NUTRIENT ANALYSIS OF SELECTED VARIETIES OF RAGI (FINGER MILLET) AND GLYCEMIC INDEX OF RAGI RECIPES INCORPORATED WITH CURRY LEAF POWDER

BY

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THESIS SUBMITTED TO THE PROFESSOR JAYASHANKAR TELANGANA STATE AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE

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DECLARATION

I, **K.SANTHI SIRISHA**, hereby declare that the thesis entitled **"NUTRIENT ANALYSIS OF SELECTED RAGI (FINGER MILLET) VARIETIES AND GLYCEMIC INDEX OF RAGI RECIPES INCORPORATED WITH CURRY LEAF POWDER",** submitted to **Professor Jayashankar Telangana State Agricultural University** for the degree of **Master of Science in Home Science** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

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CERTIFICATE

Ms. K. SANTHI SIRISHA has satisfactorily prosecuted the course of research and that thesis entitled **"NUTRIENT ANALYSIS OF SELECTED RAGI (FINGER MILLET) VARIETIES AND GLYCEMIC INDEX OF RAGI RECIPES INCORPORATED WITH CURRY LEAF POWDER"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

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This is to certify that the thesis entitled "**NUTRIENT ANALYSIS OF SELECTED RAGI (FINGER MILLET) VARIETIES AND GLYCEMIC INDEX OF RAGI RECIPES INCORPORATED WITH CURRY LEAF POWDER**" submitted in partial fulfillment of the requirements for the degree of '**MASTER OF SCIENCE IN HOME SCIENCE**' of the **Professor Jayashankar Telangana State Agricultural University, Hyderabad** is a record of the bonafide original research work carried out by **Ms. K. SANTHI SIRISHA** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Percent
<	:	Less than sign
>	:	More than sign
±	:	Plus – Minus symbol
°C	:	Degree Celsius
G	:	Gram
mg	:	Milligram
kg	:	Kilogram
ng	:	Nanogram
Ml	:	Milliliter
AAS	:	Atomic Absorption Spectrophotometer
ANOVA	:	Analysis of Variance
AOAC	:	Association of Official Analytical Chemists
et al.	:	and other people
FAO	:	Food and Agriculture Organization
Fe	:	Iron
HCl	:	Hydrochloric Acid
H_2SO_4	:	Sulphuric Acid
i.e.	:	Means
IDF	:	Indian Dietetic Federation
NaOH	:	Sodium Hydroxide
P^H	:	Log of H^+ ion concentration
SD	:	Standard Deviation
TDF	:	Total Dietary Fiber
viz.,	:	Namely
WHO	:	World Health Organization
GI	:	Glycemic Index
GL	:	Glycemic Load
CHO	:	Carbohydrate
AUC	:	Area Under Curve
IAUC	:	Increamental Area Under Curve
WRF	:	White Ragi Flour
BRF	:	Brown Ragi Roti
WRCF	:	White Ragi Flour incorporated with Curry leaf powder
BRCF	:	White Ragi Flour incorporated with Curry leaf powder
BRR	:	Brown Ragi Roti
WRR	:	White Ragi Roti
BRCR	:	Brown Ragi Roti incorporated with Curry leaf powder
WRCR	:	White Ragi Roti incorporated with Curry leaf

		powder
NIDDM	:	Non Insulin Dependent Diabetes Milletus
Mmol/L	:	Millimoles per litre
AR	:	Analytical Reagent
IHA	:	Indian Heart Hssociation
IDF	:	Insoluble Dietary Fibre
SDF	:	Soluble Dietary Fibre
NSP	:	Non Starch Polysaccharides
SD	:	Standard Deviation
RDS	:	Rapidly Digestible Starch
SDS	:	Slowly Digestible Starch
RS	:	Resistant Starch
PPG	:	Peak Plasma Glucose
MIPG	:	Maximum Increase in Plasma Glucose
2HPPG	:	2- Hour Postpandrial Plasma Glucose Level
FAO	:	Food and Agriculture Organization
B.P.	:	Boiling Point
N	:	Normality
dl	:	Deciliter

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ABSTRACT

The increasing trend of epidemiological transition is taking place in most of the States in India with decline in communicable diseases and increase in chronic non-communicable diseases. In India, more than half of patients have poor glycemic control and have vascular complications. Dietary management of diabetes involves the reduction of postprandial hyperglycemia and good glycemic control. Currently there is an urgent need to develop novel therapeutic foods for diabetics without the development and progression of the disease leading to complications.

Utilization of whole grain cereals/millets like ragi in food formulations is increasing worldwide since it is rich in polyphenols and dietary fibre which offer good glycemic control. Curry leaf widely used spice and condiment in Indian cookery which is known for its hypoglycemic activity.

The study was undertaken to assess the nutrient composition of two ragi varieties viz. SRICHAITHANYA (brown ragi) and HIMAJA (white ragi) with and without addition of curry leaf powder (CLP). Brown and white ragi were procured from Agricultural Research Station, Vizianagaram, Andhra Pradesh and processed into flours to which 5g CLP was incorporated so as to give 50g carbohydrate. Nutrient analysis was done for these flours.

Nutrient analysis of ragi flours revealed that the moisture content ranged between 9.0 -10.8%. Among the ragi flours studied, white ragi flour (WRF) had highest moisture content (10.8 %) followed by white ragi flour incorporated with CLP (WRCF) with 9.9%, brown ragi flour (BRF) with 9.6% and brown ragi flour incorporated with CLP (BRCF) with 9.0%.White ragi is superior to the brown ragi with respect to ash content. Ash content of WRCF was higher among all the ragi flours with 3.0 g/100g, followed by BRCF with 2.9 g/100g, WRF with 2.6 g/100g and BRF with 2.3 g/100g.

The increasing order of protein content was BRF (7.7 g/100g) > BRCF (7.9 g/100g) > WRF (10.3 g/100g) > WRCF (10.4 g/100g). White ragi had higher protein content than brown ragi. Analysis of fat content revealed that WRCF had highest fat with 1.7 g/100g among four ragi flours studied followed by WRF with 1.5 g/100g, BRCF with 1.4 g/100g and the least in BRF with 1.3 g/100g. White ragi is superior to brown ragi with respect to the fat content.

Incorporation of CLP increased the mineral content i.e. iron and calcium. Estimated values of iron content was maximum in WRCF (10.6 mg/100g) followed by WRF, BRCF and BRF with 10.1 mg/100g, 4.2 mg/100g, 3.5 mg/100g respectively. Iron content increased significantly ($p<0.05$) in the CLP added ragi flour than flours without CLP of both the varieties. Results showed that maximum calcium content was in WRCF (505 mg/100g), followed by BRCF (455 mg/100g), WRF (403 mg/100g) and the least amount was found in BRF (354 mg/100g). Total dietary fibre content of ragi

flours ranged from 10.2-12.2 g/100g. Among all the ragi flours BRCF had maximum dietary fibre of 14.4 g/100g followed by BRF (12.2 g/100g), WRCF (11.8 g/100g) and the least was in WRF (10.2 g/100g). Dietary fibre content in BRF was significantly higher compared to WRF ($p<0.05$). Addition of CLP resulted in increase of dietary fibre in BRF and WRF by nearly 2%.

Using these flours, ragi rotis (unleavened bread) were standardized and prepared, subjected to evaluation by semi-trained sensory panel using 5 point hedonic scale. Sensory evaluation was done for all the four variations i.e. brown ragi roti (BRR),brown ragi roti incorporated with CLP (BRCR), white ragi roti (WRR) and white ragi roti incorporated with CLP (WRCR) to identify the most acceptable roti from each of the varieties.

Results of sensory evaluation of ragi rotis revealed that plain ragi rotis of both the varieties were rated highest scores for colour, flavor, texture, taste and overall acceptability compared to CLP incorporated ragi rotis ($p<0.05$). BRR was accepted and scored best among all the variations.

Glycemic response of rotis made of two varieties of ragi with and without addition of curry leaf powder was studied. Ten healthy young adults in the age group of 22-24 years were selected to estimate glycemic index (GI) of test food ragi roti/CLP incorporated ragi roti of both the varieties. Blood glucose levels were measured using "One Touch Ultra Soft" Glucometer by finger prick method.

The results indicated that the GI of ragi rotis ranged from 56.2 to 67.3. The GI of BRCR was considerably lower than the remaining three rotis ($p<0.05$). Highest GI was observed for WRR with 67.3 followed by WRCR with 62.5. Brown ragi roti had a GI Value of 61.0 and the least was for BRCR with 56.2. All the four varieties of rotis had intermediate GI.

The present study revealed that the nutritional quality of white ragi in terms of protein, fat, ash, iron, calcium was found better than brown ragi. From this study it is evident that ragi roti/CLP incorporated ragi roti of both the varieties had intermediate glycemic index making ragi roti a good breakfast for diabetics in general. Though white ragi is slightly higher in GI than brown ragi, addition of CLP has nearly equalized the GI of brown ragi. Curry leaf powder can be incorporated in the traditional breakfast items to enhance nutritional composition while at the same time help in reducing the GI value.

Chapter I

INTRODUCTION

The increasing trend of epidemiological transition is taking place in most of the states in India with decline in communicable diseases and increase in chronic non-communicable diseases that has resulted in more than 50 per cent of total deaths in India (Thankappan, 2010).

The prevalence of diabetes one of the non communicable diseases is rapidly rising all over the world at an alarming rate (Huizinga and Rothaman, 2006), reason being population growth, ageing, urbanization and an increase in obesity and decreased physical activity. Unlike in the West, where older persons are most affected, diabetes in Asian countries is disproportionately high in young to middle–aged adults. This could have long- lasting adverse effects on the nation's health and economy, especially for developing countries. The International Diabetes Federation (IDF) estimates the total number of people with diabetes to be around 382 million in 2013, expected to rise to 592 million by 2035 (Guariguata *et al.* 2014).

India is the diabetes capital of the world with a projected number of 109 million diabetics by 2035 in India alone (IHA). India has about 62 million people with diabetes and 77 million people with prediabetes. More than 7% of India's population is diabetic. More recent studies (2015) indicate that the prevalence of diabetes to be 22.2 per 1000 person-years and prediabetes to be 29.5 per 1000 person-years, about 58.9% of prediabetics developed diabetes mellitus (Anjana *et al*. 2015).

Dietary modification, weight control and regular exercise are the main approaches in the management of diabetes, diet being the cornerstone. There is a considerable evidence to show that better control of blood sugar prevents or delays the debilitating complications of diabetes (Skyler, 1979). Consumption of foods with high glycemic index (GI) or glycemic load (GL) is hypothesized to contribute to insulin resistance, which is associated with increased risk of diabetes mellitus, obesity, cardiovascular disease, and some cancers. The risk of developing long term complications can be dramatically reduced with appropriate glycemic control, food ingredients that can attenuate postprandial glucose in persons with diabetes would be useful.

Glycemic Index is a classification of the blood glucose raising potential of the carbohydrate portion of the foods referred to as the incremental blood glucose area under the curve following a test food, expressed as the percentage of the corresponding area following a carbohydrate equivalent load of reference food (Bjorck *et al*. 2000). The postprandial glucose and insulin levels are physiological responses which are directly related with the prevalence of chronic non-transmissible diseases, such as obesity and cardiovascular diseases.

Finger millet (*Eleusine coracana* L.) also known as African millet and commonly called “ragi” in India. The word ragi originated from a Sanskrit word “raga” meaning red. In India, it is commonly grown for human consumption and also in many other arid and semi-arid areas of the world. Ragi is a good source of carbohydrate, protein, dietary fibre and minerals, and an important staple food for people under low socio-economic group (Sripriya *et al*. 1997) and those suffering from metabolic disorders like diabetes and obesity (Mathanghi and Sudha 2012). It is important because of its excellent storage properties and nutritive value (Shashi *et al*. 2007).

In recent years, ragi has gained importance, because of its nutritional strength in terms of dietary and functional fiber, starch pattern, as well as high calcium and iron contents. Ragi has high proportion of unavailable carbohydrates which slow the release of glucose and thereby becomes responsible for low glycemic index. Apart from high fibre ragi is also rich in polyphenols. The beneficial effect of phenolics is due to partial inhibition of amylase and α-glucosidase during enzymatic hydrolysis of complex carbohydrates and delay the absorption of glucose, which ultimately controls the postprandial blood glucose levels (Shobana *et al*. 2009).

In India, it is consumed generally by a small segment of population in the form of dumpling, porridge and roti. Ragi also has medicinal attributes used by diverse communities for making special foods for diabetics, gluten-free food for people suffering from celiac disease and weaning foods for infants. Starch fractions in ragi are slow in digestion and absorption hence favorable in the diet pattern for metabolic disorders such as diabetes, hypertension, and obesity.

Certain spices used commonly in Indian cooking have been mentioned to possess antidiabetic properties. *Murraya koenigii* is known as ‘Curry Leaf’ is widely used as a spice and condiment in India and other tropical countries. Ayurveda mentions its use in the treatment for diabetics. (Satyavati *et al*.1987). Various parts of curry leaf have been used in traditional or folk medicine for the treatment of rheumatism, traumatic injury and snake bite and it has been reported to have anti-diabetic, antioxidant, antimicrobial, anti-inflammatory, hepatoprotective and anti-hypercholesterolemic and anti-dysenteric activities.

The hypoglycemic activity of *Murraya koenigii* (curry leaf) was attributed to increased glycogenesis and decreased glycogenolysis and gluconeogenesis (Khan *et al*.,

1995) or due to induction of receptors and/or expression of genes required for insulin synthesis and release in the regenerated-cells of pancreas.

Several authors evaluated the hypoglycemic effect of ragi recipes and curry leaf powder and presented their benefits. In the present study a combination of both curry leaf and ragi is used to achieve additional benefits. In view of the above consideration the present study "Nutrient analysis of selected Ragi (Finger millet) varieties and glycemic index of ragi recipes incorporated with curry leaf powder" was undertaken. The following objectives will be attained to carry out the research work.

Objectives

1. To analyse the nutrient composition of two varieties of ragi
2. To study the organoleptic properties of ragi recipes with and without incorporation of curry leaf powder
3. To assess the glycemic index of ragi recipes with and without incorporation of curry leaf powder

Chapter II

REVIEW OF LITERATURE

This chapter includes literature which supports the work of the present study "Nutrient analysis of selected ragi (finger millet) varieties and glycemic index of ragi recipes incorporated with curry leaf powder" to carry out the research work.

The literature collected is classified as follows.

2.1 Nutrient composition of ragi

2.2 Impact of ragi on health

2.2.1 Glycemic activity

2.2.2 Therapeutic activity

2.3 Nutrient composition of curry leaf

2.4 Impact of curry leaf on health

2.4.1 Glycemic activity

2.4.2 Therapeutic activity

2.5 Glycemic index (GI)

2.5.1 Factors affecting glycemic index (GI)

2.5.4 Current status of glycemic index and objections

Finger millet (*Eleusine coracana*), also known as ragi is an important millet grown extensively in various regions of India and Africa. It is a staple food for a large segment of the population in these countries especially for people below low socio-economic group (Sripriya, *et al.* 1997) and those suffering from metabolic disorders like diabetes and obesity (Mathanghi and Sudha 2012).

Ragi crop is ranked fourth globally in importance among the millets, after sorghum, pearl millet, and foxtail millet (Guptha *et al*., 2012). It is cultivated in more than 25 countries, mainly in Africa and Asia. In India, it ranks sixth in production after wheat, rice, maize, sorghum and bajra. Ragi is primarily grown in the States of Karnataka, Andhra Pradesh, Odisha, and Tamil Nadu (Dass *et al*., 2013). Ragi production data for the last five years in India is given in Table 2.1.

Table 2.1 Production data for ragi in India (2009/2010–2013/2014).

Year	Area under cultivation	Production ('000 tones)	Average yield (kg ha^{-1})	References

	('000 ha)			
2009/2010	1268	1889	1489	Department of Agriculture and Cooperation, 2013.
2010/2011	1286	2194	1705	Department of Agriculture and Cooperation, 2013.
2011/2012	1176	1929	1641	Department of Agriculture and Cooperation, 2013.
2012/2013	1179	1785	1514	Department of agriculture and cooperation, 2013.
2013/2014	1138	1688	1483	Department of Agriculture and Cooperation, 2014.

Source: Raizanda, M.N and Thilakarathna, M.S. (2015)

Utilization of wholegrain cereals and millets in food formulations is increasing worldwide, since they are rich sources of phytochemicals and dietary fibre which offer several health benefits (Jones and Engleson, 2010). Nutritionally, importance of ragi is well recognized because of its high content of calcium (0.38%), dietary fibre (18%) and phenolic compounds (0.3–3%).

Certain spices used commonly in Indian cooking have been mentioned to possess antidiabetic properties. *Murraya koenigii* is known as 'Curry Leaf' is widely used as a spice and condiment in India and other tropical countries. Ayurveda mentions its use in treatment of diabetics (Satyavati *et al*. 1987).

The prevalence and exponential increase of diabetes across the globe has intrigued the scientific community to look into new ways to manage diabetes. Glycemic index is a useful tool in showing the impact of foods on blood glucose response. Studies indicated that substitution of high GI with low GI carbohydrates can reduce the risk of type-2 diabetes. This in turn will improve the glycemic control and reduce hypoglycemic episodes among those treated with insulin (Zakir *et al*. 2008).

2.1 Nutrient composition of ragi

The use of ragi diet is known for high sustaining power and is usually recommended for diabetics. Epidemiologically lower incidence of diabetes has been reported in the millet consuming population.

Ragi grain is nearly globular in shape and is very small in size (1.0 to 1.5 mm in diameter). Brown is the predominant grain color in ragi although a few varieties have white seeds.

Nutritionally, ragi is good source of nutrients especially of calcium, other minerals and fibre. Total carbohydrate content of ragi has been reported to be in the range of 72 to 79.5% (Pore and Magar, 1979; Bhatt *et al.* 2003). The carbohydrates include starch as the main constituent being 59.4 to 70.2% (Mittal, 2002).

The high fibre content of ragi contributes to the hypoglycemic effect. Ragi containing high complex carbohydrates are slowly digested and absorbed thus bring reduction in postprandial blood glucose level. Chethan and Malleshi (2007) reported that ragi grain contained 15.7 % of insoluble dietary fibre and 1.4% of soluble dietary fibre, while Shobana and Malleshi (2007) reported 22.0% total dietary fibre, 19.7% insoluble dietary fibre and 2.5% soluble dietary fibre. The principal potential health benefits for insoluble dietary fibre related to gastrointestinal transit and constipation. Fibre also has potential protective effects against colon cancer. Water soluble dietary fibre is considered to be important in preventive nutrition related to hyperlipoproteinemia and cardiovascular diseases. However, dietary fibre and some associated substances, such as phytate, have in *vitro* mineral binding capacities and may thus alter mineral availability (David and Idamarie, 2003).

Singh and Srivastava (2006) analyzed 16 ragi varieties and found that protein content ranged from 4.88 to 15.58% with a mean value of 9.72% while Shemelis *et al*. (2009) reported that protein content of local and improved varieties of ragi varieties in Ethiopia varied from 6.26 to 10.5%. Brown and red seeded cultivars generally have protein levels in the lower range, whereas protein levels in the white seeded cultivars and wild subspecies *Africana* are at the higher end of spectrum (10 to 14%) (Dida and Devos, 2006).

The crude fat content in ragi has been reported in range of 1.3 to 1.8% (Bhatt *et al*. 2003) but Antony *et al*. (1996) have reported a higher percentage (2.1%) of crude fat. The fat content in brown and white varieties of ragi ranged from 1.2 to 1.4% (Seetharam, 2001). Ragi though low in fat content, is high in polyunsaturated fatty acids (Antony *et al*. 1996).

Total ash content is higher in ragi than in commonly consumed cereal grains. Most of the studies have shown that the amount of total ash was in the range of 2.1 to 2.7% (Malleshi and Desikachar, 1986; Lupien, 1990). Singh and Srivastava (2006) showed that the total ash content of the sixteen varieties of ragi ranged from 1.47 to

2.58% with a mean value of 2.11%. Ragi is rich in calcium and iron. Calcium content of 36 genotypes of ragi ranged from 162 to 487 mg% with mean value of 320.8 mg% (Vadivoo *et al*. 1998). The average calcium content (329 mg%) in white varieties was considerably higher than the brown (296 mg%) varieties (Seetharam, 2001). Bhatt *et al*. (2003) reported the calcium content of ragi as 344 mg%.

The iron content of ragi ranged from 3.3 to 14.8 mg% (Babu *et al*. 1987). Singh and Srivastava (2006) reported that the iron content of 16 ragi varieties ranged from 3.61 mg/100g to 5.42 mg/100g with a mean value of 4.40 mg/100g. The zinc content of the sixteen varieties of ragi ranged from 0.92 to 2.55 mg with a mean value of 1.34 mg %. The phosphorous content ranged from 130 to 295 mg with a mean value of 180.43 mg.

Among millets, ragi has been reported to contain higher amounts of tannins ranging from 0.04 to 3.74% of catechin equivalents (Antony and Chandra, 1999). Rao and Prabhavati (1982) have reported that brown ragi contained 360 mg/100g tannins. Soaking, roasting, boiling, germination and fermentation have been found to reduce the tannin content.

Phytate content in ragi has been found to be in the range of 0.679 to 0.693 g/100mg (Antony and Chandra, 1999). Phytates which were earlier considered as the anti-nutrients, they are gaining importance due to their antidiabetic, anticancer, antioxidant effects now.

Table 2.2. Nutrient composition of ragi: (100 g %)

Nutrient	**Amount**
Protein	7.3 (%)
Fat	1.3 (%)
Crude fibre	3.6 (%)
Ash	3.0 (%)
Starch	59 (%)
Total dietary fibre	19.1 (%)
Total phenol	102 (mg/100 gm)

Source**:** Saldivar *et al*. (2003)

2.2 Impact of Ragi on health

2.2.1. Glycemic activity

Ragi has high proportion of unavailable carbohydrates which slow the release of sugars and thereby responsible for low glycemic index. When the GI of cooked noodles containing 30% ragi flour was tested in normal subjects it was shown to have a lower glycemic index (45.13) than the refined wheat flour noodles(62.59) (Kamini and Saritha, 2014) .

Mani *et al*. (1993) reported that ragi elicited a glycemic response equivalent to that of the glucose load when six recipes i.e cooked varagu (*Paspalum scorbiculatum*), varagu in combination with green gram dal (*Phaseolus aureus Roxb*), varagu in combination with whole green gram, roasted bread made from bajra (*Penniseteum typhoideum*), jowar (*Sorghum vulgare*) and ragi (Eleusine coracana) were tested in 36 confirmed NIDDM patients. The higher glycemic response was because of the ground ragi flour which decreases the particle size and in turn produce a higher glycemic response.

Lakshmi and Sumathi, 2002 studied the effect of consumption of ragi based diets on hyperglycemia in 6 non-insulin dependent diabetes mellitus (NIDDM) subjects. Consumption of ragi based diets resulted in significantly lower plasma glucose levels, mean peak rise, and area under curve which might have been due to the higher fiber, anti-nutritional factors of finger millet compared to rice and wheat. High fibre and anti-nutrients are known to reduce starch digestibility and absorption.

Ruhembe *et al.* (2014) studied glycemic index and glycemic load of staple foods used in Tanzania. Whole grain flours of maize, millet, cassava, dehulled white sorghum and green bananas mixed with sardines (*sardinops malanosticta*) were prepared into meals to do the glycemic index. Results showed that, cassava diet had the lowest value (49.8) followed by maize (51), while banana (57.85) and finger millet (60.92) had medium GI values. Sorghum meal had the highest GI (65.71).

Nidhi *et al*. (2014) reported that the glycemic index of ragi and pearl millet flours based cheela (36.83±1.23) and uthapam (38.72±1.879) was found to be lower than control cheela (44.07±1.67) and uthapam (39.9±1.14). The glycemic load of ragi and pearl millet flours based cheela (12.5±0.525) and ragi and pearl millet flours based uthapam (11.36±0.533) were found to be lower than control cheela (13.37±0.794) and control uthapam (14.72±0.418) respectively.

The glycemic response (GR) to 2 different ragi based preparations viz., roti and dumpling (with accompaniment) used in South India were measured in non-insulin dependent diabetes (NIDDM) and healthy subjects. GR were also determined in similar preparations replacing ragi with rice or jowar to evaluate the rationale for recommending ragi to diabetics. In NIDDM subjects ragi dumpling elicited higher GR than other meals. Glycemic index (GI) of the meals ranged from 80 to 88 in NIDDM and from 68 to 80 in healthy subjects. (Uoorj *et al*. 2006).

Shobana *et al*. (2007) formulated four different foods from whole wheat, decorticated ragi, popped, and flaked (expanded) rice, and a mixture of bengal gram, green gram, and black gram flours. Spices and condiments including cumin, pepper, cinnamon, asafoetida, turmeric powder and tamarind powder, fenugreek, guar gum, amla, and gurmar (Gymnema sylvestre) were added to a total of 11%. Oil, skimmed milk powder, and vitamins and minerals were then added in the extent of 9, 6 and 1% respectively. A 50 g equivalent carbohydrate portion of the foods in the form of thick porridge was provided to eight healthy adult subjects and the postprandial blood glucose response was determined. The Glycemic Index (GI) values were less for wheat and ragi based foods. After the decortication process also, the glycemic index of ragi was lower than that of the two rice products.

Geetha and Parvathi (1990) reported that supplementation of diets with ragi for a month showed a higher reduction of fasting and post prandial glucose levels than did supplementation with other millets.

Vijayalakshmi and Vahini (2014) evaluated the effect of Pulav mix (containing wheat, carrot, dry peas and spices) on postprandial blood glucose (PBG) in healthy subject, to determine the GI value and observed that the Pulav mix induced significantly lower PBG response ($p<0.05$) than did the glucose. This study suggested that pulav mix had an impact on the glucose tolerance with GI of 56. This study also suggested that pulav mix could be a replacement of white wheat bread since it provides a healthy and easily digestible CHO diet that can help to maintain PBG level within a normal range in healthy subjects.

Arora and Srivastava (2002) studied the hypoglycemic effects of khichidi, laddu and baati (unleavened bread) prepared from ragi and barnyard millet as a base separately with the addition of fenugreek seeds and whole green gram in khichidi, roasted soybean in laddu and Bengal gram flour in baati. The glycemic index of ragi based food products was 25.53, 34.62 and 36.12 and that of barnyard millet based food products was 27.24, 34.68 and 36.71 for khichdi, laddu and baati respectively.

2.2.2 Therapeutic activity

Antioxidant compounds are gaining importance due to their main roles as lipid stabilizers and as suppressors of excessive oxidation that causes cancer and ageing.

Ragi being a potent source of antioxidants has higher radical-scavenging activity than that of wheat, rice, and other millets. The brown or red variety of ragi had higher activity (94%) than the white variety (4%), which is low.

Health benefits associated with finger millet are delayed nutrient absorption, increased fecal bulk, lowering blood lipids, prevention of colon cancer, barrier to digestion, motility of the intestinal contents, increased fecal transit time and fermentability characteristics.

The resistant starch present in ragi escapes enzymatic digestion and provides effects by preventing several intestinal disorders, as it escapes digestion and provides fermentable carbohydrates for colonic bacteria. It also provides benefits such as the production of desirable metabolites, including short chain fatty acids in the colon, especially butyrate, which seems to stabilize colonic cell proliferation as a preventive mechanism for colon cancer (Gee *et al.*1992).

Polyphenols are known to inhibit the activity of digestive enzymes such as amylase, glucosidase, pepsin, trypsin and lipases. As ragi is rich in phenolics and dietary fiber. It may play a role in mediating amylase inhibition and therefore, have the potential to contribute to the management of type II Diabetes mellitus (Toeller, 1994).

2.3 Nutrient composition of curry leaf (*Murraya koenigii*)

Curry leaf (*Murraya koenigii*) is an aromatic more or less deciduous shrub or a small tree of the Rutaceae family. It is found almost throughout India and the Andaman Islands. The tree is cultivated for its aromatic leaves and as ornamental plant throughout India (Pruthi, 1980).

The leaves are a good source of vitamin A. They are rich source of complex carbohydrates, proteins, amino acids and alkaloids. They are also a rich source of calcium, but due to presence of oxalic acid in high concentration (total oxalates, 1.35 %, soluble oxalates 1.15%), its nutritional availability is affected.

The free amino acids present in the leaves are: asparagine, serine, aspartic acid, glutamic acid, threonine, alanine, proline, tyrosine, tryptophan, phenylalanine, leucine, isoleucine, α-amino butyric acids, traces of lysine, arginine and histidine. Leaves contain 9744 ng of lutein, 212 ng of *α*-tocopherol and 183 ng of carotene/g of fresh weight (Palaniswamy *et al*. 2003), 21.4 mg/100 g of total carotene, 7.1 mg/100 g of *β*-carotene is reported by Bhaskarachary *et al*. (1995).

The leaves of *Murraya koenigii* are said to contain a number of carbazole alkolids. These include members with C13- skeleton: Murrayanne, mukonine and mukonidine. C18- skeleton: Girinmbine, koenimbine, murrayacine, koenigine and koenigicine (Koenidine) and C23- skeleton: Mahanimbine, murrayacinine cyclomahanimbine and bicycle mahanimbine.

Table 2.3 Composition of (*Murraya koenigii*) curry leaves

Nutrients	**Amount**
Moisture	66.3 (%)
Protein	6.1 (%)
Fat	1.0 (%)
Carbohydrate	16.0 (%)
Mineral matter	4.2 (%)
Calcium	810 (mg/ 100 g)
Phosphorus	600 (mg/ 100 g)
Iron	3.1 (mg/ 100 g)
Crude fibre	6.4 (mg/ 100 g)
Niacin /Nicotic acid	2.3 (mg/ 100 g)
Vitamin C	4 (mg/ 100 g)
Insoluble dietary fibre (IDF)	13.4 (g/ 100 g)
Soluble dietary fibre (SDF)	2.9 (g/ 100 g)
Total dietary fibre (TDF)	16.3 (g/ 100 g)
Carotene (as vitamin A)	12,600 (IU/100 g)

Source : Pruthi (1980) and Ramulu (2001).

2.4 Impact of curry leaf on health

2.4.1 Glycemic activity

The synthetic oral hypoglycemic agents can produce serious side effects. In addition, they are not considered to be safe for use during pregnancy (Larner, *et al*. 1985). Furthermore, after the recommendation made by WHO on diabetes mellitus investigation on hypoglycemic agents from medicinal plants have become more important (WHO, 1980).

Suchetha and Kavitha (2013) analyzed the hypoglycemic effect of curry leaf powder in 20 male patients with Type 2 diabetes. 15g of curry leaf powder was supplemented for a period of 30 days for the diabetic experimental group (n=10).The glucose level before lunch and 2 hours after lunch was recorded on Day 0, Day 1, Day 10, Day 20 and Day 30 of the supplementation period. A significant change in the fasting and post prandial glucose levels in the diabetic experimental group after the supplementation period was found. A significant decrease in both the pre-lunch and post-lunch glucose levels was also noted. A significant difference in the post-prandial blood glucose levels between the diabetic control group and the diabetic experimental group was also observed.

Roopa, (2002) assessed the effect of curry leaf (*Murraya Koenigii*) powder supplementation at two dosage levels of 15g and 10g on blood glucose levels in NIDDM subjects and reported that the supplementation of 15g curry leaf powder/day/subject for a period of 60 days showed more beneficial effect on blood glucose levels than 10 g/day/subject.

Yadav *et al*. (2004) reported that the curry leaf supplemented diet could reduce the development of insulin resistance and diabetes. Vinuthan *et al.*(2004) studied the effect of daily oral administration of aqueous extract (600 mg/kg body weight) and methanol extract (200 mg/kg body weight) of curry leaf for a period of eight weeks on blood glucose and plasma insulin level in alloxan-induced diabetic rats. Diabetic rats treated with aqueous and methanol extracts of curry leaf showed a significant reduction in blood glucose levels ($P<0.05$) as compared to diabetic control groups.

Kesari *et al*. (2005) reported the hypoglycemic effect of aqueous extract of curry leaves. A single oral administration of variable dose levels (200, 300 and 400 mg/kg) of aqueous extract led to lowering of blood glucose level in normal as well as in diabetic rabbits. The maximum fall of 14.68% in normal and 27.96% in mild diabetic was observed after 4 hours of oral administration of 300 mg/kg. The same dose also showed a marked improvement in glucose tolerance of 46.25% in sub-diabetic and 38.5% in mild diabetic rabbits in glucose tolerance test after 2 hours.

Xie *et al*. (2006) reported the hypoglycemic and hypolipidemic activity of curry leaves in ob/ob mice. The extract significantly decreased blood cholesterol level from 277.6 ±16.6 mg/d (day 0) to 182.0±15.3 mg/d and decreased blood glucose level also from 387.0±15.6 mg/dl (day 0) to 214.0±26.6 mg/dl. In addition, body weight was reduced after treatment with extract.

Arulselvan *et al.* (2006) reported the anti-diabetic affect of ethanol extract of curry leaves (*Murraya koenigii*) in streptozotocin induced diabetic rats. Oral administration of ethanolic extract of curry leaf at a dose of 200 mg per kg body weight per day for a period of 30 days significantly decreased the levels of blood glucose, glycosylated hemoglobin, urea, uric acid and creatinine in diabetic treated group of animals. Determination of plasma insulin level revealed the insulin stimulatory effect of the extract. The results suggest that curry leaf possesses significant hypoglycemic potential in streptozotocin-induced diabetic rats. The curry leaf extract appeared to be more effective than glibenclamide, a known anti-diabetic drug.

Yadav *et al*. (2002) reported that feeding of diet containing various doses of curry leaf powder (5, 10 and 15%) to normal rats for 7 days as well as to mild and moderately diabetic rats for 5 weeks showed varying hypoglycemic and anti-hyperglycemic effect. Bawden *et al.* (2002) reported the alpha amylase inhibitory activity of cold hexane extract of curry leaf.

Grover *et al*. (2003) studied the effect of daily oral feeding of 15% of powdered leaves of *Murraya koeingii (curry leaf)* and 10% powder of seeds of *Brassica juncea* for 60 days on serum glucose concentration and kidney function in streptozotocin administered diabetic rats. Serum glucose levels, body weight, urine volume, serum creatinine, and urinary albumin levels were monitored on day 0, 10, 25, 40, and 70 of supplementation. After 60 days of streptozotocin administration, urine volume per day and urine albumin levels were significantly higher ($P<0.0005$) in diabetic control group as compared to normal control group. Although feeding of the *Murraya koeingii* / *Brassica juncea* showed a trend towards improvement in most of the parameters, results were not statistically different from the diabetic control group except in serum creatinine values in the group fed with 10% *Brassica juncea* on day 70.

2.4.2 Therapeutic activity

Curry leaves have been mentioned in the traditional medicinal system as an ingredient in Ayurveda (Sathyavati *et al*. 1987). Bark, root, leaves, fruits and fruit pulp of *Murraya koenigii* are widely used in the treatment of diabetes, obesity, vomiting, constipation,indigestion, diarrhoea, dysentery, piles, nausea, to relieve kidney pain etc. Curry leaves are extensively used in ayurvedic medicine for the preparation of Kashaya, lehya and choorna (Khan *et al*. 1995).

Hepatoprotective nature of curry leaves extract was studied by Gupta and Singh (2007). The effect was attributed to the combined effect of carbazole alkaloids – Mahanimbine, Girinimbine, Isomahanimbine, Murrayazoline, Murrayazolidine, Mahanine and ascorbic acid, α-tocopherol and mineral (Zn, Cu,Fe) contents of curry leaves extract. This study proved curry leaf as promising and a rich source of free radical quenchers, which has been mediated through hepatocyte membrane stabilizing activity along with the reduction of fat metabolism.

Curry leaves have been found to induce apoptosis in human myeloid cancer cells (HL-60). Results showed that mahanine down-regulates cell survival factors by activation of caspase-3 through mitochondrion-dependent pathway, and disrupts cell cycle progression. (Roy *et al.* 2004).

The dichloromethane and ethyl acetate extracts of curry leaf significantly reduced the body weight gain, plasma total cholesterol and triglyceride levels significantly. The observed anti-obesity and anti-hyperlipidemic activities of these extract are correlated with the carbazole alkaloids, mahanimbine. When it was given orally (30 mg/kg/day) significantly lowered the body weight gain as well as plasma total cholesterol and triglycerides levels. These findings demonstrate the excellent pharmacological potential of mahanimbine to prevent obesity (Birari *et al*. 2010).

The ethanolic extract of curry leaves was investigated for antipyretic activity in rats using yeast-induced pyrexia model. Ethanolic extract at a single dose of 300 mg/kg produced significant antipyretic activity ($P<0.01$) in albino rats as compared with the standard drug paracetamol (Patel *et al*. 2009).

2.5 Glycemic index (GI)

The concept of GI was introduced in 1981 (Jenkins *et al.*1981). According to this concept, carbohydrate- rich foods are assigned values on the basis of their influence on the blood glucose level after a meal. The GI was taken as the incremental area under the blood glucose curve (AUC) after the ingestion of 50 g of a test food, expressed as a percentage of the AUC of an equal amount of a reference food (generally glucose or white bread) (Jenkins *et al*. 1981).

$$GI = \frac{\text{Incremental area under curve (IAUC) for test Food}}{\text{Incremental area under curve (IAUC) for Reference Food}} \times 100$$

Table 2.4 Glycemic index values

Category	Glucose reference	White bread reference*
Low	<55	<60
Medium	56-69	60-85
High	>70	>85

* *The reference food is arbitrarily assigned a GI of 100. Both glucose and white bread have been used as reference foods. Glucose has a glycemic response that is 40% greater than that of white bread; conversely white bread has a GI that is 71% of glucose.*

Generally, the incremental area under the blood glucose curve is calculated geometrically by applying the trapezoid rule, ignoring the area beneath the fasting concentration. When a blood glucose value falls below the baseline, only the area above the fasting level was included.

In 1997 a committee brought together by the Food and Agriculture Organization (FAO) of the United Nations and World Health Organization endorsed the use of the GI for classifying CHO-rich foods and recommended that the GI values of foods be used in conjunction with information about food composition to guide food choices (Foster-Powell *et al*. 2002).The GI is now widely recognized as a reliable, physiologically based classification of foods according to their postprandial glycemic effect.

2.5.1 Factors affecting glycemic index (GI)

There are several factors that may alter the GI of a food including the particle size, food structure, ripeness, ratio of amylose to amylopectin, starch structure, level of food processing, cooking technique and the presence of other macronutrients such as fat and protein (Bjorck *et al.* 1994; Najjar *et al.* 2004).

2.5.1.1 Type of starch

The basic concern while designing diet plan for diabetes is to see the amount of carbohydrates into it. Though the amount of carbohydrates is important, equally important is the type of carbohydrate, as complex carbohydrates are preferred over the simple sugars. Starch digestibility is affected by several factors such as the ratio of amylose: amylopectin, particle size, starch–protein interaction, physical form, method and time of cooking, encapsulation of starch in protein or lipid matrices, and the structural type of the starch granule. The other important factor is food processing, which determines the extent of starch gelatinization, particle size and the integrity of the plant cell wall. (Gallant *et al.* 1992).

Starch may be divided into three categories based on digestibility and absorbability of the breakdown products as rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS). RDS is starch that is rapidly and completely digested in the small intestine. SDS is starch that is slowly but completely digestible in the small intestines. RS is the sum of starch and starch degradation products that, on an average, reach the human large intestine. Resistant starch is considered as non-digestible and fermentable carbohydrates.

Gastric emptying is affected by food particle size and fat content as well as by viscous fiber, which also limits enzymatic hydrolysis in the small intestine by restricting access to the food bolus.

2.5.1.2 Fat and protein

Several studies have shown that the addition of fat and protein to a carbohydrate food can significantly reduce the glycemic response (Gulliford *et al.* 1989; Intosh *et al.* 2003).

It has been suggested that fat lowers the postprandial glucose response by increasing the viscosity of the intestinal contents and delaying the rate of gastric emptying (Normand *et al.* 2001) however, other mechanisms may also be involved. There is some evidence that n-3 fats increase insulin secretion to a greater extent than n-6 fats in normal subjects, although long term consumption of n-3 fats increases blood glucose in diabetic patients (Simpson *et al.* 1985).

The addition of protein to a carbohydrate food increases the amount of insulin secreted, causing the blood glucose levels to be affected because of the effects of amino acids. Bornet *et al.* (1987) suggested that protein might form a protective network around the carbohydrate molecule and prevent the action of glycolytic enzymes.

Gannon *et al*. (2003) compared the metabolic effects of a high protein diet (30%) with that of control diet (15%), where the ratio of protein to carbohydrate to fat was 30:40:30 and 15:55:30 respectively, consumed for 5 weeks each by 12 NIDDM subjects. The high protein diet resulted in a 40 per cent decrease in the mean 24 h integrated glucose. Glycated haemoglobin decreased significantly upto 0.8 per cent after high protein diet and 0.3 per cent after control diet after 5 week period.

Moghaddam *et al*. (2006) studied the dose response effects of protein and fat on the glycemic response elicited by 50 g glucose in humans and results showed that, across the range of 0-30g, protein and fat reduced glycemic responses independently from each other in a linear, dose- dependent fashion, with protein having 3 times the effect of fat.

Hatonen *et al*. (2011) investigated how glycaemic and insulinaemic responses to a mashed potato meal changed when a high-fat food (rapeseed oil), a high-protein food (chicken breast) and/or salad were added to the meal in healthy subjects. The glycaemic index (GI) of pure mashed potato was 108, whereas combined with chicken breast, rapeseed oil and salad, it was only 54 indicating the influence of fat and protein on glycemic index.

2.5.1.3 Cooking method

The type of cooking method used (i.e., baked, boiled, microwaved) may also affect the GI, although the significance of the effect remains controversial.

Perceval *et al*. (2011) studied the effect of different traditional cooking methods on glycemic index (GI) and glycemic response of ten Sweet potato (*Ipomoea batatas*). Matured tubers were cooked by roasting, baking, frying, or boiling then immediately consumed by the ten nondiabetic test subjects. Samples prepared by boiling had the lowest GI (41±5–50±3), while those processed by baking (82±3–94±3) and roasting (79±4–93±2) had the highest GI values. The study indicates that the glycemic index of Jamaican sweet potatoes varies significantly with the method of preparation and to a lesser extent on intravarietal differences. Consumption of boiled sweet potatoes could minimize postprandial blood glucose spikes and therefore, may prove to be more efficious in the management of type 2 diabetes mellitus.

Jimoh *et al*. (2008) studied and found that postprandial glycemic response to food can be affected by the method of food preparation. The postprandial glycemic indices of peak plasma glucose (PPG), maximum increase in plasma glucose (MIPG), 2- hour postprandial plasma glucose level (2HPPG), incremental area under curve (IAUC) and glycemic index were determined for boiled yam, pounded yam and yam flour after eating a measured amount of 50 g of digestible carbohydrate as recommended by FAO/WHO. Yam flour submitted to more processing showed better postprandial glycemic response indices than the boiled yam and pounded yam.

Allen *et al*. (2012) studied the effect of cooking methods on glycemic index of sweet potato in 12 volunteers who consumed 25g of available carbohydrate from Beauregard sweet potato skin and flesh separately that were subjected to conventional cooking methods: baking at 163 °C for 1 hour, microwaving for five minutes in a 1000 watt microwave, dehydrating at 60°C for 16 hours and steaming at 100°C for 45 minutes. Glycemic indices calculated from these methods for steamed, baked and microwaved sweet potato flesh were 63 ± 3.6, 64 ± 4.3 and 66 ± 5.7, respectively, indicative of a moderate glycemic index food. However, dehydrated and raw sweet potato flesh had a low glycemic index (41 ± 4.0 and 32 ± 3.0, respectively). Steamed skin, baked skin, and dehydrated flesh did not have a statistically different glycemic index ($P > 0.05$) from that of raw sweet potatoes. Depending on cooking methods, "Beauregard" sweet potato flesh and skin may be considered low and medium glycemic index foods, which may prove beneficial for diabetic or insulin-resistant consumers.

2.5.1.4 Processing

The method of processing of a single food can greatly change its GI. Starch exists in carbohydrate foods in the form of large granules. These granules must be disrupted so that amylose or amylopectin starch macromolecules become available for hydrolysis. Grinding, rolling, pressing, or even thoroughly chewing a kernel or other starch food can disrupt the granules. Rolling or pressing foods, such as is done in the processing of many grains, disrupts the outer germ layer and granules and increase GI.

The application of heat and moisture affects starch granules. Disorganization of the crystalline structure occurs as it encounters greater heat and moisture for a longer period of time. Gelatinization occurs first, with disruption of the crystalline structure, followed by a disruption of the granules. If the starch is then let stand, or stored for a time, so that cooling occurs, the starch becomes a gel, which will vary in structure depending on the amount of moisture, the amylose to amylopectin ratio and the time and temperature of storage (Annison and Topping, 1994).

A crystallinity to the gel called retrogradation of the starch can occur. These starch complexes are insoluble and not amenable to hydrolysis in the small intestine. Repeated cycles of heating and cooling can further increase the retrogradation (Sievert *et al*.1991). Starch can also form insoluble complexes with proteins, such as in the browning (Maillard) reaction, making it unavailable for digestion and absorption.

2.5.1.4 Antinutritional factors

Ragi has a high content of antinutrients, such as phytic acid (0.48%), that bind divalent cations and tannins (0.61%) which form complex proteins and carbohydrates, thereby decreasing nutrient bioavailablity (Ravindran, 1991).

Lectin and polyphenol concentrations have also been shown to be negatively related with glycemic response in normal and diabetic individuals. The delayed appearance of glucose in the blood after ingestion of lectin-containing foods may be caused by either interference with the mucosal phase of digestion or by direct binding of lectin to the starch and the digestive enzymes.

Polyphenols are known to inhibit the activity of digestive enzymes such as amylase, glucosidase, pepsin, trypsin and lipases (Rohn *et al*. 2002). They may act as inhibitors of amylase and glucosidase (similar to acarbose, miglitol and voglibose) leading to a reduction in post-prandial hyperglycemia (Bailey, 2001). Synergy between phenolics and dietary fiber may play a role in mediating amylase inhibition and therefore, have the potential to contribute to the management of type II Diabetes mellitus (Saito *et al*. 1998).

2.5.1.5 Mixed meal

Most of the time individuals do not eat single foods but combine them in mixed meals and, furthermore, single foods are consumed as components of complex diets. Therefore, it is important to ensure that the GI concept also applies in the context of mixed meals.

Flint *et al*. (2004) examined the predictability of measured GI in composite breakfast meals when calculated from table values. The results indicated that the GI of mixed meals calculated by table values did not predict the measured GI (particularly when there is sufficient fat and protein in the meal). In fact the author's prediction models showed that the GI of mixed meals was more strongly correlated with fat, protein and energy content than with carbohydrate alone.

2.5.1.6 Organic acids

Organic acids are naturally present in certain foods which can also be produced upon fermentation of added, as in the case of some foods like idli, dosa and pickled foods. Inclusion of either lactic acid (added directly or through fermentation) or through sodium salt of propionic acid in bread products (Liljeberg and bjorck, 1996) as well as the presence of lactic acid in mixed meals with vegetables (Gustafsson *et al*. 1994), has been reported to lower post-prandial glycemic and insulinaemia. In addition, studies have reported glucose lowering effects of acetic acid in bread meals.

2.5.1.7 GI in relation with physical and mental performance

Febbraio *et al*. (2000) suggested that ingestion of a low GI prior to exercise increase the oxidation of fat and maintains blood glucose at a higher level throughout exercise, compared with a high GI pre exercise meal. Few studies have, however, reported increased endurance after a low-GI compared with a high GI meal (Thomas *et al*.1991;Kirwan *et al*. 2001).

Study by Benton *et al*. (2002) showed that the consumption of a low GI breakfast was associated with prolonged cognitive performance in both humans and rats. However, the blood glucose levels per se could not be correlated with improved cognitive performance, suggesting that the underlying mechanism is related to other features of the postpandrial metabolic state.

2.5.4 Current status of GI and objections

One objection to the GI concept has previously been the lack of long-term clinical investigations. The present lack of an adequate number of low-GI foods, particularly in the group of basic carbohydrate-rich foods, limits the application of the GI concept. In addition, concern has been raised about the complexity of communicating the GI concept to consumers (Pi-Sunyer, 2002).

Since many GI studies address factors such as the degree of gelatinization of starch and physical form of the foods, it would be necessary to make the consumer aware of the importance of handling the food in such a way as to maintain its beneficial glycemic characteristics. In order to be successful in the communication to the consumers, low-GI foods must provide attractive and comparable alternatives to the wide range of convenience foods of today.

A problem with existing international GI tables is that they often lack relevant information regarding food composition and processing conditions (Foster- Powell *et al*., 2002). It is therefore recommended that GI values be accompanied by such information in the future.

Another problem with GI tables is that in some cases there is a relatively wide variation of GI values for similar food products when tested in different laboratories (Foster-Powell *et al*., 2002). This variation reflects methodological differences and/or differences in the physical and chemical properties of the food products. Examples of differences between laboratories are: 1) how the carbohydrate content of the test food is determined (chemical analysis/calculation by difference), 2) procedure of food preparation, and 3) the method of blood sampling (venous/capillary).

A common objection to the GI concept is also that the fat and protein content of the diet can counteract the beneficial properties of low-GI foods (Pi-Sunyer, 2002). Simultaneous ingestion of fat and protein lowers the GI of the individual carbohydrate foods somewhat, but does not change their hierarchical relationship with regard to GI. (Wolever *et al*., 1996; Ludwig, 2002).

Chapter III

MATERIAL AND METHODS

Present study on "Nutrient analysis of selected ragi (finger millet) varieties and glycemic index of ragi recipes incorporated with curry leaf powder" was carried out at the Post Graduate and Research Centre (PGRC), Professor Jayashankar Telangana State Agricultural University (PJTSAU), Rajendranagar, Hyderabad.

A detailed description of the methodology followed for conducting the experiment is given below.

3.1 Procurement of raw material

3.2 Nutrient analysis of the ragi flour of two varieties SRICHAITHANYA (brown), HIMAJA (white) with and without incorporation of curry leaf powder (CLP)

3.2.1 Estimation of moisture

3.2.2 Estimation of protein

3.2.3 Estimation of fat

3.2.4 Estimation of ash

3.2.4 Estimation of calcium

3.2.5 Estimation of iron

3.2.6 Estimation of dietary fibre

3.3 Standardization and preparation of ragi rotis with and without incorporation of curry leaf powder (CLP) using brown and white ragi varieties

3.4 Study of organoleptic properties of ragi rotis prepared with and without incorporation of CLP

3.5 Studying the Glycemic response of rotis made of two varieties of ragi with and without incorporation of CLP

3.6 Statistical analysis

3.1 Procurement of raw materials

Two ragi varieties viz. SRICHAITHANYA (brown ragi) and HIMAJA (white ragi) were obtained from the Regional Agricultural Research Station, Vizianagaram, Andhra Pradesh. Curry leaves were purchased from local market. All the chemicals used for the investigation were of food grade and analytical reagent (AR) grade. Chemicals and glassware were obtained from the Post Graduate and Research Centre (PG & RC).

3.1.1 Processing of ragi

Brown and white colored ragi grains were thoroughly cleaned to remove any foreign material, dust and light materials by aspiration. The cleaned grains were ground into fine flour.

3.1.2 Processing of curry leaves

Fresh, green, un-damaged curry leaves were selected whereas, insect infested, bruised, discolored, decayed and wilted leaves were discarded before washing the leaves. The leaves were washed thoroughly under the tap water three to four times to remove all the adhering dust and dirt particles. Finally curry leaves were dried under shade and made into fine powder.

3.1.3 Chemicals and glassware

All the chemicals and glassware used for the nutrient analysis were issued from the Department of Foods and Nutrition, Postgraduate and Research Centre, Rajendranagar, Hyderabad, PJTSAU.

3.2 Nutrient analysis of the ragi flour of two varieties SRICHAITHANYA (brown), HIMAJA (white) with and without incorporation of curry leaf powder

3.2.1 Estimation of moisture: The moisture content of the samples was analyzed using standard procedure of AOAC, (1990) in Cintex precision hot air oven.

Procedure: A petridish was weighed with lid (W1) and about 10g of the sample was weighed and weighed again to obtain (W2). Petridish along with the sample was dried in an oven at 100-105 ° C for 15 -17 hours and cooled in a dessicator and weight was noted (W3). The same process was followed till a constant weight was obtained.

$$\text{Moisture (\%)} = \frac{(W2-W1) - (W2-W3)}{(W2-W1)} * 100$$

3.2.2 Estimation of Protein

The crude protein content of the sample was estimated according to the micro kjeldhal method AOAC (2005), calculated as percent nitrogen of product and multiplied with 6.25 to obtain the protein content.

Procedure

- The sample 0.5g was weighed in the digestion tube to which 5g of digestion mixture (98g of potassium sulphate + 2g copper sulphate) plus 10 ml of concentrated H_2SO_4 were carefully added and the samples were placed in the digestion unit for 1½ hour at 375°C.
- In a 100 ml conical flask, 40 ml of 4% boric acid was added along with few drops of mixed indicator containing (1ml of 0.2% bromocresol green + 3 ml of 0.2% methyl red).
- Distillation was done for 10 minutes in the kjeldhal distillation apparatus adding 15 ml of 40% NaOH and steaming for 10 seconds.
- The contents collected in conical flask were blue in colour after distillation was completed.
- Titration was done with standard 0.1 N HCl. The end point is when till the contents of the flask just turn to pink colour. Reading was noted. A blank was run simultaneously.

Calculation

$$\text{Protein (\%)} = \frac{\text{(Sample T.V – blank T.V) X0.014 X 0.1N of HCl X100 X 6.25}}{\text{Weight of the sample taken } (W_2\text{-}W_1)} \text{ X 100}$$

3.2.3 Estimation of fat

The fat content of the samples was determined by using the method of AOAC (1990).

Procedure

- The extraction beaker was cleaned, dried for an hour at 103 ºC ± 2 ºC in the drying chamber and was cooled in the dessicator to room temperature.
- An empty beaker was weighed (W_1).
- A sample of 2.0g was weighed into a thimble and covered with fat-free cotton.
- The thimble was inserted into the thimble holder and put into the beaker.
- About 150 ml of petroleum benzene (60-80°C B.P.) solvent was added.
- The extraction beaker with sample was kept into the Soxtherm instrument to fit properly to the sealing rings of the PTFE cylinders to avoid any leakage of solvent and extracted for one and half hour.

- Petroleum benzene was evaporated in the apparatus and the flask was dried with the residue in an oven at 100 ºC for 1 hour, cooled in a dessicator and weighed (W_2).

Calculations

$$\text{Fat content (\%)} = \frac{W_2 - W_1}{\text{Sample weight (g)}} \times 100$$

where

W_1 = Weight of empty beaker (g)

W_2 = Weight of beaker after fat extraction (g).

3.2.4 Estimation of ash

The ash content of the samples was determined by using the method of AOAC (2000).

Procedure

The temperature of the muffle furnace was set to 600°C and empty crucibles were heated for 1 hour and then cooled in a dessicator and weighed (W1). 2g of defatted sample was weighed into the crucible and weight was noted (W2). The sample was kept on flame for charring and then incinerated at 600°C for 8 hours in muffle furnace. After complete ashing of the sample, crucibles were transferred into the dessicator, cooled and weighed (W3). Incineration was repeated until a constant weight was obtained.

Calculation

Weight of the sample taken = W2-Wl

Weight of the ash = W3-Wl

$$\text{Ash \%} = \frac{\text{Weight of the ash}}{\text{Weight of the sample taken}} * 100 = \frac{W2-W1}{W3-W1} * 100$$

3.2.5 Estimation of Calcium

Calcium content of the samples was determined using Titrimetric method (Siong *et al*., 1989).

Chemicals required

0.01 $KMNO_4$, 0.01N Oxalic acid, 2N H_2SO_4, Standardized 0.01 $KMNO_4$, 0.1% methyl red indicator, 20% ammonia, 10% acetic acid, 6% ammonium oxalate and Wang's wash.

Procedure: 5 ml of mineral solution was taken in a 15 ml centrifuge tube. Two ml of water and a drop of methyl red indicator were added. Ammonium hydroxide was added drop wise till the pink colour disappears and then acetic acid was added drop wise till faint pink colour appears. The solution was shaked well and 1ml of 6% ammonium oxalate was added. The solution was mixed thoroughly and allowed to stand for an hour. The tube was centrifuged and inverted on a blotting paper for 5 minutes. The precipitate was washed with 4ml of Wang's wash solution thoroughly. The centrifuging process was repeated. The precipitate was dissolved in 2ml of 2N H_2SO_4. The solution was heated in a water bath up to 70-75˚C and titrated against 0.01N $KMnO_4$ (while the solution was still hot) till the end point (faint pink colour) appears.

The following readings were recorded.

- Total volume of mineral solution

-Volume of mineral solution used for estimation

-Weight of the sample taken for ashing

-Titer value

Calculation : Titer value of 1.0 ml of $KMnO_4$

$$\text{Titer value} \times \frac{\text{Total volume of mineral solution}}{\text{Volume used for estimation}} \times \frac{100}{\text{wt. of the sample taken for ashing}} = \text{mg}/100$$

3.2.6 Iron Estimation by AAS

Iron content was estimated using AAS (J. AOAC Int.2000).

Sample preparation for mineral estimation

0.5g of sample was added with 10 ml of diacid mixture of HNO_3 and $HclO_4$ in the ratio of 9:4 ratio. The mixtures were placed on hot plate until all the fumes disappear and the solution becomes light coloured. It was made up to 100 ml in a standard volumetric flask and filtered.

Preparation of working standards

- Hydrogen peroxide: 30% (w/w).
- Iron standard solution

  (1 mg/ml) dissolve 1.0 g Fe in 14 ml water + 7 ml nitric acid in 1 L volumetric flask diluted to volume with water to contain 1 mg/ml.

Atomic absorption spectrophotometry

- The flame technique was used to determine the concentration of Iron with background correction always.
- Measurements should be within the linear range when the standard curve consisting of at least 5 points.
- The concentration of the highest standard was 3–5 times the concentration in the test solution and the lowest standard should have a concentration approximately half of the highest standard.

Flame technique

- The concentration of Fe should be usually at levels suitable for determination by FAAS. When calibration curve is to be used, standards and test solutions must have the same acid concentration.

Instrumental parameters for FAAS

Metal	Flame type	Wavelength in nm
Fe	Air – acetylene, oxidizing	248.3

Calculation

$$C = \frac{(a - b)\, df \times 25}{M}$$

Where

C = Concentration in the test sample (mg / kg)

a = Concentration in the test solutions (mg / L)

df = Dilution factor

b = Mean concentration in the blank solution (mg / L)

m = Weight of the test portion (g).

3.2.7 Estimation of Dietary fiber

The dietary fiber content was determined by the following the rapid enzymatic method (Asp, 1987).

Reagents:

Sodium phosphate buffer (pH 6.0)

4 Hydrochloric acid solution

4 Sodium hydroxide solution

95 % ethanol

78 % ethnol

Acetone, Celite.

Enzymes: Pepsin**,** Pancreatin and Termamyl (alpha-amylase heat stable)
Procedure: 1. A sample of 1g was weighed into an Erlenmeyer flask (500) and 25 ml of 0.1 M sodium phosphate buffer (pH 6.0) was added and suspended thoroughly.

2. Termamyl 100µg was added and top of the flask was covered with aluminum foil and incubated in boiling water bath for 15 minutes (With occasional shaking).

3. Contents of the flasks were cooled, 20 ml of distilled water was added and pH was adjusted to 1.5 with HCl. Electrode was rinsed with few ml of water.

4. Pepsin100 mg was added, top of the flask was covered and incubated in water bath at 40° C with agitation for 60 minutes.

5. Distilled water 20 ml was added, pH was adjusted to 6.8 with NOaH. Electrode was rinsed with few ml of water.

6. Pancreatin100 mg was added, top of the flask was covered and incubated in a water bath at 40°C with agitation for 60 minutes.

7. pH was adjusted to 4.5 with HCl.

8. After adjusting the pH to 4.5 with HCl, soluble dietary fiber precipitated directly by adding 400 ml of warm (60°C) 95% ethanol to the whole digest and was allowed to precipitate for 1 hour.

9. After precipitating the whole digest was filtered through a dry and pre weighed crucible containing 0.5 gm of celite as filter aid.

10. Then the residue was washed with 2 x 10 ml of distilled water 2 x 10 ml 78% ethanol and 2 x 10 ml of acetone.

11. The residue was dried at 105°C overnight and weighed after cooling in a dessicator (D_2).

12. Then it was incinerated at 550°C for at least 5 hours weigh after cooling in a dessicator (I_2).

Blank : A blank is also run simultaneously for total dietary fibre. The blank values should be checked occasionally when new batches of enzymes are used.

Calculations

D_2- Weight of the crucible after drying; I_2 - Weight of the crucible after ashing; B_2- TDF blank;W- Weight of the sample (g)

$$\text{Total dietary fibre (\%)} = \frac{D_2 - I_2 - B_2}{W} * 100$$

3.3 Standardization and preparation of rotis using brown and white ragi flour with and without incorporation of CLP

Table 3.1: Composition of ragi and CLP

Type of roti	Ragi	Curry leaf powder	Available CHO
Brown Ragi roti (BRR)	69.44g	-	50g
Brown ragi roti with curry leaf powder (BRCR)	64.58g	5g	50g
White ragi roti (WRR)	69.44g	-	50g
White ragi roti with curry leaf powder (WRCR)	64.58g	5g	50g

3.3.1 Ingredients required:

1. Ragi flour/ ragi flour added with 5g CLP containing 50g of CHO (69.4 / 68.1g + 5g CLP)

2. 2.5 g or ½ tea spoon salt

3. Water 45 ml

Figure 3.1 Method of preparation of plain ragi roti

Add salt to water and bring it to boil

↓

Put flour in a bowl, pour hot water as needed and mix it to a soft dough

↓

Place a ball on chapathi roller and pat with fingers or use a rolling pin into thin roti

↓

Heat a tawa and place the roti over it

↓

Flip it when it is cooked on both sides

Same procedure was followed for preparing rotis with incorporating curry leaf powder. The steps for preparation of plain ragi roti / ragi roti incorporated with curry leaf powder are given in Figure 3.1

3.4 Study of organoleptic properties of ragi roti prepared with and without incorporation of CLP from both the varieties of ragi

A semi-trained panel of 15 judges comprising of staff and post graduate students of the Department of Foods & Nutrition, Post Graduate & Research Centre, PJTSAU was selected for sensory evaluation. A 5-point hedonic scale was used for sensory evaluation. The panel evaluated four products i.e. rotis prepared with normal white and brown ragi flour without addition of CLP and rotis from two varieties of ragi incorporated with 5g of CLP. The products were evaluated for colour, appearance, texture, taste, flavour and overall acceptability (5 = very good to 1 = poor) (Amerine *et al*., 1965). Samples were coded using random three-digit numbers. Panelists were provided with a glass of water and instructed to rinse and swallow water between samples. The score card for evaluation of sensory properties of the products is given in the Appendix-II.

Plate 3.1.1 Mixing of flour with water

Figure 3.1.6 Mixing flour with water

Plate 3.1.2 Dough preparation

Plate 3.1.7 Dough preparation

Plate 3.1.3 Rolling into roti

Plate 3.1.8 Rolling into roti

Plate 3.1.4 Preparation of roti

Plate 3.1.9 Preparation of roti

Plate 3.1.5 Brown ragi roti

Plate 3.1.10 Brown ragi roti incorporated with CLP

Plate 3.1. Steps in preparing brown ragi rotis

Plate 3.2.1 Mixing flour with water

Plate3.2.6 Mixing flour with water

Plate 3.2.2 Dough preparation

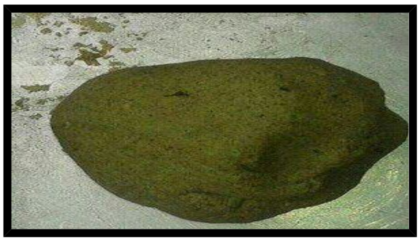

Plate 3.2.7 Dough preparation

Plate 3.2.3 Rolling into roti

Plate 3.2.8 Rolling into roti

Plate 3.2.4 Preparation of roti

Plate 3.2.9 Preparation of roti

Plate 3.2.5 White ragi roti

Plate 3.2.10 White ragi roti incorporated with CLP

Plate 3.2 Steps in preparing white ragi rotis

3.5 Study o ith and without incorporation CLP from both the varieties of ragi

Study of Glycemic response was conducted in Bhemiah Shanthi Nilayam, Hostel-D, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad.

3.5.1 Selection of subjects

Ten young adult volunteers within the age group of 22-24 years were selected for the study. Subjects were moderately active, non-smoking and non-alcoholics. The selected subjects had no past history of any illness, cold, cough, allergy, inflammation and were not on any medication. Before initiating the study, subjects were given a detailed written and oral explanation of the different procedures involved in the study and written informed consent was obtained from all subjects. They were given an opportunity to ask any doubts / questions on the study.

3.5.2. Method for Glycemic Index

The study was conducted in line with the procedure recommended by the Food and Agriculture Organization/World Health Organization (FAO/WHO,1998). To determine the GI (Glycrmic Index) of a food, the tests should be repeated in six or more subjects, thus in the present study ten subjects were selected to determine the GI of the rotis made from brown and white ragi with and without incorporation of CLP. On the day prior to the test, subjects were asked to restrict their activities and not to eat or drink after 09:00 pm, the night before the test, although water intake was allowed.

Reference food: Glucose 50g mixed in 250 ml of water served as the reference food and given to all selected 10 healthy subjects to assess the glycemic response. This was used as a tool to compare the individual differences in the glycemic response to test product.

Test food: Plain and curry leaf incorporated ragi rotis of brown and white ragi were used as test food. In order to obtain/get 50g of CHO, 69.4g brown and white ragi flour was used for plain rotis, whereas for the curry leaf incorporated rotis 64.58 ragi flour and 5g CLP was taken.

On the first day, the subjects were given the standard reference food (Glucose 50 g) followed by experimental/test food containing 50g of CHO was given to each subject and 250 ml of water was provided.

Blood glucose levels were measured using “One Touch Ultra soft” Glucometer by finger prick method in the fasting state and at 30, 60, 90 and 120 minutes after consumption of the reference and test food.

3.5.3. Determination of glycemic index of brown and white ragi rotis with and without incorporation of curry leaf powder

The Glycemic Index (GI) values were calculated by the method of Jenkins *et al.* (1981). The GI of each individual was calculated by dividing the incremental area under curve (IAUC) for the test food by the IAUC for the reference food and multiplying by 100.

Glycemic index of brown and white ragi rotis with and without incorporation of CLP was calculated by the formula.

$$GI = \frac{\text{IAUC for tested Food}}{\text{IAUC for reference Food}} \times 100$$

Plate 3.3 Glucometer Kit

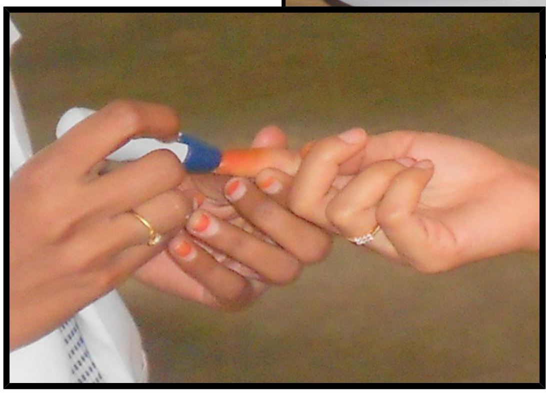

Plate 3.4.1 Finger prick with lancet

Plate 3.4.2 Collection of blood drop on the glucose strip and recording

Plate 3.4. Steps in taking blood glucose reading

3.6 Statistical analysis

All the results were statistically analysed to test the significance of the results using percentages, means, SD and analysis of variance (ANOVA) technique (Snedecor and Cochran, 1983).

Chapter IV

RESULTS AND DISCUSSION

In the light of growing popularity of millets, investigating the quality parameters of the most popular millet i.e. ragi varieties would help their promotion. The present study entitled "NUTRIENT ANALYSIS OF SELECTED RAGI (FINGER MILLET) VARIETIES AND GLYCEMIC INDEX OF RAGI RECIPES INCORPORATED WITH CURRY LEAF POWDER" was carried out to analyze the nutrient composition of two varieties of ragi viz. SRICHAITHANYA (brown ragi – BRF), brown ragi flour incorporated with curry leaf powder (BRCF) and HIMAJA (white ragi - WRF), white ragi flour incorporated with of curry leaf powder (WRCF). Using these flours, ragi rotis were standardized, prepared and studied for sensory evaluation and glycemic index. The results were subjected to statistical analysis and discussed with the help of graphs and presented under different sections as below.

4.1 Nutrient composition of ragi flour of two varieties of SRICHAITHANYA (brown ragi-BRF) and HIMAJA (white ragi - WRF), with and without incorporation of curry leaf powder (CLP).

4.2 Organoleptic properties of rotis made with two varieties of ragi with and without incorporation of CLP.

4.3 Glycemic index of rotis made with two varieties of ragi with and without incorporation of CLP.

4.3.1 Fasting and post prandial glucose on reference and test foods.

4.3.2 Area under curve for glucose and test foods.

4.3.3 Determination of glycemic index (GI).

4.1 Nutrient composition of two varieties ragi flour SRICHAITHANYA (brown ragi - BRF) and HIMAJA (white ragi - WRF), with and without incorporation of CLP

According to US National Research Council (1996) ragi is valued for its versatility as a staple food, its excellent storage quality, adaptability to various agro-climatic conditions, resistance to disease and nutritive value, which is higher than that of rice and equal to that of wheat. Ragi is high in protein, fibre content and energy and as compared to other cereals is a very rich source of calcium. In the present investigation, two varieties differing in grain colour viz. Brown (Srichaithanya) and White (Himaja) evaluated for nutrient composition with and without incorporation of CLP, to know the additional benefits of incorporation of CLP which is also rich in fibre and minerals.

Moisture, fat, protein, ash, calcium, iron and dietary fibre content of Srichaithanya (BRF) and Himaja (WRF) variety ragi flours and same flours added with 5g CLP *i.e.* (BRCF) and (WRCF) were determined and presented in the Table 4.1.

4.1.1 Moisture

Moisture content is the most influential factor in the storage of grains. A small change in seed moisture content has a large effect on the storage life of the seeds by promoting diseases. Moisture analysis of studied ragi flours revealed that the moisture content ranged between 9.0 - 10.8% (Table 3). Among all the ragi flours WRF had the highest moisture content with 10.8 % followed by WRCF with 9.9%, BRF with 9.6% and BRCF with 9.0%.

Higher moisture content of white ragi flour than brown ragi flour indicates that brown ragi had comparatively higher storage quality than that of white ragi. Significant difference was observed in the moisture content of BRF and WRF as well as between BRCF and WRCF. Curry leaf powder incorporated ragi flours had low moisture content compared to plain ragi flours.

4.1.2 Ash

Total ash content is higher in ragi than in the commonly consumed cereal grains. Ash content is generally taken to be a measure of the mineral content of the original food. It was observed that WRCF had highest ash content of 3.0 g/100g followed by BRCF with 2.9 g/100g, WRF with 2.6 g/100g and BRF with 2.3 g/100g. Higher content of ash in CLP added ragi flour of both the varieties compared to flour without CLP was due to high mineral content of CLP. Singh and Srivastava (2006) showed that the total ash content of the sixteen varieties of ragi ranged from 1.47 to 2.58%**.**

From the table 4.1, it is clear that there was a significant difference in the ash content of WRF and BRF. No significant difference was found in the ash content of WRCF, BRCF but it was significantly higher than that of WRF and BRF ($p<0.05$).

Name of the flour	Moisture (%)	Ash (g/100g)	Protein (g/100g)	Fat (g/100 g)	Iron (mg/100g)	Calcium (mg/100g)	Dietary Fibre (g/100g)
BRF	9.6± 0.15^{c}	2.3± 0.20^{c}	7.7± 0.10^{b}	1.3± 0.14^{b}	3.5± 0.15^{d}	354.3± 1.00^{d}	12.2± 0.20^{b}

BRCF	9.0± 0.10^{d}	2.9± 0.15^{a}	7.9± 0.47^{b}	1.4± 0.03^{b}	4.2± 0.05^{c}	455.6± 1.52^{b}	14.4± 0.10^{a}
WRF	10.8± 0.10^{a}	2.6± 0.10^{b}	10.3± 0.10^{a}	1.5± 0.12^{ab}	10.1± 0.20^{b}	403.3± 1.00^{c}	10.2± 0.10^{c}
WRCF	9.9± 0.10^{b}	3.0± 0.10^{a}	10.4± 0.10^{a}	1.7± 0.16^{a}	10.6± 0.11^{a}	505.3± 1.00^{a}	11.8± 0.72^{b}
C.D Value	0.2643	0.2745	0.4877	0.2847	0.2684	2.6429	0.7024

Table 4.1 Nutrient composition of (SRICHAITHANYA) brown and (HIMAJA) white ragi flours with and without incorporation of CLP

Note: Mean values with different superscripts within a column/row show significant difference ($p<0.05$).

Values are mean ± standard deviation of three determinations.

BRF: Brown ragi flour

BRCF: Brown ragi flour incorporated with CLP

WRF: White ragi flour

WRCF: White ragi flour incorporated with CLP

4.1.3 Protein

The protein content of the ragi flours ranged between 7.7 to 10.4g/100g (Table 4.1). It was observed that the protein content was 10.4 g/100g, 10.3 g/100g, 7.9 g/100g, 7.7 g/100g in WRCF, WRF, BRCF and BRF respectively.

White ragi flour had significantly higher ($p<0.05$) protein than brown ragi flour. Similar observations were reported by Dida and Devos, (2006); Vadivoo *et al*. (1998) and Virupaksha *et al*. (1975). Variation in protein content between white and brown ragi flours may be due to varietal difference, water availability, temperature, soil fertility and environmental conditions during grain development (Shimelis *et al*., 2009; McDonough *et al*., 2000 and Iren Ledde, 2004). There was no significant difference in the protein content of BRCF and BRF as well as WRCF and WRF. WRCF had significantly higher protein (10.4 g/100g) than BRCF and BRF ($P<0.05$).

4.1.4 Fat

The fat content of the four ragi flours ranged between 1.3-1.7 g/100g among which WRCF had the highest fat content of 1.7 g/100g. WRF had 1.5 g/100g fat followed by 1.4 g/100g in BRCF. BRF was found to have a low fat content of 1.3

g/100g. There was no significant difference found in the fat content of WRCF and WRF as well as BRCF and BRF ($P<0.05$). Fat content of WRF (1.5 g/100g) was slightly higher than BRF (1.3 g/100g), however it was not significant.

Seetharamam (2001) reported that the fat content in brown and white varieties of ragi ranged from 1.2 to 1.4%.The results in this study pertaining to BRF and WRF were in accordance with the results reported by above mentioned author. Lower lipid content of the ragi compared to other millets could be one of the factors contributing to better storage properties of ragi compared to other millets as higher fat content exposes the grains to spoilage during storage due to oxidation (Okaka, 2005).

4.1.5 Iron

The mineral composition of millet grains is highly variable. The genetic factors and environmental conditions prevailing in the growing region affect the mineral content of these food grains. Iron is an essential micronutrient extremely vital to human health. Identifying sources and improving iron content in cereal grains would be a pertinent approach to combat wide-spreading malnutrition.

It was observed that the iron content of four types of ragi flours analyzed ranged from 3.5 to 10.6 mg/100g (Table 4.1). Estimated values of iron showed that WRCF had a maximum of 10.6 mg/100g followed by WRF, BRCF and BRF with 10.1 mg/100g, 4.2 mg/100g and 3.5 mg/100g respectively. There was a significant difference ($P<0.05$) in the iron content among all the samples. Iron content increased in the CLP added ragi flours than flours without CLP of both the varieties. WRF was superior to the BRF with respect to iron.

Drisya *et al*. (2015) reported that cookies with acceptable quality and typical curry leaf flavor could be obtained by incorporating dried curry leaf powder, up to 10%. The contents of protein, dietary fiber, minerals, and β-carotene and radical scavenging activity in cookies increased with incorporation of increasing levels of CLP from 0% to 10%. Thus, the nutritional and functional properties of food products could be enhanced by incorporating CLP.

4.1.6 Calcium

Ragi is exceptionally rich in calcium with 344 mg/100g and 5-10 % more compared to all other cereals and millets (Gopalan *et al*., 2009). Calcium deficiency leading to bone and teeth disorders, can be overcome by introducing ragi in our daily diet.

There was a wide variation in the calcium content of ragi flours in the present study. Results pertaining to calcium indicated that the maximum calcium content was in WRCF (503 mg/100g), followed by BRCF (455 mg/100g), WRF (403 mg/100g) and least was found in BRF (354 mg/100g) (Table 4.1). The average calcium content (403mg/100g) in white variety was considerably higher than in brown variety (354 mg/100g) and this result was in accordance with the result reported by Seetharamam (2001). As CLP is rich in calcium, addition of CLP resulted in a considerable increase in the calcium content of two varieties of ragi flours studied. Statistically significant difference ($p<0.05$) was observed among all ragi flours.

4.1.7 Dietary Fibre

Total dietary fibre (TDF) content of the studied ragi flours varied from 10.2 to 14.4 g/100g (Table 4.1). BRCF scored maximum (14.4 g/100g) followed by BRF (12.2 g/100g), WRCF (11.8 g/100g) and the least was observed in WRF (10.2 g/100g). Wide variations (7-21.2 g/100g) in TDF content of ten varieties of whole grain ragi have been reported by Premavalli *et al*. (2004). BRF had significantly higher dietary fibre (12.2 g/100g) compared to WRF (10.2 g/100g), furthermore addition of CLP resulted in increase of dietary fibre in BRF and WRF by nearly 2%. There was a significant difference in the total dietary fibre content of BRCF, WRCF as well as BRF, WRF.

The health benefits associated with high fibre foods are delayed nutrient absorption, increased fecal bulk, lowering of blood lipids, prevention of colon cancer, barrier to digestion, mobility of intestinal contents, increased fecal transit time and fermentability.

Ragi like any other cereal is a source of dietary carbohydrate but the proportion of dietary fiber in ragi is relatively higher than many other cereals. Carbohydrate in Ragi (72%) comprises of starch as the main constituent and the non starchy polysaccharides (NSP) which amounts to 15–20% of the seed matter as unavailable carbohydrate. Dietary fibre can be divided into two categories according to the water solubility. Each category provides different therapeutic effects. Water-soluble fibre (SDF) consists of NSP, mainly β-glucan and arabinoxylan. Water-insoluble fibre (IDF) contains lignin, cellulose, hemicelluloses and NSP such as water-unextractable arabinoxylan. DF, principally the NSP. Lignin is not digested by endogenous enzymes within the human intestinal tract, but is an important component of our diet (DeVries *et al*., 1999).

SDF fraction is important in foods because they trap fatty substances in the gastro-intestinal tract and therefore, reduce cholesterol level in the blood and lower the risk of heart disease. SDF in general has a wide range of functionality due to its ability to absorb water and form gel like structure, and is almost fully fermented in the large intestine by microflora, bringing about many desired metabolic effects of fiber. The ability of SDF to retard absorption of glucose in the small intestine is also a desirable characteristic in the development of foods for diabetic individual.

4.2 Organoleptic properties of rotis made with two varieties of ragi with and without incorporation of CLP

Flours from the two varieties of ragi, (brown and white) were blended with 5g of CLP separately and these flours were utilized to make rotis giving 50g carbohydrate. The proportion of ingredients in the product code BRR (brown ragi roti) was 69.44g of ragi flour, 2.5g salt and 45 ml of water and same quantity of ingredients was used for WRR (white ragi roti) replacing brown ragi flour with white ragi flour. But for the BRCR (brown ragi roti incorporated with CLP) and WRCR (white ragi roti incorporated with CLP) 64.58g of ragi flour and 5g of curry leaf powder, 2.5g salt and 45 ml water were used.

Sensory evaluation for roti prepared with white and brown ragi flour with and without incorporation of CLP was done by semi trained panel of judges in the sensory evaluation lab of the department of Foods & Nutrition, Post Graduate & Research Centre, PJTSAU, Hyderabad. The mean scores of sensory evaluation for the products is given in table 4.2.

Sensory evaluation was done for all the four variations *i.e.* brown ragi roti (BRR), brown ragi roti incorporated with CLP (BRCR), white ragi roti (WRR) and white ragi roti incorporated with CLP (WRCR) to identify the most acceptable roti from each of the varieties. They were evaluated for taste, texture, flavour, colour and overall acceptability.

Results of sensory evaluation of ragi rotis revealed that BRR scored highest for colour (3.93±0.96) followed by WRR (3.26±0.88), BRCR (3.20±0.94) and WRCR

(3.00±0.92). BRR was the most accepted and WRCR was the least accepted with respect to colour. Slightly higher scores for BRR was due to its characteristic brown colour compared to greenish colour of CLP added rotis which were less preferred by the panelists. Rotis incorporated with CLP were less preferable compared to rotis without CLP. However there was no significant difference in the colour of BRCR, WRR and WRCR. Significant difference ($p<0.05$) was observed between BRR and remaining rotis.

Table 4.2 Mean organoleptic scores of ragi rotis prepared with and without incorporation of CLP

S. No	Product	Mean sensory scores				
		Colour	Flavor	Texture	Taste	Overall Acceptability
1	BRR	$3.93±0.96^a$	$3.26±0.88^a$	$2.73±0.96^a$	$4.06±0.96^a$	$4.06±0.59^a$
2	BRCR	$3.20±0.94^b$	$2.86±0.74^b$	$2.46±0.74^a$	$2.15±0.88^d$	$3.33±0.97^b$
3	WRR	$3.26±0.88^b$	$2.93±1.22^b$	$3.00±0.65^a$	$3.40±0.91^b$	$3.60±0.70^b$
4	WRCR	$3.00±0.92^b$	$2.60±0.63^b$	$2.73±0.88^a$	$2.73±1.03^c$	$2.5±0.74^b$
	CD Value	0.61092	0.63682	0.61619	0.64289	0.57905

Note: Values are mean ± standard deviation of three determinations**.**

Mean values with different superscripts within a column/row show significant difference ($p<0.05$).

BRR: Brown ragi roti

BRCR: Brown ragi roti incorporated with CLP

WRR: White ragi roti

WRCR: White ragi roti incorporated with CLP

As per the results obtained, it was seen that the sensory score for flavor of rotis ranged from 2.60±0.6 to 3.26±0.88 (Table 4.2). The flavor of the BRR was rated the highest with a score of 3.26±0.88; WRR was given a score of 2.93±1.22; WRCR was given a score of 2.86±0.74 and the least score was for BRCR (2.60±0.6). As per the results obtained, BRR with and without CLP was better than WRCR but not lower than WRR with respect to flavour. WRR awarded the highest score (3.00±0.65) for texture among all the rotis followed by BRR (2.73±0.96), WRCR (2.73±0.88) and the least scored was BRCR (2.46±0.74). The results indicated significant difference was not observed among all the rotis in texture ($p<0.05$).

With respect to taste, BRR (4.06±0.96) rated the highest among four types of rotis followed by WRR (3.40±0.91), WRCR (2.73±1.03) and the least score was given to BRCR (2.15±0.88). There was a significant difference in the taste of all the rotis ($p<0.05$). Sensory evaluation for taste of rotis studied indicated that CLP added rotis of both the varieties were less preferred compared to rotis without CLP.

Results of sensory evaluation for overall acceptability indicated that BRR was the most accepted with (4.06±0.59) score whereas WRR scored (3.60±0.70), BRCR scored (3.33±0.97) and the least scored was WRCR with (2.53±0.74) score. Significant difference was found among all the four rotis with respect to the overall acceptability ($p<0.05$). It was clear from the above data that BRR was the best accepted among all rotis. Plain rotis (BRR&WRR) were preferred more compared to the CLP incorporated rotis (BRCR, WRCR). In case of CLP incorporated rotis BRCR was given more preference than WRCR. Overall acceptability scores of the BRCR and WRCR in the present study were slightly lower which could be due to slight bitter taste of curry leaf powder.

Shanthala and Prakash, (2005) explored the possibility of incorporating oven dried curry leaf powder at 5 and 10% level to common dish like chapathi (unleavened Indian bread), spiced potatoes and cooked rice. The addition of CLP affected the color and appearance of the products. The texture, odor and taste were accepted by panel of members at the level of 5%. Scores decreased as the level of CLP was increased. A significant reduction was observed in all the sensory attributes and the acceptability of the product was also decreased at 10% level of incorporation of CLP in chapathi.

4.3 Glycemic index of rotis made with two varieties of ragi with and without addition of CLP

The glycemic index ranks carbohydrates on a scale of 0 to 100 based on changes in blood sugar levels after eating the food. Glycemic indexing of the rotis made of two varieties of ragi with and without addition of curry leaf powder (CLP) are presented in the following subheads.

4.3.1 Fasting and Post Prandial Glucose Level for Reference Food and for Test Foods

Ragi is generally used in the form of whole meal for preparation of traditional foods, such as roti (unleavened bread), mudda (dumpling) and ambali (thin porridge).

In the malted form ragi is used for the preparation of weaning foods and composite flour which can be used in the preparation of bakery products (cakes and biscuits). With the development of processing technology ragi is made into grits, flakes and flour and used as a replacement for rice/cereal based ingredients in various Indian preparations like dosa, upma, idly and ladoo etc.

In this study roti, a common breakfast dish roti was made from brown and white variety of ragi flours with and without incorporation of CLP (5g). Finger millet rotis prepared with and without addition of CLP from both the varieties were consumed by the selected subjects (22-24yr old) after an overnight fast. The mean fasting and post prandial blood sugar levels for reference food, glucose and the test food *i.e.* brown ragi roti (BRR), CLP incorporated brown ragi roti (BRCR), white ragi roti (WRR), CLP incorporated white ragi roti (WRCR) are given in the table 4.3.

Table 4.3 Average blood glucose levels at different time intervals for reference food (glucose) and test foods

Product	**Blood glucose level mg/dl**				
	Time interval (min)				
	Fasting	**30 min**	**60 min**	**90 min**	**120 min**
Reference	78.4± 6.25	155.1±9.64	130.8±11.83	112.1±9.55	93.6±4.11
BRR	83.2±3.04	139.0±11.22	116.4±6.13	101.1±6.69	88.9±5.46
BRCR	78.9±3.08	111.1±19.27	111.4±7.74	100.0±10.78	86.2±6.03
WRR	77.7±4.56	133.6±11.32	119.0±12.80	109.9±10.54	90.1±7.60
WRCR	77.8±5.07	130.1±9.08	117.1±11.43	97.2±10.99	82.6±10.38

Note: Values are mean ± standard deviation of ten determinations**.**

BRR: Brown ragi roti

BRCR: Brown ragi roti incorporated with CLP

WRR: White ragi roti

WRCR: White ragi roti incorporated with CLP

The fasting glucose levels for all five tests namely reference (glucose), test foods (rotis-BRR, BRCR,WRR and WRCR) were nearly similar before all the test meals were taken, which ranged between 77.7± 6.25 to 83.2±3.04 mg/dl. For reference food the peak rise was observed after 30 min with 155.1±9.64 which gradually came down with an increase in time and last value recorded was 93.6±4.11 mg/dl which was more than the fasting value. For brown ragi roti (BRR), the peak value 139±11.22

mg/dl reached at 30 min and gradually reduced down to 88.9±5.46 mg/dl by the end of 120 min.

For brown ragi roti incorporated with CLP (BRCR) peak rise in the glucose was observed at 60 min with 111.4±7.74 which gradually reduced to 86.2±6.03 at the end of 2 hours. The mean peak rise for white ragi roti (WRR) was observed at 30 min 133.6±11.32 mg/dl which gradually tapered down to 90.1±7.60 by the end of 120 min. For the CLP incorporated white ragi roti (WRCR) similar results were obtained for one hour as WRR, after which slightly lower values were observed. The mean peak rise in glucose with 130.1±9.08 mg/dl for WRCR was observed after 30 min and gradually decreased to 117.1±11.43, 97.2±10.99 and 82.6±10.38 mg/dl after 60, 90 and 120 min respectively.

4.3.2 Area Under Curve (AUC) of Reference food and Test Food

There are different methods that are used to calculate the area under the curve. For most glycemic index data, the area under the curve has been calculated as the incremental area under the blood glucose response curve (AUC), ignoring the area beneath the fasting concentration. This was calculated geometrically by applying the trapezoid rule. When a blood glucose value falls below the baseline, only the area above the fasting level is included (FAO/WHO, 1998). The AUC for reference, brown ragi roti (BRR), brown ragi roti incorporated with CLP (BRCR), white ragi roti (WRR) and white ragi roti incorporated with CLP (WRCR) is given in the figure 4.1, 4.2, 4.3 and 4.4 respectively.

Net incremental AUC (netAUC) includes all the incremental area below the curve, including the area below the fasting concentration. Since it is calculated by applying the trapezoid rule to both positive and negative blood glucose increments, the effect is to subtract the area below the fasting level from that above. AUCcut is calculated in the same way as iAUC, but only includes the area before the blood glucose concentration drops below (cuts) the baseline (fasting concentration); the area after the glucose concentration cuts the baseline is not included (Ha *et al*., 1992). The iAUC above the lowest blood glucose concentration attained (AUCmin) is calculated by subtracting the lowest blood glucose concentration attained during the test period from each of the other blood glucose concentrations and calculating the AUC by applying the trapezoid rule to the resulting increments.

Figure 4.1 Area under curve for glucose and roti made with brown ragi

Figure 4.2 Area Under Curve for Glucose and Brown Ragi Roti incorporated with CLP

Figure 4.3 Area Under Curve for Glucose and White ragi Roti

Figure 4.4 Area Under Curve for Glucose and White Ragi Roti incorporated with CLP

The AUC for reference and test foods ranged from 646.1 to 1125.8 the AUC calculated for glucose, brown ragi roti (BRR), brown ragi roti incorporated with CLP (BRCR) was 1125.8, 687.0, 646.1 respectively whereas, for white ragi roti (WRR), white ragi roti incorporated with CLP (WRCR) was 757.8 and 703.9 respectively which is represented by the Figure: 4.5.

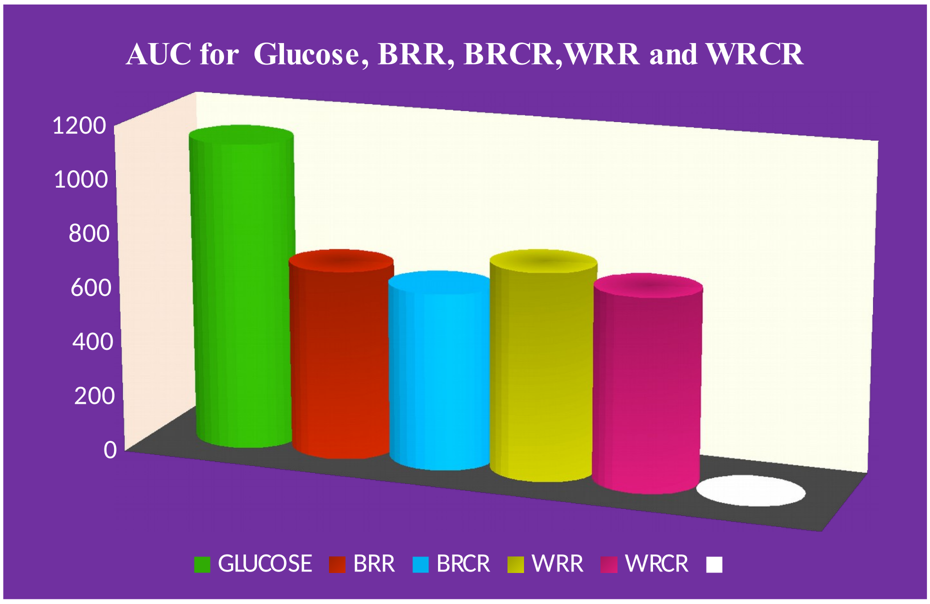

Figure: 4.5 AUC of Glucose and Experimental Rotis.

Figure 4.5 depicts that among the four rotis tested, consumption of brown ragi roti incorporated with CLP (BRCR) resulted in lower AUC followed by brown ragi roti (BRR), white ragi roti incorporated with CLP (WRCR) and white ragi roti (WRR). The AUC was higher for white ragi roti compared to brown ragi roti. Incorporation of CLP resulted in lower AUC for BRCR and WRCR compared to BRR and WRR respectively. There is a wide difference in the AUC of reference (glucose) and that of test rotis with BRR showing only 38.8% AUC as compared to that of glucose. AUC for BRCR was slightly lower than BRR and nearly 42.6% less than AUC of glucose. AUC of WRR was 32.6 % of glucose AUC, whereas WRCR was with lower AUC than WRR and about 37.4% AUC as compared to glucose. AUC for all the rotis was much lower compared to that of glucose.

4.3.3 Determination of Glycemic Index (GI)

The GI is defined as the incremental area under the blood glucose response curve (AUC) after consumption of a 50g available-carbohydrate portion of a food expressed as a percentage of that after 50g oral glucose. GI indices of test foods i.e. brown ragi roti (BRR), brown ragi roti incorporated with CLP (BRCR), white ragi roti (WRR) and white ragi roti incorporated with CLP (WRCR) were obtained by calculating mean AUC for reference glucose and test foods for ten selected subjects and given in the Table 4.4.

Table 4.3 Glycemic index of BRR, BRCR, WRR and WRCR

Product	Glycemic index
Brown ragi roti (BRR)	61.0±5.77[b]
Brown ragi roti incorporated with CLP (BRCR)	56.2±5.56[c]
White ragi roti (WRR)	67.3±2.78[a]
White ragi roti incorporated with CLP (WRRC)	62.5±4.23[b]
CD Value	4.26263

Note: Values are mean ± standard deviation of ten determinations (n=10)

Mean values with different superscripts within a column/row show significant difference ($p<0.05$).

The GI of rotis ranged from 56.2±5.56 to 67.3±2.78 (Table 4.4). WRR had the highest GI with 67.3±2.78 (medium) flowed by WRCR with 62.5±4.23 (medium). BRR had GI Values of 61.0±5.77 (medium) and the least was for BRCR with 56.2±5.56 (medium). The BRCR resulted in significantly lower GI than BRR, WRR and WRCR. There was no significant difference between the GI of BRR and WRCR ($p<0.05$).

Jayasinghe *et al*. (2013) compared the glycemic response of foods *i.e.* Roti and Puttu prepared with finger millet flour using traditional stone grinding and industrial milling. GI for roti made of stone ground was 44±5 and that of roti made of industrially milled flour was 59±7. The higher GI for industrially milled ragi roti was due to smaller particle size of the flour makes the starch gelatinization relatively difficult and thus slows the enzyme attack, resulting in slow release of glucose from food. The result obtained in this study pertaining to the BRR was similar to the result reported by the above author.

Ragi has high proportion of unavailable carbohydrates which slows down the release of glucose and thereby responsible for low glycemic index. When cooked noodles containing 30% ragi flour was tested in normal subjects it was shown to have a lower glycemic index (45.13) than the refined wheat flour noodles (62.59) (Kamini and Saritha, 2014) .

Lakshmi and Sumathi (2002) studied the effect of consumption of ragi on hyperglycemia in six NIDDM men and reported that glycemic responses were lower in whole ragi based roti and dosa than germinated ragi roti.

The difference shown by the tested ragi rotis of two varieties in GI values may be due to differences in the rate of digestion, absorption and utilization of the grain CHO. The digestion of CHOs is mainly dependent upon the structure and composition of the starches and other non starchy components. The difference in the physical as well as the chemical nature of polysaccharides and their physical distribution in the grain which differ from genotype to genotype apparently seem to alter their response to amylase action, resulting in slower digestion and absorption, there by resulting in low GI.

The lower GI for BRR may be explained on the basis of its fibre content. The dietary fibre content of BRF used for the preparation of BRR was 12.2 g/100g whereas, WRF had 10.2 g/100g. The beneficial effect of fibre is usually attributed to the slower gastric emptying or formation of un-absorbable complexes with available CHOs in the gut lumen.

Geetha and Parvathi (1990) reported that supplementation of diets with ragi for one month showed a higher reduction of fasting and post prandial glucose levels than did supplementation with other millets. This was attributed to the fact that the crude and dietary fibre content of maize and jowar are lower compared to the ragi and samai.

Apart from carbohydrates, protein, fat and fibre in diet, anti-nutritional factors like polyphenols, phytic acid and enzyme inhibitors are known to reduce the starch digestibility and absorption. They either form complexes with CHOs to prevent them from enzymatic attack or inhibit the activity of enzymes there by reducing the rate of hydrolysis of starch to maltose. This lowers the rate of maltose transport and glucose absorption (Shobana *et al*., 2009). The GI of BRR compared to WRR, BRR was found to be much lower. This might be due to a noticeable difference in the polyphenols in the brown (1.2- 2.3 %) and white (0.3-0.5%) varieties which could be due to the presence of the red pigments, which are generally polymerized phenolics present in brown cultivars (Ramachandra *et al.*, 1977).

It was suggested that phytates probably affect the starch digestibility through interaction with amylases, proteases and/or binding salivary minerals such as calcium which is essential for amylase activity. Thus it decreases the digestion and absorption of CHOs resulting in lowered post-prandial glycemia (Yoon *et al*., 1983).

Lower AUC and GI observed on consumption of CLP added ragi rotis of both the varieties which may be due to higher fibre and bioactive compounds content of CLP added ragi flour compared to normal ragi flour without CLP. The beneficial effect of fibre is usually attributed either to slower gastric emptying or formation of un-absorbable complexes with available CHO in the gut lumen. Therefore it has been suggested that these two properties might result both in delayed absorption of CHO and in the reduction of absolute quantity absorbed (Jenkins *et al.,* 1988; Rasmussen *et al*., 1991).

Fibre may act as a barrier for diffusion of nutrients from the gut lumen to gut mucosa and result in slower absorption from fibre rich foods than fibre free foods. Hence high fibre foods would result in improved glucose control due to delayed digestion and absorption and also increase transit time from mouth to cecum (Kiehm *et al*., 1976).

Wolver (1990) investigated the relationship between the glycemic index and the dietary fiber content and composition of 25 foods. Results revealed that total dietary fibre was significantly related to GI. Soluble fibre was not significantly related to GI but uronic acids in insoluble fibre were most closely associated to GI. More variation in GI was explained by nature of uronic acids in insoluble fiber which is 34 per cent when compared to total dietary fibre alone (21%). The combination of pentoses, hexoses and uronic acids in soluble and insoluble fiber explained 50 per cent of GI variability.

Bawden *et al.* (2002) explained the alpha amylase inhibitory activity of cold hexane extract of curry leaves. The aqueous extract of curry leaves contains a range of active pharmacological agents, which include carbazole alkaloids, flavonoids and tannins (Wang *et al*., 2003) known to be bioactive for the management of diabetes (Oliver-Bever, 1986). It is known that certain alkaloids and flavonoids exhibit hypoglycemic activity (Pathak *et al*., 1991; Ahmad *et al*., 2000) and also known for their ability of beta cell regeneration of pancreas (Chakravarti *et al*., 1981). Tannins have also shown to decrease blood sugar in experimental animal models (Suba *et al*., 2004). Thus, the significant hypoglycemic effect of CLP added rotis may be due to the presence of more than one hypoglycemic principle and/or their synergistic effects.

Yadav *et al*. (2002) reported that feeding of diet containing various doses of curry leaf powder (5, 10 and 15%) to normal rats for 7 days as well as to mild and moderate diabetic rats for 5 weeks showed varying hypoglycemic and anti-hyperglycemic effect.

Jenkins *et al.* (1982) have reported that if maximal benefit (lowest blood glucose level) is to be realized from low glycemic foods, attention must be paid to the amount of heat used in the preparation as it affect on digestibility and hence glycemic response to a food. It is possible that prolonged heat might alter the relationship between starch and fibre, making the starch more readily available and resulting in abolishing the effect on glycemia. The lesser time for the preparation of ragi roti may have been responsible for the lesser or no fracturing the starch granules, resulting in lower glycemic response.

Chapter V

SUMMARY AND CONCLUSIONS

The increasing trend of epidemiological transition is taking place in most of the States in India with decline in communicable diseases and increase in chronic non-communicable diseases. In India, more than half of patients have poor glycemic control and have vascular complications. Dietary management of diabetes involves the reduction of postprandial hyperglycemia and good glycemic control. Currently there is an urgent need to develop novel therapeutic foods for diabetics without the development and progression of the disease leading to complications.

Finger millet (*Eleusine coracana*), also known as ragi is an important millet grown extensively in various regions of India and Africa. Utilization of whole grain cereals like ragi in food formulations is increasing worldwide since it is rich in polyphenols and dietary fibre which offer good glycemic control. Curry leaf is a widely used spice and condiment in the Indian cookery which is known for its hypoglycemic activity.

The present study was designed to assess the nutrient composition of two ragi varieties viz. SRICHAITHANYA (Brown ragi) and HIMAJA (White ragi) with and without addition of CLP to know the additional benefits in their nutrient composition. Brown and white ragi were procured from Agricultural Research Station, Vizianagaram, Andhra Pradesh and made into flour to which 5g CLP was incorporated so as to give 50g CHO (Carbohydrate), nutrient analysis was done for these flours.

Using these flour, ragi rotis (unleavened bread) were standardized and prepared, subjected to evaluation by semi-trained sensory panel using 5 point hedonic scale. Sensory evaluation was done for all the four variations *i.e.* brown ragi roti

(BRR),brown ragi roti incorporated with CLP (BRCR), white ragi roti (WRR) and white ragi roti incorporated with CLP (WRCR) to identify the most acceptable roti from each of the varieties. They were evaluated for taste, texture, flavour, colour and overall acceptability.

Ten healthy young adults in the age group of 22-24 years were selected to estimate glycemic index (GI) of test food *i.e.* ragi roti/CLP incorporated ragi roti of both the varieties. Blood glucose levels were measured using "One Touch Ultra Soft" Glucometer by finger prick method in the fasting state and at 30, 60, 90 and 120 minutes after consumption of the reference food (50g glucose) and test food (plain ragi roti /CLP incorporated ragi roti) each providing 50g carbohydrate and the two hour glucose response curves (AUC) were drawn to determine glycemic index (GI).

The results of the study are as follows

- Nutrient analysis revealed that plain ragi flours have higher moisture than CLP added ragi flours. Addition of CLP resulted in lower moisture content. Compared to white ragi, brown ragi has less moisture content. The ash content of CLP added flours was higher than plain flours. In the case of ash CLP added flours, higher ash content was found than plain ragi flours. White ragi was found to be superior to the brown ragi with respect to ash content.
- The increasing order of protein content was BRF (7.7 g/100g) > BRCF (7.9 g/100g) > WRF (10.3 g/100g) > WRCF (10.4 g/100g). White ragi had higher protein content than brown ragi ($p<0.05$).
- Result obtained for fat revealed that WRCF had highest fat (1.7 g/100g) among the four ragi flours studied followed by WRF (1.5 g/100g), BRCF (1.4g/100g) and the least was in BRF (1.3 g/100g). White ragi was superior to the brown ragi with respect to fat content.
- Incorporation of CLP increased the mineral content i.e. iron and calcium. Estimated values of iron showed that WRCF scored maximum (10.6 mg/100g) followed by WRF, BRCF and BRF with 10.1 mg/100g, 4.2 mg/100g and 3.5 mg/100g respectively. WRF and WRCF had significantly higher iron content than BRF and BRCF ($p<0.05$). Iron content increased in the CLP added ragi flours compared to flours without CLP of both the varieties. WRF was superior to the BRF with respect to iron.
- Results pertaining to calcium indicated that the maximum calcium content was in WRCF (505 mg/100g), followed by BRCF (455 mg/100g), WRF (403

mg/100g) and the least was found in BRF (354 mg/100g). The average calcium content (403 mg/100g) in white variety was considerably higher than brown (354 mg/100g) variety. As CLP is rich in calcium, addition of CLP resulted in a considerable increase in the calcium content of two varieties of ragi flours.

- Total dietary fibre (TDF) content of ragi flours studied ranged from 10.2 to 14.4 g/100g. BRCF scored maximum (14.4 g/100g) followed by BRF (12.2 g/100g), WRCF (11.8 g/100g) and the least was observed in WRF (10.2 g/100g). BRF had significantly higher dietary fibre compared to WRF ($p<0.05$). Addition of CLP resulted in increase of dietary fibre in BRF and WRF by nearly 2%.
- Results of sensory evaluation of ragi rotis revealed that BRR scored highest for colour (3.9±0.96) followed by WRR (3.26±0.88), BRCR (3.20±0.94) and WRCR (3.0±0.92). BRR was the most accepted and WRCR was the least accepted with respect to colour. Rotis incorporated with CLP were less preferable compared to rotis without CLP.
- As per the results obtained, it was seen that the sensory score for flavor of rotis ranged from 2.6±0.6 to 3.26±0.88. The flavor of the BRR was rated the highest with a score of 3.26±0.88; WRR was given a score of 2.93±1.22; WRCR was given a score of 2.86±0.74 and the least score was for BRCR (2.60±0.6). There was a significant difference among the rotis ($p<0.05$), BRR with and without CLP was better than WRCR with respect to flavor. Plain ragi rotis were rated with highest score than CLP incorporated rotis.
- BRCR awarded the highest score for texture (3.00±0.65) among all the rotis followed by BRR (2.73±0.96), WRCR (2.73±0.88) and the least scored was BRCR (2.46±0.74). However, the results indicated that all the rotis did not differ significantly in texture ($p<0.05$).
- Sensory evaluation for taste of rotis indicated that CLP added rotis of both the varieties were less preferred compared to rotis without CLP. BRR (4.06±0.96) rated the highest among four types of rotis followed by WRR (3.40±0.91), WRCR (2.73±1.03) and the least score was given for BRCR (2.15±0.88). There is a significant difference in the taste of all the four ragi rotis ($p<0.05$).
- BRR was the best accepted among all rotis and plain rotis (BRR&WRR) were preferred more compared to the CLP incorporated rotis (BRCR, WRCR). In case of CLP incorporated rotis BRCR was given more preference than WRCR.
- The results indicated that the GI of ragi rotis ranged from 56.2±5.56 to 67.3±2.78. WRR had the highest GI 67.3±2.78 (medium) followed by WRCR 62.5±4.23 (medium). BRR had GI Value of 61.0±5.77 (medium) and the least was for BRCR 56.2±5.56 (medium).

- According to the results obtained from GI all the four test foods in the form of rotis possessed intermediate GI values. Brown ragi can be suggested for diabetic patients since it has less GI when compared to white ragi. Though White ragi is slightly higher in GI than Brown ragi, addition of CLP has nearly equalized the GI of Brown Ragi.
- Addition of CLP has benefited more when compared to normal intake of ragi flours. Thus, it is beneficial to have herbs like CLP with millet flours like ragi to support and reduce the complications of diabetes.

The present study revealed that white ragi is superior to the brown ragi in all the nutrients analyzed except dietary fibre. Promotion and utilization of such varieties with high yield potential will be of immense value in alleviating the under nutrition of economically backward sections of population and it can also be formulated in therapeutic diets. Incorporation of CLP improved the nutrient content in ragi flours of the two varieties.

From this study it is evident that ragi roti/CLP incorporated ragi roti of both the genotypes have intermediate glycemic index making ragi roti a good breakfast for diabetics in general. Curry leaf powder can be incorporated in the traditional breakfast items to enhance nutritional composition while at the same time help in reducing the GI value.

Suggestions for future research

- Other traditional breakfast items using finger millet can be tested for GI study.
- Effect of long term use of/increased dose of curry leaf powder.

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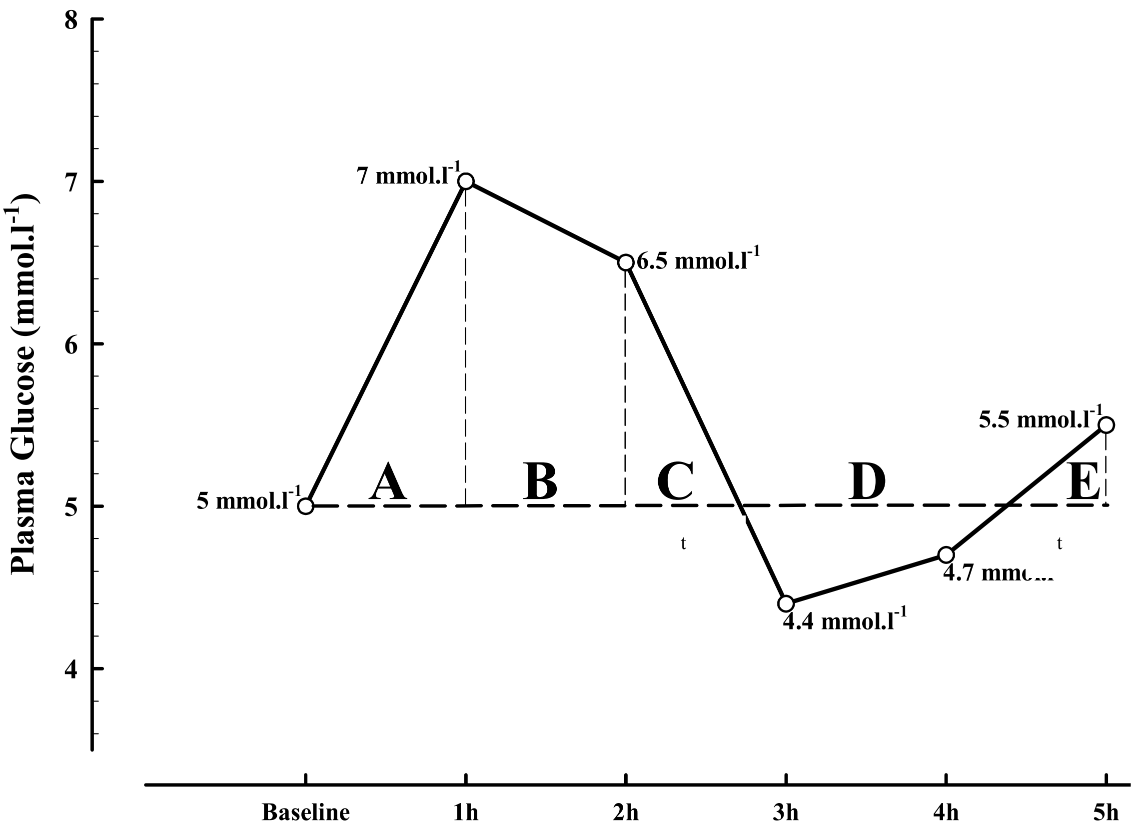
APPENDIX I

Calculation of Incremental Area Under Curve (IUAC)

Incremental area under curve (IAUC) for a given time-period can be calculated as described below in accordance with the method recommended by Wolever *et al.*(1986).



The total IAUC for the above example will be the sum of periods A+B+C+D+E

Triangle A = (start conc. + end conc.) x ½ time (min) – baseline area

= (5 + 7) x 30 – (5 x 60)

= **60 mmol·60 min·l^{-1}**

Trapezoid B= (7 + 6.5) x 30 – (5 x 60)

= **105 mmol·60 min·l^{-1}**

Triangle C = (start conc. – baseline conc.) x t / 2

= (6.5 – 5) x 42.9 / 2

= **32.2 mmol·60 min·l^{-1}**

where t = (start conc. – baseline conc.) / (start conc. – end conc.) x time (min)

= (6.5 – 5) / (6.5 – 4.4) x 60

= 42.9 min

Period D the concentrations both at the start end the end of this period are below baseline so IAUC = **0 mmol·60 min·l^{-1}**

Triangle E = (end conc. – baseline conc.) x t / 2

= (5.5 – 5) x 37.5 / 2

= **9.4 mmol·60 min·l^{-1}**

where t = (end conc. – baseline conc.) / (end conc. – start conc.) x time (min)

= (5.5 – 5) / (5.5 – 4.7) x 60

= 37.5 min

Therefore the total IAUC for the 5 h period =

60 mmol·60 min·l^{-1}

+ 105 mmol·60 min·l^{-1}

+ 32.2 mmol·60 min·l^{-1}

+ 0 mmol·60 min·l^{-1}

+ 9.4 mmol·60 min·l^{-1}

206.6 mmol·300 min·l^{-1}

APPENDIX II

Score card

Name of the evaluator: Date:

- Please evaluate the following samples using the 5 point Hedonic scale
- Write the preffered score in the columns as per evaluation
- Rinse your mouth in between evaluating each sample

5-Very good
4-Good
3-Fair
2- Poor
1-Very poor

Product Code	**Colour**	**Flavor**	**Texture**	**Taste**	**Overall acceptability**
677					
566					
455					
344					

Suggestions and comments

Signature of the evaluator.