ANNEX: 2.5

Report on

Proving the Health Benefits and Developing Healthful Products of Small Millets

(Part of Objective 3)

IDRC Project Number: 106506

Research Institutions:

Tamil Nadu Agricultural University (TNAU), India

All India Coordinated Small Millets Improvement Project (AICSMIP), ICAR, India

Arthacharya Foundation (AF), Sri Lanka

University of Guelph (UG), Canada

Location of Study

India, Sri Lanka & Canada

Report period:

(March 2011 to August 2014)

Part of

Revalorizing Small Millets in the Rainfed Regions of South Asia

Foreign Affairs, Trade and Development Canada   Affaires étrangères, Commerce et Développement Canada

IDRC | CRDI

International Development Research Centre

Centre de recherches pour le développement international

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Acronyms

AICSMIP : All India Coordinated Small Millets Improvement Project
CMU : Canadian Mennonite University
DFATD : Department of Foreign Affairs, Trade and Development
DHAN : Development of Humane Actions
FGD : Focus Group Discussion
IDRC : International Development and Research Centre
LI-BIRD : Local Initiatives for Biodiversity, Research and Development
RESMISA : Revalorizing Small Millets in rainfed regions of South Asia
TNAU : Tamil Nadu Agricultural University
UG : University of Guelph
AICRP : All India Coordinated Research Project

Proving the Health Benefits and Developing Healthful Products of Small Millets

(Part of Objective 3)

1. Introduction

Small millets are small-seeded grasses that include a group of six crops viz. finger millet (*Eleusine coracana*), kodo millet (*Paspalum scrobiculatum*), proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*) and barnyard millet (*Echinochloa utilis*). They are hardy and grow well in dry zones as rainfed crops, under marginal conditions of soil fertility and moisture. They are one of the oldest food grains known to humans and possibly the first cereal grain to be used for domestic purposes. Small millets are the staple food of the millions inhabiting the arid and semiarid tropics of the world. They are distributed in most of the Asian and African countries and parts of Europe. They are the most important species in terms of cropped area and contributions to food security in regions of Africa and Asia. (Rao, *et al*., 2011). They are also unique due to their short growing season and can develop from planted seeds to mature, ready to harvest plants in as little as 65 days. This is important in heavily populated areas. If properly stored, whole grains can be kept for two or more years.

Small millets are highly nutritious, non glutinous and non-acid forming foods. Hence, they are soothing and easy to digest. They are considered to be the least allergenic and most digestible grains available. Small millets contain about 8 percent protein and 4 percent fat. They are rich source of vitamins and minerals. Small millets are especially rich in calcium. The dietary carbohydrate content of millets is also relatively high. Starch is the main carbohydrate component and they contain a higher proportion of non-starchy polysaccharides (dietary fiber) also. In spite of these nutritional advantages the consumption of small millets has drastically declined in the last four decades across South Asia. Some of the important reasons for the decline of small millets consumption are: Lack of adequate scientific proof of the nutritional benefits and near absence of small millet food products in the market. This is in turn a reflection of inadequate research on nutrient analysis, development of attractive food products and bioavailability of products. Any effort for increasing consumption of small millets to address the malnutrition and rising incidence of non-communicable diseases have to address these research gaps.

In this background, the Revalorising Small Millets in Rainfed Regions of South Asia Project, initiated with the objective of addressing the constraints related to production and consumption of small millets, has undertaken research under its objective 3 on two major aspects: (i) Proving the health benefits of small millets (ii) Developing healthy and attractive products both for home and market based consumption. The specific objectives of the research are:

1. Evaluation of different small millets varieties for their nutritional values and consumption qualities
2. Development of small millets based food products for rural and urban consumers
3. Bioavailability of nutrients from different product matrices

The research was carried out by Tamil Nadu Agricultural University (TNAU) and All India Coordinated Small Millets Improvement Project (AICSMIP) in India, Arthacharya Foundation in Sri Lanka and University of Guelph (UG) in Canada. The following sections share the materials and methods, research results and the conclusions related to the research activities.

2. Material and methods

2.1. Materials

2.1.1. Small millets: The different varieties of small millets were collected from the project sites of India, Nepal, and North America (Canada and the US). The small millets namely kodo millet, little millet, foxtail millet, finger millet and barnyard millet were selected for the study based on their popularity, nutritional characteristics and other specific characteristics.

2.1.2. Miscellaneous: The commercial refined wheat flour was purchased from flour mill. The remaining ingredients namely sugar, yeast, shortening, oil, bread improver and calcium propionate were purchased from the local market.

2.1.3. Packaging materials: Poly Propylene (PP) pouches with 70 gauge, 100 gauge thickness and plastic containers were purchased from the dealer.

2.1.4. Chemicals: The chemicals with analytical reagent (AR) or laboratory reagent (LR) or guaranteed reagent (GR) grade were used for analysis.

2.1.5. Equipment: The equipments available in the University were used in the present investigation for the development of millet incorporated bread, cookies and porridge.

Table 1: Equipments used for investigation for the development of millet product

1.	Processing equipments	Satake dehusker (Type THU35A, Satake Engineering Co., Japan), Satake grain testing mill (TypeM05, Satake Engineering Co., Japan), Buhler Laboratory Mill (Model MLV-202, Switzerland), pulverizer,
2.	Dough mixing equipments	Flour sifter (M/S Sheet Master, CBE), Spiral kneader (M/S Sheet Master, CBE), Bread moulder (M/S Sheet Master, CBE)
3.	Baking equipments and other cooking utensils	Rotary rack oven-Diesel operated (M/S Sheet Master, CBE), Baking oven (Memmert model 854, Schwabach, West Germany), Bread slicer (M/S Sheet Master, CBE) Stainless steel vessels, Mixer grinder, etc.,
4.	Storage commodity	Refrigerator (Godrej)
5.	Texture analyzer	Texture analyzer (TA-XT2i, Stable Micro Systems, Surrey, UK), Hunter Lab Colour Flex (Hunter Associates Laboratory Inc., Model: $45^0/0^0$, Reston, Virginia, USA 20190, 471-6870)
6.	Packing equipment	Sealing machine (Preethi)

7.	Weighing equipments	Avery balance (2 kg capacity), Electronic balance (Shimadzu BL-120-H)
8.	Analytical equipments	Sedimentation shaker (Muhlenbau sedimentation shaker, Model:189, Peenya Industrial Area, Bangalore), Moisture meter (Model:RSMA 2, Rajdhani Scientific Instt. Co, New Delhi), Centrifuge (Universal model:11), Kjeldahl digestion mantle (Gerhardt), Soxhlet extraction apparatus (Pisces Instruments, Chennai), Muffle furnace (Gambak make, UK), Hot air oven (Narang Scientific company, India), U.V. Spectrophotometer (Varian, USA), Spectronic 20 (Bosch and Lamb, USA), Laminar air flow chamber, Water activity meter (HygroPalm AW1 (Cole Parmer A-37910-35, Huntington, New York, USA), Sedimentation shaker (Muhlenbau sedimentation shaker, Model: 189).

2.1.6. Experimental Animals: Wistar albino rats weighing 180-220 g were obtained from Medical College, Thiruvananthapuram, India and the study was conducted in K.M. College of Pharmacy, Madurai. The experiments were approved by the institutional animal ethics committee, Tamil Nadu Agricultural University, Coimbatore. The wistar albino rats were housed in large spacious cages and they were fed with standardized small millet cookies and porridge and access to water *ad libitum*. The animals were acclimatized to the standard environmental condition of temperature ($22^oC \pm 5^oC$) and humidity (55 ± 5%) and 12 hrs light and dark cycles throughout the experimental period.

Diabetes mellitus was induced into wistar albino rats by single intraperitoneal injection of freshly prepared solution of Alloxan monohydrate (150mg/kg BW) in physiological saline after overnight fasting for 12 hrs. Alloxan is commonly used to produce diabetes mellitus in experimental animals due to its ability to destroy the β-cells of pancreas possibly by generating the excess reactive oxygen species such as H_2O_2, O_2 and HO. The development of hyper glycaemia in rats was confirmed by plasma glucose estimation on 72hrs post alloxan injection. The rats with fasting plasma glucose level of >150 mg/dL were used for this experiment.

2.2. Methods

2.2.1. Evaluation of different small millets varieties for their nutritional values and consumption qualities

(i) Screening of small millet varieties: The small millets varieties were evaluated for their physical characteristics, nutritional characteristics and analysed for their suitability for the standardization of products.

(ii) **Physical characteristics of small millet varieties:** Physical appearance of grain is an important characteristic which determines consumer acceptability and hence the study of physical characteristics of the grains becomes a basic step in any research. The characteristics like thousand grain weight, volume and bulk density were studied by following the procedures as described below.

All the estimations were done in triplicates. The size of the seed was measured using calipers to the nearest of 0.01 mm.

Thousand grain weight: Weight of randomly selected thousand grains was recorded in grams using electronic balance with a sensitivity of 0.01 mg.

Thousand grain volume: Thousand randomly selected grains were dropped in a measuring cylinder containing known volume of distilled water. The difference in volume was recorded in ml.

Bulk density: A 30 g (14 per cent wt moisture content) of the sample was put into a 100 ml measuring cylinder. The cylinder was tapped continuously until a constant volume was obtained. The bulk density was calculated as weight of grain (g) divided by grain volume (ml) and the bulk density was expressed as g per ml.

(iii) Nutritional characteristics of the small millet varieties: The chemical composition of the small millet varieties was analyzed. The nutrients like moisture, crude protein, carbohydrate, crude fibre, ash, calcium, iron, zinc and tannin were analyzed. The detailed procedure developed and agreed upon by Dr. Koushik Seetharaman and Dr. Malathi is given in Annex 1**.**

Table 2 Methods for analysing nutrients of small millets

Parameters	Methods	References
Moisture	Hot air oven method	Ranganna (1995)
Carbohydrate	Phenol sulphuric acid method	Dubois *et al*, (1956)
Protein	Micro kjelplus method	AOAC, (1980) and Ma and Zuazaga, (1942)
Fat	Solvent extraction	AOAC, (1980) and Cohen, (1917)
Crude fibre	Acid and alkali digestion	Sadasivam & Manickam (1996)
Ash	Muffle furnace - dry ashing	AOAC, (1980)
Calcium	Titration	AOAC, (1980) and Clark and Collip, (1925)
Iron	Colorimetric method	AOAC, (1980) and Wong, (1928)
Tannin	Colorimetric method	Sadasivam & Manickam (1996)

a) TNAU analysed different small millet varieties for carbohydrate, protein, fat, crude fibre, calcium and iron.
b) The AICSMIP analysed released varieties of finger millet for protein, zinc and calcium contents. The experiment was conducted at Project Coordinating Unit (PC Unit Small Millets), UAS, GKVK, Bangalore using 39 land races of finger millet and laid out in Randomised Complete Block Design (RCBD) in two replicates with each variety in two rows of 3 meter row length during rainy season between July to December, 2013 with protective irrigation during rain free period. The grain of all land races were analyzed for grain Zn, Fe and calcium using Atomic Absorption Spectrophotometer (AAS) and expressed as mg/100 g.
c) The experiment was conduted at two locations, PC Unit (Small millets), GKVK, Bangalore, Karnataka and All India Coordinated Project (AICRP ,Small millets), Nandyal, Andhra Pradesh during kharif, 2012 using reference set constituting 199 accessions which includes a few leading varieties also. From these experiments grain samples were collected, cleaned and dehusked to

obtain foxtail millet rice. Such rice material ground to a fine powder and used for estimation. Care was taken to avoid the contamination of grains with dust and metal particles during their cleaning.

d) Analysis was made for grain Zn, Fe and calcium using Atomic Absoption Spectrophotometer by wet digestion method using Tri-acid (HNO_3, H_2SO_4 and $HClO_4$) mixture (Sahrawat *et al.,* 2002). In this method, 0.5 g of powdered rice sample and 10 ml of tri acid mixure were taken in digestion tube and kept for over night as a pre-digestion. After pre-digestion the digestion tubes were transferred to digestion unit and heated at 120^0C for first one hour and 230^0C for another two hours. The digested samples were diluted to 75 ml and micronutrients were determined using AAS at respective wavelength against standard checks (Merck standards). The standard concentrations for calcium were 0 to 10 PPM and for iron, zinc the standard concentrations were 0.4 to 2 PPM.

e) Protein analysis was made indirectly using micro-kjeldahl method, which gives Nitrogen content (%). For the analysis, 1 g of powdered rice samples were digested with 10 ml of sulfuric acid for 2 hrs, which leads to the formation of ammonium sulfate solution. Through the alkalinization with NaOH, the ammonia was displaced from the ammonium sulfate and over-distilled into a boric acid receiver via steam distillation. This is then titrated with 0.1 N sulfuric acid to get Nitrogen percent. Such percentage was multiplied with conversion factor (6.25) to arrive at protein content (AOAC, 1980).

(iv) Mapping the compositional and functional variability of small millets: Doctoral students from India and Canada analysed the fats, proteins, phenolics and antioxidants, fibre content and carbohydrates of different varieties of small millets obtained from the project sites of India and Canada. The functional qualities of small millets like glycemic activity of some small millets as compared to rice, wheat, and other major cereals were studied. Research on cooking and staling properties of small millets was compared with other major cereals.

(v) **Identification of finger millet varieties for popping:** Grains of 86 released finger millet varieties were dehusked, cleaned and used for popping. Initial grain moisture content was estimated by taking about 10 g of sample in each variety, oven dried at 105^0c for 4 hrs and moisture content was computed as below.

$$\text{Moisture content (\%)} = \frac{\text{Initial wt. of the sample (g)} - \text{Oven dried wt. of the grain sample (g)}}{\text{Initial weight of the grain sample (g)}} \times 100$$

After determining the initial grain moisture content of each variety, 20 g of grain sample in three replicates was sprayed with required quantity of water so as to adjust 19% moisture, the samples were mixed well and equilibrated for 24 hrs in a desiccator (Malleshi, and Desikachar, 1981). Such conditioned samples (20 g) were used for popping. These grains were placed in the iron frying pan containing fine sand (0.85 mm) as heat exchange medium, mixed and heated as sufficient for puffing (Approx. 270^0c). When puffing sound was stopped the pan was removed immediately from the flame and sand was separated by sieving through 0.85 mm sieve. The number of completely popped, partially popped and unpopped grains was separated manually and weighed separately. The popping percent was computed as below. The popping percent was analysed statistically in completely randomised design.

$$\text{Popping yield (\%)} = \frac{\text{Weight of popped (complete + partial) grains}}{\text{Weight of popped (complete + partial) grains + unpopped grains}} \times 100$$

2.2.2. Development of healthful products and assessing consumer acceptance and health impact Standardization of value added products from small millets: Studies were done for the products on physical properties, sensory attributes, nutrient analysis, packaging materials and shelf life. Consumer acceptability survey was conducted for the developed products.

(i) **Sensory evaluation:** The developed products were subjected to sensory evaluation for their organoleptic properties viz., colour and appearance, flavour, texture, taste and overall acceptability by a panel of 25 members using a nine point hedonic scale. Ratings of 9-1 are rated as 9- Like extremely, 8-Like very much, 7-Like moderately, 6-Like slightly, 5-Neither like nor dislike, 4-Dislike slightly, 3-Dislike moderately, 2-Dislike very much, 1-Dislike extremely (Watts *et al*., 1989). The mean score was obtained for all the characters. The score card used for the evaluation is given in Annex 2.

In the present study, nine point hedonic scale rating was used to assess the organoleptic characteristics of the value added products from small millets.

(ii) **Microbial analysis**: The microbial load of the stored samples were enumerated initially and at the end of the storage period by the method described by Istavankiss (1984).

(iii) **Cost analysis**: The cost of the products was analyzed systematically.

2.2.3. Bioavailability of nutrients from different product matrices

TNAU - Ethical Clearance: The study protocol was presented before the ethical committee of Tamil Nadu Agricultural University, Coimbatore and after obtaining due clearance from the ethical committee the study on bio-availability and anti-diabetic effect of small millets was undertaken. Copy of the ethical clearance certificate is appended (Annex 3).

Dr. Seetharaman's team evaluated the sensory quality and acceptability, nutritional value and glycemic index of bread from finger millet and pearl millet by comparing them with bread produced from refined wheat flour.

Dr. Malathi, TNAU conducted study of the product matrix effect on low, intermediate and high moisture products. The different grain varieties based on their physical properties and nutritional characteristics were selected and utilized for the standardization of bread and cookies. Porridge was developed from kodo, little and foxtail millet as high moisture food. The standardized small millet products were analyzed for their starch digestibility, dietary fibre and antioxidant properties**.** The anti-diabetic effect of the standardized cookies and small millet flour was analyzed. The detailed protocol followed for bioavailability studies is given in Annex 4**.**

2.2.4 Conducting survey on food and nutritional status of the community

Dr. D. Malathi developed a detailed questionnaire to study the socio-economic and nutritional status of the people of the project site of Tamil Nadu (Annex 5). Nutrition education was given to rural women, which included hands on training on value addition of small millets and using posters, pamphlets, live specimens and lecturing. The impact of the programme was studied to assess the Knowledge, Attitude and Practice (KAP) (Annex 6, 7& 8).

3. Results and Discussion

3.1 Evaluation of different small millets varieties for their nutritional values and consumption qualities

3.1.1 Studies by UG

The nutritional analysis of different varieties of small millets collected from India, Nepal and North America (Canada and the US) was completed at the University of Guelph by Dr. Koushik Seetharaman. The results showed significant differences in dietary fibre, starch fractions, total free lipids and fatty acid profiles. Dr. Seetharaman and his graduate students conducted structural analysis of starch in kodo millet, little millet, foxtail millet, proso millet, finger millet and barnyard millet. They also studied the effect of parboiling on the nutrient composition and on-vitro digestibility of millet products, effect of germination on alpha amylase and free sugars in proso millet and on millet amylopectin. Proso and foxtail millet starches had similar starch characteristics but were different from finger and pearl millet starches, which were also similar. The former had more of shorter amylose chains with shorter chain segments between branch points, and higher K/S values when compared to the latter two millets. X-ray diffract grams of proso and foxtail millet starches were also similar but different from pearl and finger millet starches when exposed to iodine vapor. Finger millet amylopectin crystals melted over the widest temperature range (10.2°C), while foxtail and proso millets exhibited narrower melting temperature ranges (7.6°C) and higher gelatinization onset temperatures. Unit and internal chain profiles of the millet amylopectins showed significant differences. Differences in internal structure suggest differences in the fine structure of their clusters and building blocks. Values of 17.9–18.1, 11.9–12.3, 4.8–5.1 and 11.6–12.3 were calculated for average chain lengths (CL), external chain length (ECL), internal chain length (ICL) and total internal chain length (TICL), respectively, of the millet amylopectins. Millet amylopectins could be structurally classified as type 2 based on the classification of amylopectins (Bertoft et al 2008). Removal of proteins, lipids or both significantly increased enzymatic hydrolysis of starch and the expected glycemic index, with the effects of starch-lipid interaction being more significant than that of starch-protein interaction. Small millet starches complexed with palmitic, oleic, linoleic and elaidic acids to different extent. The complexing index (CI) of fatty acids with millet starches increased with increasing degree of unsaturation. Reductions in the starch hydrolysis rates of the complexes depended on the amounts of the fatty acids added. Unsaturated fatty acids generally resulted in less starch being hydrolyzed, with oleic acid being the most effective in reducing starch hydrolysis rates. Linoleic acid-complexed starches were much less resistant to hydrolysis. Elaidic acid-complexed starches were generally hydrolyzed more than oleic acid-complexed starches, suggesting the *cis* form of the fatty acid as more effective in reducing glycemic index than the *trans*. In conclusion, the millet starches were structurally very different from each other and their starch hydrolysis rates and glycemic index were significantly affected by starch-protein-lipid interactions. Not only did the type of fatty acid have an effect on the glycemic index of the millet starches, but also their amounts in the millets.

Doctoral students from India and Canada analysed the fats, proteins, phenolics and antioxidants, fibre content and carbohydrates of different varieties of small millets obtained from the project sites of India and Canada. The functional qualities of small millets indicated slow glycemic activity of some small millets as compared to rice, wheat, and other major cereals. The preliminary results of the compositional analysis indicated that lipids and starch contribute to low glycemic attributes of small millets, even in the absence of bran (fibre). Further, research has also shown that the cooking and staling properties of small millets differ from each other as well as from other major cereals. This highlights that small millet starch or flour has enormous potential in developing unique food products with health benefits.

The above mentioned research activities resulted in many theses and publications in peer reviewed journals like *Journal of Cereal Science, Cereal Chemistry, Journal of Food Science and Technology.*

3.1.2 Studies by TNAU

Dr. Malathi, TNAU analyzed 20 samples of different small millet varieties grown on project sites in India for their nutritional characteristics. The moisture content of the grains ranged from 4.58 to 8.81 g/100 g of the grain. The protein content of the barnyard millet variety obtained from Peraiyur was found to be 8.52 g/100 g of the grains. The kodo millet grain variety from Coimbatore was found to be high in crude fibre and iron content than the other millet grains. Finger millet was found to contain the maximum calcium content of 134.63 g. The nutritionally rich millet varieties were selected for the standardization of therapeutic foods (for diabetic, cardiovascular disease, obesity etc.) and traditional foods commonly consumed by the farmers replacing rice and wheat.

Finger millet is a versatile source of carbohydrate, protein and mineral that is comparable to other common cereal grain. It is also a rich source of minerals having significant amount of calcium, iron and phosphorus. Eleven landraces from three sites were analyzed for their nutrient content. The protein content of the varieties ranged from 5.97 to 7.41g per 100g. The calcium content was found to be maximum in the variety of Saratha (334mg/100g). The iron content of the varieties ranged from 2.37 to 3.96mg per 100g.

Table 3 : Nutrient contents of small millet varieties from project sites (per 100g)

Sl. No.	Sample crop	Project site	Variety	Form (Flour)	Moisture (g)	Ash	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Calcium (mg)	Iron (mg)	β Carotene (mg)
1.	Little Millet	Jawadhu Hills	CO2	Grain	6.86	**3.91**	68.84	5.68	4.36	10.35	53.66	33.47	0.12
2.	Little Millet	Jawadhu Hills	CO2	Dehulled	7.54	0.36	**85.22**	5.68	0.89	0.31	32.80	17.43	N
3.	Little Millet	Jawadhu Hills	CO3	Grain	**8.81**	3.70	66.57	5.68	4.40	10.84	48.01	21.01	0.15
4.	Little Millet	Jawadhu Hills	CO3	Dehulled	6.62	1.23	82.82	5.68	3.03	0.62	36.53	16.90	N
5.	Little Millet	Jawadhu Hills	CO4	Grain	6.65	3.64	69.31	5.68	4.79	9.93	47.48	25.40	0.15
6.	Little Millet	Jawadhu Hills	CO4	Dehulled	7.26	0.59	84.72	5.68	1.21	0.54	29.10	20.35	N
7.	Little Millet	Jawadhu Hills	Sittan samai (LR)	Grain	5.59	**3.91**	69.72	5.68	4.80	10.30	46.10	22.63	0.14
8.	Little Millet	Jawadhu Hills	Sittan samai (LR)	Dehulled	7.21	1.01	82.89	5.68	2.79	0.42	34.57	29.70	N
9.	Little Millet	Jawadhu Hills	Koluthana samai (LR)	Grain	7.26	3.51	68.50	5.68	5.24	9.81	49.73	43.85	0.17
10.	Little Millet	Jawadhu Hills	Koluthana samai (LR)	Dehulled	6.99	0.66	84.85	5.68	1.46	0.36	34.93	44.95	N
11.	Kodo Millet	Coimbatore	Market Variety	Grain	5.46	3.41	72.25	3.98	3.02	**11.88**	47.74	**62.31**	0.17
12.	Kodo Millet	Coimbatore	Market Variety	Dehulled	6.62	0.43	86.12	5.11	1.16	0.56	33.88	24.06	N
13.	Little Millet	Coimbatore	Market Variety	Grain	6.52	3.37	69.16	7.39	4.78	8.78	93.25	16.70	0.13
14.	Little Millet	Coimbatore	Market Variety	Dehulled	7.29	0.67	82.39	7.39	1.56	0.70	93.13	9.63	N
15	Foxtail Millet	Coimbatore	Market Variety	Grain	6.37	3.57	68.21	6.82	**5.93**	9.10	**134.63**	14.63	0.15
16.	Foxtail Millet	Coimbatore	Market Variety	Dehulled	6.59	0.80	81.19	7.95	2.71	0.70	81.25	26.05	N
17.	Barnyard Millet	Peraiyur	Sadai kuthiraivali	Grain	5.32	3.80	67.94	**8.52**	4.88	9.54	102.88	16.63	0.15
18.	Barnyard Millet	Peraiyur	Sadai kuthiraivali	Dehulled	5.76	1.20	80.76	**8.52**	3.09	0.67	20.50	10.05	N
19.	Kodo millet	Peraiyur	CO3	Grain	4.58	3.38	73.67	5.68	2.59	10.10	76.75	32.70	**0.34**
20.	Kodo millet	Peraiyur	CO3	Dehulled	4.89	1.36	84.41	6.82	2.11	0.41	17.13	14.79	N

3.1.3 Studies by AICSMIP

(i) Analysis of nutrient traits of finger millet varieties

AICSMIP analyzed 60 released varieties of finger millet for protein content and landraces of finger millet for zinc, iron and calcium contents. The results showed that five and two land races were found to be superior to the widely grown check variety GPU 28 with reference to zinc and calcium, respectively. These results need to be linked to varietal selection research taken up in the project.

Table 4 : Nutritional traits in land races of finger millet

Parameter	**Zn (mg/100 g)**	**Fe (mg/100g)**	**Ca (mg/100g)**
Range	0.26-4.06	0.55-6.93	13. 6-393.7
Mean	2.63	4.16	200.1
GPU 28	3.2	6.93	283.1
Better varieties (> GPU 28)	Kada mandia (3.99), Lohardagia (3.30), Katti (3.73), San mandia (3.33), Sunamani (4.06)		Katti (326.8), Bonda (393.7)

(ii) Evaluation of foxtail germplasm for nutritional traits

The reference set constituting 199 accessions including a few leading varieties of foxtail millet were analysed for nutritional contents in view of identifying accessions with superior nutritional traits as a variety or for future breeding programme. Hence, the experiment was conduted at two centres, PC Unit (Small millets), GKVK, Bangalore and AICRP (Small millets), Nandyal. The grain were analysed for Zn, Fe and Calcium in two replicates using AAS. The details of the study are given in Annex 9**.** The pooled data over two locations is presented. Large variations were observed for the said nutrient contents, however no significant variations could be noticed between the locations (Table - 5). The superior accessions identified are listed in Table- 6.

Table 5 : Evaluation of 199 germplasm accessions of foxtail millet for Calcium, Iron and Zinc at two centres

Elements in units	Calcium (mg/100gm)		Iron (mg/100gm)		Zinc (mg/100gm)	
(Range)	GKVK	Nandyal	GKVK	Nandyal	GKVK	Nandyal
Max	31.61	31.44	8.57	8.48	7.94	7.91
Min	1.51	1.50	0.25	0.25	0.23	0.25
Mean	12.20	12.08	5.04	5.02	3.89	3.80

Table 6 : Superior lines at both centres for Calcium, Iron and Zinc in order

Nutrients	Range	Germplasm
Calcium	High >20mg/100g	Ise 1181, Ise 1277, Ise 1059, Ise 1418, GS 2259, Ise 1161, Ise 1400, Ise 758 and Ise 1474
Iron	High >7.5mg/100g	GS 754, GS 2040, GS 563, GS 2164, GS 2155, GS 760, GS 2029 and Ise 1511
Zinc	High >6.0mg/100g	Ise 748, Ise 1387, Ise 1511, GS 2239, GS 2040 and GS 1929

(iii) **Identification of finger millet varieties for popping**: Better popping is one of the essential pre-requisite in manufacturing of veining foods from finger millet. Therefore, identification of variety with superior popping percentage was taken up as part of the project. While the detailed report is given in Annex 10, the important results are given below.

In India, the popping percent among 86 varieties ranged from a minimum of 17% to maximum of 87% with a mean of 53.7%. Among the popped grains more percentage of grains were completely popped (Table 7). This indicated that, finger millet has an average popping percent as approximately 50%, among this 30% is completely popped and the remaining 20% is partially popped.

Table 7 : Range and mean for popping percent in 86 varieties

Parameter	Complete popping	Partial popping	Total popping
Range of popping %	5-65	9-45	18-88
Mean	31.7	22.5	54.2
SEm	1.4	1.4	1.92
CD @ 5 %	3.8	3.9	5.3
CV (%)	7.6	11.1	6.2

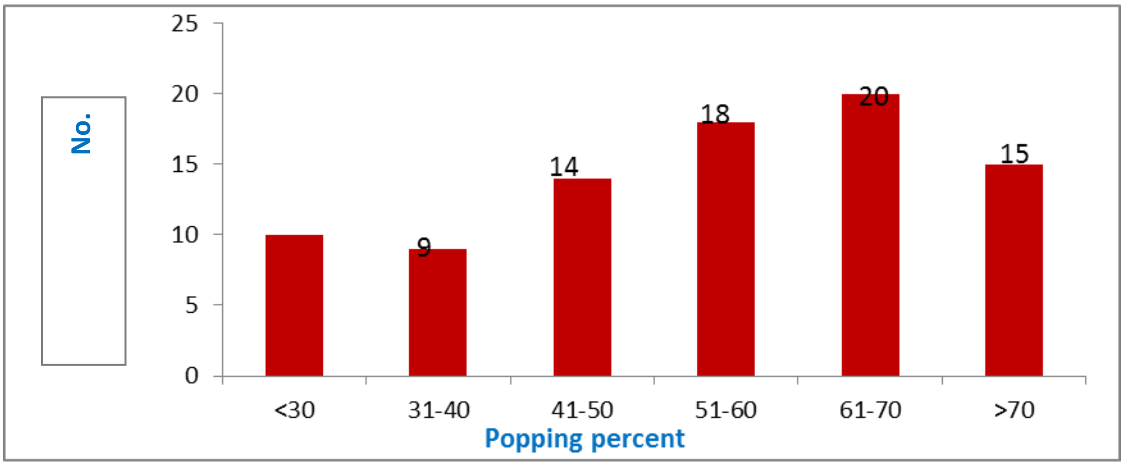


Fig.1: Frequency distribution of varieties for popping

Of the 86 released varieties majority lies in 50-70% popping (Fig.3). This indicates that, finger millet has 60% popping in general, with an exception of both low and high popping varieties.

High popping varieties

Low popping varieties

Fig.2: Difference between high popping varieties and low popping varieties

The results of the study reveal that, Co-10, Indaf-3, Karun kaddi ragi, PR-202, GN-4, ES-11 and PRM-2 are highly popped varieties with > 70% popping (Fig.2) while Picha kaddi ragi, PRM-802, Jenu Bonda ragi, Indaf-11, KOPN-933, VL-315, GPU-75 and PRM-901 are poor poppers (<30%). It is interesting to note that, GPU-66 (72.4%) has high popping percent, which is the product of GPU-28 (56.9) and PR-202 (78.8%) indicates the heritability of this character. AF standardized the popping of locally available varieties. However the popping properties were not satisfactory.

3.2 Development of small millets based food products for rural and urban consumers

3.2.1 University of Guelph

Different low GI products were developed by the UG team from refined proso millet (couscous like product, porridge, bread, and extruded snack) and their chemical analysis was completed. Consumer acceptability trials showed that the millet-incorporated bread was well accepted by consumers. Finger millet- incorporated bread had higher overall acceptability scores than those with pearl millet.

3.2.2 TNAU – INDIA

The detailed report on products developed by TNAU is given in Annex 11. The traditional food items, novel processed foods and pasta products were prepared with small millets that are being grown and used (Barnyard millet, Kodo millet, Finger millet and Little millet) by the farmers of the project sites. Millet was substituted for rice flour in the preparation of various traditional foods commonly consumed by the farmers. The developed products were analyzed for their nutrients and the sensory attributes were evaluated using a nine point hedonic scale by a panel of trained members.

(i) Traditional recipes

- **Breakfast food:** Idli, Dosa, Idiappam, Rotti, Pittu, Upma, Adai, Porridge, Khakra, Paniyaram and Chappathi.
- **Sweets:** Halwa, sweat kolukattai, Adhirasam, Kesari, Nutritious ball and Kheer.
- **Snacks:** Vadai, Pakoda, Ribbon pakoda, Omapodi, Murukku, Thattu vadai, Hot kolukattai and Vadagam.

(ii) Bakery Products

1. The bread prepared with 20% incorporation of small millets was found to be more acceptable up to 3 days. The cost of millet bread was calculated to be Rs. 17.00.
2. The millet based cakes were highly acceptable at 50% incorporation level for a period of 7 days. The cost of millet based cakes range from Rs.40 per 250 g of the product.
3. The small millets incorporated cookies were highly acceptable at 50% incorporation level and the shelf life of the product was 15 days. The cost of cookies was Rs.14 per 100 g of the product.

(iii) Pasta Products

Vermicelli and Macaroni were found to be acceptable up to an incorporation level of 30 per cent. The calcium and phosphorus of vermicelli ranged from 19.5 to 103.03mg/ 100 g of the product respectively. The iron content of the developed products ranged from 3.73 to 4.75 mg/100g and at 30 per cent incorporation level. The cost of the millet based products ranged from Rs.7 to Rs 15/100 g of vermicelli and Rs.10 to Rs.20/100g of macaroni.

Instant food mixes from Barnyard and Kodo millet (Idli mix, Dosa mix, Paniyaram mix, Aapam mix and Halwa mix) were standardized and evaluated for their nutrient content, organoleptic characters and shelf life. Health mix was developed from small millets. The mean score of overall acceptability of the kodo millet instant food mixes ranged from 8.1 to 8.8 and barnyard millet instant mixes ranged from 8.0 to 8.72. The cost of the developed mixes ranged from Rs.9.80/- to Rs. 13.40/- per 100 gm of the product.

(iv) Flaked and Popped Value added Small Millet Products

The developed small millet flakes and popped products were highly acceptable.

3.2.3 AF, Sri Lanka

AF developed ten finger millet products, such as finger millet hoppers, string hoppers, pittu, roti, thalapa, Kandgi, cake, oil cake (kewum), kokis and wandu hopper, and demonstrated to the rural and urban population. Recipes for all these products are now available as a small booklet (Available at http://www.dhan.org/smallmillets/booklets.php). The consumer survey showed high acceptability among adults but children did not like most of the products because of the colour, except the cake. Three new products were introduced to Helabojun (a restaurant opened by the DOA to introduce traditional food to consumers) at Peradeniya.

3.3 Bio-availability of nutrients from different product matrices

Dr. Malathi, TNAU conducted study of the product matrix effect on low, intermediate and high moisture products. The different grain varieties based on their physical properties and nutritional characteristics were selected and utilized for the standardization of bread and cookies. Porridge was developed from kodo, little and foxtail millet as high moisture food. The standardized small millet products were analyzed for their starch digestibility, dietary fibre and antioxidant properties**.** The anti-diabetic effect of the standardized cookies and small millet flour was analyzed. More details are given in Annex 12**.** The important results are:

- Cookies were highly acceptable at 50 per cent incorporation levels of small millets. The physical characteristics viz., spread ratio, colour index and texture showed positive effects in small millet cookies.
- The rapidly digestible starch of composite cookies was lower and slowly digestible starch was higher than the refined wheat cookies.
- The estimated glycemic index of composite cookies was lower than the refined wheat cookies.
- The total anti-oxidant activity, total dietary fibre and soluble dietary fibre content of composite cookies were higher than refined wheat cookies.
- The glycemic index had positive effect in humans for composite cookies, which was lower than the control.
- The standardized composite cookies exerted a hypoglycemic effect when compared to refined wheat cookies and was more pronounced in kodo millet cookies which was confirmed by animal study.
- The standardized composite cookies provided maximum calcium, iron and crude fibre. The standardized composite cookies packed in plastic container (P_2) exhibited higher acceptability than cookies packed in poly propylene bag (P_1) and the shelf life was found to be 15days with the microbial load within the safer limit.
- The composite bread was highly acceptable at 20 per cent incorporation level of small millets.
- The physical characteristics of standardized composite bread were found to be higher in bulk density and lower in water activity and sedimentation value.
- The estimated Glycemic index of composite bread was lower than control.
- The total anti-oxidant activity and the total dietary fibre content of composite bread were slightly higher than the control.
- The standardized composite bread was highly acceptable in 100gauge polypropylene bags than in 70gauge polypropylene (P_1), the shelf life was 3 days and the microbial load was within the safer limit. The crude fibre and calcium content was high in little millet and foxtail millet.
- Small millet porridge was highly acceptable at 100 per cent levels. The physico-chemical characteristics viz. water activity was lower and sedimentation value was higher in small millet flour.
- The estimated glycemic index of millet flour was lower compared to rice porridge. The small millets contained higher dietary fibre which exerts a hypoglycemic effect.
- The glycemic response was low in little millet followed by foxtail millet, kodo millet porridge.
- The small millet based products had good source of nutritious and therapeutic value and involved low cost of production.

The research on product development has resulted in many research papers which were published by *International Journal of Food and Nutrition Science, American Association of Cereal Chemists and Madras Agricultural Journal*.

Dr. Seetharaman's team evaluated the sensory quality and acceptability, nutritional value and glycemic index of bread from finger millet and pearl millet by comparing them with bread produced from refined wheat flour. The major findings are:

a) Significant increases in the *in-vitro* starch digestibility and EGI (expected glycemic index) of millet samples were seen after protein and/or lipid removal.
b) Finger-millet-incorporated bread (25 per cent incorporation) had the lowest GI of 67.5 per cent and this was similar to bread produced with pearl millet (also at the 25 per cent level) which had a GI of 71.1 per cent.
c) Expected glycemic index of proso millet flour, porridge and extruded products were seen to be lower than flour, porridge and extruded products from corn.

3.4. Improving the nutritional status of site community through recipe demonstration and nutritional education

Dr. D. Malathi and her team conducted a survey to study the socio-economic and nutritional status of the people of the project site of Peraiyur block of Madurai district to analyze the consumption of small millets, dietary diversity, and health and socio economic conditions of households. The senior research fellows of the project were involved in collecting data from the project site. The survey involved 120 households. The data on mean daily food intake of farm women showed that the consumption of all the food groups except pulses was lower than the recommended dietary allowance. The biochemical assessment of the respondents showed that 67 per cent and 50 per cent of women belonging to the 31-40 and 41-50 year age groups respectively were anemic. The random blood sugar test was normal for 83 per cent and 67 per cent in the 20-30 and 31-40 year age groups respectively.

Fig.3: TNAU TEAM – Conducting Survey

Table 8 : Frequency of food consumption pattern among the respondents (in percentage) in Peraiyur, Madurai, TN, India

Sl. No	Particulars	Daily	Alternate days	Once in a week	Once in a fortnight	Once in a month	Occasion ally	Never
1	Cereals a. Rice b.Wheat	100	20	50	8		-	22
2	Millets **a. Jowar** **b. Bajra** **c. Ragi** **d. Barnyard** **e. Kodo**	 - - - - -	 - - - - -	 - - - - -	 - - - - -	 - 5 - - 5	 **12** **28** **14** **22** **-**	 **-** **14** **-** **-** **-**
3	Pulses	100	-	-	-	-	-	-
4	Roots & Vegetables	-	-	90	10	-	-	-
5	Green leafy vegetables	-	-	88	12	-	-	-
6	Other vegetables	100	-	-	-	-	-	-
7	Fruits	-	-	33	-	45	22	-
8	Nuts& oils	100	-	-	-	-	-	-
9	Flesh foods a. Eggs	- -	- -	18 60	18 40	51 -	13 -	- -
10	Milk & milk products	68	12	20	-	-	-	-
11	Sugar & jaggery	100	-	-	-	-	-	-
12	Processed foods	18	-	32	23	-	-	27
13	Beverages	-	32	-	-	-	-	-

The survey results revealed that millet consumption of the people was very low.

Table 9 : Biochemical assessment of rural women

Biochemical assessment (N=40)	No. of Volunteers	Age Group	Normal Range	Anaemic (%)	Normal (%)
Haemoglobin	11	20-30	12-15.5	2 (27%)	9 (83%)
	12	31-40	12-15.6	8 (67%)	4 (33%)
	10	41-50	12-15.7	5 (50%)	5 (50%)
	7	51-60	12-15.8	5 (71%)	2 (29%)
			Normal range	**Diabetic (%)**	**Normal (%)**
Random blood sugar	11	20-30	80-120	2 (27%)	9 (83%)
	12	31-40	80-120	4(33%)	8 (67%)
	10	41-50	80-120	4 (40%)	6 (60%)
	7	51-60	80-120	1 (14%)	6 (86%)

The biochemical assessment of the respondents revealed that 67% and 50% of the women belonging to the age group of 31-40 and 41-50 years were found to be anemic. The random blood sugar test of the respondents was normal for 83% and 67% of them in the age group of 20-30 and 31 to 40 years.

3.4.1 Nutrition Education

Nutrition education was given to the 120 participants from Peraiyur and 100 participants from each of the project sites of Anchetty and Jawadhu Hills. Rural women were given hands on training on value addition of small millets. The education class emphasized on nutritional significance, nutrient composition, health benefits, product diversification and general hygiene and sanitation and usage of millet products as a dietary component. Hands on training were given to the selected subjects on the method of preparation of the developed instant kodo millet and barnyard millet mixes through demonstration. Packaging, labelling requirements of the instant mixes was also given as a part of the training programme.

Fig.3: Nutrition Education Programme

3.4.2 Nutrition knowledge

In Anchetty, before nutrition education, 58 percent of the rural women obtained a very low score of 0-25 followed by 32 percent of the rural women having a score of 26-50, only 8 percent and 2 percent of the women had scores of 51-75 and 76 -100 respectively. After nutrition education 73 percent of the women scored maximum scores 76-100, 15 percent of the women had knowledge scores ranging from 51-75. Around 4 percent of the women had obtained scores from 0-50.

In Jammunamarathur, before nutrition education, 55 per cent of the rural women obtained a very low score of 0-25 followed by 30 per cent of the rural women having a score of 26-50, only 10 per cent and 5 per cent of the women had scores of 51-75 and 76 -100 respectively. After nutrition education 67 per cent of the women scored maximum scores 76-100, 22 per cent of the women had knowledge scores ranging from 51-75. Around 3 per cent of the women had obtained scores from 0-50.

Comparatively, the participants in the project site Anchetty in Krishnagiri district had obtained better scores than the participants in the other project site. But participants from both the project sites positive changes in the level of knowledge on small millets gained through nutrition education.

3.4.3 Attitude of the rural women

After nutrition education, all of them realised the state of health is related to food, and illness is due to the lack of balanced diet. Initially, only three of them had the attitude that mixed diet provides all the nutrients but after participating in nutrition education, all women understood that only a mixed diet provides nutrition. Nutrition education had brought about a remarkable change in the attitude of the participants regarding the relation between millets and life style disorders. After nutrition education, the participants accepted that all millets can be used as a food in their daily diet and are tasty and cheap. They also accepted that millets can be used in the preparation of traditional sweets, snacks, flakes and popped products. All the participants came to know about the possibility of using millet flour instead of wheat flour and also about the preparation of small millet based instant food mixes. A positive attitude was created among the women participants towards using small millet based instant food mixes as a tool for self employment and income generation.

3.4.4 Practices of the rural women

After nutrition education, women started using millets in their daily diet. They also started using flaked and popped millet products. After nutrition education, eighty eight of them were self employed by processing millet based instant mixes and fifty three of them had started generating income from it. The observations on knowledge, attitude and practice are indicative of the possibility of commercializing millet based instant mixes among population groups.

3.4.4 Training and Demonstrations

The training and demonstration programmes were conducted in the project sites Anchetty (Krishnagiri District), Jawadhu Hills (Tiruvannamalai District), Peraiyur (Madurai District) and Tamil Nadu Agricultural University, Coimbatore. The programme enriched the rural women by explaining them the methods of processing to add value to their produce, so as to generate consumer demand for millet-based food products. The focus of the training was to improve production technologies and increase the utilization of millets by value addition for better marketing prices and sharing experiences by entrepreneurs.

3.4.5 Follow-up Study

- Follow up study for millet utilization at house hold level was conducted at the project sites.
- 90% of the participants felt that the training was useful.
- 95% of the participants increase the utilization of the millets in their home.
  - Once in a week - 40%
  - Twice a week - 45%
  - Once in 15days - 10%
- **30%** of the participants felt changes in their health after consuming millets.
- Recipes commonly prepared and liked by the participants and their family - dosa, paniyaram, adai, roti, uppma, pakoda, murukku, pittu, halwa, payasam, kozhukkattai, porridge, and health mix.
- Constraints in cooking millet
  - Lack of facilities for milling of millet grains
  - Unavailability of processed millet flour and raw ingredients
  - Lack of time

3.5 Dissemination of products developed in the project

Fig.5: Product development training

TNAU organised training programmes and demonstrations for women, farmers, entrepreneurs and self group members on small millets production technology, post-harvest technologies, value added small millet products, packaging and commercialization of small millets. A brochure has been prepared and disseminated to the food industries (See Webpage). TNAU team initiated the Agro processing centers at three project sites of India viz., Peraiyur (Madurai district), Jawadhu Hills (Tiruvannamalai district) and Anchetty (Krishnagiri district) for the rural and urban women for value addition of small millets. This initiative is expected to increase the utilization of small millets and pave way for the income generation of local entrepreneurs in the project sites (See **Annex XIII** for more details). In Sri Lanka, AF introduced the developed products to the site community to obtain their feedback. Training cum awareness programme was held for rural mothers. LI-BIRD provided finger millet recipe training in 2013 which included farmers, school teachers and cooks, local entrepreneurs and women cooperatives . They were trained to prepare cake, malt, namkeen, halwa, cookies and doughnut. Two government primary schools in Jogimara, and 1 Boarding school in Dhikur Pokhari, introduced finger millet recipes in mid day meal. Recipes are served 2-4 times in a month.

Fig.6: Finger millet recipes for school children

4. Summary and Conclusion

Among the constraints that hindered consumption of small millets most important ones were lack of adequate proof regarding the health benefits of small millets, inadequate development of small millets products and drudgery related to post-harvest operations, mainly dehulling. Within the context of this objective, the project focused on the following three major research areas: (i) Testing the nutritional quality of small millets, with special attention to local landraces and examining why millet is healthful and whether these health claims can be validated, (ii) Developing healthy and attractive products both for home and market based consumption and (iii) Improvising and developing technologies to address the post harvest constraints.

4.1 Evaluation of different small millets varieties for their nutritional values and consumption qualities

Dr. Koushik Seetharaman and Dr. Malathi, Food Scientist, TNAU undertook nutritional analysis of small millet samples from India, Nepal and North America (Canada and the US). The AICSMIP analyzed finger millet landraces for zinc and calcium contents. AF in collaboration with ITI, Colombo analyzed nutritional and consumption attributes of few varieties of finger millet, foxtail millet and pulses. The important results are:

(i) Significant differences in dietary fibre, starch fractions, total free lipids and fatty acid profiles among the different millet types. Variance found in millet starches in terms of different organization of starch polymers and their degree of crystallinity, and varying degrees of gelatinization and retro gradation characteristics can be exploited in various food applications

(ii) Parboiling significantly altered the nutrient composition and in vitro digestibility of millet products.

(iii) Protein content, crude fibre, calcium, and amino acids (tryptophan, cysteine, and methionine) of 20 small millet varieties grown on project sites in India were analysed and nutritionally rich millet varieties identified.

(iv) Analysis of landraces of finger millet in Indian project sites for zinc, iron and calcium contents indicated that five and two land races had higher amount of zinc and calcium compared to the standard variety GPU 28, respectively.

(v) Foxtail millet accessions rich in protein and micronutrients were identified in India and the relationship between these nutrient contents was analysed.

(vi) **Mapping the compositional and functional variability of small millets:** It indicated slow glycemic activity of some small millets as compared to rice, wheat, and other major cereals. The preliminary results of the compositional analysis indicated that lipids and starch contribute to low glycemic attributes of small millets, even in the absence of bran (fibre). Further, research has also shown that the cooking and staling properties of small millets differ from each other as well as from other major cereals. This highlights that small millet starch or flour has enormous potential in developing unique food products with health benefits.

(vii) **Identification of finger millet varieties for popping:** Screening of finger millet varieties for popping ability by AICSMIP indicated that (i) The average popping percent was around 60 percent, (ii) CO 10, INDAF-3, *Karun kaddi* ragi, PR 202, Purna, GN 4, ES 11 and PRM 2 were found to be superior finger millet varieties for popping and (iii) The popping character may be inheritable. The popping ability of Sri Lankan varieties was found not satisfactory.

4.2 Development of millets based food-products for rural and urban consumers

In India, incorporation of small millets (barnyard, kodo, finger and little millets) in traditional south Indian breakfast, in sweets and in snack foods was standardised. Bakery products like bread, cookies, cake, soup sticks and *khari*, pasta products like vermicelli, Idiappam, macaroni and noodles, flaked and popped products and instant mixes using small millets were standardized and analyzed for their nutritive value. These products were disseminated to 1473 persons including site families and to the entrepreneurs and food industries. In Sri Lanka ten finger millet products (finger millet hoppers, string hoppers, *Pittu, Roti, Thalapa, Kandgi, Cake, Oil cake, Kokis* and wandu hopper) were standardised and demonstrated to the rural and urban population. Three new products were introduced to Helabojun (a restaurant opened by the DOA to introduce traditional food to consumers) at Peradeniya.

4.3 Bioavailability of nutrients from different product matrices

The developed products were evaluated the sensory quality and acceptability, nutritional value and glycemic index (GI). The major findings from UG are:

- (i) Finger-millet-incorporated bread (25 per cent incorporation) had the lower GI (67.5 per cent) than wheat bread.
- (ii) Expected GI of proso millet flour, porridge and extruded products were lower than flour, porridge and extruded products from corn.
- (iii) Finger-millet-incorporated bread had higher overall acceptability scores than pearl millet bread.

The major findings of TNAU are:

- (iv) The millet based cookies were highly acceptable at 50per cent and bread at 20per cent incorporation level.
- (v) The reduction in the blood glucose levels and improvement in plasma insulin level and haemoglobin content was higher in the rats fed with kodo millet cookies.

Way forward

- Assessing the bioavailability of value added products recipes from small millets.
- Developing small millet products with therapeutic values including diabetic, obesity, cardio vascular diseases, etc.,
- Client oriented research for adoption of food products developed by various clients including street vendors and small scale food entrepreneurs under different contexts in terms of crops, agro-climatic regions and socio-political environments.
- Popularization and commercialization of small millets through trainings and demonstration programmes to empower women.

ANNEXES

Annexure- 1: Protocol for chemical analysis

Moisture

The moisture content of the sample was estimated by the hot air oven method suggested by Ranganna (1995). About 5.0g of sample was weighed accurately and dried in an air oven at 110^0C. The drying was continued till a constant weight was obtained. The moisture content was expressed as percentage.

Estimation of protein

Protein was analysed by the amount of nitrogen available in the sample by micro kjeldhal method (AOAC, 1980). One gram of sample was transferred into 250 ml digestion flask along with one to two gram of catalyst mixture and 25 ml of concentrated sulphuric acid. The catalyst mixture consists of 2.5 g of powdered selenium-dioxide, 10g of potassium sulphate and 20 g of copper sulphate. The sample was digested until the solution becomes colorless.

The digested sample was made upto 100 ml with distilled water in a volumetric flask. A known amount of aliquot was transferred into the distillation flask. To this 10 ml of saturated sodium hydroxide solution was added. The solution was distilled and the ammonia evolved was trapped in boric acid placed in a beaker at the tip of the condenser. The solution was titrated against the N/70 hydrochloric acid for the end point, until the colour changes. The same procedure was repeated to get the blank titre value and the nitrogen content of the sample can be calculated. The nitrogen value multiplied by factor 6.25, gives the crude protein content of the sample in per cent.

Estimation of fat

The fat content of the sample was estimated by the method described by AOAC, (1980). The lipid in the sample was extracted with petroleum ether (60-80^{o}C) in a soxhlet-apparatus for 16 hours. The solvent was evaporated and the remaining residue was weighed. The fat content was expressed as percentage.

Estimation of total carbohydrate Dubois *et al*., (1956)

An aliquot of 0.2 ml of the supernatant was taken in a test tube and the volume was made upto 1.0 ml using distilled water. To this 3 0 nil phenol solution was added and mixed well. Then 5ml of concentrated sulphuric acid was added from a fast flowing pipette and agitated. After 10 min, the absorbance of the solution was measured at 490 nm. Standard curve was prepared by taking glucose in the range of 20 - 100 ug and the amount of total carbohydrate was calculated using the standard curve.

Estimation of crude fibre

The crude fibre content was determined by the method described by Sadasivam and Manickam (1996). The dried sample was taken in a beaker and 200ml of 1.25 per cent H_2SO_4 was added and boiled for 30 min. The contents were filtered through muslin cloth and washed with distilled water until washings were no longer acidic. The residue was transferred into the same beaker and boiled with 1.25 per cent NaOH for 30 min and filtered through a muslin cloth, washed with 50ml of distilled water and 25ml of alcohol. The residue was transferred into a preweighed silica crucible, dried for 2-4 hrs at 130^0C, cooled and weighed. It was ignited and ashed for 30 min at 600^0C, cooled and weighed. The loss in weight due to the fibre content was expressed in percentage.

Estimation of ash

About 5 to 10 g of the sample was weighed accurately into a crucible (which has previously been heated to about 600^0C and cooled (AOAC, 1980). The crucible was placed on a clay pipe triangle and heated first over a low flame till all the material was completely charred followed by heating in a desiccators and weighed. To ensure completion of ashing the crucible was again heated in the muffle furnace for ½ hour, cooled and weighed. This was repeated till two consecutive weights were same and the ash was almost white or gryish white in color.

Preparation of ash/mineral solution for estimation of calcium, iron

The mineral solution of all samples were prepared by dissolving the ash obtained after ashing the samples in a muffle furnace in dilute hydrochloric acid (1:1). This mixture was then heated over a water bath to dryness before another 5 ml of the solution was added. It was heated further over the water bath until it started fuming and at this point, the crucible was retrieved and its contents filtered into a 100ml volumetric flask using Whatman No.40 filter paper. After thorough rinsing of the crucible and the filter paper, the volume was made up to the mark with distilled water. Aliquots of this mineral solution were taken for the estimation of all the minerals in this study.

Estimation of calcium

Two ml prepared ash solution and calcium standard were taken in duplicate. One ml of ammonium oxalate was added to each test tube. The solution was allowed to stand for 30 min with shaking at intervals and centrifuged. The supernatant was discarded and to the residue, 3 ml of ammonia was added again and centrifuged.

The supernatant was discarded and 2 ml of 1 N sulphuric acid was added and kept in the boiling water bath for 8 minutes and then the hot solution was titrated against 0.02 N potassium permanganate till the appearance of pale pink colour. Blank was prepared with 2 ml of sulphuric acid and titrated against 0.02 N potassium permanganate. The difference between the two titration indicated the volume of potassium permanganate required to titrate the oxalic acid formed from calcium oxalate. The result was expressed as mg of calcium per 100 g of sample (AOAC, 1980; Clark and Collip, 1925).

Estimation of iron

Two ml of ash solution was taken in a test tube to which 1.0 ml of saturated potassium sulphate and 1.0 ml of 30 per cent sulphuric acid were added and made upto to 8.5 ml with double distilled water. About 1.5 ml of 3 N potassium thiocyanate was added to the tube for colour development. The intensity of colour was read at 530 nm in a colorimeter. A standard graph was drawn using standard iron solution (ferrous ammonium sulphate). The mg per cent of iron was calculated by the values on the standard graph (AOAC, 1980 and Wong, 1928).

Estimation of Tannin

The tannin content in the sample was determined as per the method described by Sadasivam and Manickam (1996). The powdered sample of 0.5g was transferred to a 250ml conical flask. To it 75ml water was added and heated gently for 30 min, then centrifuged at 2,000 rpm for 20 min and supernatant was collected in 100ml volumetric flask and the volume was made up. One ml of the sample extract was transferred to 100ml volumetric flask containing 75ml water to it 5ml of folin-denis reagent and 10ml of sodium carbonate solution were added and made up to 100ml with water. The absorbance was read at 700nm after 30 min. A blank was prepared with water. Standard solution was prepared by diluting 5ml of stock solution to 100ml with distilled water. The standard graph was prepared by using 10-100µg tannic acid. The tannin content of the sample was calculated as tannic acid equivalents from the standard graph.

Annexure -2: Score card

Name of the Judge : **Date:**

Name of the product :

Sensory attributes	T_0	T_1	T_2	T_3
Colour and appearance 9 8 7 6 5 4 3 2 1 ---------------------------- Highly acceptable Not acceptable				
Flavour 9 8 7 6 5 4 3 2 1 ------------------------------ Highly acceptable Not acceptable				
Texture 9 8 7 6 5 4 3 2 1 ------------------------------ Highly acceptable Not acceptable				
Taste 9 8 7 6 5 4 3 2 1 ------------------------------ Highly acceptable Not acceptable				
Overall acceptability 9 8 7 6 5 4 3 2 1 ------------------------------ Highly acceptable Not acceptable				

9 – Like extremely 8 – Like very much 7 – Like moderately
6 – Like slightly 5 – Neither like nor dislike 4 – Dislike slightly
3 – Dislike moderately 2 – Dislike very much 1 – Dislike extremely

Remarks:

Signature

Annexure – 3: Ethical Clearance

Department of Nano Science & Technology
Directorate of Natural Resource Management
Tamil Nadu Agricultural University
Coimbatore - 641 003, India

Dr. K.S. SUBRAMANIAN, Ph.D.,
Professor & Head

Tele/Fax : +91 422-661 1567
Office : +91 422-661 1568
Mobile : 98940 65449
Residence : +91 422 244 5449
Email : nanotech@tnau.ac.in

11.1.2013

INSTITUTIONAL ETHICS CLEARANCE CERTIFICATE

The First Institutional Ethics Committee of TNAU reviewed the Project Proposal on *"Revalorizing small millets: Enhancing the food and nutritional security of women and children in rainfed regions of South Asia using underutilized species"* submitted by Dr. D. Malathi, Professor (FSN) and Principal Investigator of the project funded by CIDA – IDRC - CIFSRF, Canada.

The Committee has awarded the Ethics Clearance for the project and permitted her to carry out the following works:

1. To study the bioavailability of the small millet based products (Cookies, bread and porridge) using albino rats / human subjects.

2. Evaluation of the antidiabetic effect of small millets using albino rats / human subjects

3. To study the health and knowledge impact of selected functional foods involving Survey on nutritional and socio economic status, anthropometric, clinical, dietary survey and Biochemical estimation.

4. Nutrition education survey on Knowledge Attitude Practice (KAP) before and after the nutrition education

11/1/13

Member Secretary
(Institutional Ethics Committee)

Annexure – 4: Protocol for bioavailability studies of small millets

Starch Digestibility: Starch fractions of the sample were determined by Englyst (1992). Use the round-bottom boiling flasks. Weigh 0.5g of sample (ground using mortar and pestle and 850mm mesh) into round bottom flasks. If sample's starch content is low (i.e. cookies) then weigh more of the sample. Make sure that the amount of starch does not exceed 0.8 grams (dry matter). Note: if analysing samples like cookies, flour, starch, use them as they are (no need to dry). If analysing high moisture foods, such as bread, freeze the sample in liquid nitrogen and freeze dry. Add 7 glass beads. Pipette 10ml sodium acetate buffer (0.1M, pH 5.2) into all flasks. Cover with parafilm. Place the samples into 37C shaking water bath for 5 min. After 5 min, remove the first flask and pipette 5 ml of enzyme making sure to wash the walls of the flask. Immediately, place the flask back into the water bath and start the timer. 2 min after, add the enzyme to the second sample. Repeat for the remaining samples. At exactly 20 min, pipette 0.1 ml from the first flask into and eppendorf tube containing 0.8 ml 80% ETOH. Place the tray with the eppendorf tubes back into -20C freezer. Since all samples are 2 min apart from each other, make sure to sample at the appropriate times (22min for 2^{nd} sample, 24min for 3^{rd} sample, etc). Continue sampling from the flasks every 20 min for 2 hours.

Glucose Determination: Take all tubes from the freezer. Centrifuge at 1500g/3min (for the microcentrifuge, 1500g = 4900 RPM). Pipette 40µl of sample into test tubes. Add 3 ml of GOPOD. Cover the test tubes (with caps or parafilm). Incubate at 50C for 20 min. Read abs at 510nm.

Enzyme Preparation: Pancreatin 10g in 66.7 ml water. Cover and stir for 10 min at medium speed (high speeds will damage the enzyme!). Centrifuge 1500g/10 min. Take 54 ml of the supernatant. Invertase: dissolve 0.03 g of invertase in 4 ml sodium acetate buffer. Take 0.26 ml of amyloglucosidase (AMG, from Megazyme) and add to 5.74 ml water.

(It's best to prepare this enzyme by pipetting 6ml of water into a small beaker, removing 0.26ml of water and then adding 0.26ml of AMG). Combine 54ml of pancreatin, 4 ml invertase, and 6 ml of AMG in a beaker. Cover with parafilm and swirl gently to mix.

Sodium acetate buffer (0.1M, pH 5.2): Prepare saturated benzoic acid by dissolving 0.85g of benzoic acid in 250 ml water over low heat. Stir in a closed bottle to avoid evaporation. Best to stir overnight. Dissolve 13.6 g of trihydrate sodium acetate or 8.2 g of anhydrous sodium acetate in 250 ml of saturated benzoic acid. Dilute to 800-850 ml with water. Adjust pH to 5.2 with glacial acetic acid. Add 0.59 g of calcium chloride dihydrate. Dilute to 1L. Store in a fridge. 80% ETOH: 842 ml of 95% ETOH + 158 ml water. Glucose standard 25mg/ml: weigh 1.25 g of dry glucose standard and make it up to 50 ml with sodium acetate buffer. GOPOD: refer to Total Starch procedure by Megazyme. Note: it is a good idea to do the following the day before the experiment: Grind and weigh your samples into round bottom flasks, add glass beads and cover with parafilm. Make sure that the water bath is at 37C. Measure the temperature while the shaker is on. Prepare your eppendorf tubes by pipetting 0.8ml of 80% ETOH into each tube and storing them in the -20C freezer for next day.

Antioxidant activity

FRAP (ferric reducing antioxidant power) assay: The principle of this method is based on the reduction of a ferric-tripyridyltriazine complex to its ferrous colored form in the presence of antioxidants, according to the method of Benzie and Strain (1996).

Reagents used

1. Acetate buffer, 300 mmol/l (pH 3.6): Sodium acetate (3.1g) was mixed with 16 ml glacial acetic acid and made up to l00ml with distilled water. This solution was prepared freshly and warmed at 37°C.
2. TPTZ reagent, 10 mmol/l. TPTZ (2, 4, 6- tripyridyl-*s*-triazine, was dissolved in 40 mmol/l HCl.
3. Ferric chloride reagent, 20 mmol/l.Ferric chloride reagent was prepared by dissolving 3.24 mg of ferric chloride in 100ml of water.
4. FRAP working solution was prepared by mixing 25 ml acetate buffer, 2.5 ml TPTZ solution and 2.5 ml $FeCl_3$. This solution was freshly prepared before use.

Procedure: Aliquots of 50 µl sample supernatant were mixed with 0.2 ml distilled water and 1.5 ml FRAP reagent and the absorbance of reaction mixture was measured at 593 nm spectrophotometrically after incubation at 37°C for 10 min. Adequate dilution was made if the FRAP value measured was over the linear range of standard curve. FRAP reagent was used as a blank. Ascorbic acid was used as the standard. Different concentration of ascorbic acid was added in to the cuvette containing 3ml reagent and the absorbance value was noted.

Total dietary fibre (Soluble and Insoluble, AOAC)

Reagents

1. 95% ETOH
2. 78% ETOH. Place 207 ml of water into 1 L volumetric flask and dilute to 1 L with 95% ETOH
3. Acetone
4. Phosphate buffer 0.08M, pH 6.0. dissolve 1.400 g of Na phosphate anhydrate (Na_2HPO_4) (or 1.753 g dihydrate) and 9.68 g of Na phosphate monobasic monohydrate (NaH_2PO_4) (or 10.94 g dihydrate) in 800 ml of water. Check pH. Dilute to 1 L.
5. NaOH, 0.275N. dissolve 11.00 g of ACS grade NaOH in 700 ml of water. Cool and dilute to 1L.
6. HCl, 0.325N. Add 325 ml of 1.0 N HCl to 600 ml water. Dilute to 1 L.

Preparation

1. Weigh 1g of celite into clean crucibles.
2. Dry overnight at 105^0C, cool and weigh.

Procedure: Weigh 1 gram of each sample in duplicates into tall-form beakers. Add 50 ml of pH 6 phosphate buffer. Add 0.10 ml of thermostable amylase to each beaker and mix, cover with foil. Incubate at 95^0C for 35 min. Cool to room temperature. Adjust to pH of samples to 7.5±0.2 by adding 10 ml of 0.275 N NaOH to each beaker. Add 0.1 ml of protease, mix and incubate at 60^0C for 35 min. Cool to room temperature. Adjust pH to 4.0-4.6 by adding 10 ml of 0.325N HCl. Add 0.1 ml of AMG and cover with foil. Incubate at 60^0C for 35 min. IDF Filtration. Wet the celite bed with water and filter the precipitate. Wash residue with 2X10ml of water and pour the filtrate and water washings back into the beakers. Wash the residue twice with 10ml of 95% ETOH and acetone. Dry crucibles overnight at 105^0C air oven. Cool crucibles and weigh. Analyse one rep for protein and second rep for ash (525°C for 5 hours). Add 4 volumes of 95% ETOH preheated to 60^0C to the beakers with the filtrate and let precipitate overnight. SDF Filtration. Wet the celite bed using 78% ETOH and filter the precipitate. Wash the residue with 3X20ml of 78% ETOH, 2X10ml of 95% ETOH and acetone. Dry crucibles overnight at 105^0C air oven. Cool crucibles and weigh. Analyse one rep for protein and second rep for ash.

The standardized small millet cookies (50%) and small millet balls (100%) were studied for their bioavailability. The protein intake was computed from the feed intake and protein content of the respective diets. The gains in body weight, faecal and urinary nitrogen contents were used to compute the following growth parameters and nitrogen balance indices. The minerals calcium, iron and zinc were determined by reading in an atomic absorption spectrophotometer. The relative mineral bioavailability was defined as the ratio between the total content of the mineral in the organ and its consumption and for zinc it was also estimated from the ratio between weight-gain and zinc consumption.

Feeding trials of cookies

Group	**Product**	**Non-diabetic volunteers (nos)**	**Test carbohydrate (g)**
Group I	Standard glucose	6	50
Group II	Refined wheat cookies	6	74
Group III	Kodo millet cookies	6	75
Group IV	Little millet cookies	6	76
Group V	Foxtail millet cookies	6	75

Feeding trials of Millet balls

Group	**Product**	**Non-diabetic volunteers (nos)**	**Test carbohydrate (g)**
Group I	Standard glucose	6	50
Group II	Rice porridge	6	32
Group III	Kodo millet porridge	6	38
Group IV	Little millet porridge	6	38
Group V	Foxtail millet porridge	6	41

Animal Experiment Protocol: The experiment involved 60 wistar albino rats which were grouped into two main groups with 30 each. The first group being normal was further divided into 5 groups with six rats per group which was fed with standardized composite cookies. The second group being the diabetic group was also further divided into 5 groups with six rats per group which was fed with standardized composite cookies with fructose. These rats are induced with diabetes just 3 days before the start of the experiment**.** The study was conducted for a period of 28 days including the period to standardize their feed intake for first three days. Rats were given free access to diet and water, daily food intake, weekly body weights and faecal bulk were recorded.

Treatment groups

Normal Group		Diabetic Group	
Group I	Control (normal feed)	Group VI	Diabetic control (given 150mg per kg of Body weight, Alloxan monohydrate through intraperitoneal to induce diabetes)
Group II	Refined wheat cookies	Group VII	Refined wheat cookies with fructose
Group III	Kodo millet cookies	Group VII	Kodo millet cookies with fructose
Group IV	Little millet cookies	Group IX	Little millet cookies with fructose
Group V	Foxtail millet cookies	Group X	Foxtail millet cookies with fructose

Food consumption: The individual food and water consumption record of the animals was maintained during the entire experimental protocol. Animals were continued on control and composite cookies and repeated for 100 per cent flour until the end of the study. The food left over and spilled rat feeds by the rats were collected daily from the tray and weighed. The difference between the food provided and the leftover and spilled food was taken as the food consumed by the rat in 24hours.

Body weight: The individual body weight of the animals was recorded by weighing them in an animal weighing balance on day one prior to group allocation and end of the study. The fractions of weights were adjusted to the nearest gram unit.

Sample collection: The blood samples were collected retro-orbitally from the eye under light ether anesthesia using capillary tubes in fresh vials containing EDTA as anticoagulant agent and serum was separated in a T8 electric centrifuge at 2000 rpm for two minutes. Then serum samples were used for various biochemical tests (Al-shamaony *et al*., 1994).

Bio-chemical analysis (Animal Assay): The standardized small millet cookies (50%) and small millet balls (100%) were studied for their bioavailability. The albino wistar rats were divided into 12 groups of 6, housed in individual metabolic cages and received both diet and water *ad libitum* with a 12 hour light/dark cycle, temperature of 25±1ºC and relative humidity of 60-80%.

The levels of blood glucose, hemoglobin glycosylated hemoglobin and lipid profile were measured at the start and after 28 days of feeding trial.

The protein intake was computed from the feed intake and protein content of the respective diets. The gains in body weight, faecal and urinary nitrogen contents were used to compute the following growth parameters and nitrogen balance indices:

Protein efficiency ratio (PER) = Gain in body weight (g)/ protein intake (g)
Protein utilization (PU) = Protein intake (g)/ gain in body weight

The minerals calcium, iron and zinc were determined by reading in an atomic absorption spectrophotometer. The relative mineral bioavailability was defined as the ratio between the total content of the mineral in the organ and its consumption, and for zinc it was also estimated from the ratio between weight-gain and zinc consumption. The anti-diabetic effect of the standardized cookies and small millet flour was analyzed.

Annexure – 5: Interview schedule to elicit information on socio economic and health profile of the rural women

1. Name of the respondent :

2. Address :

3. Type of family : Joint/nuclear

4. Family size : 1-3 Members
   4-6 Members
   >6 Members

5. Religion Hindu/Christian/Muslim

6. Education and occupational status of the rural women

S.No	Age	Educational qualification	Occupation	Monthly income

7. Do you have own land? : Yes/No
   If yes, total acres of land :

8. Do you have any Domestic animals? : Yes/No
   If yes, specify :

9. Type of House : Own/ Rent
   a. [ ] Shed thatched
   b. [ ] Mud walled and thatched
   c .[ ] Brick wall and tiled
   d .[ ] Concrete house
   e. [ ] Concrete and double storied

a. Does the household utilised electricity? : Yes/No
b. Do you have proper toilet facilities? : Yes/No
   If yes, specify : Own/public/open area
c. Source of drinking water : Own well/public tap/public well/pond

10. Personal habits
    a. Do you or any member of the family have the habit of : Chewing tobacco/chewing betel leaf/snuffy/nil

11. Do you have any health facilities in your locality? : Yes/No
    If yes, specify PHC/Private Hospital/Government Hospital

12. Monthly expenditure pattern of the selected subjects

Expenditure	Amount spent/month	Percentage of total income
Food		
Clothing		
Rent		
Education		
Health		
Fuel		
Transport		
Remittance		
Recreation		
Savings		

13. Details on morbidity and mortality

a. Have you or any member suffered from any illness during the last one year? : Yes/No

Specify the illness : Fever/cough/cold/diarrhoea/dysentery/other conditions

b. Epidemic prevalent in the locality in the past one year : Measles/chicken box/Typhoid/whooping cough/Mumps

c. Do you or any member used any deworming treatment during the past one year? : Yes/No

14. Anthropometric measurements

Name of the respondent	Age	Weight (Kg)	Height (cm)	BMI	MUAC	WHR	Per cent body fat

15 Biochemical assessment

Haemoglobin (g/dl) :

Random Blood glucose (mg/dl) :

16. Details about food habit and meal pattern

a. Are you : Vegetarian/ non vegetarian

b. Do you plan your meals in advance : Yes/No

c. No. of meals per day : Two/Three/Four

c. Do you keep the time schedule for taking meals : Yes/No

Annexure -6: Proforma for nutritional knowledge of the rural women

1. Which foods or food items should be eaten daily
   a) Rice, Vegetables/green leafy vegetables b) Dhal, milk, fruits and fleshy foods
   b) Do not know

2. Why should we eat food daily
   a) To give us energy b) Growth c) Maintenance d) Do not know

3. Name the food that gives us energy
   a) Starchy foods b) Protein foods c) Starch and fat d) Do not know

4. Mention the method of cooking cereals
   a) Boiling b) Frying c) Steaming d) Do not know

5. Mention the method used for cooking pulses
   a) Boiling b) Frying c) Steaming d) Do not know

6. What is the best method for cooking vegetables?
   a) Boiling b) Frying c) Steaming d) Do not know

7. Suggest the best method for cooking green leafy vegetables?
   a) Boiling b) Frying c) Steaming d) Do not know

8. Do you wash vegetables before cutting?
   a) Yes b) No

9. What size do you cut the vegetables?
   a) Small pieces b) Big pieces c) Minced

10. Do you include salads in your daily diet?
    a) Yes b) No c) Do not know

11. Do you germinate pulses/ millets?
    a) Yes b) No c) Do not know

12. How do you include the germinated pulses/ millets in your daily diet?
    a) Salad b) Any other c) Do not know

13. Millets are rich source of
    a) Starch b) Fibre c) Minerals d) Do not know

14. Mention names of two fibre rich cereal grains _____________

15. Have you heard of millets that grow in your area

a) Yes   b) No

16. What Millets do you consume?

a) Ragi   b) Bajra   c) Samai   d) Thenai
e) Sorghum   f) Barnyard millet   g) Kodo millet   h) any other

17.What is the common method used for cooking small millets?

a) Boiling   b) Roasting   c) Frying   d) Steaming   e) Do not know

18. How often do you prepare millet based foods?

a) Daily   b) Alternate days   c) Once in a week   d) Once in 15 days
e) Once in a month   g) Not at all

19. In what form do you include millets in your regular diet?

a) Snacks foods   b) Breakfast food   c) Dinner
d) Lunch   e) Do not know

20. Do you have any special occasions for using the millet based foods?

a) Yes   b) No   c) Do not Know

21. Do you think that millets are good for our health?

a) Yes   b) No

22. Calcium and phosphorus required for bone health

a)Yes   b) No

23. Kodo millet rich

a) Calcium and phosphorus   b) Fibre   c) Do not know

24. Iron deficiency causes

a) Anaemia   b) Protein energy malnutrition c) Do not know

25. Constipation occur due to lack of

a) Fibre   b) Starch   c) Do not know

26. Kodo millet and barnyard millet are rich in fibre and prevents constipation

a)Yes   b) No

27. Barnyard millet and kodo millet prevents diabetes

a)Yes   b) No

29. Hands should be wash properly before handling food

a)Yes   b) No

30. Six steps of hand washing should followed

a)Yes b) No

31. Hands should be washed after using the wash room

a)Yes b) No

32. Use portable drinking water

a)Yes b) No

33.Stored the drinking water in clean containers

a)Yes b) No

34. Have a regular bath and tooth care

a)Yes b) No

35. Take care of the nails and hair properly

a)Yes b) No

36. Open defecation should not practiced

a)Yes b) No

37. Soak pit should be present in every house

a)Yes b) No

38. Safe disposal of kitchen waste is necessary

a)Yes b) No

39.Proper drainage should be present in every house

a)Yes b) No

40. Maintain personal hygiene to avoid communicable disease.

a)Yes b) No

Annexure -7: Proforma for assessing attitude regarding small millet utilization among the rural women

Attitude	Yes	No	Don't know
Health is directly related to food			
Adequate diet improves health			
Mixed diet provide all the nutrient			
Millet is good for health			
Millet has vitamins and minerals			
Millet contains fibre			
Kodo millet and barnyard millet can be used in daily diet			
Calcium and phosphorus required for bone health			
Kodo millet rich in calcium and phosphorus			
Iron required for blood health			
Iron deficiency causes anaemia			
Barnyard millet is rich in iron			
Constipation occur due to lack of fibre			
Kodo millet and barnyard millet are rich in fibre and prevents constipation			
Diabetic due to high carbohydrate diet			
Increased consumption of rice causes diabetes			
Carbohydrate content of barnyard millet and kodo millet is low			
Sugar is high glycemic index foods			
Barnyard millet and kodo millet are low glycemic foods			
Barnyard millet and kodo millet prevents diabetes			
Hypertension is influenced by the cholesterol content			
Increase in cholesterol is also due to consumption of refined foods.			
Barnyard and kodo millet have hypocholesterlemic effect.			
Consumption of barnyard millet and kodo millet reduce the hypertension			
Foods rich in antioxidants prevent cancer			
Kodo millet and barnyard millet are rich in antioxidants and prevent cancer			
Hands should wash properly before handing food			
Six steps of hand washing should followed			
Hands should be washed after using the wash room			
Use portable drinking water			
Stored the drinking water in clean containers			
Have a regular bath and tooth care			
Take care of the nails and hair properly			
Open defecation should not practiced			
Soak pit should be present in every house			
Safe disposal of kitchen waste is necessary			
Proper drainage should be present in every house			
Maintain personal hygiene to avoid communicable disease.			

Proforma for assessing attitude of the rural women towards millet diversification

Attitude	Yes	No	Neutral
All small millets can be used as food			
Millet should be a part of daily menu			
Millets are tasty and cheap			
Millet can be used in preparation of regular breakfast foods (Idli, dosa, idiyappam, pittu, adai)			
Millet can be used for the preparation of kali and porridge in daily diet			
Millet can be used for the preparation of sweet meat			
Millet can be malted and use			
Millet can be puffed and used as a snack food			
Millet flaked can also be used like rice flakes			
Millet flour can be used like wheat flour			
Instant idli, dosa, adai and kali mix can be prepared from millets			
Varieties of product can be prepared instant mixes			
Products can be easily prepared from instant mixes			
Instant millet products are tasty and cheap			
Training on instant mixes paves way for self employment			
Processing of millet based instant mixes can be income generating activity			
Instant millet mix enterprise is a promising enterprise for women during non crop season.			
Income generation leads to women empowerment			

Annexure -8: Proforma for assessing changes in practices of the rural women

Practices	Yes	No	Neutral
Using millets in daily diet Using millets in breakfast foods Using millets flour like wheat flour Using millets kali and porridge daily Using millets based instant mixes for idiyapam, pittu, roti, kali, paniyaram, idli, doda preparation Using millet based instant mixes for sweets preparation Using malted millet products Using flaked and popped millet products Keeping the environment clean Maintaining personal hygiene Processing of millet based instant mixes as self employment activity Income generation thought millet based instant mixes			

Annexure – 9: Identification of foxtail millet varieties rich in micronutrients

The main obective of the present study is to assess genetic variability and identify superior accessions for grain Zn, Fe, Ca and protein contents of foxtail millet germplasm for use in the crop improvement programmes. Wide genotypic variations were observed for micronutrients as well as protein, with no distinct variations between the locations (Table 1). In general, the calcium content was high followed by protein and no distinct difference between zinc and iron (Fig. 1).

Table - 1. Varaiability in grain protein, calcium, iron and zinc content in foxtail millet

	Calcium content (mg/100gm)		Iron content (mg/100gm)		Zinc content (mg/100gm)		Protein percent	
	GKVK	Nandyal	GKVK	Nandya l	GKVK	Nandyal	GVK	Nandyal
Max.	31.61	31.44	8.57	8.48	7.94	7.91	14.06	14.30
Min.	1.51	1.50	0.25	0.25	0.23	0.25	6.68	6.50
Mean	12.20	12.08	5.04	5.02	3.89	3.80	11.16	11.32

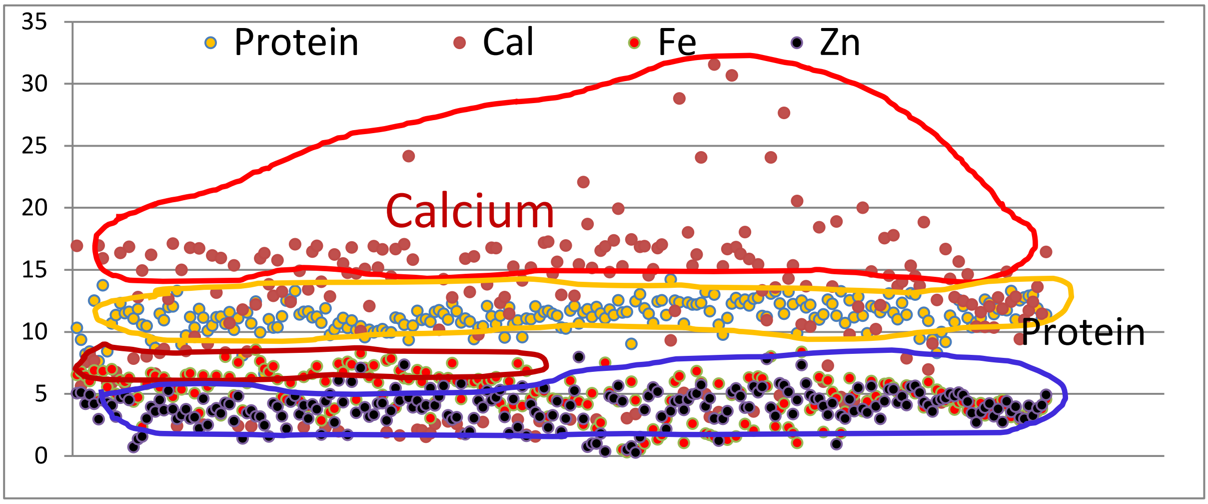


Fig.1 Protein and micronutrient levels in foxtail millet

Wide varietal variation was observed for all micronutrients and protein. The accessions having high protein content are having low or medium calcium content. Only two accessions having both Fe and Zn are, ISe 1511 and GS 2040. The accessions rich in protein, calcium, iron and zinc are presented in Table-1.

Table -2: List of varieties rich in Protein, Calcium, Iron and Zinc

Protein (%)		Calcium content (mg/100g)		Iron content (mg/100g)		Zinc content (mg/100g)	
Variety	**Content**	**Variety**	**Content**	**Variety**	**Content**	**Variety**	**Content**
ISe 1026	13.81	ISe 1181	31.53	GS 754	8.52	ISe 748	7.93
GS 125	13.65	ISe 1227	30.64	ISe 1511	8.36	ISe 1387	7.79
GS 961	13.32	ISe 1059	28.79	GS 2040	8.24	GS 2239	7.32
ISe 1647	13.24	ISe 1418	27.61	ISe 1400	7.99	ISe 1511	7.30
ISe 1406	13.21	GS 2259	24.14	GS 563	7.96	GS 2040	7.07
GS 118	13.11	ISe 1161	24.04	GS 2164	7.80	GS 1929	6.05
ISe 1454	13.10	ISe 1400	24.02	GS 2155	7.65	GS 2035	5.94
GS 430	13.07	ISe 758	22.04	GS 760	7.59	ISe 1408	5.82
ISe 1808	13.07	ISe 1474	20.51	GS 2029	7.55	ISe 195	5.80
ISe 1767	13.06	ISe 1685	19.96	GS 639	7.49	ISe 1547	5.78
PS-4*	11.19	PS-4*	16.4	PS-4*	4.52	PS-4*	4.88

Correlation study show that the nutrients analyzed have negative relationship especially between protein and Iron (Table – 2). The positive correlations are not significant.

Table –3: Relationship between grain protein and micronutrients

	Calcium	**Iron**	**Zinc**
Protein	0.06	-0.22*	0.12
Calcium	-	-0.10	0.10
Iron	-	-	0.15

Protein is major nutritional component in foxtail millet and it is believed that among all millets it has more protein content next to proso millet. Protein variability is quite large. Frequency distribution shows that majority accessions (57+87+46) have the protein content between 10.1 and 13.0 percent (Fig.2). So the foxtail millet is a cereal grain with moderate protein content about 12 %. Among 223 foxtail millet germplasm lines and varieties, protein content ranged from 6.92 % (GS 763) to 13.81 % (Ise 1026) with a mean of 11.22 percent.

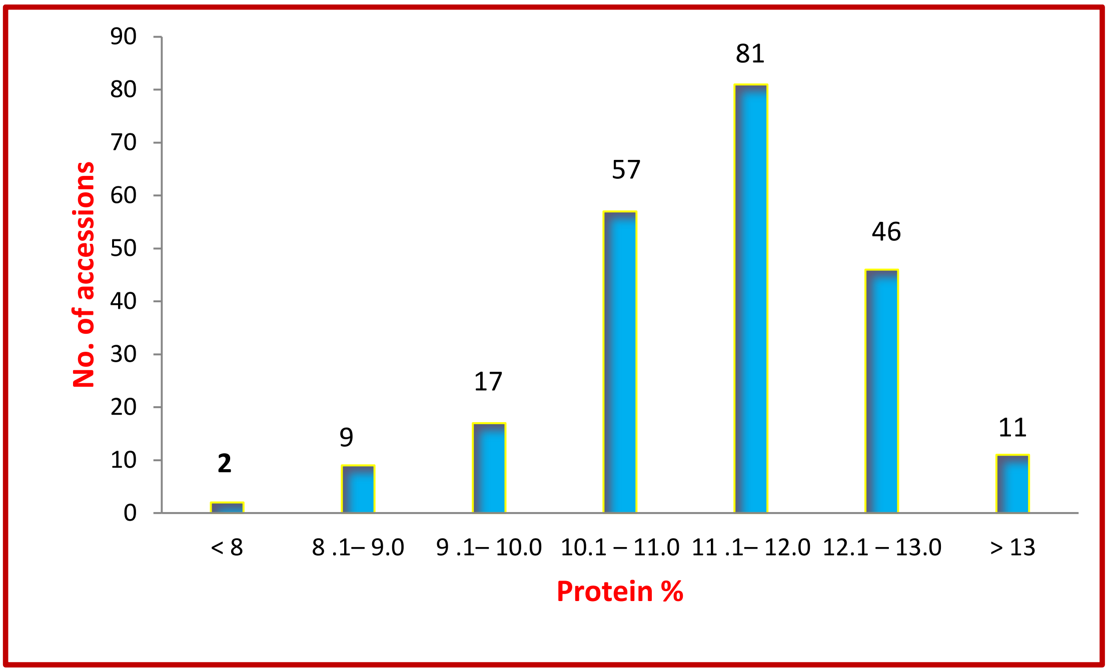


Fig. 2 Frequency distribution of foxtail millet germplasm and varieties for Protein percent

In case of calcium content, ISe 1181 showed maximum calcium content (31.53 mg/100g) and ISe 31 showed minimum calcium content (1.51 mg/100g) with mean of 12.19 mg/100g. Frequency distribution shows that majority varieties have the calcium content of 1-10 mg/100g (< 10 mg/100g), only few varieties were having the calcium content ranged from 18.1 to 32.0 mg/100g (Fig.3). Significant varietal variation was observed for iron content and ranged from 0.25 mg/100g (ISe 914) to 8.52 mg/100g (GS 754) with mean of 4.90 mg/100g (Fig. 4). Frequency distribution shows that majority of the varieties were having iron content ranged between 4.1 and 7.0 mg/100g. The zinc content was maximum in ISe 748 (7.93 mg/100g) and minimum in ISe-936 (0.24 mg/100g) with mean of 3.88 mg/100g. Majority of the varieties were showing the zinc content ranges from 3.1 to 6.0 mg/100g (Fig.5). This result indicates that, in general foxtail millet has an average zinc content of 4 mg/100g.

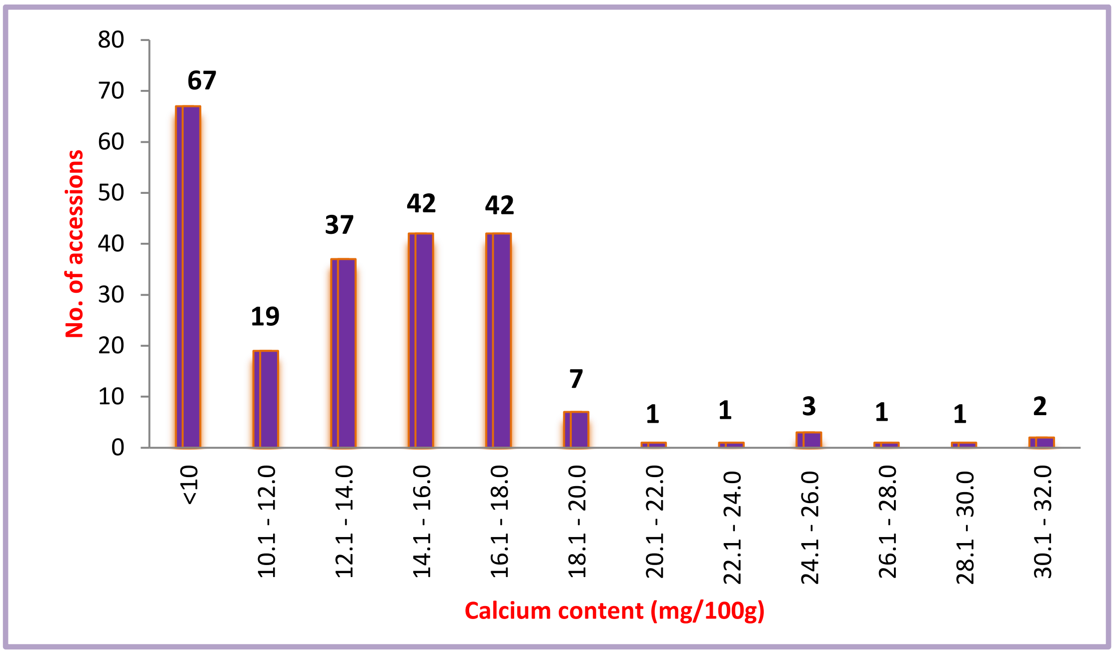


Fig. 3 Frequency distribution of foxtail millet germplasm and varieties for Calcium content

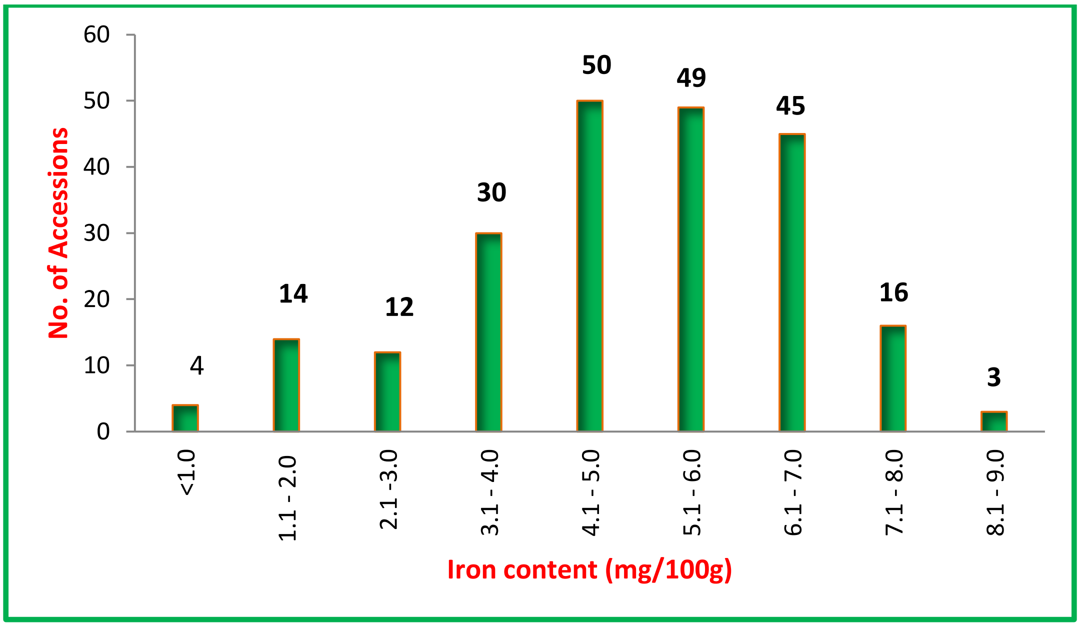


Fig. 4 Frequency distribution of foxtail millet germplasm and varieties for Iron content

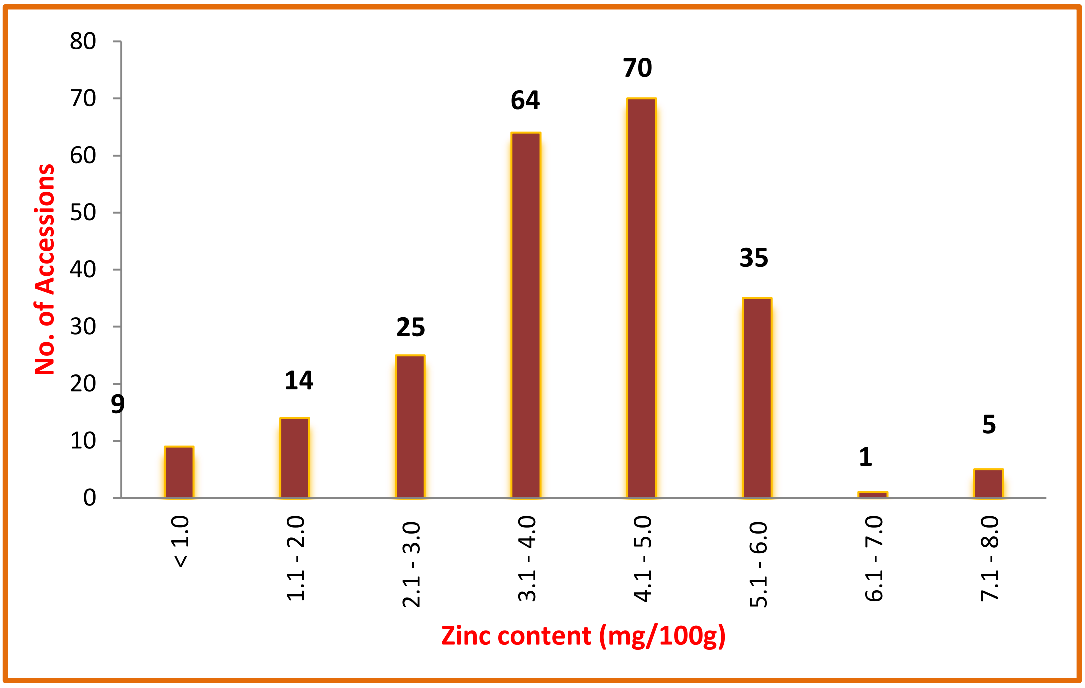


Fig. 5 Frequency distribution of foxtail millet germplasm and varieties for Zinc content

From the present study, a few of the accessions were significantly rich in protein content and few are rich in micronutrients. These accessions could be involved in hybridization with agronomically superior accessions to combine grain nutrients and consumer preferred traits.

Annexure - 10: Genotypic Variation for Popping in Finger Millet (Elusine coracana)

Nutritional well being is a sustainable force for health and maximization of human genetic potential. Cereals and millets constitute a major component of diet in developing countries like India. Finger millet is an important staple food in southern Karnataka and in parts of eastern, central Africa. Finger millet is considered as neutraceuticular crop being rich in minerals viz, calcium, iron and zinc. In addition, it has several health benefits such as preventing cancer and cardiovascular diseases, reducing tumor incidence, lowering blood pressure, risk of heart disease, cholesterol and rate of fat absorption, delaying gastric emptying (Truswell, 2002; Gupta *et al.,* 2012). Generally, the millet is consumed as a whole meal, but the presence of inhibitory factors in the grain especially the seed coat, availability of nutrients is limited. Processing of these products found to reduce the inhibitory factors, and made as more bioavailable (Mamiro*et al.,* 2011; Platel*et al.,* 2010; Usha Antony and Chandra, 1998). The process of popping in ragi found to increase the bioavailability of Iron and Zinc (Rateesh*et al.,* 2012). Further, popping is also an age old practice in preparation of pediatric foods.

Popping is a simplest, inexpensive and quickest traditional method of dry heat application, wherein grains will be exposed to high temperature for short period of time (HTST). Super heated vapours are produced inside the grains due to instantaneous heating, then the grain will be cooked and expand the endosperm, while escaping the vapours with great force through the micropores of the grain structure puffing is observed. During popping grains are dehydrated to the extremely low level of moisture content, nearly 3-5%, the shelf-life is enhanced. Many cereal crops viz. amaranth grain (Pant, 1985), sorghum (Sailaja, 1992), paddy (Srinivas*et al.,* 1973) and maize (Gupta *et al.,* 1986) including minor millets (Malleshi and Desikachar, 1985) are found to be suitable for popping. This simple processing technique helps in developing value added ready-to -eat snacks and health foods for different segments of the population as supplementary food. Different methods of popping that are followed in general are conventional method of dry heat, sand and salt treated, hot air popping, gun puffing, popping in hot oil and microwave popping throughout the world. However, the most widely used technique in rural household is conventional method of dry heat.

Popped grain of finger millet is crunchy, porous and precooked product. Popped grains have slightly higher fiber content and carbohydrates. Popping of millets produces a porous product of low bulk density and pleasing texture with a distinct appealing flavor (Lewis *et al.,* 1992). Popped grains especially of finger millet posses a pleasant aroma and acceptable taste (Malleshi, 1996). Identification of varieties for superior popping quality can be an economic and effective method in food processing industry. Hence, the present investigation was carried out to select the best popping varieties amongst the released varieties of finger millet in the country.

Materials and Methods

Grains of 86 released finger millet varieties were dehusked, cleaned and used for popping. Initial grain moisture content was estimated by taking about 10 g of sample in each variety, oven dried at 105^{0}c for 4 hrs and moisture content was computed as below.

$$\text{Moisture content (\%)} = \frac{\text{Initial wt. of the sample (g)} - \text{Oven dried wt. of the grain sample (g)}}{} \times 100$$

Initial weight of the grain sample (g)

After determining the initial grain moisture content of each variety, 20 g of grain sample in three replicates was sprayed with required quantity of water so as to adjust 19% moisture, the samples were mixed well and equilibrated for 24 hrs in a desiccator (Malleshi, and Desikachar, 1981). Such conditioned samples (20 g) were used for popping. These grains were placed in the iron frying pan containing fine sand (0.85 mm) as heat exchange medium, mixed and heated as sufficient for puffing (Approx. 270^{0}c). When puffing sound was stopped the pan was removed immediately from the flame and sand was separated by sieving through 0.85 mm sieve. The number of completely popped, partially popped and unpopped grains (Plate.1) was separated manually and weighed separately. The popping percentage was computed as below. The popping percent was analysed statistically in completely randomised design.

$$\text{Popping yield (\%)} = \frac{\text{Weight of popped (complete + partial) grains}}{\text{Weight of popped (complete + partial) grains + unpopped grains}} \times 100$$

Plate 1. Comparison between completely (fully) and partially (half) popped grains

Results and Discussion

(A) Moisture content in finger millet varieties

One of the major factors that influence the popping is grain moisture content at the time of popping. Malleshi and Desikachar (1981) reported that the adjusted moisture content of 19% was best for popping. In view of calculating the adjusted moisture content (19%), the initial grain moisture content was monitored. The initial grain moisture content among 86 varieties ranged from 8.2% (Cv. Purna) to 12.4% (Cv. Shakti) with a mean of 10.7 percent. Frequency distribution shows that majority varieties have initial moisture content of 10-11% (Fig. 1). Such varietal variation for initial grain moisture content, to the extent of 12.67% has been reported by Anuradha, (2009).

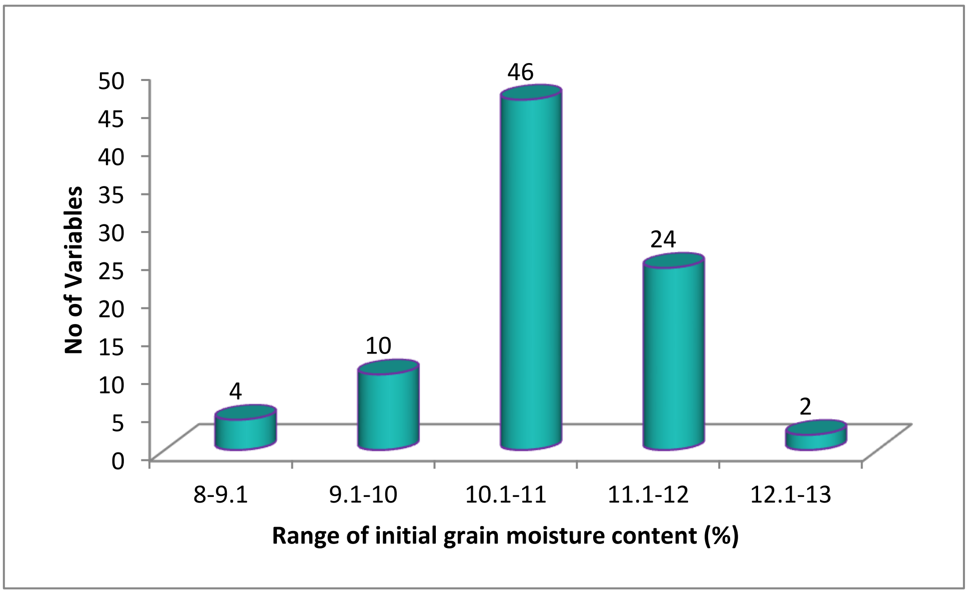


Fig. 1. Frequency distribution of varieties for moisture content

(B) Relationship between initial grain moisture content and popping percent

In view of identifying the relevance of the initial grain moisture content for popping, correlations were carried out with popping percent. Majority of varieties which are having moisture content between 8% and 10% popped less than 50% excepting a few varieties like Purna, Indaf-8 and Co-12. The varieties having high moisture content (> 12%) showed an average popping percent (56-68%). The moisture content between 10-12% showed a wide range from 18.6 to 88.2% popping. However, no significant relationship exists between initial grain moisture content and complete or partial or total popping percent (Fig. 2) and also across the selected contrast varieties for high and low popping relationship did not exist (Fig. 3). The goodness of fit for regression between initial grain moisture content and popping in the present study is only 18.6%. Therefore, initial grain moisture content is not a limitation for popping in ragi as the grain moisture content will be adjusted to 19% uniformly.

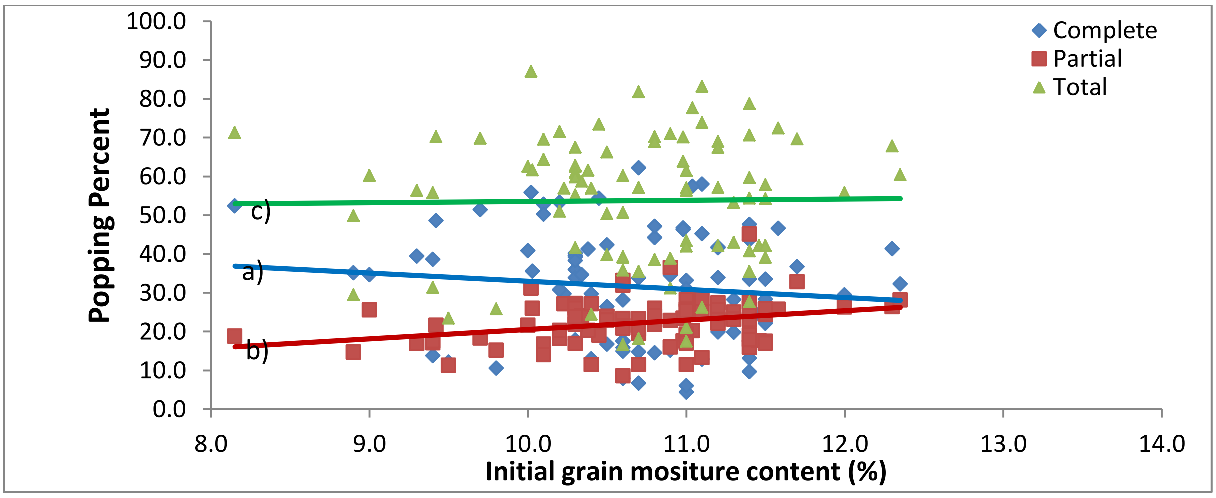


Fig. 2. Relationship between initial grain moisture content and popping percent

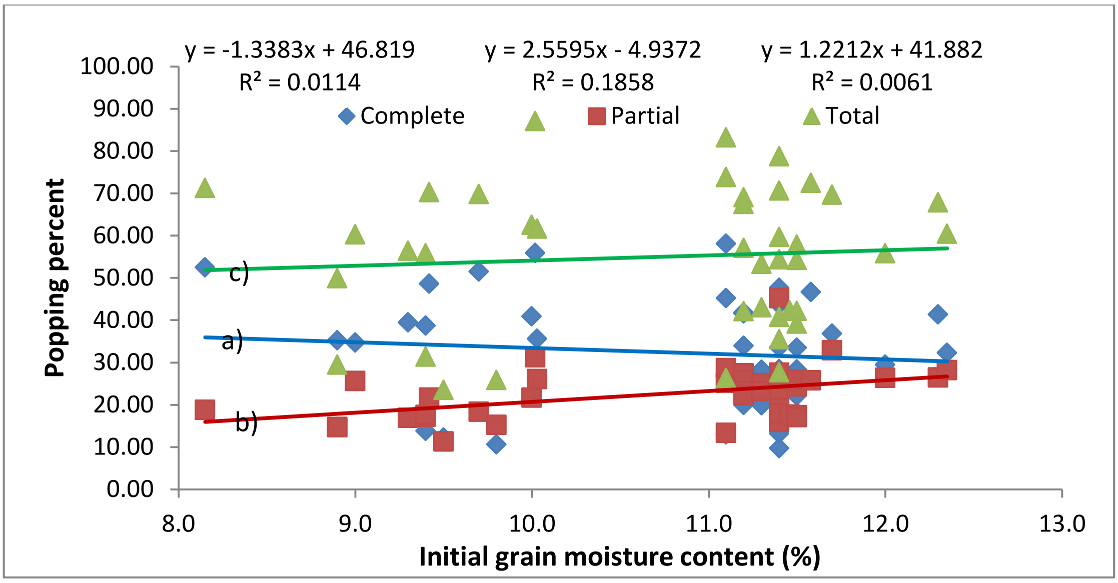


Fig. 3. Relationship between initial grain moisture content and popping percent in selected varieties (high and low popping varieties)

(C) Popping of grain samples

The results of popping percent showed a significant ($P < 0.05$) variation among the 86 finger millet varieties (Table 1). The popping percent ranged from a minimum of 18.6% (Cv. Picha kaddi ragi) to as maximum as 88.2% (Cv. Co-10) with a mean of 54.2% (Table 2). Similar genotypic variations of course in less number of varieties have been reported (Malleshi and Desikachar, 1981; Shukla*et al.,* 1986; Hiremath, 2011; Srivastava and Batra 1998). Majority of released varieties fall in the category of 50 to 70% popping (Fig. 3). These results indicate that, in general finger millet has an average popping capacity of 60 percent. The varieties viz, Co-10, Indaf-3, Karun kaddi ragi, PR-202, Purna, GN-4, ES-11 and PRM-2 are highly popped with > 70% popping while Picha kaddi ragi, PRM-802, Jenu Bonda ragi, Indaf-11, KOPN-933, VL-315, GPU-75 and PRM-901 are poor poppers (<30%) (Plate 2). Malleshi and Desikachar (1981) also showed that Purna, PR-202 and Indaf-3 possessed good popping percent.

Table – 1: Analysis of variance with respect to popping percentage in 86 varieties

Source of variance	**Degrees of freedom**	**MSS**		
		Complete popping	**Partial popping**	**Total popping**
Replication	2	8.5	8.2	12.9
Varieties	85	608.2*	117.2*	838.5*
Error	170	5.8	6.2	11.1

Table – 2: Range and mean for popping percent in finger millet varieties

Parameter	Complete popping (%)	Partial popping (%)	Total popping (%)
Range	4.7- 65	8.7- 45.2	18.6- 88.2
Mean	31.7	22.5	54.2
SEm	1.4	1.4	1.9
CD @ 5 %	3.8	3.9	5.3
CV (%)	7.6	11.1	6.2

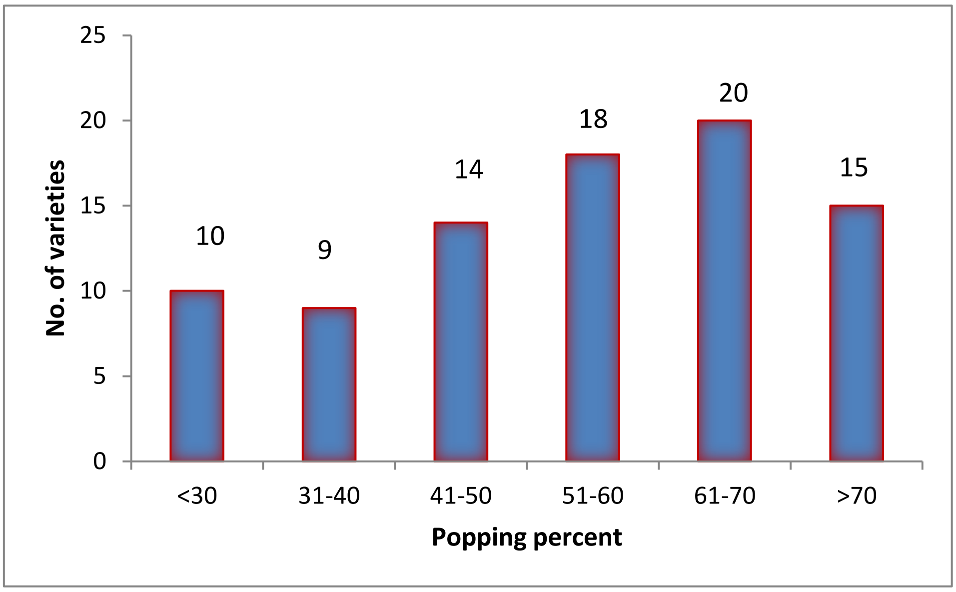


Fig. 3. Frequency distribution of varieties for popping

Completely popped grains are being more useful than the partially popped grains in preparation of food products, varieties need to be identified for complete popping percent. In the present study, among the popped grains, the number of grains that are completely popped (31.7%) is more compared to the partially popped grains (22.5%). The grains that are completely popped were highest in Co-10 (65.0%) and least in PRM-802 (4.7%). Among the high popping varieties (Co-10, Indaf-3, Kari kaddi ragi, PR-202, GN-4, ES-11 and PRM-2), the completely popped varieties are Co-10, Indaf-3, Kari kaddi ragi, GN-4 and PRM-2 with more than 54.4 percent. These may be highly useful both for household popping and food industry.

Table – 3: Genotypic variation for popping (%) in finger millet

Genotypes	Initial grain moisture (%)	Popping (%)		
		Complete	Partial	Total
GPU28 (check)	10.2	29.7	27.2	56.9
PR-202 (check)	11.4	33.6	45.2	78.8
Co-10	10.0	55.9	31.2	87.1
Indaf-3	11.1	58.1	25.2	83.2
Kari kaddi ragi	10.7	62.2	19.6	81.8
GN-4	11.0	57.5	20.2	77.7
ES-11	11.1	45.2	28.6	73.8
PRM-2	10.5	54.4	19.1	73.5
GPU 66	11.6	46.6	25.8	72.4
Indaf-9	10.2	53.3	18.2	71.6
Purna	8.2	52.5	18.8	71.3
RAU-3	10.9	34.5	36.5	71.0
Hullubele	11.4	47.7	23.0	70.7
BM-1	10.8	44.2	26.0	70.3
Co-12	9.4	48.6	21.6	70.2
Co-14	11.0	46.8	23.4	70.2
Indaf-8	9.7	51.5	18.4	69.8
Dapoli-1	11.7	36.8	32.9	69.7
KMR 301	10.1	52.8	16.8	69.6
Bhairabi	11.2	41.6	27.4	69.0
Co-13	10.8	47.2	21.8	69.0
Paiyur	12.3	41.4	26.5	67.8
PES 110	10.3	40.2	27.3	67.5
HR-911	11.2	41.8	25.7	67.5
RAU-8	10.5	42.4	23.9	66.3
Saptagiri	10.1	50.3	14.1	64.4
VR-708	11.0	46.3	17.6	63.9
TRY-1	10.3	39.6	23.2	62.8
A-404	10.3	36.0	26.6	62.5
Nashini	10.0	40.9	21.7	62.5
Kalyan	10.0	35.6	26.0	61.6
VR-762	10.4	41.3	20.3	61.6
PRM 1	11.0	33.2	28.3	61.5
VL-149	10.3	39.2	21.9	61.1
Shakti	12.4	32.3	28.2	60.5
GE-4	9.0	34.7	25.6	60.3
Hasirukaddi ragi	10.6	28.2	32.0	60.2
GPU 70	10.3	33.8	26.0	59.9
VR-847	11.4	43.7	16.0	59.7
KMR 305	10.3	34.7	24.1	58.8

Genotypes	Initial grain moisture (%)	Popping (%)		
		Complete	Partial	Total
MR-6	11.5	33.5	24.3	57.9
Indaf-5	10.7	33.8	23.3	57.2
Dibyasinha	11.2	33.9	23.1	57.1
MR-1	11.0	29.4	25.8	57.0
Chilka	10.4	29.7	27.2	56.9
L-5	9.3	39.5	16.9	56.4
CO-7	11.0	31.1	25.4	56.4
KMR 204	12.0	29.5	26.3	55.8
GPU 76	9.4	38.7	17.1	55.8
Co-9	10.3	38.3	16.9	55.3
GPU 67	11.4	28.4	26.0	54.4
JWM-1(OLD)	11.5	28.4	25.9	54.2
GPU 26	11.3	28.3	25.0	53.3
VL-146	10.2	30.8	20.3	51.1
HasiruDundaga ragi	10.6	17.6	33.2	50.7
GPU 45	10.5	26.5	23.9	50.4
GPU 48	8.9	35.2	14.7	49.9
Hamsa	11.0	24.1	19.4	43.4
BM-2	11.3	19.8	23.2	43.1
HR-374	11.5	24.6	17.7	42.2
GN-5	11.5	24.7	17.5	42.2
Sharada	11.2	19.9	22.2	42.1
CO-11	11.0	26.4	19.0	42.0
HPB-7-6	10.3	17.8	23.8	41.6
VL-330	11.4	13.2	27.6	40.8
MR-2	10.5	16.8	23.0	39.8
Bonda ragi	10.6	15.9	23.4	39.3
VL-324	11.5	22.1	17.1	39.2
Srichaithanya	10.6	17.6	21.5	39.2
OUAT-1	10.9	16.0	22.9	38.9
Bilikaddi ragi	10.8	14.5	24.0	38.6
Nilachal	10.6	15.0	20.9	35.9
Indaf-15	10.7	14.8	20.7	35.5
GPU 75	11.4	16.3	19.2	35.5
Hejje ragi	9.4	13.8	17.6	31.4
PRM 901	10.9	15.3	16.0	31.3
VL-315	8.9	14.8	14.7	29.5
VL-351	11.4	9.7	17.9	27.6
JWM-1(new)	11.1	12.9	13.4	26.3
GN-1	9.8	10.6	15.3	25.9
Kari kaddi ragi	10.4	13.0	11.5	24.5

Genotypes	Initial grain moisture (%)	Popping (%)		
		Complete	Partial	Total
KOPN-933	9.5	12.2	11.3	23.5
Indaf-11	11.0	4.4	17.1	21.1
Jenu Bonda ragi	10.7	6.8	11.5	18.2
PRM-802	11.0	6.0	11.5	17.5
Picha kaddi ragi	10.6	7.9	8.7	16.7
Mean	10.7	31.6	22.2	53.7
SEm		1.9	1.4	2.9
CD (5%)		5.4	3.9	8.1
CV(%)		14.4	17.0	9.4

High popping varieties

Low popping varieties

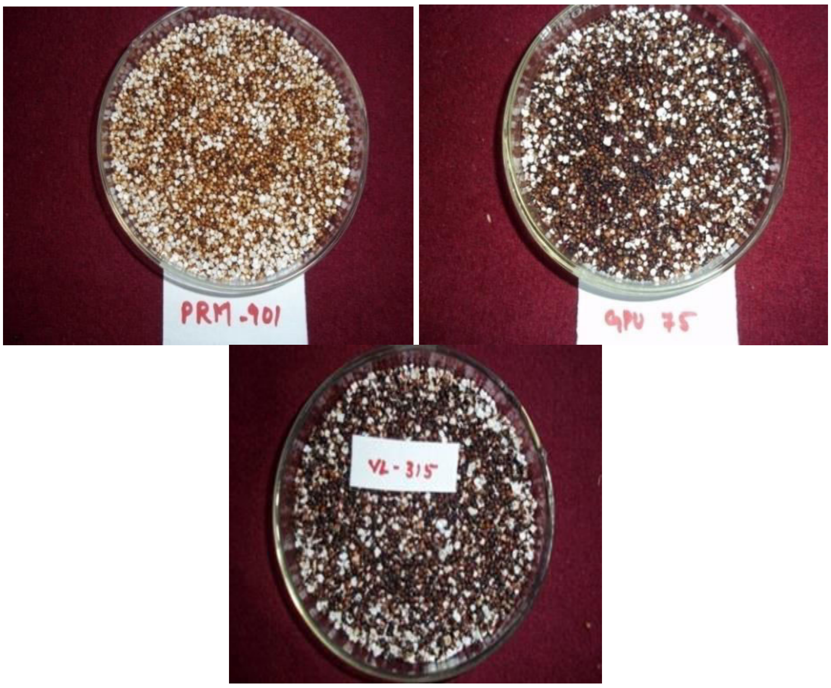


Plate 2. Varieties with high and low popping varieties

(D)Seed coat colour and popping

Interestingly it was observed that brown coloured grains showed a higher popping percent compared to the white coloured grains (Table 4). Among 86 varieties, the white seeded are Co-9 (55.3%), Hamsa (43.4%), GN-5 (42.2%), OUAT-1 (38.9%), PRM-901 (31.3%), JWM-1 (26.3%), Indaf-11 (21.1%) and PRM-802 (17.5%). In this issue, Shukla*et al.* (1986) also reported that the brown grain varieties have more popping percent (> 90%) compared to white grain varieties (≤ 66%).

Table – 4: Comparison of popping between brown and white seeded varieties of finger millet

Seed colour	**No. of varieties**	**Mean Popping %**			**Range for total popping %**
		Partial	**Complete**	**Total**	
White	8	16.8	17.7	34.5	17.5 – 55.3
Brown	78	22.7	33.0	55.7	18.6 – 88.2

Conclusions

From this study, it is inferred that (i) Initial grain moisture content is not a limiting factor in the process of popping. (ii) The popping percent in finger millet is generally 60 percent. (iii) Varieties Co-10, Indaf-3, Karun kaddi ragi, PR-202, Purna, GN-4, ES-11 and PRM-2 are superior finger millet varieties for popping. (iv) The brown seeded varieties are better for popping and (v) Interestingly, the variety GPU-66 (72.4%) has high popping percent, which is derived from the parentage of GPU-28 (56.9%) and PR-202 (78.8%) indicates the heritability of popping character.

Annexure -11: Development of small millets based food products for rural and urban consumers in India in RESMISA project

TNAU has developed and standardized both traditional and modern food products from small millets. The details of these products are shared in the following sections.

Traditional recipes: The traditional food items, novel processed foods and pasta products were prepared with small millets that are being grown and used (Barnyard millet, Kodo millet, Finger millet and Little millet) by the farmers of the project sites. Millet was substituted for rice flour in the preparation of various traditional foods commonly consumed by the farmers. The developed products were analyzed for their nutrients and the sensory attributes were evaluated using a nine point hedonic scale by a panel of trained members.

- **Breakfast food:** Idli, Dosa, Idiappam, Rotti, Pittu, Upma, Adai, Porridge, Khakra, Paniyaram and Chappathi.
- **Sweets:** Halwa, sweat kolukattai, Adhirasam, Kesari, Nutritious ball and Kheer.
- **Snacks:** Vadai, Pakoda, Ribbon pakoda, Omapodi, Murukku, Thattu vadai, Hot kolukattai and Vadagam.

Finger Millet based Traditional Recipes

Table - 1: Nutrient Content of Finger Millet Recipes

Nutrient Content of Finger Millet Breakfast Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Idli and Dosa (80%)	68.96	11.02	1.40	**3.12**	3.93	302.32	305.14	1.27	42.35
Idiappam (100%)	**72.00**	7.30	1.30	3.60	3.90	**344.00**	283.00	1.10	18.30
Roti (100%)	51.04	5.59	1.01	2.93	3.37	251.45	209.93	0.95	13.40
Pittu (100%)	70.21	5.93	**5.13**	3.06	3.11	260.80	236.40	0.90	14.97
Upma (100%)	56.78	9.22	1.52	2.70	3.55	245.14	275.58	1.22	41.20
Adai (60%)	67.07	**13.50**	1.97	2.56	**4.08**	253.30	**315.30**	**1.52**	**66.10**
Porridge(100%)	70.75	4.55	1.70	1.80	1.21	222.00	174.00	0.55	11.27

Nutrient Content of Finger Millet Sweet Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Halwa (100%)	53.65	4.33	**35.08**	1.21	1.79	111.80	130.20	0.45	5.49
Sweet Kolukattai (100%)	**70.13**	**6.09**	4.35	3.39	3.54	**273.40**	**240.65**	**0.90**	**14.72**

Nutrient Content of Finger Millet Health Drink

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Finger millet malt (100%)	77.48	5.86	1.04	2.88	31.51	277.60	226.40	0.88	14.64

Nutrient Content of Finger Millet Snack Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Vadai (40%)	58.38	**16.96**	2.52	2.05	3.66	223.88	**322.63**	1.65	**88.37**
Pakoda (85%)	62.62	6.28	25.93	2.76	2.95	244.00	225.47	1.10	15.52
Ribbon pakoda (70%)	65.20	6.52	6.21	12.25	3.15	175.68	225.20	1.65	25.50
Omapodi (85%)	**69.37**	10.68	2.73	3.87	**4.55**	266.75	279.24	**1.78**	41.16
Murukku (75%)	67.53	7.83	6.67	**12.52**	3.04	178.90	228.42	1.68	25.27
Thattuvadai (90%)	49.18	6.46	**31.34**	2.28	2.87	**278.24**	202.90	0.90	25.73

Kodo Millet based Traditional Recipes

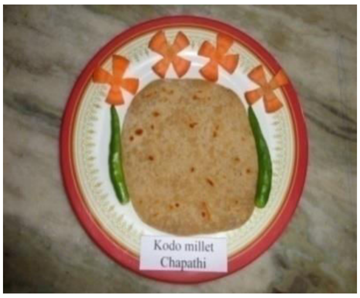



Table - 2: Nutrient Content of Kodo Millet Recipes

Nutrient Content of Kodo Millet Breakfast Recipes

Name of the Product	**CHO (g)**	**Protein (g)**	**Fat (g)**	**Crude Fibre (g)**	**Iron (mg)**	**Calcium (mg)**	**Phosphorus (mg)**	**Niacin (µg)**	**Folic acid (µg)**
Idli and Dosa (75%)	63.89	12.6	1.49	**6.94**	1.45	61.40	241.00	1.98	**51.60**
Paniyaram (80%)	45.57	9.94	11.40	5.10	1.73	92.00	193.00	1.70	43.20
Idiappam (75%)	60.80	5.03	11.00	4.50	0.69	20.30	129.00	1.15	11.60
Adai (50%)	62.25	**13.10**	**11.90**	6.35	2.58	**103.00**	**243.00**	2.60	51.00
Roti (80%)	47.50	5.96	11.20	4.80	2.38	90.60	139.70	1.45	14.80
Pittu (80%)	61.14	5.96	9.18	6.12	1.14	34.20	169.00	1.36	16.40
Upma (100%)	45.40	6.91	8.84	6.07	3.13	56.30	158.00	1.57	22.80
Chappathi (50%)	54.12	8.16	11.20	4.36	2.16	30.00	217.00	2.52	23.50
Khakra (50%)	**67.65**	10.20	1.55	5.45	**11.70**	37.50	272.00	**3.15**	29.50

Nutrient Content of Kodo Millet Sweet Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Halwa (90%)	56.03	3.97	**32.80**	2.06	0.93	16.90	96.00	0.89	8.20
Sweet Kolukattai (100%)	65.30	7.97	7.48	**6.41**	1.99	**110.00**	**199.70**	**1.67**	9.92
Kheer (100%)	54.43	4.33	11.30	3.22	1.77	55.70	109.00	0.71	7.78
Adhirasam (50%)	**83.50**	3.98	0.53	2.30	**16.30**	49.30	107.00	0.98	7.78
Kesari (100%)	64.90	5.05	13.20	2.82	0.95	33.90	93.80	0.69	7.78
Sweet adai (70%)	72.57	**10.50**	1.55	3.87	3.01	54.80	199.00	1.35	**51.10**

Nutrient Content of Kodo Millet Snack Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Vadai (75%)	51.40	**9.97**	2.19	5.56	**2.13**	52.50	193.00	1.79	**52.60**
Pakoda (75%)	52.90	7.33	1.57	7.67	1.15	76.75	170.00	1.75	20.70
Ribbon pakoda (90%)	60.76	8.32	6.37	9.07	0.71	58.10	192.00	2.18	23.50
Kolkata (100%)	45.11	6.55	**11.90**	6.12	1.78	70.70	151.00	1.51	19.80
Murukku (100%)	56.50	8.12	6.98	8.52	1.77	**105.00**	189.80	**2.07**	22.50
Thattuvadai (80%)	59.85	9.49	5.90	8.34	1.44	48.80	**197.00**	2.07	34.30
Vadagam (90%)	**62.7**	9.20	2.32	**10.2**	1.16	86.3	213	1.16	20.8

Little Millet based Traditional Recipes


LITTLE MILLET
IDLI


LITTLE MILLET
DOSA


LITTLE MILLET
ADAI


LITTLE MILLET
PORRIDGE


LITTLE MILLET
PUTTU


LITTLE MILLET
HALWA


LITTLE MILLET
HOT KOZHUKATTAI


LITTLE MILLET
PAKODA


LITTLE MILLET
RIBBON PAKODA


LITTLE MILLET
MURUKKU


LITTLE MILLET
THATTUVADAI

Table - 3: Nutrient Content of Little Millet Recipes

Nutrient Content of Little Millet Breakfast Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Idli and Dosa (80%)	65.06	11.32	4.05	6.24	8.14	13.44	211.92	2.91	35.10
Idiappam (100%)	67.00	7.00	4.70	**7.60**	9.30	17.13	215.12	3.20	9.00
Roti (100%)	47.79	5.85	3.22	5.53	6.88	16.14	214.89	2.32	7.36
Pittu (100%)	66.46	6.23	**7.66**	6.06	7.16	15.55	215.05	2.48	8.00
Upma (100%)	53.78	9.46	3.57	5.10	6.79	**18.94**	216.10	2.48	35.61
Adai (65%)	64.07	**13.74**	4.01	4.96	**12.90**	12.10	160.15	2.78	**60.52**
Porridge (100%)	**68.25**	4.75	3.40	3.80	5.36	16.50	**216.32**	1.60	6.62

Nutrient Content of Little Millet Sweet Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Halwa (80%)	52.15	4.45	**36.10**	2.41	3.41	13.70	111.30	1.08	2.70
Sweet Kolukattai (100%)	**66.38**	**6.39**	6.87	**6.39**	**7.59**	**28.15**	**193.40**	**2.48**	**7.75**

Nutrient Content of Little Millet Snack Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)	Folic acid (µg)
Vadai (40%)	56.88	**17.08**	2.31	3.25	5.28	11.88	**303.73**	**2.92**	**85.58**
Pakoda (85%)	59.12	6.56	28.38	**5.56**	6.73	15.10	181.37	2.57	9.01
Ribbon pakoda (50%)	61.87	7.51	1.54	3.42	3.54	13.24	268.65	1.10	23.69
Omapodi (85%)	**66.62**	10.90	4.65	6.07	**7.52**	14.90	244.59	2.94	36.05
Murukku (75%)	65.53	8.37	8.07	4.12	5.20	13.15	203.22	2.52	21.55
Thattuvadai (90%)	46.18	6.70	**33.38**	4.80	6.11	**15.80**	165.10	2.16	20.15

Barnyard Millet based Traditional Recipes

Table – 4: Nutrient Content of Barnyard Millet Recipes

Nutrient Content of Barnyard Millet Breakfast Recipes

Name of the Product	**CHO (g)**	**Protein (g)**	**Fat (g)**	**Crude Fibre (g)**	**Iron (mg)**	**Calcium (mg)**	**Phosphorus (mg)**	**Niacin (µg)**
Idli and Dosa (75%)	63.10	11.1	2.08	**7.52**	4.73	56.30	307.00	3.59
Paniyaram (80%)	45.39	8.99	11.7	5.46	3.75	14.40	233.00	2.69
Idiappam (100%)	60.58	3.98	1.14	4.90	2.94	16.75	175.00	2.25
Adai (75%)	62.05	**12.00**	**12.30**	6.75	4.83	**80.24**	289.00	3.70
Roti (80%)	23.40	5.12	11.50	5.12	4.18	17.80	176.50	2.33
Pittu (100%)	60.90	4.70	9.66	6.60	3.84	16.63	224.00	2.68
Upma (100%)	45.20	5.65	9.32	6.55	3.83	18.54	213.00	2.89
Chappathi (50%)	53.90	7.32	11.50	4.68	3.96	12.20	254.00	3.40
Khakra (50%)	**67.45**	9.60	1.95	5.85	**4.95**	11.68	**317.00**	**4.25**

Nutrient Content of Barnyard Millet Sweet Recipes

Name of the Product	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)	Iron (mg)	Calcium (mg)	Phosphorus (mg)	Niacin (µg)
Halwa (80%)	55.95	3.55	**32.90**	2.22	1.83	15.50	124.00	1.33
Kheer (100%)	54.30	10.80	11.30	3.46	1.37	19.80	213.12	-
Sweet Kolukattai (100%)	65.04	6.61	8.00	**6.93**	4.90	**30.45**	198.50	**3.10**
Sweet adai (70%)	72.40	9.66	1.86	4.19	4.81	17.56	**205.14**	2.23
Adhirasam (50%)	**83.43**	3.45	0.73	2.50	**17.40**	27.50	132.25	1.53
Kesari (100%)	64.70	11.60	13.50	3.06	2.30	25.80	121.36	1.35
Nutritious ball (30%)	61.27	**13.70**	21.30	3.12	2.89	16.90	159.48	1.63

Nutrient Content of Barnyard Millet Snack Recipes

Name of the Product	**CHO (g)**	**Protein (g)**	**Fat (g)**	**Crude fibre(g)**	**Iron (mg)**	**Calcium (mg)**	**Phosphorus (mg)**	**Niacin (µg)**
Vadai (75%)	51.20	**8.92**	2.59	5.96	4.38	49.00	239.00	2.89
Pakoda (100%)	49.40	5.44	2.06	7.78	4.27	70.50	225.00	3.19
Ribbon pakoda(100%)	60.40	6.43	**70.90**	9.79	4.76	51.80	274.00	4.16
Murukku (100%)	56.20	6.44	7.62	9.16	**5.37**	**99.70**	263.00	3.83
Thattu vadai (100%)	59.50	7.81	6.54	8.98	5.04	43.20	270.00	3.83
Kolukkattai (100%)	44.87	5.29	12.30	6.60	4.48	66.46	206.00	2.83
Vadagam (100%)	**62.36**	7.31	3.04	**10.90**	5.21	80.00	**296.00**	**4.39**

Bakery Products

The small millets incorporated bread was standardized by incorporating millets at different proportions (10% to 70%). The bread prepared with 20% incorporation of small millets was found to be more acceptable up to 3 days. The cost of millet bread was calculated to be Rs. 17.00.

Small millets based cakes were standardized in various levels of incorporation. The millet based cakes were highly acceptable at 50% incorporation level for a period of 7 days. The cost of millet based cakes range from Rs.40 per 250 g of the product.

The small millets incorporated cookies was standardized by incorporating millets at 25%, 50% and 75%. The products were evaluated for their sensory attributes using a nine point hedonic scale by panel of members. The developed cookies were highly acceptable at 50% incorporation level and the shelf life of the product was 15 days. The cost of cookies was Rs.14 per 100 g of the product.

Soup sticks -20%

Twist Khari -40%

Foxtail millet

Little millet

Kodo millet

Pasta Products

Vermicelli and Macaroni were prepared at various substitution levels of small millet flour (10, 20, 30, 40, 50, 60 and 70%). The products were found to be acceptable up to an incorporation level of 30 per cent. During storage a gradual increase in moisture content was observed, and the moisture uptake was minimum in the products packed in P_2 compared to P_1. The final moisture content was higher in the products packed in P_1 than P_2 (6.31 and 6.27% respectively). The mineral content increased with increase in millet flour incorporation. The calcium and phosphorus of vermicelli ranged from 19.5 to 103.03mg/ 100 g of the product respectively. The iron content of the developed products ranged from 3.73 to 4.75 mg/100g and at 30 per cent incorporation level. The marginal decrease observed in calcium, phosphorus and iron levels during storage was non-significant. A slight reduction in sensory scores was observed throughout storage and the reduction was higher in the samples packed in P_1 compared to P_2. The final values were maximum for the millet incorporated samples (30%) packed in P_2 (7.28) followed by the same treatment packed in P_1 (7.22). The cost of the millet based products ranged from Rs.7 to Rs 15/100 g of vermicelli and Rs.10 to Rs.20/100g of macaroni.

Instant food mixes

Standardization of instant food mixes from small millet grains: Idli mix, Dosa mix, Paniyaram mix, Aapam mix and Halwa mix from Barnyard and Kodo millet were standardized and evaluated for their nutrient content, organoleptic characters and shelf life. Health mix was developed from small millets. The protein content was high in kodo millet based mixes ranging from 9.50 to 11.37g/100g and the barnyard millet mixes ranging from 9.62 to 9.4g/100g of the product. Meager changes were observed for all the mixes (Kodo and Barnyard) in calcium, phosphorus and iron during storage. The mean score of overall acceptability of the kodo millet instant food mixes ranged from 8.1 to 8.8 and barnyard millet instant mixes ranged from 8.0 to 8.72. The microbial load of Total plate count was below detectable level. The cost of the developed mixes ranged from Rs.9.80/- to Rs. 13.40/- per 100 gm of the product.

Table - 5: Nutritive value of Kodo millet and Barnyard millet Instant food mixes

Nutrients	Kodo millet					Barnyard millet				
	T_1	T_2	T_3	T_4	T_5	T_1	T_2	T_3	T_4	T_5
Moisture (g)	9.60	9.60	9.80	10.0	11.00	10.10	10.10	9.60	10.10	10.80
Starch (g)	57.00	57.00	54.30	51.00	56.03	55.80	55.80	48.50	50.10	55.95
FFA (mg KOH/g)	1.00	1.00	1.90	2.40	2.95	1.20	1.20	2.10	2.00	3.00
Protein (g)	11.37	11.37	9.50	10.45	3.97	9.62	9.62	8.15	9.40	55.95
Fat (g)	1.50	1.50	1.20	1.55	32.8	2.80	2.80	2.90	2.70	3.55
Crude fibre(g)	4.20	4.20	4.30	4.35	2.06	6.90	6.90	4.33	3.90	2.25
Tannin (g)	3.40	3.40	3.10	3.50	4.26	4.10	4.10	3.80	4.15	3.89
Calcium (mg)	53.20	53.20	55.00	59.10	16.9	57.18	57.18	81.78	55.28	15.5
Phosphorus(mg)	121.70	121.70	200.30	120.60	96.0	277.60	277.60	224.00	217.68	124
Iron (mg)	2.17	2.17	1.98	2.34	1.93	2.34	2.34	3.75	3.25	1.83

T_1- Idli, T_2- Dosai, T_3- Paniyaram, T_4- Appam, T_5- Halwa

Table - 6: Cost analysis of the Kodo and Barnyard millet Instant Food Mixes

S.No.	Instant Food Mixes	Kodo millet		Barnyard millet	
		(Rs./100g)	(Rs./ kg)	(Rs./100g)	(Rs./1 kg)
1.	Idli mix	12.00	120.00	13.40	134.00
2.	Dosai mix	12.00	120.00	13.40	134.00
3.	Paniyaram mix	13.10	131.00	12.20	122.00
4.	Sweet Aapam mix	9.80	98.00	9.90	99.00
5.	Halwa mix	11.5	115.00	12.00	120.00

Flaked and Popped Value added Small Millet Products

The developed small millet flakes and popped products were highly acceptable.

Little millet

Kodo millet

Ragi millet

Barnyard millet

Little millet

Barnyard millet

Ragi millet

Kodo millet

Annexure – 12: Bio-availability of nutrients from different product matrices of small millets

TNAU conducted study of the product matrix effect on low, intermediate and high moisture products. The different grain varieties based on their physical properties and nutritional characteristics were selected and utilized for the standardization of bread and cookies. Porridge was developed from kodo, little and foxtail millet as high moisture food. The standardized small millet products were analyzed for their starch digestibility, dietary fibre and antioxidant properties**.** The anti-diabetic effect of the standardized cookies and small millet flour was analyzed. More details are given below.

Physical Characteristics of small millet grains
The whole millet grains and the dehulled grains were assessed for their physical properties. The physical characteristics of millet varieties viz., thousand grain weight, thousand grain volume and bulk density were studied and presented in Table 8.

Table - 1: Physical characteristics of the different varieties of grains

Sl. No.	Varieties	1000 Grains Weight (g)		1000 Grains Volume (ml)	
		Grain	Raw Rice	Grain	Raw Rice
TNAU Varieties					
1	CO 2 (Little Millet)	2.60	1.79	3.60	2.20
2	CO 3 (Little Millet)	2.70	1.90	3.55	2.40
3	CO 4 (Little Millet)	2.71	2.06	3.60	2.60
Landraces Varieties					
4	Sittan samai (Little Millet)	2.74	1.98	3.60	2.50
5	Koluthana samai (Little Millet)	2.59	1.89	3.50	2.17
Market Varieties					
6	Kodo Millet (Varagu)	5.87	3.82	8.20	4.95
7	Little Millet (Samai)	2.87	2.47	4.00	3.20
8	Foxtail Millet (Thenai)	2.71	2.25	3.75	2.90

Based on the physical, nutritional and sensory properties the best suited varieties were identified for the product formulation.

Product Matrix Effect: The different grain varieties based on their physical properties and nutritional characteristics were selected and utilized for the standardization of bread and cookies. Millet bread was standardized at different levels of incorporation of kodo millet, little millet and foxtail millet. Based on the physical characteristics of dough, sensory and nutritional characteristics of the developed bread, 20% incorporation level was found to highly acceptable. The shelf life of the developed millet bread was 3 days in different packaging materials.

Low Moisture – Cookies: The standardized small millet cookies which were found to be highly acceptable at 50% incorporation levels were analyzed for their physical characteristics, starch digestibility, glycemic index, dietary fibre and antioxidant properties. The rapidly and slowly digestible starches (RDS and SDS) and resistant starch (RS) of the composite flour and cookies were measured based on the enzymic hydrolysis patterns. The RDS of composite cookies was lower and SDS was higher. The estimated Glycemic index was also analyzed.

The anti-diabetic effect of the standardized cookies was analyzed. The data on hypolidemic and hypoglycemic effect of the composite cookies indicated that the reduction in the blood glucose levels was high in the rats fed with kodo millet cookies and the groups fed with composite cookies had an improved plasma insulin level and haemoglobin content. The HDL cholesterol of the perse control was higher than the diabetic treatment group. The standardized composite cookies exerted hypoglycaemic and hypolipidemic effect and was more pronounced in kodo millet cookies.

LOW MOISTURE – COOKIES

KODO MILLET COOKIES - 50 %, LITTLE MILLET COOKIES - 50% FOXTAIL MILLET COOKIES- 50%

Table - 2: Physical properties of standardized composite cookies

Treatments	Diameter (mm)	Thickness (mm)	Spread Ratio	Water Activity (a_w)
T_0	41.46 ± 0.20	7.57 ± 0.25	5.47 ± 0.15	0.223 ± 0.03
$T_1 V_1$	39.79 ± 0.37	7.19 ± 0.02	5.53 ± 0.06	0.293 ± 0.01
$T_2 V_2$	42.25 ± 0.23	7.39 ± 0.30	5.72 ± 0.19	0.212 ± 0.00
$T_3 V_3$	40.60 ± 0.40	7.05 ± 0.00	5.75 ± 0.05	0.201 ± 0.00

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour

Table – 3: Starch digestibility of standardized composite flour and cookies

	composite cookies (%)			
Treatments	**TS**	**RDS**	**SDS**	**RS**
T_0	43.00	12.27	11.64	19.09
$T_1 V_1$	38.00	10.79	12.18	17.13
$T_2 V_2$	40.00	11.64	14.92	13.44
T_3V_3	36.00	10.29	13.56	12.15

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour

The Rapidly Digestible Starch for $T_1V_{1,}$ T_2V_2 and T_3V_3 was 10.79, 11.64, 10.29g/100g of the total starch, which was lower than the T_0 (12.27g). The most predominant starch fraction of $T_1V_{1,}$ T_2V_2 and T_3V_3 showed the values of Slowly Digestible Starch as 12.18, 14.92 and 13.56 g per 100g of the total starch and it was higher than the T_0 (11.64g). The resistant starch content of $T_1V_{1,}$ T_2V_2 T_3V_3 and T_0 was 17.13, 13.44, 12.15 and 19.09g. The resistant starch was higher than the slowly digestible starch and rapidly digestible starch. The total starch content of the $T_{0,}$ $T_1V_{1,}$ T_2V_2 and T_3V_3 was 43.00, 38.00, 40.00 and 36.00g per 100g for the standardized composite cookies.

Table – 4: In-vitro effect of Glycemic Index (GI) of the standardized composite flour and cookies

Treatments	**Glycemic Index (GI)**	
	Flour	**Cookies**
T_0	71.33	58.61
$T_1 V_1$	43.91	41.69
$T_2 V_2$	41.42	40.04
T_3V_3	41.04	37.77

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour

The expected Glycemic index of $T_1V_{1,}$ T_2V_2 and T_3V_3 was 43.91, 41.42 and 41.04 respectively, which was lower than T_0 (71.33). The values for GI of composite cookies were 1.69, 40.04, 37.77 and 58.61 for $T_1V_{1,}$ T_2V_2 T_3V_3 and T_0 respectively.

Table – 5: Total anti-oxidant activity (mg/g) of the standardized composite cookies

Cookies	**Total anti-oxidant activity (mg/g)**
T_0	0.28
$T_1 V_1$	0.31
$T_2 V_2$	0.33
T_3V_3	0.35

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour

The total anti-oxidant activity of $T_1V_{1,}$ T_2V_2 and T_3V_3 was 0.31, 0.33 and 0.35mg per g respectively, which was slightly higher than T_0 with the value of 0.28mg per g.

Table - 6: Dietary fibre status of the standardized composite cookies

Items	Total Dietary Fibre (TDF)	Soluble Dietary Fibre (SDF)	Insoluble Dietary Fibre (IDF)
T_0	0.42 ± 0.08	0.07 ± 0.03	0.35 ± 0.10
$T_1 V_1$	0.98 ± 0.11	0.11 ± 0.01	0.89 ± 0.10
$T_2 V_2$	1.05 ± 0.07	0.15 ± 0.01	0.90 ± 0.08
T_3V_3	2.57 ± 0.10	0.36 ± 0.06	2.21 ± 0.11

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour

The total dietary fibre content of T_1V_1, T_2V_2 and T_3V_3 were 0.98 ± 0.11, 1.05 ± 0.07 and 2.57 ± 0.10g respectively, was higher than T_0 (0.42 ± 0.08g). The soluble and insoluble dietary fibre content were also higher in composite cookies than T_0. The total dietary fibre, soluble dietary fibre and insoluble dietary fibre content of T_3V_3 was higher than T_1V_1 and T_2V_2.

Table - 7: Glycemic Index (GI) of the standardized composite cookies in humans

Treatments	Glycemic Index (GI)
T_0	37.89
$T_1 V_1$	31.71
$T_2 V_2$	30.74
T_3V_3	32.34

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour

The rise in blood glucose after consumption of the standardized composite cookies was observed and significant differences were found for the mean blood glucose levels between time intervals 0, 15, 30, 45, 60, 90 and 120 min with values 90.25, 96.50, 100.75, 103.00, 101.50, 94.25 and 104.00 mg/dl for T_0, 81.75, 89.00, 98.00, 100.00, 101.50, 91.75 and 93.00 mg/dl for T_1V_1, 88.25, 97.25, 106.50, 99.50, 93.25, 100.50 and 101.00 mg/dl for T_2V_2 and 82.50, 88.50, 94.75, 96.75, 99.75, 98.75 and 92.75 mg/dl for T_3V_3 respectively. The Glycemic index of T_1V_1, T_2V_2 and T_3V_3 was 31.71, 30.74 and 32.34, was lower than T_0 (37.89) respectively.

Table - 8: Effect of standardized composite cookies on body weight and blood glucose in normal and treated animals

GROUP	Body weight (g)		Blood glucose (mg / 100ml)	
	Initial	Final	Initial	Final
G1	205 ± 8.8	220 ± 9.1	77.50 ± 3.20	73.54 ± 4.25
G2	195 ± 7.6	150 ± 5.2**(a)	140.62 ± 3.64	220.25 ± 9.19**(a)
G3	207 ± 8.4	222 ± 9.6	91.90 ± 3.75	99.05 ± 4.15
G4	190 ± 7.4	228 ± 9.4	90.35 ± 2.95	80.25 ± 3.85
G5	204 ± 8.2	230 ± 9.8	91.42 ± 3.93	86.15 ± 3.68
G6	212 ± 8.6	232 ± 9.9	90.15 ± 4.05	83.15 ± 4.26
G7	220 ± 8.8	226 ± 8.4	172.09 ± 4.30	205.25 ± 6.60**(b)
G8	215 ± 8.0	230 ± 8.9	158.12 ± 4.65	115.16 ± 6.95**(b)
G9	222 ± 8.9	235 ± 9.1	163.15 ± 4.70	129.45 ± 5.92**(b)
G10	218 ± 8.5	232 ± 8.8	154.22 ± 3.55	121.20 ± 6.88**(b)

G1- Normal; **G2**- Diabetic Control; **G3**- **G6** (*Perse control*) (Normal Rat +50%incoporated millet cookies)*);* **G7-G10**- Treatment control (Diabetic Rat +50%incoporated millet cookies).

Table - 9: Effect of standardized composite cookies on hematological parameters

Groups	Haemoglobin (gm/100ml)	Glycosylated haemoglobin HbA_1 (%)	Plasma Insulin (µU/ml)
G1	12.16 ± 1.18	0.25 ±0.06	25.21 ± 0.70
G2	6.05 ± 0.66**(a)	0.90 ±0.10**(a)	11.83 ± 0.19**(a)
G3	11.90 ± 1.12	0.32 ±0.08	21.2 ± 0.40
G4	11.50 ± 1.04	0.30 ± 0.06	20.21 ± 0.47
G5	12.02 ± 1.14	0.29 ± 0.05	22.53 ± 0.54
G6	11.92 ± 1.08	0.31 ± 0.06	22.88 ± 0.62
G7	9.90 ± 0.95**(b)	0.52 ± 0.06**(b)	17.40 ± 0.36**(b)
G8	10.02 ± 0.90**(b)	0.38 ± 0.05**(b)	18.32 ± 0.40**(b)
G9	9.84 ± 0.98**(b)	0.40 ± 0.04**(b)	17.90 ± 0.32**(b)
G10	9.25 ± 0.82**(b)	0.41 ± 0.04**(b)	18.22 ± 0.38**(b)

G1- Normal; **G2**- Diabetic Control; **G3**- **G6** (*Perse control*) (Normal Rat +50%incoporated millet cookies)*;* **G7-G10**- Treatment control (Diabetic Rat +50%incoporated millet cookies).

- Values are expressed as mean **±** SEM.
- Values were compared by using analysis of variance (ANOVA) followed by Newman-Keul's multiple range tests.
- ** (a) Values are significantly different from normal control G1 at P<0.001.
  ** (b) Values are significantly different from Diabetic control G2 at P<0.01.

The hypoglycemic effect of the standardized composite cookies was studied by conducting experiments on wistar albino rats. The diabetic group the rats fed with composite cookies (G8 to G10) showed an increase in the body weight when compared to the rats fed with refined wheat cookies (G7).

The initial blood glucose level of the normal rats was 77.50 ± 3.20 (G1) while that of the diabetic group was 140.62 ± 3.64mg per 100 ml (G2). At the end of the feeding trial the blood glucose level was decreased in G1 and increased in G2 with the values 73.54 ± 4.25 and 220.25 ± 9.19g respectively. Among the perse control group (G3-G6) the blood glucose level was observed to be decreased in the rats fed with composite cookies when compared to rats fed with refined wheat cookies. A similar trend of reduction in the blood glucose was noticed in the diabetic groups. The final blood glucose levels of G7 was 205.25 ± 6.60, G8 was 115.16 ± 6.95, G9 was 129.45 ± 5.92mg and that of G10 was 121.20 ± 6.88 mg per 100ml of blood respectively. The overall result indicated that the reduction in the blood glucose levels was high in the rats fed with kodo millet cookies than the rats fed with control cookies.

The plasma insulin level of diabetic control (G2) was 11.83 ± 0.19 while that of treatment control was 17.40 ± 0.36 (G7), 18.32 ± 0.40 (G8), 17.90± 0.32 (G9) and 18.22 ± 0.38 (G10) µU per ml respectively. The results concluded that the groups fed with composite cookies had an improved plasma insulin level and was near to the normal level.

The hemoglobin content of normal (G1) and diabetic control (G2) group was 12.16 ± 1.18 g and 6.05 ± 0.66g per 100ml. The hemoglobin content of perse control group ranged from 11.50 ± 1.04 (G4) to 12.02 ± 1.14 (G5) per cent and that of diabetic treatment control group was 9.25 ± 0.82 (G10) to 10.02 ± 0.90 (G9) g per 100ml. The results showed that the feeding of composite cookies had a remarkable effect in the improvement of hemoglobin content.

Among the perse control group HbA_1 of G5 fed with composite cookies (T_2) was lesser than the other millet cookies and refined wheat cookies. The HbA_1 level of the perse control ranged between 0.29 ± 0.05 to 0.32 ± 0.08 per cent. Similarly among the diabetic treatment group HbA_1 of kodo millet fed group (G8) was the lowest with the value of 0.38 ± 0.05 per cent and the refined wheat cookies fed group (G7) had the highest HbA_1 with the value of 0.52 ± 0.06 per cent.

Table- 10: Mean value for sensory evaluation of cookies during storage

Treatments	Packaging	Storage Days	Sensory Attributes				
			Color and Appearance	Flavor	Texture	Taste	Overall Acceptability
T_1	P_1	1	8.9	9.0	8.8	9.0	8.7
		15	8.1	8.7	8.0	8.5	8.3
	P_2	1	8.9	9.0	8.8	9.0	8.7
		15	8.2	8.72	8.1	8.52	8.34
T_2	P_1	1	8.65	8.4	8.20	8.48	8.40
		15	8.0	8.1	7.98	8.19	8.02
	P_2	1	8.65	8.4	8.20	8.48	8.40
		15	8.05	8.13	8.00	8.20	8.05
T_3	P_1	1	8.60	8.65	8.55	8.70	8.48
		15	8.1	8.25	8.29	8.4	8.25
	P_2	1	8.60	8.65	8.55	8.70	8.48
		15	8.15	8.28	8.30	8.43	8.29
T_4	P_1	1	8.8	8.55	8.40	8.65	8.65
		15	8.4	8.30	8.08	8.2	8.30
	P_2	1	8.8	8.55	8.40	8.65	8.65
		15	8.4	8.36	8.10	8.25	8.35

T_1- Refined wheat flour, T_2- Kodo millet flour, T_3 - Little millet flour, T_4 - Foxtail millet flour
P_1- 200 gauge polyethylene pack P_2- 600 gauge plastic container

It was observed that the storage period and packaging material had less effect on colour and appearance of the standardized composite cookies. The scores for flavour attributes in T_0 decreased from 9.0 to 8.7, in T_1V_1 the scores decreased from 8.40 to 8.10 in P_1 and 8.13 in P_2. Similar decrease was also observed in T_2V_2 from 8.65 to 8.25 in P_1 and 8.28 in P_2 and in T_3V_3 from 8.55 to 8.30 and 8.36 in P_1 and P_2 respectively during the storage period of 15 days. Sensory scores for flavour decreased significantly in T_0 and standardized composite cookies in P_1 than in P_2. With regard to the texture and taste of the standardized composite cookies, sensory scores decreased significantly as the storage period increased. Overall acceptability of T_0 was 8.7 initially which decreased to 8.30 in P_1 and 8.34 in P_2. T_1V_1 scored 8.40 initially which decreased to 8.02 in P_1 and 8.05 in P_2. T_2V_2 scored 8.48 on the 1st day and decreased to 8.25 and 8.29 and T_3V_3 scored 8.65 initially decreased to 8.30 and 8.35 in P_1 and P_2 respectively during the storage period. The results concluded that the cookies packed in plastic container (P_2) exhibited higher acceptability than cookies packed in poly propylene bag (P_1) and the shelf life to be 15days.

Changes in Nutritional composition of the standardized composite cookies during storage

The results revealed that the incorporation of millet flour significantly affected the compositional characteristics of cookies.

Nutrient changes in the standardized composite cookies during storage (per100g)

Nutrients	**T_0**				**T_1V_1**				**T_2V_2**				**T_3V_3**			
	P_1		**P_2**		**P_1**		**P_2**		**P_1**		**P_2**		**P_1**		**P_2**	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Moisture (g)	12.58	12.72	12.58	12.65	9.13	9.35	**9.13**	9.21	8.24	8.36	8.24	8.31	8.25	8.34	8.25	8.30
Carbohydrate (g)	66.54	65.42	66.54	65.51	66.48	66.45	66.48	66.47	66.85	66.82	**66.85**	66.84	64.81	64.78	64.81	64.80
Protein (g)	13.65	13.44	13.65	13.50	6.45	6.43	6.45	6.44	6.25	6.22	6.25	6.24	7.79	7.73	**7.79**	7.77
Fat (g)	20.12	20.08	20.12	20.11	20.77	20.74	20.77	20.76	21.87	21.83	**21.87**	21.86	21.73	21.70	21.73	21.72
Crude Fibre (g)	0.46	0.38	0.46	0.44	3.10	3.07	**3.10**	3.09	2.65	2.61	2.65	2.64	2.77	2.73	2.77	2.76
Ash (g)	1.00	0.79	1.00	0.86	0.92	0.83	0.92	0.88	0.90	0.87	0.90	0.89	0.98	0.92	0.98	0.96
Calcium (mg)	17.62	17.45	17.62	17.54	19.07	19.04	19.07	19.06	15.73	15.69	15.73	15.72	20.40	20.36	**20.40**	20.39
Iron (mg)	1.83	1.79	1.83	1.82	1.51	1.47	1.51	1.50	4.03	4.00	**4.03**	4.02	1.86	1.83	1.86	1.85
Tannin (mg)	43.88	43.75	43.88	43.81	47.87	47.82	47.87	47.85	45.47	45.39	**45.47**	45.44	45.12	45.08	45.12	45.10

T_0 - Refined wheat flour, **T_1V_1** - Kodo millet flour, **T_2V_2** - Little millet flour, **T_3V_3** - Foxtail millet flour,
P_1 - Poly Propylene 200 gauge, P_2 – Plastic container 600 gauge

Source	**Moisture**			**Carbohydrate**			**Protein**			**Fat**		
	SED	CD (0.05)	CD (0.01)	SED	CD (0.05)	CD (0.01)	SED	CD (0.05)	CD (0.01)	SED	CD (0.05)	CD (0.01)
T	0.016	0.034	0.047**	0.015	0.032	0.044**	0.017	0.036	0.050**	0.012	0.026	0.036**
P	0.011	0.024	0.033**	0.010	0.022	0.031**	0.012	0.025	0.035 NS	0.008	0.018	0.025NS
S	0.011	0.024	0.033**	0.010	0.022	0.031**	0.012	0.025	0.035**	0.008	0.018	0.025*
TP	0.022	0.048	0.046 **	0.021	0.045	0.063**	0.024	0.051	0.070 NS	0.017	0.037	0.051NS
PS	0.016	0.034	0.047 **	0.015	0.032	0.044**	0.017	0.036	0.050 NS	0.012	0.026	0.036 NS
TS	0.022	0.048	0.046 **	0.021	0.045	0.063**	0.024	0.051	0.070**	0.017	0.037	0.051NS
TPS	0.032	0.048	0.044 **	0.030	0.064	0.089**	0.034	0.072	0.100**	0.025	0.053	0.073NS

Source	**Fibre**			**Calcium**			**Iron**			**Tannin**		
	SED	CD 0.05)	CD (0.01)	SED	CD(0.05)	CD(0.01)	SED	CD (0.05)	CD (0.01)	SED	CD (0.05)	CD (0.01)
T	0.008	0.018	0.025**	0.014	0.031	0.043**	0.009	0.019	0.027**	0.010	0.022	0.031**
P	0.006	0.013	0.018**	0.010	0.022	0.030NS	0.006	0.014	0.019NS	0.007	0.016	0.022*
S	0.006	0.013	0.018**	0.010	0.022	0.030**	0.006	0.014	0.019**	0.007	0.016	0.022**
TP	0.012	0.026	0.036NS	0.020	0.044	0.061NS	0.013	0.028	0.038NS	0.015	0.032	0.044NS
PS	0.008	0.018	0.025**	0.014	0.031	0.043NS	0.009	0.019	0.027NS	0.010	0.022	0.031*
TS	0.012	0.026	0.036NS	0.020	0.044	0.061**	0.013	0.028	0.038NS	0.015	0.032	0.044*
TPS	0.017	0.037	0.051NS	0.029	0.062	0.086NS	0.018	0.039	0.054NS	0.021	0.045	0.062NS

Moisture: The initial moisture content of T_1V_1, T_2V_2 and T_3V_3 was 9.13, 8.24 and 8.25g respectively, whereas T_0 exhibited 12.58g of moisture. A slow increase in the moisture content was observed in P_2 than P_1.

Carbohydrate: The initial carbohydrate content of T_1V_1, T_2V_2 and T_3V_3 was 66.48, 66.85 and 64.81g respectively which were found to be more or less equal to T_0 which exhibited 66.54g of carbohydrate content. The carbohydrate content of T_1V_1 was 66.45 in P_1 and 66.47 in P_2 and that of T_2V_2 was 66.82 in P_1 and 66.84 in P_2 and that of T_3V_3 was 64.78 in P_1 and 64.80 in P_2 at the end of the storage period.

Protein: The protein content of T_0 was 13.65g which was higher as compared to 6.45, 6.25 and 7.79g in T_1V_1, T_2V_2 and T_3V_3 respectively. The protein content of the standardized composite cookies were found to decrease at the end of the storage period and the foxtail millet cookies was found to contain higher protein than the kodo millet and little millet cookies.

Fat: The fat content of the cookies increased slightly with the incorporation of millets. The initial fat content of T_0 was 20.12g and that of T_1V_1 was 20.77, T_2V_2 was 21.87g and T_3V_3 was 21.73g. The results showed that the fat content at the end of the storage period in T_0 was 20.08 in P_1 and 20.11 in $P_{2,}$ in T_1V_1 it was 20.74 in P_1 and 20.76 in $P_{2,}$ in T_2V_2 it was 21.83 in P_1 and 21.86 in P_2 and in T_3V_3 it was 21.70 in P_1 and 21.72 in $P_{2.}$

Crude fibre: The initial crude fibre content was 3.10, 2.65 and 2.77g for T_1V_1, T_2V_2 and T_3V_3 respectively and that of T_0 was 0.46g. The storage period of 15 days showed a decreasing trend in the crude fibre content as 3.07 and 3.09 in P_1 and P_2 for T_1V_1, 2.61 and 2.64 in P_1 and P_2 for T_2V_2 and 2.73 and 2.76 in P_1 and P_2 for T_3V_3. The P_2 packaging material showed better retention of crude fibre content than P_1 packaging material.

Minerals: The calcium content of T_3V_3 was 20.40mg which was comparatively higher than T_0, T_1V_1 and T_2V_2, which showed the calcium levels of 17.62, 19.07 and 15.73 respectively. The cookies developed from little millet were found to be less in calcium than control. The increase in storage period showed a decreasing trend in the calcium content. The values of calcium content was 19.04 and 19.06 in P_1 and P_2 for T_1V_1, 15.69 and 15.72 in P_1 and P_2 for T_2V_2 and 20.36 and 20.39mg in P_1 and P_2 for T_3V_3. The iron content of $T_{0,}$ T_1V_1, T_2V_2 and T_3V_3 was 1.83, 1.51, 4.03 and 1.86mg respectively. The final iron content exhibited by T_1V_1 was 1.47 and 1.50mg, by T_2V_2 was 4.00 and 4.02 and by T_3V_3 was 1.83 and 1.85 in P_1 and $P_{2.}$ The P_2 packaging material was found to be better than the P_1 packaging material in retaining the mineral content.

Tannin: The initial tannin content of composite cookies was 43.88, 47.87, 45.47 and 45.12mg in $T_{0,}$ T_1V_1, T_2V_2 and T_3V_3 respectively. The increase in storage period decreased the tannin content of the cookies to 43.75 in P_1 and 43.81mg in P_2 for T_0, 47.82 in P_1 and 47.85 in P_2 for T_1V_1, 45.39 in P_1 and 45.44 in P_2 for T_2V_2 and 45.08 in P_1 and 45.10 in P_2 for T_3V_3.

Table - 11: Microbial load for cookies

Treatments	Total plate count ($x10^4$ cfu / g)		Total yeast and mold count ($x10^4$ cfu / g)	
	Initial	**Final**	**Initial**	**Final**
T_1	nil	0.65	nil	0.62
T_2	nil	0.42	nil	0.35
T_3	nil	0.35	nil	0.41
T_4	0.33	0.61	nil	0.38

T_1- Refined wheat flour, T_2- Kodo millet flour, T_3 - Little millet flour, T_4 - Foxtail millet flour

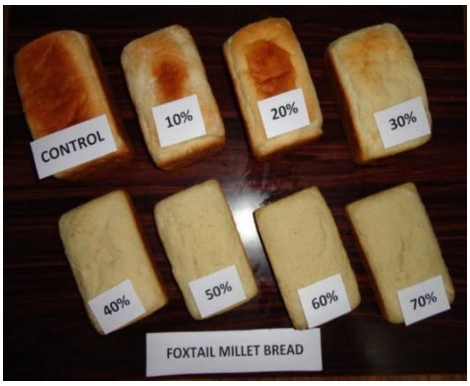
The microbial load was found to be within in the safer limit. Initially all the samples showed nil microbial loads and a gradual increase was observed during the storage period of 15 days.

Intermediate Moisture - Bread: The composite flour and bread were analyzed for their physical characteristics starch digestibility, glycemic index, and dietary fibre and antioxidant properties. The total starch and the rapidly digestible starch of composite breads were lower. The total anti-oxidant activity and the total dietary fibre content of composite bread were slightly higher.

<u>**Millet incorporated Bread**</u>

Kodo Millet Bread (20%)

Little Millet Bread (20%)



Foxtail Millet Bread (20%)

Table - 12: Effect of Incorporation of Millet Flour on the Sensory Characteristics of Bread (20%)

Millet Bread	PACKAGE	STORAGE	External properties				Internal properties			Taste properties			Total score (100)	Acceptability Rating	
			Volume (15)	Crust Colour (5)	Symmetry & Appearance (10)	Total Points (30)	Texture (15)	Crumb Colour (10)	Grain Colour (10)	Total Points (35)	Aroma (15)	Taste (20)	Total Points (35)		
T_1	P_1	1^{st} Day	14.5	4.5	9.0	**28.0**	13.0	9.0	9.0	**31.0**	13.0	18.0	**31.0**	90.0	**G**
		7^{th} Day	14.0	4.2	8.7	**26.9**	12.7	8.8	8.7	**30.2**	12.6	17.6	**30.2**	87.3	**G**
	P_2	1^{st} Day	14.5	4.5	9.0	**28.0**	13.0	9.0	9.0	**31.0**	13.0	18.0	**31.0**	90.0	**G**
		7^{th} Day	14.2	4.4	8.9	**27.5**	12.9	8.9	8.9	**30.7**	12.8	17.8	**30.6**	88.8	**G**
T_2	P_1	1^{st} Day	14.0	4.0	8.5	**26.5**	11.0	9.0	9.0	**29.0**	13.0	17.5	**30.5**	86.0	**G**
		7^{th} Day	13.8	3.8	8.3	**25.9**	10.7	8.7	8.8	**28.2**	12.7	17.2	**29.9**	84.0	**G**
	P_2	1^{st} Day	14.0	4.0	8.5	**26.5**	11.0	9.0	9.0	**29.0**	13.0	17.5	**30.5**	86.0	**G**
		7^{th} Day	13.9	3.9	8.4	**26.2**	10.9	8.9	8.9	**28.7**	12.9	17.4	**30.3**	85.2	**G**
T_3	P_1	1^{st} Day	13.5	4.0	9.0	**26.5**	11.5	9.0	9.0	**29.5**	13.0	18.0	**31.0**	87.0	**G**
		7^{th} Day	13.3	3.7	8.8	**25.8**	11.2	8.8	8.7	**28.7**	12.7	17.8	**30.5**	85.0	**G**
	P_2	1^{st} Day	13.5	4.0	9.0	**26.5**	11.5	9.0	9.0	**29.5**	13.0	18.0	**31.0**	87.0	**G**
		7^{th} Day	13.4	3.9	8.9	**26.2**	11.4	8.9	8.9	**29.2**	12.9	17.9	**30.8**	86.2	**G**
T_4	P_1	1^{st} Day	13.5	4.0	8.5	**26.0**	11.0	9.0	9.0	**29.0**	13.0	17.5	**30.5**	85.5	**G**
		7^{th} Day	13.3	3.8	8.2	**25.3**	10.7	8.8	8.7	**28.2**	12.8	17.2	**30.0**	83.5	**G**
	P_2	1^{st} Day	13.5	4.0	8.5	**26.0**	11.0	9.0	9.0	29.0	13.0	17.5	**30.5**	85.5	**G**
		7^{th} Day	13.4	3.9	8.4	**25.7**	10.9	8.9	8.9	**28.7**	12.9	17.4	**30.3**	84.7	**G**

100 point scale - AACC method 1983; Data reported are the averages of 30 judges

External Properties (30): Volume (15), Colour of the Crust (5), Symmetry & Appearance (10)

Internal Properties (35): Texture (15), Colour of the Crumb (10), Grain (10) Taste Properties (35): Aroma (15), Taste (20) Rating: Excellent (E) - 91 to 100, Good (G) - 81 to 90, Satisfactory (S) - 66 to 80, Fair (F) - 51 to 65, Poor (P) - 50 & < 50

The initial overall acceptability of the sample was maximum for T_0 with score 90.00 followed by T_2V_2, T_1V_1 and T_3V_3 with scores 87.00, 86.00 and 85.50 respectively. Overall average qualities of bread were significantly influenced by the storage period of 7 days. The final scores were 87.30 and 88.80 in P_1 and P_2 for $T_{0,}$ 84.00 and 85.20 in P_1 and P_2 for T_1V_1, 85.00 and 86.20 in P_1 and P_2 for T_2V_2 and 83.50 and 84.70 in P_1 and P_2 for T_3V_3.

Table - 13: Nutrient Changes in the Optimized Millet Incorporated Bread during Storage (per 100g)

Nutrients	**T_1**				**T_2**				**T_3**				**T_4**			
	P_1		**P_2**		**P_1**		**P_2**		**P_1**		**P_2**		**P_1**		**P_2**	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
Moisture (%)	10.33	10.25	10.33	10.29	11.01	10.94	**11.01**	10.97	10.84	10.65	10.84	10.78	10.75	10.62	10.75	10.70
CHO (%)	73.78	73.12	73.78	73.34	74.79	74.13	**74.79**	74.54	74.58	74.19	74.58	74.32	73.96	73.21	73.96	73.76
Protein (%)	11.26	11.14	11.26	11.20	8.69	8.42	8.69	8.51	8.59	8.46	8.59	8.50	9.35	9.11	**9.35**	9.23
Fat (g)	2.86	2.81	2.86	2.83	2.90	2.84	2.90	2.86	3.76	3.73	**3.76**	3.75	3.24	3.20	3.24	3.22
Crude Fibre (g)	0.36	0.33	0.36	0.35	1.31	1.29	1.31	1.30	1.46	1.42	1.46	1.44	1.53	1.51	**1.53**	1.52
Calcium (mg)	20.61	20.58	20.61	2.60	21.54	21.51	21.54	2.53	19.88	19.86	19.88	19.87	22.21	22.18	**22.21**	22.19
Iron (mg)	2.24	2.21	2.24	2.23	1.96	1.93	1.96	1.95	3.36	3.33	**3.36**	3.35	2.28	2.26	2.28	2.27

T_1- Refined wheat flour, T_2- Kodo millet flour, T_3 - Little millet flour, T_4 - Foxtail millet flour

P_1- 70 gauge polypropylene pack P_2- 100 gauge polypropylene pack

Source	**Moisture**			**Carbohydrate**			**Protein**			**Fat**		
	SED	**CD (0.05)**	**CD (0.01)**	**SED**	**CD (0.05)**	**CD (0.01)**	**SED**	**CD (0.05)**	**CD (0.01)**	**SED**	**CD (0.05)**	**CD (0.01)**
T	0.008	0.018	0.025**	0.008	0.017	0.024**	0.009	0.019	0.027**	0.009	0.020	0.028**
P	0.006	0.013	0.018**	0.005	0.012	0.017**	0.006	0.014	0.019**	0.006	0.014	0.020 NS
S	0.006	0.013	0.018**	0.005	0.012	0.017**	0.006	0.014	0.019**	0.006	0.014	0.020 NS
TP	0.012	0.026	0.036*	0.011	0.024	0.034**	0.013	0.028	0.038 **	0.013	0.029	0.040 NS
PS	0.008	0.018	0.025**	0.008	0.017	0.024**	0.009	0.019	0.027**	0.009	0.020	0.028 NS
TS	0.012	0.026	0.036**	0.011	0.024	0.034**	0.013	0.028	0.038**	0.013	0.029	0.040 NS
TPS	0.017	0.037	0.051*	0.016	0.035	0.048**	0.018	0.039	0.054 **	0.019	0.041	0.056 NS

Source	Fibre			Calcium			Iron			Tannin		
	SED	**CD (0.05)**	**CD (0.01)**	**SED**	**CD (0.05)**	**CD (0.01)**	**SED**	**CD (0.05)**	**CD (0.01)**	**SED**	**CD (0.05)**	**CD (0.01)**
T	0.008	0.018	0.025**	0.007	0.014	0.020**	0.008	0.017	0.024**	0.010	0.022	0.031**
P	0.006	0.013	0.018 NS	0.005	0.010	0.014NS	0.005	0.012	0.017NS	0.007	0.016	0.022NS
S	0.006	0.013	0.018 **	0.005	0.010	0.014**	0.005	0.012	0.017**	0.007	0.016	0.022*
TP	0.012	0.026	0.036 NS	0.010	0.021	0.029NS	0.011	0.024	0.034NS	0.015	0.032	0.044NS
PS	0.008	0.018	0.025 NS	0.007	0.014	0.020NS	0.008	0.017	0.024NS	0.010	0.022	0.031NS
TS	0.012	0.026	0.036 NS	0.010	0.021	0.029NS	0.011	0.024	0.034NS	0.015	0.032	0.044NS
TPS	0.017	0.037	0.051 NS	0.014	0.029	0.041NS	0.016	0.035	0.048NS	0.021	0.045	0.062NS

The results revealed that the incorporation of composite flour to refined wheat flour significantly affected the nutrient composition of the bread.

Moisture: The initial moisture content of standardized composite bread was 10.33g in T_0, 11.01g in T_1V_1, 10.84g in T_2V_2 and 10.75g per 100 g in T_3V_3. At the end of the storage period the moisture content of T_0, T_1V_1, T_2V_2 and T_3V_3 was 10.25, 10.94, 10.65 and 10.62g per 100 g in P_1 and 10.29, 10.97, 10.78 and 10.70g per 100 g in P_2 respectively.

Carbohydrate: The mean carbohydrate content of T_1V_1, T_2V_2 and T_3V_3 was 74.79, 74.58 and 73.96g per 100 g respectively and was found to be higher than the control, which was 73.78g. A notable decrease in the carbohydrate content was observed during the storage period of 7days.

Protein: The initial protein content of T_0 was 11.26g whereas the protein content of T_1V_1, T_2V_2 and T_3V_3 was 8.69, 8.59 and 9.35g per 100 g respectively. The protein content was found to be higher in control. The protein content of the samples at the end of the storage period in P_1 and P_2 was 11.14 and 11.20 for T_0, 8.42 and 8.51 for T_1V_1, 8.46 and 8.50 for T_2V_2 and 9.11 and 9.23g per 100 g for T_3V_3 respectively.

Fat: The fat content was found to be high in standardized composite bread than the control. The fat content of T_0 was 2.86g whereas in the composite bread it increased to 2.90, 3.76 and 3.24 g per 100g in T_1V_1, T_2V_2 and T_3V_3 respectively. Over the storage period the fat content of T_0, T_1V_1, T_2V_2 and T_3V_3 was 2.81, 2.84, 3.73 and 3.20g in P_1 and 2.83, 2.86, 3.75 and 3.22g per 100 g in P_2 packaging materials respectively.

Crude Fibre: The crude fibre content of T_0 was 0.36g per 100g, which decreased to 0.33 and 0.35g per 100 g in P_1 and P_2 on storage. The increasing trend in crude fibre content was observed initially in T_1V_1, T_2V_2 and T_3V_3 with values 1.31g, 1.46 and 1.53g per 100g and at the end of storage period negligible the values were 1.29 and 1.30g, 1.42 and 1.44g and 1.51 and 1.52g per 100g for in P_1 and P_2 respectively. The results confirmed that the crude fibre content was maximum in T_3V_3.

Ash: The initial ash content of T_0 1.29 g which decreased to 1.26g and 1.28g per 100g in P_1 and P_2 at the end of the storage period. Among the samples T_1V_1 was found to be high in ash content and there was a very slight decrease in the ash content in all the samples at the end of the storage period in both packaging materials.

Calcium: The calcium content of the control (20.61mg) was lesser than T_1V_1 (21.54mg) and T_2V_2 (22.21mg). . At the end of the storage period there was a slight decrease in the calcium content with values 21.51 and 21.53 for $T_1V_{1,}$ 19.86 and 19.87 for T_2V_2 and 22.18 and 22.19mg for T_3V_3 in P_1 and P_2 respectively.

Iron: The initial iron content was 2.24, 2.33, 3.36 and 2.28mg per 100g for T_0, T_1V_1, T_2V_2 and T_3V_3 respectively. The storage period showed minimal decrease in the iron content of the samples in both packaging materials with the corresponding values of 2.21 and 2.23 for $T_{0,}$ 2.30 and 2.32 for T_1V_1, 3.33 and 3.35 and T_2V_2 and 2.21 and 2.23mg per 100g for T_3V_3 respectively.

Tannin: The tannin content of control was lesser than the standardized composite bread. The initial tannin content of T_0, T_1V_1, T_2V_2 and T_3V_3 was 54.71, 55.86, 58.86 and 73.22mg per 100g respectively. A decrease in tannin content was observed during storage period with the minimum values being recorded in P_2 than P_1.

Table - 14: Microbial load for bread

Treatments	Total plate count ($x10^4$ cfu / g)		Total yeast and mold count ($x10^4$ cfu / g)	
	Initial	Final	Initial	Final
T_1	0.66	2.25	nil	1.25
T_2	1.00	1.78	nil	0.85
T_3	0.66	1.65	nil	0.96
T_4	nil	1.73	nil	0.89

T_1- Refined wheat flour, T_2- Kodo millet flour, T_3 - Little millet flour, T_4 - Foxtail millet flour

The microbial load of the developed products was found to be within in the safer limit.

Table - 15: Cost of the Millet Products

Sl.No.	Products	Cost (Rs.)
1.	Millet Incorporated Bread	17.00 / Pack (400g)
2.	Millet Cookies	14.00 / 100 g

High Moisture – Porridge: The small millet flour was analyzed for physical characteristics starch digestibility, glycemic index, dietary fibre and antioxidant properties at 100 per cent level. The Glycemic index of millet porridge was lower. The small millets contained higher dietary fibre which exerts a hypoglycemic effect. The glycemic response was low in little millet followed by foxtail millet and kodo millet porridge.

Table - 16: Gelatinization temperature and time taken for standardized small millet porridge

Treatments	Temperature (^oC)		Time duration (min)
	Initial	Final	
T_0	68	74	5
$T_1 V_1$	71	79	5
$T_2 V_2$	72	76	5
$T_3 V_3$	70	78	3

T_0 - Rice porridge, **$T_1 V_1$** - Kodo millet porridge, **$T_2 V_2$**- Little millet porridge, **T_3V_3** - Foxtail millet porridge,

The initial and final gelatinization temperature of T_0 was 68°C and 74°C, which was lower when compared with that of 71^{o}C and 79^{o}C in T_1V_1, 72^{o}C and 76^{o}C in T_2V_2 and 70^{o}C and 78^{o}C in T_3V_3. The time taken for gelatinization was five minutes for all the samples.

Table - 17: Digestibility of Starch for standardized small millet Flour

Treatments	TS	RDS	SDS	RS
T_0	79.11	14.35	28.63	36.13
$T_1 V_1$	68.57	10.83	18.07	39.67
$T_2 V_2$	70.05	8.27	22.91	38.87
$T_3 V_3$	67.42	12.10	17.56	37.76

T_0 - Rice flour, **$T_1 V_1$** - Kodo millet flour, **$T_2 V_2$**- Little millet flour, **T_3V_3** - Foxtail millet flour,

The total starch of $T_{0,}$ T_1V_1, T_2V_2 and T_3V_3 was 79.11, 68.57, 70.05 and 67.42 g respectively. Resistant starch accounted for 36.13-39.67g, whereas rapidly digestible starch and slowly digestible starch represented 8.27-14.35 g and 18.07-28.63 g, respectively of the total starch.

Table - 18: Digestibility of Starch for standardized small millet Porridge

Treatments	TS	RDS	SDS	RS
T_0	73.00	14.07	25.77	33.16
$T_1 V_1$	67.20	12.26	20.04	34.90
$T_2 V_2$	69.05	11.18	21.92	35.95
$T_3 V_3$	66.10	12.74	19.73	33.63

T_0 - Rice porridge, **$T_1 V_1$** - Kodo millet porridge,
$T_2 V_2$- Little millet porridge, **T_3V_3** - Foxtail millet porridge

The total starch of the T_1V_1, $T_2V_{2\,,}$ T_3V_3 and T_0 was 67.20, 69.05, 66.10 and 73.00 respectively. Resistant starch accounted for 33.16-35.95 g, whereas rapidly digestible starch and slowly digestible starch represented 11.18-14.07 g and 19.73-25.77 g respectively of the total starch. Among the millets T_3V_3 had the highest amount of rapidly digestible starch (12.74 g).

Anti-oxidant activity of the standardized small millet porridge : The total anti-oxidant activity of T_1V_1 and T_2V_2 was 0.37 and that of T_3V_3 and T_0 was 0.40 mg per g respectively.

Table - 19: Total anti-oxidant activity (mg/g) of the standardized small millet Porridge

Porridge	Total anti-oxidant activity (mg/g)
T_0	0.40
$T_1 V_1$	0.37
$T_2 V_2$	0.37
$T_3 V_3$	0.40

T_0 - Rice porridge, **$T_1 V_1$** - Kodo millet porridge,
$T_2 V_2$- Little millet porridge, **T_3V_3** - Foxtail millet porridge

Table - 20: Dietary fibre status of the standardized small millet flour

Porridge	Total Dietary Fibre (TDF)	Soluble Dietary Fibre (SDF)	Insoluble Dietary Fibre (IDF)
T_0	0.80 ± 0.06	0.10 ± 0.01	0.70 ± 0.07
$T_1 V_1$	1.52 ± 0.03	0.13 ± 0.03	1.39 ± 0.01
$T_2 V_2$	1.65 ± 0.03	0.22 ± 0.01	1.43 ± 0.01
$T_3 V_3$	4.97 ± 0.07	0.42 ± 0.01	4.55 ± 0.03

T_0 - Rice porridge, **$T_1 V_1$** - Kodo millet porridge, **$T_2 V_2$**- Little millet porridge, **T_3V_3** - Foxtail millet porridge

The soluble, insoluble and total dietary fibre content was 0.13, 1.39 and 1.52g for $T_1V_{1,}$ 0.22, 1.43 and 1.65 for T_2V_2 and 0.42, 4.55 and 4.97g per 100g for T_3V_3, which was higher than T_0 (0.10, 0.70 and 0.80g) respectively. Among the small millets, T_3V_3 exhibited higher soluble (0.42g), insoluble (4.55g) and total dietary fibre (4.97g) content. The study concluded that the small millets contained higher level of dietary fibre which could exert a hypoglycemic effect.

Table - 21: Effect of small millet flour on body weight and blood glucose

GROUP	Body weight (g)		Blood glucose (mg / 100ml)	
	Initial	Final	Initial	Final
G1	220 ± 9.4	245 ± 9.8	86.48 ± 3.45	92.60 ± 3.80
G2	205 ± 7.2	162 ± 4.9**(a)	88.70 ± 3.60	238.88 ± 9.22**(a)
G3	222 ± 9.5	248 ± 9.9	89.90 ± 3.82	72.22 ± 3.02**(b)
G4	204 ± 7.0	242 ± 8.8	86.56 ± 3.05	76.35 ± 2.72**(b)
G5	212 ± 7.6	248 ± 8.0	87.35 ± 3.47	74.35 ± 2.25**(b)
G6	212 ± 8.6	245 ± 8.2	89.20 ± 3.60	78.09 ± 2.60**(b)
G7	225 ± 8.6	280 ± 9.6	96.32 ± 4.85	92.10 ± 2.78**(b)
G8	226 ± 8.4	246 ± 8.9	94.30 ± 4.70	85.38 ± 2.72**(b)
G9	230 ± 9.2	252 ± 9.4	92.55 ± 3.98	84.37 ± 2.45**(b)
G10	227 ± 8.4	255 ± 9.2	96.88 ± 4.62	83.35 ± 2.30**(b)

G1- Normal; **G2**- Diabetic Control; **G3**- **G6** (*Perse control*) (Normal Rat +100%incoporated millet flour*);* **G7-G10**- Treatment control (Diabetic Rat +100%incoporated millet flour).

Table - 22: Effect of standardized small millet flour on hematological parameters

GROUPS	Haemoglobin (gm/100ml)	Glycosylated haemoglobin HbA_1 (%)	Plasma Insulin (µU/ml)
G1	13.25 ± 1.65	0.32 ±0.08	30.30 ± 1.75
G2	6.22 ± 0.71**(a)	0.98 ±0.16**(a)	11.45 ± 0.45**(a)
G3	12.88 ± 1.18**(b)	0.45 ±0.12**(b)	26.3 ± 1.32**(b)
G4	12.45 ± 1.08**(b)	0.42 ±0.10**(b)	27.30 ± 1.47**(b)
G5	12.20 ± 1.22**(b)	0.38 ±0.07**(b)	25.60 ± 1.30**(b)
G6	12.65 ± 1.30**(b)	0.42 ±0.12**(b)	24.95 ± 1.20**(b)
G7	12.30 ± 1.52**(b)	0.45 ±0.13**(b)	27.32 ± 1.68**(b)
G8	12.88 ± 1.60**(b)	0.40 ±0.12**(b)	26.40 ±1.58**(b)
G9	12.05 ± 1.15**(b)	0.39 ±0.10**(b)	28.55 ± 1.86**(b)
G10	12.48 ± 1.38**(b)	0.36 ±0.11**(b)	27.30 ± 1.65**(b)

G1- Normal; **G2**- Diabetic Control; **G3**- **G6** (*Perse control*) (Normal Rat +100%incoporated millet flour*);* **G7-G10**- Treatment control (Diabetic Rat +100%incoporated millet flour).

- Values are expressed as mean **±** SEM.
- Values were compared by using analysis of variance (ANOVA) followed by Newman-Keul's multiple range tests.
- ** (a) Values are significantly different from normal control G1 at P<0.001.
  ** (b) Values are significantly different from Diabetic control G2 at P<0.01.

Hypoglycaemic and hypolipidemic effect of standardized small millet flour in albino rats.

The mean initial body of the normal and diabetic control groups were

220 ± 9.4g and 205 ± 7.2g. The initial body weight of the normal groups (G3 - G6) ranged from 204 ± 7.0 to 222 ± 9.5g. After 28 days of feeding trial the body weight of the normal group fed with rice flour and small millet flour (G3 to G5) with values ranging from 242 ± 8.8 to 248 ± 8.0g increased when compared with G1. Similarly the body weight of the diabetic group the fed with small millet flour (G8 to G10) showed an increase in the body weight when compared to the group fed with rice flour (G7).

The initial blood glucose level of perse control group ranged between 86.56 ± 3.05 (G4) to 89.90 ± 3.82 (G3), whereas the diabetic group ranged from 92.55 ± 3.98 (G9) to 96.88 ± 4.62 (G10) mg per 100ml. The overall result indicated that the reduction in the blood glucose levels was high in the rats fed with kodo millet flour than the rats fed with control flour (92.10±2.78).

A notable difference existed in the plasma insulin level of the diabetic control group when compared to the treatment control. The haemoglobin content of normal (G1) and diabetic control (G2) group was 13.25 ± 1.65g and 6.22 ± 0.71g per 100ml. The haemoglobin content of perse control group ranged from 12.20 ± 1.22 (G5) to 12.88 ± 1.18 (G3) g per 100ml and that of diabetic treatment group ranged from 12.05 ± 1.15 (G9) to 12.88 ± 1.60 (G8) g per 100ml. The results concluded that the feeding of small millet flour had a remarkable effect in the improvement of haemoglobin content. The hypoglycaemic effect was more pronounced in kodo millet flour followed by foxtail and little millet flour. The reduction of blood glucose levels was high in the rats fed with kodo millet flour. The groups fed with small millet flour had an improved plasma insulin level and haemoglobin content.

Table - 23: Effect of 50% incorporated millet cookies on PER, PU AND BIOLOGICAL VALUE in normal and treated animals

GROUPS	Protein efficiency ratio(PER)	Protein utilization(PU)	Biological value (%)
G1	2.60 ± 0.42	0.58 ±0.07	95.20 ± 0.75
G2	1.84 ± 0.15**(a)	0.32 ±0.01**(a)	45.83 ± 0.19**(a)
G3	2.12 ± 0.23**(b)	0.40 ±0.03**(b)	56.2 ± 0.40**(b)
G4	2.30 ± 0.28**(b)	0.42 ±0.04**(b)	58.2 ± 0.46**(b)
G5	2.36 ± 0.32**(b)	0.48 ±0.05**(b)	60.40 ± 0.50**(b)
G6	2.30 ± 0.35**(b)	0.44 ±0.04**(b)	62.60 ± 0.53**(b)
G7	2.42 ± 0.38**(b)	0.46 ±0.05**(b)	59.70 ± 0.50**(b)
G8	2.45 ± 0.40**(b)	0.43 ±0.05**(b)	63.45 ± 0.56**(b)
G9	2.44 ± 0.36**(b)	0.40 ±0.05**(b)	66.30 ± 0.45**(b)
G10	2.22 ± 0.18**(b)	0.48 ±0.06**(b)	62.88 ± 0.45**(b)
G11	2.48 ± 0.46**(b)	0.45 ±0.05**(b)	64.30 ± 0.42**(b)
G12	2.46 ± 0.42**(b)	0.46 ±0.05**(b)	58.08 ± 0.34**(b)

G1- Normal; **G2**- Diabetic Control; **G3**- G7 (*Perse control*) (Normal Rat +50%incoporated millet cookies)*);* **G8-G12**- Treatment control (Diabetic Rat +50%incoporated millet cookies).

Table - 24: Effect of 100% incorporated millet flour on PER, PU AND BIOLOGICAL VALUE in normal and treated animals

GROUPS	Protein efficiency ratio(PER)	Protein utilization(PU)	Biological value (%)
G1	2.85 ± 0.50	0.68 ±0.10	105.32 ± 1.80
G2	1.95 ± 0.32**(a)	0.43±0.05**(a)	52.60 ± 0.28**(a)
G3	2.60 ± 0.35**(b)	0.52 ±0.06**(b)	68.4 ± 0.45**(b)
G4	2.65 ± 0.36**(b)	0.58 ±0.04**(b)	70.4 ± 0.50**(b)
G5	2.70 ± 0.40**(b)	0.48 ±0.08**(b)	72.45 ± 0.56**(b)
G6	2.55 ± 0.42**(b)	0.52 ±0.06**(b)	74.65 ± 0.60**(b)
G7	2.68 ± 0.46**(b)	0.59 ±0.06**(b)	75.76 ± 0.65**(b)
G8	2.65 ± 0.43**(b)	0.60 ±0.07**(b)	78.50 ± 0.68**(b)
G9	2.68 ± 0.48**(b)	0.62 ±0.05**(b)	77.35 ± 0.70**(b)
G10	2.63 ± 0.46**(b)	0.63 ±0.06**(b)	76.45 ± 0.66**(b)
G11	2.66± 0.45**(b)	0.61 ±0.05**(b)	75.65 ± 0.60**(b)
G12	2.69 ± 0.40**(b)	0.60 ±0.06**(b)	78.12 ± 0.65**(b)

G1- Normal; **G2**- Diabetic Control; **G3**- G7 (*Perse control*) (Normal Rat +50%incoporated millet cookies)*);* **G8-G12**- Treatment control (Diabetic Rat +50%incoporated millet cookies).

- Values are expressed as mean ± SEM.
- Values were compared by using analysis of variance (ANOVA) followed by Newman-Keul's multiple range tests.
- ** (a) Values are significantly different from normal control G1 at $P<0.01$.
  ** (b) Values are significantly different from Diabetic control G2 at $P<0.01$.

The protein intake was computed from the feed intake and protein content of the respective diets. The gains in body weight, faecal and urinary nitrogen contents were used to compute the following growth parameters and nitrogen balance indices. The minerals calcium, iron and zinc were determined by reading in an atomic absorption spectrophotometer. The relative mineral bioavailability was defined as the ratio between the total content of the mineral in the organ and its consumption and for zinc it was also estimated from the ratio between weight-gain and zinc consumption.

Annexure -13: Details of machineries installed in Agro Processing Centre, India

S.No.	Particulars	Peraiyur Madurai district	Jawadhumalai Tiruvannamalai district	Anchetty Krishnagiri district
1.	Destoner	1	1	1
2.	Dehulling machine	1	1	1
3.	Pulverizer	1	1	1
4.	Extruder	1	1	1
5.	Hand operated sealing Machine	2	2	2
6.	Weighing balance	2	2	2
7.	Stainless steel vessels (1 set- 13 pieces)	1 set	1 set	1 set
8.	Bakery oven	1	-	-
9.	Dough mixing unit	1	-	-
10.	Bread slicer	1	-	-
11.	Baking accessories	1 set	-	-