dietary management of diabetes mellitus*, Baroda, p.56-66.

SINGH VERMA, N.P., BALASUBRAMANIAH, V.R., CHAKRABARTHY, A.S. AND JAIN, S.K., 1989, Glycemic index of some Indian food and fruits. *Journal of Diabetes Association of India*,**24**(1):26-41.

SLAVIN, J.L. AND DWYER, J.,1994, Whole grain and health. *Nutrition Today*,**29**(4): 6-10.

SOLANKI,S., 1986, Formulation and shelf life study of malted ready to eat mixes Part-I. *The Indian Journal of Nutrition and Dietetics,* **23**:35-40.

SRINIVASAN, K., 1997, Spices as beneficial food adjuncts in the management of diabetes. *Proceedings of the symposium on trends in the management of diabetes mellitus,* Mysore, p.41.-43.

SUBBULAKSHMI, G. AND BOLAKI, L.D., 1991, Glycemic response of diabetics and non-diabetes to different spy supplemented food mixes. *Journal of Diabetes Association of India,* **31**(1):4-7.

SUMA, C., 1998, Development of infant food using grain amaranthus. *M.H.Sc. Thesis,* University of Agricultural Sciences, Dharwad.

SWAMINATHAN, M., 1985, *Advanced text book on Food and Nutrition,* Vol.1 Bappco, Bangalore, p.102.

TOMA, E.D., LINTAS, C., CLEMERTI.A. AND MARCELLI, M., 1988, Soluble and insoluble dietary fibre in diabetic diets. *European Journal of Clinical Nutrition,* **42** (4)*:313- 319.*

TORANGATTI, G., 1995, Glycemic and lipidemic response of composite food in normal and NIDDM patients. *M.H.Sc.Thesis* Univerity of Agricultural Sciences, Dharwad.

TRIPATHY,B.D. AND DATE, W.B.,1975, Partial substitution of wheat flour by other flour for bread preparation Part-I and II. *Indian Food Packer,* **29**(3):62-69.

TROWELL, H.L., 1974, Definition of dietary fibre and hypothesis that it is a protective factor in certain disease. *American Journal of Clinical Nutrtion,* **29**:417-427.

UMA,L.A., 1998, Development and evaluation of Ready-to-Eat (RTE) foods for the elderly. *Ph.D.Thesis*, University of Agricultural Sciences, Dharwad.

*VAALER, S., HANSSEN, K.F. AND AAGENAES, O., 1980, Effect of different kinds of fibre on post prandial blood glucose in insulin dependent diabetics. *Acta Medical Journal of Scandinavia,* **202**(5):389-391.

VAIJAYANTHI, T.V.N., 1988, Acceptability, nutritive value and storage study of wheat germ supplemented ready mixes. *M.H.Sc. Thesis,* University of Agricultural Sciences, Bangalore.

VERMA, N.P.S., MEHTA, S.P., MADHU, S. , MATHER, H.M. AND KEEN, H., 1986, Prevalence of known diabetes in an urban Indian environment the Dariya ganj Diabetes Survey. *British Medical Journal,* **293**:423-424.

VESSBY, B., 1994, Dietary carbohydrates in diabetes. *American Journal of Clinical Nutrition,* **59**(Suppl):742S-746S.

VISWANTHAN, M., 1990, Diet in diabetes mellitus. In, *A hand book of diabetes mellitus*. Ed.Mogre, V.M. Nav Prakash Printing Press, Bombay,p.39-44.

VISWANTHAN AND MOHAN V. (1991) Dietary management of Indian vegetarian diabetes , *NFI* , *Bulletin,***12**(2):1-3.

VISWANTHAN, M., MOHAN, V. AND RAMCHANDRAN, A. 1988, Diabetes in India, *NFI, Bulletin,***9**(4):5-8.

VISHWANATHAN, M., MOHAN, V., REDDY, R.R. AND MOSES, 1981, High carbohydrate high fibre diet in diabetics. *Journal of Diabetes Association*, **21**:90-96.

*WALKER, A.R.P. AND WALKER, B.R., 1984, Glycemic index of South African foods determined in rural blocks- a population at low risk to diabetes. *Human Nutrition and Clinical Nutrition,* **36C**:215-222.

WESTRATE, J.A. AND AMELSCOORT, J.M.M., 1993, Effects of the amylase content of breakfast and lunch on post-prandial variables in male volunteers, *American Journal of Clinical Nutrition,* **58**:180-186.

WILLIAM, F., LAKSHMINARAYANAN, S. AND CHEQU, H., 1993, Effect of some Indian vegetables on the glucose and insulin response in diabetic subjects. *International Journal of Food Science and Nutrition,* **44**:191-196.

WINNIE, C.K.V. AND EASWARAN, P.P.,1988, Glycemic indices of selected south Indian breakfast items. *Indian Journal Nutrition and Diabetics,* **25**(1):1-6.

WOLEVER, T.M.S., 1990a, The glycemic index. Aspects of some vitamins, minerals and enzymes in health and diseases. *World Review of Nutrition and Dietetics,* **62**120-185.

WOLEVER, T.M.S., 1990b, Relation between dietary fibre content and composition in foods and the glycemic index. *American Journal of Clinical Nutrition,* **51**: 72-75.

WOLEVER, T.M.S. AND JENKINS, D.J.A., 1986, The use of glycemic index in predicting the blood glucose response to mixed needs. *American Journal of Clinical Nutrition,* **43**:167-172.

WOLEVER, T.M.S. AND JENKINS, D.J.A., JENKINS, A.L. AND JOSSE, R.G., 1991, The glycemic index: methods – and clinical implication. *American Journal of Clinical Nutrition,* **54**:846-54.

WOLEVER, T.M.S., JENKINS, D.J.A., THOMSON, L.V., WONG, G.S. AND JOSSE, R.G., 1987, Effect of canned beans on the blood glucose response in in-patients with type 2 diabetes. *Human Nutrition and Clinical Nutrition,* **41**(2):135-140.

WOLEVER, T.M.S., JENKINS, D.J.A., VUKSAN, V., JENKINS, V.L., WONG, G.S., AND JOSSE, R.G., 1992, Beneficial effect of low glycemic index diet in over weight NIDDM. subjects. *Diabetes Care,* **15**(4):562-564.

YAJNIK, C.S., 1995a, Early life nutrition and non-insulin dependent diabetes in adult Indians. *Proceedings of the Nutrition Society of India,* **42**:83-92.

YAJNIK, C.S.,1995b, Diabetes and insulin resistance syndrome in Indians, *NFI Bulletin,* **16**(3):1-4.

YENAGI, N.B., HANCHINAL, R.R., PATIL, C.S., KOPPIKAR, V. AND HALGERI, M., 2001, Glycemic and lipidemic response to dicoccum wheat in the diet of diabetic patients. *International Journal of Diabetes in Developing Countires,* **21**:153-154.

* Original not seen

Appendices

Appendix 1. Score card for the evaluation of standardized recipes from diabetic composite mixes

Name of the Recipe :

Name of the Judge :

(Note : Please '✓' mark against appropriate quality characters)

Quality characters	Score	Any Remarks
1. Appearance (Colour)		
Excellent	4	
Good	3	
Acceptable	2	
Poorly acceptable	1	
2. Texture		
Excellent	4	
Good	3	
Acceptable	2	
Poorly acceptable	1	
3. Aroma (Flavour)		
Excellent	4	
Good	3	
Acceptable	2	
Poorly acceptable	1	
4. Taste		
Excellent	4	
Good	3	
Acceptable	2	
Poorly acceptable	1	
5. Over all acceptability (OAA)		
Excellent	4	
Good	3	
Acceptable	2	
Poorly acceptable	1	

Signature of the Judge

Appendix 2. Standardized recipes from diabetic composite mixes (foxtail/ little millet based)

Sl. No.	Particulars	
1	**Rice**	
	Grain mix	40 g
	Salt	to taste
	Water	180-190 ml
	Butter milk	150 ml (optional)
	Procedure:Boil the water, add grain mix and salt, cook till the grains become soft, serve the rice with butter milk (flavoured with cumin powder and coriander leaves).	
	Yield : 1½ katori	
2	***Upma***	
	Grain mix	40 g
	Onion	20 g
	Green chilly	One
	Oil	1 tsp
	Coriander leaves	1 few
	Turmeric	a pinch
	Mustard	¼ tsp
	Lemon	¼ piece
	Water	180-185 ml
	Salt	to taste
	Procedure: Heat oil, crackle the mustard seeds then add chopped onion, green chilly, turmeric powder and water. To the boiling water add salt and grain mix. Cook it and squeeze the lemon. Mix it and serve hot with garnished coriander leaves.	
	Yield : 1½ katori	
3	***Chapathi***	
	Composite flour	40 g
	Salt	to taste
	Water	30-32 ml
	Oil	½ tsp
	Procedure: Add salt to the flour and make soft dough with lukewarm water. Roll the *chapathi* and bake it on hot *tava.* Apply oil after baking it.	
	Yield: 1 (5 ½ " diameter)	

4	***Pancake*** Composite flour — 40 g Sour buttermilk — 20 ml Water — 60 ml – 70 ml Salt — to taste Turmeric — a pinch Oil — 1 tsp Procedure: Mix water, buttermilk and flour together. Add turmeric and salt to batter of *dosa* consistency without any lumps. Keep it for half an hour, then make *pancake* on hot *tava* by smearing little oil. Yield: 2 (5" diameter)
5	***Mudde/Pitla*** Composite flour — 40 g Onion — 15 g Tomato — 15 g Green chilly — One Oil — 1 tsp Turmeric — a pinch Mustard — ½ tsp Salt — to taste Water — 80-85 ml Procedure: Heat the oil, crackle the mustard seeds add chopped onion, green chilly and tomato. Add water, salt and turmeric. When water starts boiling add flour mix and cook. Yield: 1 big katori
6	***Masla Roti*** Composite flour — 40 g Spinach — 20 g Turmeric — a pinch Salt — to taste Water — 28-30 ml Oil — 1 tsp Procedure: Clean and chop spinach or any green leafy vegetable and little water and make a paste. Add flour mix, turmeric and salt to vegetable paste. Make soft dough and roll the *chapathi* on plastic sheet and bake on hot *tava* apply oil. Yield: 2 No (4" diameter)

7	***Thalipatti***	
	Composite flour	40 g
	Onion	20 g
	Salt	to taste
	Turmeric	a pinch
	Water	30-35 ml
	Oil	1 tsp
	Coriander	leaves few
	Procedure: Mix chopped onion, salt, turmeric and flour. Add lukewarm water and knead the dough. Pat it round and bake on hot *tava* with addition of little oil. Yield: 1 (diameter-6", thickness-3 mm)	

Appendix 3. Estimation of peroxide value

Reagents: Solvent mixture of glacial acetic acid and chloroform (2:1)
5% Potassium Iodide solution
N/500 Sodium Thiosulphate solution
1% Starch solution

Procedure: 1. Extract fat by using chloroform and methonol mixture (2:1) by filtration and evaporation

2. Weigh one gram of oil into dry clean boiling tube and add one gram of powdered, KI and 20 ml solvent mixture.

3. Place the tube in boiling water so that the liquid boils within 30 seconds and allow to boil vigorously for not more than 30 seconds.

4. Transfer the contents quickly to a conical flask containing 20 ml of KI solution and collect the washing of the flask

5. Tritrate against N/500 sodium thiosuplhate solution until pale yellow colour disappears.

6. Add 0.5 ml of starch solution, shake vigorously and tritrate carefully till the blue colour disappears.

7. Repeat with the blank

$$\text{Peroxide value (mill equivalent /kg of fat)} = \frac{S \times N \times 1000}{\text{Weight of sample (g)}}$$

S - ml of sodium thiosulphare solution (Test –blank)

N – Normality of sodium thiosulphare solution

Appendix 4. Score card for the evaluation of recipes from stored Diabetic Composite Mixes

Name of the Judge:

(Note: Please '✓' make against appropriate quality characters)

Sl. No.	Quality Charcters	Score	Sample Code					
			A	B	C	D	E	F
1	**Appearance**							
	Highly Acceptable	4						
	Acceptable	3						
	Fairly Acceptable	2						
	Poorly Acceptable	1						
2	**Texture**							
	Highly Acceptable	4						
	Acceptable	3						
	Fairly Acceptable	2						
	Poorly Acceptable	1						
3	**Aroma**							
	Highly Acceptable	4						
	Acceptable	3						
	Fairly Acceptable	2						
	Poorly Acceptable	1						
4	**Taste**							
	Highly Acceptable	4						
	Acceptable	3						
	Fairly Acceptable	2						
	Poorly Acceptable	1						
5	**Overall Acceptability (OAA)**							
	Highly Acceptable	4						
	Acceptable	3						
	Fairly Acceptable	2						
	Poorly Acceptable	1						
6	**Any Remarks**							
	Highly Acceptable	4						
	Acceptable	3						
	Fairly Acceptable	2						
	Poorly Acceptable	1						

Signature of the Judge

Appendix 5. 't' values for the nutrient composition of millet and diabetic composite mixes

Nutrient	Between processing			Grain mix and composite flour		Between Millet Composite mixes
	Foxtail Millet	Little Millet	Between Millets	Foxtail Millet	Little Millet	
Moisture	3.01 NS	0.0002**	0.81 NS	0.46 NS	0.04*	0.00002**
Protein	0.12 NS	0.19NS	1.00 NS	0.02*	0.02*	3.48 NS
Fat	0.008**	0.04*	0.001**	0.01**	0.29 NS	0.21 NS
Ash	0.04*	0.38 NS	0.25 NS	0.25 NS	0.26 NS	0.005**
Crude fibre	0.02*	1.00 NS	6.90 NS	6.90 NS	0.09 NS	0.26 NS
Carbohydrate	0.0002**	0.003**	0.06 NS	0.06 NS	0.005**	0.00003**
Energy	2.23NS	0.0008**	0.50 NS	0.55 NS	0.34 NS	0.0008**

Note: ** - Significant @ 1%
 * - Significant @t 5%
 NS - Not Significant

Appendix 6.Mean moisture content (%) of diabetic composite grain mixes

Days of storage	Foxtail millet			Little millet		
	Al.B.	P.B.	Al.P.	Al.B.	P.B.	Al.P.
0	2.99	3.00	3.00	5.96	5.97	5.96
15	3.23	2.80	2.23	5.83	5.60	5.05
30	3.45	2.85	2.25	5.75	5.53	5.05
45	3.65	2.73	2.05	5.50	5.35	4.93
60	3.95	2.78	2.00	5.40	5.06	4.71
75	3.90	3.13	1.98	5.40	4.96	4.56
90	4.30	3.63	2.35	5.32	4.68	4.45
105	4.95	3.89	2.88	5.35	4.72	4.55
120	4.96	3.90	3.18	5.53	4.38	4.22
135	5.30	3.93	3.30	5.63	4.29	3.55
150	5.40	3.94	3.51	5.98	4.63	3.38
165	5.70	4.28	3.45	6.22	5.65	3.97
180	5.75	4.33	3.48	6.50	5.60	4.05
Mean	4.43	3.48	2.74	5.72	5.11	4.49
Sd±	0.97	0.61	0.61	0.36	0.54	0.69

Source	F value	S.E.M.	CD (0.05%)	CD (0.01%)
Days	117.05**	0.028	0.079	0.102
Days x Mix	270.38**	0.041	0.113	0.149
Days x Container	48.20**	0.050	0.138	0.182
Mix x Container	75.01**	0.020	0.054	0.073
Days x Mix x Container	15.00**	0.070	0.195	0.255

Note: Al.B. - Aluminium box
P.B. - Polyethylene bag
Al.P. - Aluminium pouch

Appendix 7. Mean moisture content (%) of diabetic composite flours

Days of storage	Foxtail millet			Little millet		
	Al.B	P.B	Al.P	Al.B	P.B	Al.P
0	3.25	3.25	3.25	5.95	5.95	5.95
15	3.25	2.88	2.72	5.80	5.57	5.23
30	3.15	2.75	2.45	5.75	5.40	5.05
45	3.25	2.65	2.15	5.68	5.25	4.52
60	3.15	2.63	2.10	5.65	4.83	3.93
75	3.45	2.60	2.10	5.15	4.05	3.60
90	3.75	2.80	1.90	4.45	3.60	3.08
105	3.83	2.80	1.75	4.50	3.23	2.53
120	4.05	2.90	1.95	4.58	3.60	2.13
135	4.37	3.20	1.95	5.15	3.98	2.35
150	4.55	3.20	1.98	5.73	4.35	2.70
165	4.82	3.40	2.03	5.93	4.75	2.95
180	5.05	3.60	2.08	6.05	5.05	3.30
Mean	3.84	2.97	2.19	5.41	4.59	3.64
Sd±	0.67	0.32	0.40	0.58	0.85	1.21

Source	F value	S.E.M.	CD (0.05%)	CD (0.01%)
Days	136.72**	0.039	0.107	0.142
Days x Mix	120.78**	0.055	0.152	0.200
Days x Container	51.37**	0.067	0.185	0.244
Mix x Container	4.90**	0.026	0.072	0.095
Days x Mix x Container	2.08**	0.095	0.263	0.346

Note: Al.B. - Aluminium box
P.B. - Polyethylene bag
Al.P. - Aluminium pouch

Appendix 8.Mean peroxide content (meq/kg of fat) of diabetic composite grain mixes

Days of storage	Foxtail millet			Little millet		
	Al.B	P.B	Al.P	Al.B	P.B	Al.P
0	1.78	1.77	1.77	1.90	1.90	1.90
15	1.85	1.85	1.80	1.95	1.90	1.90
30	1.95	1.73	1.75	1.95	1.75	1.70
45	1.98	1.68	1.60	1.85	1.62	1.57
60	1.95	1.75	1.75	1.80	1.50	1.60
75	2.02	1.73	1.65	1.85	1.20	1.30
90	2.08	1.75	1.58	1.85	1.13	1.10
105	2.35	1.75	1.55	1.88	1.00	0.98
120	2.25	2.00	1.58	1.90	0.95	0.95
135	2.40	1.90	1.60	2.48	1.35	1.45
150	3.15	2.20	1.78	2.48	1.50	1.40
165	3.87	2.50	1.95	2.50	1.58	1.48
180	4.35	2.85	2.00	2.73	1.62	1.58
Mean	2.46	1.96	1.72	2.09	1.46	1.45
Sd±	0.82	0.35	0.14	0.33	0.32	0.31

Source	F value	S.E.M.	CD (0.05%)	CD (0.01%)
Days	81.10**	0.032	0.087	0.116
Days x Mix	35.32**	0.045	0.116	0.164
Days x Container	26.08**	0.055	0.152	0.200
Mix x Container	13.91**	0.021	0.059	0.076
Days x Mix x Container	5.08**	0.077	0.213	0.280

Note: Al.B. - Aluminium box
P.B. - Polyethylene bag
Al.P. - Aluminium pouch

Appendix 9. Mean peroxide content (meq / kg of fat) of diabetic composite flours

Days of storage	Foxtail millet			Little millet		
	Al.B	P.B	Al.P	Al.B	P.B	Al.P
0	0.95	0.95	0.95	0.95	0.95	0.95
15	0.95	0.93	0.85	0.98	0.85	0.73
30	1.05	0.80	0.85	0.97	0.80	0.73
45	1.10	0.77	0.75	0.98	0.75	0.65
60	1.18	0.70	0.70	0.95	0.75	0.63
75	1.38	0.65	0.63	0.93	0.73	0.60
90	1.65	0.60	0.57	0.90	0.75	0.55
105	1.75	0.63	0.60	0.85	0.60	0.53
120	1.90	0.75	0.73	1.20	0.57	0.48
135	1.90	0.83	0.75	1.33	0.50	0.43
150	1.98	0.90	0.80	1.35	0.65	0.77
165	2.05	0.90	0.93	1.45	0.75	0.90
180	2.10	1.05	1.00	1.45	1.00	1.00
Mean	1.53	0.80	0.78	1.10	0.74	0.69
Sd±	0.44	0.14	0.14	0.22	0.14	0.18

Source	F value	S E M	CD (0.05%)	CD (0.01%)
Days	46.73**	0.020	0.055	0.073
Days x Mix	10.10**	0.029	0.088	0.105
Days x Container	27.92**	0.035	0.097	0.127
Mix x Container	104.96**	0.014	0.039	0.051
Days x Mix x Container	6.77**	0.050	0.138	0.182

Note: Al.B. - Aluminium box
P.B. - Polyethylene bag
Al.P. - Aluminium pouch

Appendix 10.Sensory scores of foxtail millet grain mix during storage (rice)

Period of	Aluminium Box					Polyethylene Bag					Aluminium Pouch				
storage	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.
0	3.25	3.50	3.25	3.37	3.50	3.25	3.50	3.25	3.37	3.50	3.25	3.50	3.25	3.37	3.50
15	3.00	3.38	3.25	3.38	3.50	3.13	3.00	3.00	3.38	3.25	3.38	3.50	3.25	3.13	3.25
30	2.88	3.13	3.00	3.00	3.13	2.75	3.00	3.00	3.00	3.00	2.88	3.00	3.00	3.38	3.13
45	2.88	2.88	2.88	2.75	2.75	2.75	2.88	2.88	3.00	3.00	2.88	2.88	2.88	3.00	2.88
60	3.00	2.63	2.63	2.63	2.50	2.75	2.88	2.88	3.00	2.88	2.88	2.88	2.88	3.00	3.00
75	2.88	2.38	2.50	2.63	2.38	3.00	3.00	2.75	3.00	2.88	3.00	3.00	2.75	3.00	3.00
90	2.63	2.50	2.25	2.50	2.00	3.00	3.00	2.63	2.63	2.75	3.00	3.00	2.75	2.88	2.75
105	2.88	2.63	2.25	2.50	2.00	3.00	3.00	2.63	2.63	2.63	3.13	3.00	2.63	2.63	2.75
120	3.00	2.75	2.13	2.37	2.25	3.13	3.25	2.63	2.38	2.63	3.25	3.13	2.50	2.63	2.88
135	2.88	2.88	2.13	2.25	2.25	3.00	3.25	2.63	2.38	2.63	2.88	3.13	2.50	2.63	2.88
150	2.63	2.88	2.13	2.13	2.00	2.88	3.25	2.88	2.38	3.00	3.00	3.13	2.38	2.63	3.00
165	2.50	2.25	1.88	1.50	1.88	2.50	2.38	2.00	2.00	2.88	3.00	2.88	2.00	2.00	2.50
180	2.25	2.50	1.38	1.25	1.38	2.25	2.38	1.50	1.50	1.50	2.38	2.63	1.38	1.38	1.50
r' value	-0.258**	-0.293**	-0.632**	-0.668**	-0.720**	-0.194*	-0.126	-530**	-0.681**	-0.449**	-0.172	-0.181	-0.637**	-0.564	-0.480**

Note : O.A.A. - Over All Acceptability

Appendix 11. Sensory scores of little millet grain mix during storage (rice)

Period of	Aluminium Box					Polyethylene Bag					Aluminium Pouch				
storage	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.
0	3.50	3.25	3.25	3.50	3.50	3.50	3.25	3.25	3.50	3.50	3.50	3.25	3.25	3.50	3.50
15	3.25	3.00	3.25	3.50	3.50	3.38	3.00	3.13	3.25	3.25	3.38	3.13	3.25	3.25	3.38
30	3.13	3.00	2.88	3.13	3.13	3.00	3.00	2.88	3.00	3.13	3.00	3.00	3.00	3.00	3.25
45	3.00	3.00	3.00	3.00	3.25	3.00	3.00	3.00	3.13	3.13	3.00	3.00	3.00	3.13	3.13
60	3.00	2.88	2.75	3.12	3.25	3.00	2.88	3.13	3.00	3.25	3.13	3.00	3.13	3.13	3.38
75	2.88	2.75	2.75	3.13	3.00	2.88	2.88	2.88	3.00	2.75	2.88	3.00	2.88	3.00	3.00
90	2.88	2.50	2.50	2.88	2.75	2.88	2.83	2.75	2.88	3.00	2.88	2.63	2.88	3.00	3.00
105	2.75	2.63	2.50	2.75	2.75	3.00	3.00	2.75	3.00	3.13	3.00	2.88	2.63	3.00	3.13
120	2.75	2.88	2.75	2.63	2.75	3.25	3.13	2.88	3.13	3.25	3.00	2.88	2.63	3.00	3.13
135	3.13	3.00	2.75	2.63	2.88	3.25	3.25	2.88	2.38	3.00	3.25	3.00	2.88	2.25	3.00
150	3.13	3.25	2.75	2.75	3.00	3.38	3.38	3.00	2.88	3.00	3.25	3.50	3.00	2.88	3.00
165	3.13	3.25	2.75	2.75	3.00	3.25	3.25	2.88	2.88	2.88	3.25	3.25	2.88	2.88	2.88
180	3.13	3.25	2.63	2.38	2.75	3.00	3.00	2.75	2.00	2.88	3.13	3.00	2.63	2.50	2.75
r' value	-0.105	0.071	-0.256**	-0.428**	-0.356**	-0.024	0.088	-0.160	-0.345**	-0.213*	-0.040	0.026	-0.256**	-0.394**	-0.321**

Note : O.A.A. - Over All Acceptability

Appendix 12.Sensory scores of foxtail millet composite flour during storage (pancake)

Period of	Aluminium Box					Polyethylene Bag					Aluminium Pouch				
storage	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.
0	3.50	3.50	3.00	3.25	3.50	3.50	3.50	3.00	3.25	3.50	3.50	3.50	3.00	3.25	3.50
15	3.00	3.13	2.75	2.88	2.75	3.50	3.13	3.13	3.00	3.38	3.25	3.25	3.25	3.25	3.00
30	2.88	2.88	2.63	2.75	2.75	2.75	3.00	3.00	2.88	3.13	3.00	3.13	3.00	2.88	3.00
45	3.13	3.13	2.63	2.63	2.88	3.00	3.13	3.00	2.75	2.88	3.13	3.13	3.00	2.75	2.88
60	3.38	3.13	2.63	2.50	2.50	3.25	3.13	3.13	2.63	3.00	3.38	3.25	2.88	2.50	3.00
75	3.25	3.00	2.50	2.50	2.63	3.13	3.25	2.63	2.50	2.75	3.13	3.25	2.88	2.50	3.00
90	3.13	2.75	2.50	2.50	2.50	3.00	3.00	2.50	2.38	2.75	3.00	3.00	2.50	2.50	2.75
105	3.00	2.88	2.50	2.75	2.50	3.00	2.88	2.38	2.38	2.75	2.88	3.13	2.50	2.50	2.75
120	3.00	2.63	2.50	2.50	2.50	3.00	2.63	2.25	2.38	2.50	2.75	2.75	2.25	2.25	2.25
135	3.00	3.00	2.75	2.75	2.75	3.00	3.00	2.75	2.88	2.75	2.75	3.00	2.63	2.63	2.88
150	3.00	3.00	3.00	2.75	3.00	3.13	3.13	3.00	2.88	3.00	3.25	3.13	2.88	3.00	3.00
165	2.75	2.88	2.75	2.25	2.38	3.00	2.88	2.75	2.50	2.75	2.88	2.88	2.75	2.63	2.75
180	2.75	2.75	2.50	1.88	2.38	2.88	2.88	2.75	2.50	2.75	2.88	2.88	2.75	2.63	2.75
r' value	-0.210*	-0.202*	-0.052	-0.337*	-0.264**	-0.178	-0.219*	-0.210*	-0.251*	-0.307*	-0.236*	-0.252**	-0.221*	-0.242*	-0.226*

Note : O.A.A. - Over All Acceptability

Appendix 13.Sensory scores of little millet composite flour during storage (pancake)

Period of	Aluminium Box					Polyethylene Bag					Aluminium Pouch				
storage	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.	Appearance	Texture	Aroma	Taste	O.A.A.
0	3.50	3.63	3.50	3.38	3.50	3.50	3.63	3.50	3.38	3.50	3.50	3.63	3.50	3.38	3.50
15	3.38	3.13	2.88	3.13	3.25	3.13	3.38	3.25	3.13	3.13	3.25	3.50	3.50	3.13	3.25
30	3.13	3.13	2.88	3.38	3.25	3.13	3.13	3.13	3.13	3.28	3.25	3.13	3.50	3.00	3.63
45	3.13	3.25	3.00	3.00	3.25	3.13	3.25	3.25	3.13	3.50	3.13	3.25	3.50	3.13	3.63
60	3.00	3.38	3.13	3.00	3.13	3.25	3.25	3.50	3.13	3.25	3.25	3.25	3.38	3.13	3.13
75	3.38	3.50	3.13	3.00	3.13	3.38	3.63	3.25	3.38	3.25	3.38	3.63	3.25	3.25	3.13
90	3.38	3.50	3.13	3.00	3.13	3.38	3.50	3.00	3.00	3.25	3.38	3.50	3.00	3.00	3.13
105	3.50	3.50	3.00	3.00	3.13	3.63	3.50	2.88	2.88	3.25	3.50	3.50	2.88	2.88	3.25
120	3.25	3.25	3.00	2.50	3.13	3.25	3.38	2.88	2.88	3.25	3.38	3.50	2.88	2.88	3.25
135	3.25	3.25	3.00	2.75	3.13	3.25	3.50	3.00	3.13	3.13	3.50	3.00	3.00	3.13	3.25
150	3.38	3.00	3.00	3.00	3.00	3.50	3.25	3.00	3.25	3.00	3.50	3.25	3.00	3.13	3.25
165	2.88	2.88	3.00	2.75	2.88	2.75	3.00	2.88	2.88	3.00	2.63	3.00	2.88	2.88	2.88
180	2.50	2.88	2.88	2.75	2.88	2.50	3.00	2.88	2.88	3.00	2.50	3.00	2.88	2.88	3.00
r' value	-0.195*	-0.223*	-0.105*	-0.284*	-0.259*	-0.183	-0.159	-0.269**	-0.202*	-0.248*	-0.207*	-0.172	-0.389**	-0.184	-0.275**

Note : O.A.A. - Over All Acceptability

Appendix 14. Blood glucose response of diabetic composite foods as compared to glucose in non-diabetics

Type	Volunteers	Glucose values (mg / dl)			GI
		FBS	1hr PP	2hr PP	
Glucose	1	104	179	109	77.50
	2	100	159	127	72.50
	3	101	168	120	76.50
	4	99	160	100	61.50
	5	119	178	127	63.00
	6	104	174	106	71.00
	Mean	104.50	169.67	114.83	70.33
Foxtail Millet					
Grain (Rice)	1	86	130	94	60.65
	2	96	133	112	63.45
	3	104	149	105	59.47
	4	99	131	101	53.65
	5	109	140	112	51.58
	6	89	120	110	58.45
	Mean	97.17	133.83	105.67	57.88
Grain mix (Rice)	1	100	139	107	54.86
	2	106	148	108	59.31
	3	104	148	105	58.16
	4	104	129	108	43.99
	5	109	140	112	51.58
	6	89	120	110	58.45
	Mean	102.00	137.33	108.33	54.39
Little Millet					
Grain (Rice)	1	100	139	107	54.86
	2	93	140	98	68.27
	3	99	138	123	67.32
	4	94	126	106	65.04
	5	105	137	109	53.96
	6	84	123	96	62.07
	Mean	95.83	133.83	106.50	61.92
Grains (Rice)	1	99	137	112	57.74
	2	96	133	112	63.44
	3	106	146	124	64.05
	4	94	128	106	65.04
	5	108	140	109	51.58
	6	106	142	107	50.70
	Mean	101.50	137.67	111.67	58.76
Composite Flour					
Foxtail Millet	1	103	148	119	68.39
	2	84	123	96	62.07
	3	109	150	120	60.73
	4	96	130	100	58.53
	5	108	149	110	66.66
	6	105	148	115	61.97
	Mean	100.83	141.33	110.00	63.06
Liittle Millet	1	86	130	94	60.65
	2	94	140	98	66.21
	3	100	138	123	64.70
	4	100	130	121	65.85
	5	96	140	96	69.84
	6	100	138	106	57.75
	Mean	96.00	136.00	106.33	64.17

Note: FBS - Fasting blood glocuse value
PP - Post prandial blood glucose value
GI - Glycemic Index

Appendix 15. 't' values for capillary blood glucose response after feeding of diabetic mixes (4 weeks)

Sl. No.	Type	N	Between volunteers for composite food		Between Mixes
			Foxtail Millet	Little Millet	
I	Experimental (Diabetics x Non-Diabetics)	15	0.007**	0.01 NS	0.11 NS
II	Control (Diabetics x Non-Diabetics)	12	0.009**	0.02*	0.39 NS
III	Diabetics (Experimental x Control)	15	0.00006**	0.006**	0.045*
IV	Non-Diabetics (Experimental x Control)	12	0.0002**	0.0002**	0.17 NS

Note : * - Significant @ 5%
** - Significant @ 1%
NS - Not Significant

Appendix 16. 't' values for plasma constituents after feeding of diabetic mixes (4 weeks)

Type	N	Foxtail Millet Mix				Little Millet Mix			
		Glucose	Triglycerides	Total Cholesterol	HDL Cholesterol	Glucose	Triglycerides	Total Cholesterol	HDL Cholesterol
1. Experimental (Diabetic x Non-diabetic)	15	0.27 NS	0.34 NS	0.25 NS	0.48 NS	0.04*	0.09 NS	0.26 NS	0.17 NS
2. Control (Diabetic x Non-diabetic)	12	0.44 NS	0.36 NS	0.51 NS	0.42 NS	0.49 NS	0.24 NS	0.17 NS	0.17 NS
3. Diabetics (Experiemtnal x Control)	15	0.0005**	0.45 NS	0.16 NS	0.12 NS	0.0001**	0.34 NS	0.18 NS	0.18 NS
4. Non-diabetics (Experimental x Control)	12	0.0601**	0.26 NS	0.49 NS	0.33 NS	0.005**	0.05*	0.31 NS	0.16 NS

Between the mixes

1. Experimental					
a.Diabetics	9	0.24 NS	0.42 NS	0.31 NS	0.17 NS
b.Non-diabetics	6	0.02*	0.13 NS	0.28 NS	0.39 NS
Combined	15	0.03*	0.29 NS	0.44 NS	0.12 NS
2. Control	12	0.28 NS	0.49 NS	0.15 NS	0.45 NS
3. Diabetics	15	0.31 NS	0.34 NS	0.29 NS	0.16 NS
4. Non-diabetics	12	0.0009**	0.18 NS	0.23 NS	0.31 NS

Note : * - Significant @ 5%
** - Significant @ 1%
NS - Not Significant

Appendix 17. 't' values for plasma lipid ratios after feeding of diabetic mixes (4 weeks)

Type	N	Foxtail Millet Mix		Little Millet Mix	
		TC:HDL	LDL:HDL	TC:HDL	LDL:HDL
1. Experimental (Diabetic x Non-diabetic)	15	0.27 NS	0.12 NS	0.49 NS	0.45 NS
2. Control (Diabetic x Non-diabetic)	12	0.37 NS	0.35 NS	0.03*	0.06 NS
3. Diabetics (Experiemtnal x Control)	15	0.07 NS	0.007**	0.06 NS	0.04*
4. Non-diabetics (Experimental x Control)	12	0.36 NS	0.38 NS	0.43 NS	0.42 NS

Between the mixes

1. Experimental	15	0.24 NS	0.43 NS
2. Control	12	0.41 NS	0.43 NS
3. Diabetics	15	0.04*	0.05*
4. Non-diabetics	12	0.13 NS	0.36 NS

Note : * - Significant @ 5%
** - Significant @ 1%
NS - Not Significant

DEVELOPMENT AND EVALUATION OF MILLET BASED COMPOSITE FOOD FOR DIABETICS

SUNANDA K. ITAGI 2003 RAMA K. NAIK
MAJOR ADVISOR

ABSTRACT

The study was undertaken to develop composite diabetic mix from regional millets (foxtail and little 80%) along with wheat (10%) and black gram dal (10%) and spice mixture (8%). The nutrient composition of the millets and mixes was statistically not significant except for fat and mineral content respectively. These millets increased four times it volume after cooking thus providing 19-22 per cent of dietary fibre. The traditional products prepared from developed diabetic mix were acceptable on basis of sensory attributes.

A significant increase in moisture and peroxide value of diabetic mixes stored in aluminium box compared to sealed packages (polyethylene bag and aluminium pouch) were evident during six months. There was no apparent change ins sensory qualities of the products prepared from stored mix of all the three packages, highlights the best suitability of polyethylene bag from economical and convenience point of view.

The lowest glycemic index was noted for foxtail millet grain mix (54.39) followed by foxtail millet (57.91) little millet grain mix (58.75), little millet (61.98), foxtail and little millet composite flour (63.07 and 64.51, respectively) in six non diabetics when tested against 50 g carbohydrate load.

Intervention study of four weeks (80 g mix/day) revealed that the blood glucose in six non-diabetics and nine diabetics reduced to 17 and 19 and HDL cholesterol increased to 2 and 6 per cent respectively. Besides, intervention with foxtail millet mix exhibited considerable reduction in *triglycerides* without apparent changes in total cholesterol values in experimental volunteers as compared to little millet mix. In feeding trial (4 weeks), 60 per cent of diabetics switched over to normal ratio at TC:HDL and LDL:HDL cholesterol along with maintenance of body weight. Thus therapeutically potential diabetic mix was *popularizdizol* through print media exhibitions, melas, displays and seminars in many diabetic centres, health clubs and clinics reading the target sales of four quintals mix within a year.