STORAGE QUALITY OF LITTLE MILLET (*Panicum miliare*) AND DIVERSIFICATION OF UTILIZATION OF LITTLE MILLET THROUGH HYDROTHERMAL AND BAKING TECHNOLOGIES

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

Doctor of Philosophy

In

FOOD Science AND NUTRITION

By
MAMATA MANNURAMATH

DEPARTMENT OF FOOD SCIENCE AND NUTRITION

COLLEGE OF RURAL HOME SCIENCE, DHARWAD

UNIVERSITY OF AGRICULTURAL SCIENCES,

DHARWAD - 580 005

JUNE, 2013

ADVISORY COMMITTEE

DHARWAD
JUNE, 2013

(NIRMALA B. YENAGI)
MAJOR ADVISOR

Approved by :

Chairman : ______________________________
(NIRMALA B. YENAGI)

Members :

1. ______________________________
(USHA MALAGI)

2. ______________________________
(KASTURIBA, B.)

3. ______________________________
(JAYASHREE HANDIGOL)

4. ______________________________
(S. S. DOLLI)

CONTENTS

LIST OF TABLES

Contd…..

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

INTRODUCTION

Nutritional well being is a sustainable force for health and maximization of human genetic potential. The nutritional status of a community has therefore been recognized as an important indicator of national development. In other words, malnutrition is an impediment in national development and hence assumes the status of national problem. For solving the problem of deep-rooted food insecurity and malnutrition, dietary quality should be taken into consideration. Diversification of food production must be encouraged both at national and household level in tandem with increasing yields. Growing of traditional food crops suitable for the area is one of the possible potential successful approaches for improving household food security.

In the world even though there is surplus food production still endemic under nutrition is prevalent. India has the highest number of undernourished people (212.00 million) in the world. Even in Ethiopia (31.50 million) the number of such people is much less than that of in India. The proportion of children in India who are underweight (47 %) (low weight for age, indicating both chronic and acute malnutrition), stunting (45 %) (low height for age, indicating chronic malnutrition) and wasting (16 %) (low weight for height, indicating acute malnutrition in the period before the survey) is among the worst in the developing world. The number of adults whose body mass index is below normal or those who are overweight is very high in India. The number of persons whose body mass index is below normal is larger in rural area but the number of overweight persons is high in urban area. The number of persons (male, female, children and pregnant women) suffering from different type of anaemia in India is very high. This incidence is as high as around 80 per cent among children and more than 50 per cent among women. The prevalence of anaemia is more in rural areas as compared to that in urban areas. The most alarming fact about anaemia is that incidence is increased during NFHS 3 as compared to NFHS 2 (Ojha., 2010).

The term "Millets " refers to any of the small-seeded cereal and forage grasses used for food, feed or forage. The common names used are coarse cereals, miscellaneous cereals pseudo cereals, nutri-cereals and siridhanya (ಸಿರಿಧಾನ್ಯಗಳು). "Millet" is a generic term for a heterogeneous group of forage grasses known for their small ""coarse" grains. Millets represented in the prehistoric world can be placed in to one of nine common genera; *Brachiaria, Digitaria, Echinochloa, Eleusine, Panicum, Paspalum, Pennisetum, Setaria, Sorghum*. Amongst ""millets" are a wide range of grasses that have been domesticated in many different parts of the world. Small millets comprising six species are grown in India over a 2 million ha, mostly in semi-arid, hilly and mountainous regions. India has the third largest area under small millets cultivation in the world. The six small millet species grown are finger millet (*Eleusine coracana*), little millet (*Panicum miliare*), Italian or foxtail millet (*Setaria italica*), barnyard millet (*Echinochloa crus-galli*), proso millet (*Panicum miliaceum*) and kodo millet (*Paspalum scrobiculatum*). Among these, finger millet occupies about 60 per cent of the area and contributes 70 per cent to the overall small millet production. These are hardy crops and quite resilient to a variety of agro-climatic adversities, such as poor soil fertility and limited rainfall. In view of their superior adaptability (compared for instance to rice), they play an important role in supporting marginal agriculture, which are commonly practiced in hilly and semi-arid regions of India. Among these crops, finger millet has got the most attention and widely grown in India, from the semi-arid plains to the foot hills of the Himalayas, up to an elevation of 3,500 msl. These millets are the source of important food grain in their areas of cultivation, while their straw is highly valued as fodder. Many kinds of traditional foods and beverages are made with these species across the country and hence they play an important role in the local food culture. Nutritionally, they are characterized by high micronutrient content, particularly with regard to calcium and iron, and high dietary fiber. Their grain protein is richer in sulphur-containing and other essential amino acids than all other major cereals. For this reason, Prof. M.S. Swaminathan, Chairman, MSSRF, Chennai had suggested to call them more appropriately as "*nutritious millets*", rather than coarse grains. The nutraceutical value of these grains, by virtue of their high dietary fiber and low glycemic index, is receiving increasing attention.

Globally the millet production is more concentrated in the Asian and African countries. A few millets were independently being cultivated in the Americas' prehistory, although these were relatively restricted and unimportant at the time of European contact. There has been systematic decline in the production of millets after the Green revolution. This can be understood by the production trends of millet vs. other crops such as rice and wheat which were relentlessly promoted for intensive cropping. Over the years the cultivation area of millets has also decreased. The decline in production may be due to reduced cultivation area, which is shifted to other crops like rice, wheat, maize etc (Anon., 2009).

In India minor millets are cultivated mainly as rainfed crops and occupy area of about 2.7 million ha which is about 12 per cent of the whole area under coarse cereals in the country. The most popular minor millet across India is finger millet (ragi) cultivated nearly 1.6 million ha, with annual production of 2.4 million tonnes and a productivity approximately 1,534kg/ha. In contrast, the remaining area under other minor millets (1.1 million ha) has a production of 0.7 million tonnes and a productivity of around 635kg/ha. The area under minor millets cultivation in India has significantly decreased since 1950s. However, while the production of finger millet has been increasing due to the enhanced productivity except for the period of 2001-2005, the production of the other minor millets has constantly been dropping. The areas cultivated with minor millets are categorized by poor agro ecosystems and largely inhibited by socio-economically fragile, very traditional farming communities (large sections of who fall below the poverty line). The production systems followed for their cultivation are generally marginal based mainly on locally available seeds, with minimum or no external inputs or often under default organic farming conditions. Most commonly, they are grown only in season coinciding with the main monsoon season (June-November). For this reason, they are predominantly grown as mixed or intercrop along with fodder-yielding crops like maize and sorghum, high value crops such as grain legumes (pigeon pea, green gram or black gram) or oilseed crops (mustard or niger). Among the minor millets, finger millet has received better R & D inputs in terms of agronomy and improved varieties. About 86 improved varieties of finger millet have been released during 1935-2008 with seed production system available for a few of these varieties. These crops are virtually free from insect-pests in the field, while they are affected by a few major diseases. Plant protection measures, which are seldom used by farmers, can contribute to productivity increase by minimizing the disease-induced yield crops (Padulosi *et al.,* 2009). From the global pattern of millet consumption it can be seen that India is the highest consumer of millet followed by African countries like Nigeria and Niger.

Of the world's poor, 70 per cent live in rural areas and are often at the mercy of rainfall-based resources of income. India ranks first among the rainfed agricultural countries in terms of both extent (86 Mha) and value of produce. Due to low opportunities and higher population of landless households and agricultural laborers as well as low land and labor productivity, poverty is concentrated in rainfed regions. In India, out of the total net sown area of 141.00 Mha, rainfed area accounts for 85.0 Mha spread over 177 districts. This constitutes approximately 60 per cent of the total farming area in the country. Rainfed agriculture contributes 44 per cent of the total food grain production of the country and produces 75 per cent of pulses and more than 90 per cent of sorghum, millet and groundnut from arid and semiarid regions. Even after half a century of neglect, the rainfed regions provide livelihood to nearly 50 per cent of the total rural workforce and sustain 60 per cent of cattle population of the country. Marginal and sub-marginal farm households, that own or/and cultivate less than 2.0 hectare of land - constitute about 78 per cent of the country's farmers (Agricultural Census 1990-91) in the rainfed agriculture. Interestingly they only grow the millets more. These small-holders owned only 33 per cent of the total cultivated land; their contribution to national grain production was nonetheless 41 per cent (Sharma *et al.*, 2006)

Within India, the genetic resources of minor millets are represented by six cultivated species. Little millet is reported to be originated in South East Asia or India. The Indian Barnyard millet and Kodo millet have also originated in India, the other species of Barnyard millet is considered to have Japanese origin. Proso millet has central or eastern Asia origin, where as foxtail millet is considered to have originated in eastern Asia, probably China. The origin of finger millet is traced to Uganda and its neighbourhood in Africa, while India is considered as a secondary centre of its genetic diversity. Finger millet domestication has been traced back to 5,000 years ago in Ethiopia. In India their cultivation extends from sea level in coastal Andhra Pradesh to 2,400 msl in the mountains of Uttarakhand and covers a broad range of eco-geographic conditions, diverse soils, varying rainfall regimes and area widely differing in thermo photo periods as reflection of their wide genetic adaptability. With regarding to their distribution within the country kodo millet, little millet and foxtail millet are more popular in Madhya Pradesh, Chattisgarh, Orissa, Tamil Nadu, Jharkhand, Karnataka, Andhra Pradesh and Maharashtra states. Madhya Pradesh is the most important state for kodo millet and little millet cultivation. Barnyard millet and proso millet are grown in Uttarakhand, Northeast region, Uttar Pradesh, Bihar and Maharashtra (Padulosi *et al.,* 2009). Millets are astonishingly low water consuming crops. The rainfall needed for Sorghum, Pearl Millet and Finger Millet is less than 25 per cent of sugarcane and banana and 30 per cent that of rice. To grow one kg of rice 4000 liters of water is used while all millets grow without irrigation. This can turn out to be a tremendous national gain especially in the ensuing decades of climate crisis. In future, where water and food crisis stares us in the face, millets can become the food of security.

Most millet can be grown on low fertility soils, some in acidic soils and some on saline soils. Millets such as Pearl millet can also be grown on sandy soils, as is done in Rajasthan. In fact, finger millet grows well in saline soils. Barnyard millet too thrives in problem soils, where other crops like rice, struggle to grow in such soils. Many of them are also grown to reclaim soils. Poor farmers especially in dryland India are owners of very poor lands. Much of the cultivable fallows and low fertility farms have been handed to them through the process of land reforms. In fact, the capacity of millets to grow on poor soils can be gauged from the fact that they grow in Sahelian soil conditions in West Africa which produces 74 per cent of all the millets grown in Africa and 28 per cent of the world production. If they flourish in such ecological zones where average rainfall can be less than 500 mm using soils that are sandy and slightly acid, it is a testimony for their, hardiness and extraordinary capacity to survive very harsh conditions. That is why millets can withstand drought like conditions in the Deccan and Rajasthan and produce food and fodder for people and livestock, respectively. A strategic feature in minor millets with regards to climate change is their short biological cycle they mature fast, a trait important in risk avoidance under rainfed farming. Millet grains are smaller in size and they are long lasting no storage pests will attack. Millets do not demand chemical fertilizers. In fact, under dry land conditions, millets grow better in the absence of chemical fertilizers. Therefore, most millet farmers grow them using farmyard manure under purely ecofriendly conditions. In recent years farmers have also started using biofertilizers such as vermi compost produced in their backyard. Growing traditional local landraces and under ecological conditions, most millets such as foxtail are totally pest free and hence do not need any pesticides. Even in storage conditions, most millets such as foxtail need not any fumigants, but act as anti pest agents to store delicate pulses such as green gram. By any nutritional parameter, millets are miles ahead of rice and wheat in terms of their mineral content, compared to rice and wheat (Gopalan *et al.*, 2007). Finger millet has thirty times more calcium than rice while every other millet has at least twice the amount of calcium compared to rice. In their iron content, foxtail and little millet are so rich that rice is nowhere in the race. While most of us seek a micronutrient such as β-carotene in pharmaceutical pills and capsules, millets offer it in abundant quantities. The much privileged rice, ironically, has zero quantity of this precious micronutrient. In this fashion, nutrient to nutrient, every single millet is extraordinarily superior to rice and wheat and therefore is the solution for the malnutrition that affects a vast majority of the Indian population.

In millet cultivation, farmers follow some traditional farming methods. There are mainly two popular traditional farming systems they are “Akadi system” it is Indian traditional mixed farming system where two or more crops grown together. It is followed in Karnataka e.g., little millet with red gram and *Barhanaja (a dozens of crops)* cropping system, as the name suggests in this system millets are embedded 12 different crop varieties. It is famous in Himalayan region of Uttharkhand.

Nutritionally the millets are good sources especially in micronutrients and fiber. Health benefits of millets are known from historic days. Millets are nutritious food and they are rich in phytochemicals, fiber and minerals. Magnesium in millet can help reduce the affects of migraines and heart attacks, Niacin (vitamin B3) in millet can help lower cholesterol, Phosphorus in millet helps with fat metabolism, body tissue repair and creating energy (phosphorus is an essential component of *adenosine triphosphate* or ATP, a precursor to energy in your body), millet can help lower risk of type 2 diabetes, fiber from whole grains has been shown to protect against breast cancer and whole grains have been shown to protect against childhood asthma. Many studies have been conducted to explore the health benefits. The concepts of food are changing from a previous emphasis on survival, hunger satisfaction, absence of adverse effects on health, and health maintenance to a current emphasis on the use of nutraceutical foods which promise to promote better health and well-being, thus helping to reduce the risk of chronic illnesses such as cardiovascular diseases, some cancers and obesity. An important factor of the nutraceutical food which is required to reduce the risk of chronic illness is "antioxidants". In recent years the powerful antioxidant properties of phenolics aroused more interest. The small millets are cheap sources nutrients for poor and the working class people and hence their health depends on the quality of food consumed.

The qualitative analysis for different bioactive phytochemical compounds reveals that, all the small millets tested were found to contain phenols, tannins, alkaloids, flavonoids and saponins and reported to possess anti-carcinogenic properties, immune modulation activities and regulation of cell proliferation as well as health benefits such as inhibition of the growth of cancer cells and cholesterol lowering activity. In the light of these observations the presence of phenols, tannins, alkaloids, flavonoids and saponins in the millets samples indicates that they have medicinal properties.

Public Distribution System (PDS) is an Indian food security system. Established by the Government of India under Ministry of Consumer Affairs, Food, and Public Distribution and managed jointly with state governments in India, it distributes subsidized food and non-food items to India's poor. Major commodities distributed include staple food grains, such as wheat, rice, sugar, and kerosene, through a network of Public distribution shops (PDS) established in several states across the country. Food Corporation of India, a Government-owned corporation, procures, maintain and issue food grains to the state. Distribution of food grains to poor people throughout the country are managed by state governments. In view of nation's food security and the declining ground water scenario, Dr. M.S. Swaminathan's report on 'National Commission on Farmers' suggested for bringing in the millets under the preview of the PDS. Once the millets are made available for consumption to the public, it was envisaged that it may trigger the production of the same. Millets are climate change compliant crops. Due to all the qualities mentioned above, millets remain our agricultural answer to the climate crisis that the world is facing. Since they are already capable of growing under drought conditions, they can withstand higher heat regimes.

Millets grow under non-irrigated conditions in such low rainfall regimes as between 200mm and 500 mm. Thus, they can also face the water stress and grow. Each of the millets is a storehouse of dozens of nutrients in large quantities. They include major and micro nutrients needed by the human body. Hence they can help people withstand malnutrition. In view of all these features that they so amazingly combine, millets can only be called as Miracle Grains. However, their presence in the Indian food basket has been declining over the years. One reason for this decline is the increased availability of rice, wheat and maize (particularly rice and wheat under subsidized public distribution system). These grains are neglected in research and development. The lack of modern technologies for their effective processing and utilization is an important reason for their declining importance. There is a policy gap in all countries of the south Asian region with regard to the promotion of cultivation and consumption of these underutilized grains. All these elements have collectively contributed to the neglect and underutilization of these millets leading to their increased marginalization, accelerated loss of their genetic diversity and traditional food culture associated with them. An appropriate food processing technology stimulates agriculture production, ensures the availability of quality products and value addition helps in creating jobs. Such an approach is thus strategic in supporting both the economic progress and industrial development of millets. Hence, the present study was under taken with the following objectives:

- Evaluation of local cultivars and high yielding little millet varieties for nutritional and processing qualities.
- To study the changes in physicochemical, processing and nutritional qualities of little millet during storage.
- To study the changes in physicochemical processing and nutritional qualities of hydrothermally treated little millet.
- To develop value added products from little millet through different technologies

REVIEW OF LITERATURE

The present study is focused on development of suitable technologies for diversified utilization of little millet in rural and urban area. Millets are good sources of essential nutrients which may help in controlling non communicable diseases as well as to prevent hidden hunger. The study reviews the literature pertaining to physico-chemical characteristics of millets, phyto nutrient composition, and quality changes during storage of cereals, hydrothermal treatment to cereals and value added products from millets and cereals.

2.1 Physico- chemical properties of minor millets

Little millet is one among the minor millets; the group also includes foxtail millet, proso, barnyard and kodo millet. These millets are very small in size unlike other food grains. The minor millets have been studied for their physical, chemical and nutritional qualities.

2.1.1 Physical properties of minor millets

One of the important factors which contribute to product quality in terms of appearance is the colour of the grain, which is determined by the presence of pigments. Variation in colour within the species is common, which is evident in almost all minor millets. The dehulled little millet was reported to be white and foxtail millet was dark yellow in colour (Itagi, 2003). Veena *et al.* (2005) revealed that the dehulled grains of barnyard millet varieties ranged from dull cream to brownish colour. Thus, genetic variation in seed colour was evident in millets.

The thousand grain weight of little millet varieties was reported to be ranging from 1.90 to 2.70 g. Little millet was relatively smaller compared to other minor millets (Malleshi, 2002). Broad genotypic studies on 20 foxtail millet varieties indicated thousand grain weight to be ranging between 1.20 to 3.10 g. Barn yard millet varieties were relatively smaller than kodo millet varieties, with values ranging between 2.7 to 4.0 g and 4.2 to 5.0 g respectively. Proso millet was relatively big seeded with thousand grain weight ranging between 5.4 to 6.9 g (Hadimani and Malleshi, 1993, Srivastava and Batra, 1998, Itagi, 2003 and Veena *et al.*, 2005). Ninganagoudar *et al.* (2012) reported that kernel weight and volume of little millet (2.09 g and 2.23 ml) was lower than rice varieties (17.64 to 18.79) whereas the density of little millet grain was higher than rice varieties.

The little millet recorded lowest seed volume compared to other minor millets with values ranging between 1.30 to 2.50 ml/1000 grains. The seed volumes of foxtail, barnyard and kodo millet varieties were reported to be 1.50 to 3.50, 1.50 to 5.80, 2.80 to 3.60 ml/1000 grains, respectively. Proso millet was observed to be more consistent in seed volume with values ranging between 3.80 to 4.10 ml/1000 grains (Hadimani and Malleshi, 1993, Srivastava and Batra, 1998, Itagi, 2003 and Veena *et al.* 2005).

Density of grains is one of the important parameters determining dehulling and milling performance. The density of little millet was found to be ranging between 1.21-1.46 g/ml. While the density of foxtail and barnyard millet was recorded to be 1.18 and 1.42 g/ml and 1.07-1.40 g/ml, respectively. (Hadimani and Malleshi, 1993, Srivastava and Batra, 1998, Itagi, 2003 and Veena *et al.*, 2005).

2.1.2 Chemical composition of minor millets

Grains are the storehouse of many chemical components including nutrients, phyto-chemicals and non-nutritive functional constituents. The nutritive value of millets is comparable to other cereals with slightly higher content of protein and minerals (Gopalan *et al.*, 2007). Varietal differences in nutrient composition within the species of minor millets were reported by several investigators. Studies indicated that little millet genotypes recorded a moisture content of 8.56 to 12.34 per cent. It was also reported that proso millet recorded a high moisture content ranging from 10.60 to 15.00 per cent, followed by foxtail millet, kodo millet and barnyard millet with values of 10.70, 11.5, 10.20 and 9.53 per cent, respectively (Kulkarni *et al.*, 1992, Kulkarni and Naik, 1999 & 2000, Itagi, 2003, Veena *et al.*, 2005).

Studies have indicated that the protein content of little millet ranged from 7.70 to 12.50 per cent. The protein content in foxtail, kodo, proso and barnyard millet were reported to be ranging between 9.70-13.70, 8.50-10.50, 9.00-10.50 and 9.50-12.00 per cent, respectively with varietal differences within species as reported by several investigators (Kulkarni *et al.*, 1992, Hadimani and Malleshi, 1993, Mogra *et al.*, 1998, Kulkarni and Naik, 1999 and 2000, Itagi, 2003, and Veena *et al.*, 2005).

With respect to fat content of minor millets, little millet recorded 2.0 to 5.4 per cent fat, with varietal differences. The fat content of foxtail millet (2.1-5.2%), kodo millet (1.1-3.3%), proso millet (2.1 to 5.2%) and barnyard millet (3.20-9.84%) was reported by several investigators (Kulkarni *et al.*, 1992, Hadimani and Malleshi, 1993, Kulkarni and Naik, 1999 and 2000, Itagi, 2003, and Veena *et al.*, 2005,).

Ninganagoudar *et al.*(2012) reported that ash content (1.04 to 1.34 g/100g) showed a significant difference between rice and little millet varieties, while starch content did not show any significant difference.

Millets in general are considered as a good source of crude fiber (Gopalan *et al.*, 2007). Little millet was reported to contain crude fiber in the range of 1.20 to 7.60 per cent. The crude fiber content reported in foxtail millet was 2.70 to 5.40 per cent, proso millet was 5.51 per cent, kodo millet was 6.30 per cent and barnyard millet was 5.35 to 7.90 per cent (Kulkarni *et al.*, 1992 , Kulkarni and Naik, 1999 and, 2000, Itagi, 2003 and Veena *et al.*, 2005). Veena *et al.*, (2005) documented a starch content ranging between 51.52 and 59.55 per cent in nine varieties of barnyard millet.

Millets in general are rich in dietary fiber content. Little millet is reported to have a total dietary fiber content of 15.90 per cent. In which the soluble dietary fiber content was 5.70 per cent and insoluble dietary fiber was 10.20 per cent. It was reported that barnyard millet recorded a highest proportion of soluble dietary fiber of about 5.90-6.50 per cent (Hadimani and Malleshi, 1993 and Veena *et al.*, 2005). Proso and foxtail millets were shown to contain lowest proportions of soluble fractions of dietary fiber (4.4 and 3.4 %, respectively) as reported by Hadimani and Malleshi (1993).

Lorenz (1983) observed that the tannin content of the dehulled proso millet varieties ranged from 0.023 to 0.034 per cent catechin equivalent and dehulling reduced tannin levels by 65-80 per cent. Kulkarni *et al.,* (1992) analysed the tannin content of five minor millets and reported that little millet contained 147.76 mg tannin. Highest tannin content was recorded in kodo millet (167.10 mg), followed by proso millet (156.65 mg), foxtail millet (129.29 mg) and Barnyard millet (102.96 mg). The phytate content of proso millet varieties was 0.18 to 0.27, and a reduction of 27-53 per cent in phytates upon dehulling was reported by Lorenz (1983).

A study conducted by National Institute of Nutrition on mineral and trace elements of six varieties each of little millet and barnyard millet revealed that the mean ionisable iron content was 1.78 and 1.42 mg/100 g, respectively. Relatively higher concentration of zinc, copper and chromium in little millet and a higher concentration of calcium, phosphorous, manganese and magnesium were recorded in barnyard millet (Anon., 1983). Kulkarni *et al.* (1992) reported similar values for ionisable iron contents in little (1.76 mg), foxtail (0.56 mg), proso (1.47 mg), kodo (1.50 mg) and barnyard (1.38 mg) millets.

A significant variation in calcium content of five minor millets was recorded with values ranging from 12.36 to 29.17 mg/100 g and little millet was reported to contain 12.36 mg calcium (Kulkarni *et al.*, 1992). Veena *et al.*, (2005) reported that the calcium and iron content of barnyard millet varieties ranged from 17.1-32.7 and 1.2-1.5 mg/100, respectively.

Ushakumari and Malleshi (2007) studied the nutritional composition of the millets. Small millets are comparable to major cereals such as rice, wheat and maize with respect to their nutrient composition. On the other hand some of these millets contain considerably higher proportion of phytochemicals with neutraceuticals qualities. The protein content of small millets ranges from 7-12 per cent and fat content varies from 3-5 per cent. The protein quality is of fairly good biological value since they contain about 2.2 to 3.0 g of lysine and other amino acids in desirable proportions including leucine to isoleucine ratio. Some of the millets contain good amount of arginine, which is considered as an essential amino acid for growing children. Prolamines, albumins, globulins and glutelins are the proteins of these millets and among these prolamines form the major constituent. Similar to other cereals, the millet proteins are also deficient in lysine and tryphtophan. Among small millets, foxtail and proso millet contain about 5 per cent fat and the fat is distributed in bran as well as in endosperm. The fat generally consists of more than 60 per cent unsaturated fatty acids including essential fatty acids namely linoleic acid. The millet carbohydrates comprising of free sugars, non starchy polysaccharides and starch form the major source of energy to the consumers. While free sugars hardly amount to 2-3 per cent in the milled grains, the non-starchy poly saccharides account for 15-20 per cent and starch content varies from 60-75 per cent.

2.1.3 Phyto nutrient composition of millets

The millet polyphenols are highly complex in nature unlike other polyphenols of plant source. They are sparingly soluble in water, but can be extracted effectively in acidic methanol solvent system. Out of the large number of phenolics present in the millet, gallic acid forms the major constituent of the seed phenolics where as the ferrulic acid forms the major phenolic of the endosperm cell walls. Nearly 70 per cent of the millet polyphenols are concentrated in its seed coat tissue (Chethan and Malleshi, 2007).

The effect of germination, steaming and roasting on the nutraceutical and antioxidant properties of little millet (*Panicum sumatrense*) was investigated by Pradeep and Guha (2011). The nutraceutical properties were determined by evaluating the total phenolic, flavonoid and tannin contents while the antioxidant properties were studied by the DPPH free radical scavenging activity and the iron reducing power assay. The results showed that the total phenolic, flavonoid and tannin contents of processed little millet increased by 21.2, 25.5 and 18.9 mg/100 g, respectively, compared to native sample. The DPPH radical scavenging activity and the iron reducing power of roasted millet extract were the highest compared to the other processed millet. The results indicate that processing has significant effects on the nutraceutical and antioxidant properties of little millet phenolic extracts.

Chandrasekara *et al.* (2012) studied effect of processing on antioxidant activities on several millet grains, namely kodo, finger (Ravi), finger (local), proso, foxtail, little and pearl millet. Antioxidant activities of phenolic extracts obtained from whole grains, as well as their corresponding dehulled and cooked grains and hulls were studied for their total phenolic content (TPC), radical scavenging capacity, and antioxidant activity in a β-carotene/linoleate emulsion. The phenolics present in whole grains were identified and quantified using HPLC and HPLC/MS and results were expressed as total for each of the phenolic groups. The TPC ranged from 2 to 112 mol ferulic acid equivalents/g defatted meal. All varieties exhibited effective inhibition of 2,2-diphenyl-1-picrylhydrazyl (DPPH), hydroxyl, peroxyl and superoxide radicals. Dehulling and cooking affected the TPC and radical scavenging and antioxidant activities of the grains, depending on the variety. In general, the antioxidant activity of phenolic extracts was in the order of hull > whole grain > dehulled grain > cooked dehulled grain.

Kundgol *et al.* (2013) studied 10 landraces for their antioxidant activity. The antioxidant activity in whole little millet grain ranged from 19.06 to 24.33 per cent in millets collected from Chadaval-66 and Mantrodi-77. Antioxidant activity in decorticated grain varied from 12.80 to 23.52 per cent in millets collected from Chikkayagatti-07 millet and Jekinkatti-82 millet. Bran contained highest antioxidant activity compared to decorticated grain and whole millet grain. Bran contained 27.85 to 33.89 per cent in millets collected from Chikkayagatti-07 millet and Chikkayagatti-01 millet. Numerically, there was no difference found in antioxidant activity based on locality, colour, size and shape. Antioxidant activity in decorticated grain and whole millet was statistically significant and there was no significant difference observed in bran for antioxidant content.

2.2 Quality changes during storage of cereals

Daniels *et al.* (1998) studied the effects of long-grain rough rice storage history on end-use quality. Rough rice (cv. Cypress) from the 1995 season was harvested, dried, and stored in laboratory-scale studies. Treatments included pre-drying conditions, drying conditions, storage temperatures, and storage durations. Temporary wet storage prior to drying affected cooking properties ($p<0.05$) and peak viscosity ($p<0.05$). Drying treatments affected head rice yield ($p<0.05$), cooking properties ($p<0.01$), and peak viscosity ($p<0.05$). Storage temperature was related ($p<0.05$) to cooking properties and peak viscosity via a second-order relationship. Head rice yield and cooking properties were also affected ($p<0.05$) by storage duration.

Perdon *et al.* (1999) investigated the effect of storing cooked Bengal and Cypress milled rice at –13, 3, 20, and 36 ℃ on texture and degree of starch retrogradation. Cooked rice firmness increased, while stickiness decreased, during storage at –13 and 3 ℃. Starch retrogradation, measured with a differential scanning calorimeter, was observed for both cultivars during storage at –13 and 3 ℃, but not at 36 ℃. At 20 ℃, retrogradation occurred in Cypress, but not in Bengal. Starch retrogradation showed positive linear trends with firmness for both cultivars at all storage temperatures ($R^2 = 0.80$) and with stickiness for Bengal stored at –13 and 3 ℃ and for Cypress stored at 3 and 20 ℃ ($R^2 = 0.88$).

Biochemical changes in wheat grains stored at 10, 25 and 45°C for six months were studied by Rehman and Shah (1999). A significant decrease in pH and an increase in titratable acidity were observed during storage of wheat grains at 25 °C and 45 °C. Moisture contents of wheat grains decreased by 15 per cent at 25 °C and 26per cent at 45 °C during six months of storage. A significant decrease in water soluble amylose (20–28%) along with an increase in insoluble amylose contents (7.6–17%) were observed during storage at 25 and 45 °C. Amylase activity of the samples showed a decrease as the storage progressed. Total soluble sugars increased by 9per cent at 10 °C and 12per cent at 25 °C; a 37per cent decrease was observed after six months storage at 45 °C. Total available lysine decreased by 18.0 per cent and 22.6 per cent at 25 and 45 °C, respectively, after six months storage. *In vitro* protein digestibility of wheat grains decreased by 5.00 per cent at 25°C and 10.28 per cent at 45 °C during six months of storage. However, no significant biochemical changes occurred during storage at 10 °C.

Pearce *et al*. (2001) studied effects of postharvest parameters on functional changes during rough rice storage. The expansion of value-added uses for rice has created a demand for quantitative models of functional changes during postharvest handling. Consequently, this study evaluated the effects of postharvest parameters on the functional properties of long-grain (Cypress and Kaybonnet) and medium-grain (Bengal) rice. The experimental treatments included rough rice drying conditions (low vs. high temperature drying), storage moisture content (10, 12, and 14%), storage temperature (4, 21, and 38°C), and storage duration (up to 36 weeks). Milling, cooking, and amylograph pasting properties were analyzed. Polynomial models (up to third-order) were developed to describe the effects of postharvest factors on the functional properties. Drying treatments, storage moisture content, and storage duration affected ($P < 0.05$) all of the functional properties. Storage temperature influenced ($P < 0.01$) cooking and pasting properties, but not milling properties. Overall, there were significant interactions among the postharvest parameters.

Effect of accelerated aging on the physicochemical and textural properties of brown and milled rice was studied by Gujral and Kumar (2003). They observed that the physicochemical properties of rice like water absorption, swelling capacity and cooking time increased markedly after accelerated ageing, whereas solid loss of cooked rice decreased. The textural properties of cooked rice like cohesiveness, springiness and hardness increased whereas adhesiveness of cooked rice decreased significantly.

Nutritional changes in maize grains stored at 10, 25 and 45 °C for 6 months were studied by Rehman *et al* (2002). Significant decrease in pH and increase in titratable acidity was observed during storage of maize grains at 25 and 45 °C. Moisture contents of maize grains decreased by 25 per cent at 25 °C and 38 per cent at 45 °C after six months of storage. Total soluble sugars increased by 10.7 per cent at 10 °C and 17.3 per cent at 25 °C, whereas a 39.5 per cent decrease was observed after 6 months storage at 45 °C. Total available lysine and thiamine contents in maize grains decreased by 13 and 9.26 per cent at 25 °C, 16 and 20.4 per cent at 45 °C, respectively, after 6 months of storage. Protein digestibility decreased by 5.19 and 9.0 per cent at 25 and 45 °C, respectively, whereas decrease in starch digestibility was 9.86 per cent at 25 °C and 15.1 per cent at 45°C on storage of maize grains for 6 months. However, no significant nutritional changes occurred during storage of maize grains at 10 °C.

Zhou *et al.* (2003) investigated the pasting properties of rice flour following storage of the grain for up to 16 months. Storage produced changes in the Rapid Visco Analysis (RVA) pasting curves of the flour as a varietal, time and temperature dependent phenomenon. The data confirm that viscograms from samples stored at 4 and 37 °C provide a valid comparison of the effects of ageing on pasting behaviour. The most significant change in the pasting curve was the decrease in BD (bulk density over time and the gradual disappearance of a clearly defined peak in aged samples. Chemical (β-mercaptoethanol) and enzyme treatments (hemicellulase, cellulase and protease) of flour obtained from aged rice produced various changes in the RVA viscograms. The most notable effect was produced by protease treatment which increased PV (peak viscosity) and decreased FV (final viscosity) of flours from aged (higher temperature storage) rice samples. Aged samples treated in this way showed a peak and trough as normally seen in fresh rice. Thus, protein appears as a key component in the ageing process. The data suggest that changes in protein properties contribute to the effects of ageing on pasting properties and particularly BD. These changes in protein during storage may contribute to a more rigid structure which restrains starch swelling during the heating process.

Sodhi *et al.* (2003) investigated the effect of aging on the physicochemical, thermal, cooking and textural properties of milled rice obtained from two rice cultivars (Basmati-370 and Sharbati). The physicochemical properties like amylose content decreased while the free fatty acid content increased with aging. Basmati-370 milled rice had higher cooking time and elongation ratio which subsequently increased with aging in both the cultivars. Water uptake and gruel solids loss also decreased significantly with the aging of the milled rice from both the cultivars. Sharbati milled rice showed higher transition temperatures, enthalpy of gelatinization and peak height index than Basmati-370 rice cultivar when determined by Differential Scanning Calorimeter. All the thermal parameters decreased with the aging of milled rice from both the cultivars. Basmati-370 cooked rice had higher packability, hardness, cohesiveness, extrudability and chewiness value as compared to Sharbati cooked rice. The values for all textural parameters in both the cultivars increased during aging; however, the increase were greater in Basmati-370 rice.

McDonough *et al.* (2004) conducted a study on effect of accelerated aging on maize, sorghum, and sorghum meal. Accelerated aging at 50° C significantly affected the physical and chemical properties of sorghum and maize. Aging caused associations between starch granules, protein matrix, and cell walls. During aging, floury areas of the endosperm became more corneous; as the endosperm hardened, strong associations between starch and protein developed, causing the endosperm to fracture through endosperm cells instead of along cell walls, which is common for non-aged maize. Aging significantly decreased the pasting viscosity of starch, molecular solubility at 85 ºC and the molecular weight of solubilized starch. Solubility of albumins and globulins decreased while solubility of proteins extracted by a reducing agent and/or in alkaline pH increased during aging. Decreased solubility and functionality of starch and protein in aged grain appear to be due to protein oxidation.

Chemical properties and textures of cooked rice prepared with aged rice grains were investigated by Ohno and Ohisa (2005) and compared with those of cooked rice prepared with new rice grains. Aged rice became hard and the stickiness/hardness (S/H) ratio of aged rice became lower than that of new rice differences in S/ H ratios between new rice and aged rice were eliminated by the removal of the external layer of rice grains. Analysis by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) showed that the proteins of the external layer in aged rice grains were oxidized to a greater extent than those of new rice grains. Addition of a reducing agent to cooking water increased the S/H ratio of aged rice to approximately that of new rice. The reducing agent cleaves the disulfide linkages of the proteins. Therefore, textural changes in aged rice were inferred to be due to oxidation of proteins in the external layers of grains.

Patindol *et al.* (2005) investigated the effects of rough rice storage conditions on starch fine structures and physicochemical properties. Dried rough rice samples (medium-grain Bengal and long-grain Cypress) were stored at 4, 21, and 38℃ in temperature-controlled chambers and then periodically removed and evaluated after 1, 3, 5, 7, and 9 months. Flour (powdered head rice) and starch (extracted from head rice by alkali steeping) samples were evaluated for pasting and thermal properties. High-performance size-exclusion chromatography and high-performance anion exchange chromatography were used to characterize starch molecular size and amylopectin chain-length distribution, respectively. Significant changes in starch fine structure were observed primarily on the 38℃ lots, and to some extent on the 21℃ lots. The decreased amylose: amylopectin ratio, shortened amylopectin average chain length, and the shift in chain-length distribution to shorter branch chains were implicative of molecular-level starch degradation. The flour and starch samples showed inconsistent trends in pasting and thermal properties, thus suggesting the role of not only starch but also its interaction with non-starch components in rice aging.

Rehman (2006) studied storage effects on nutritional quality of commonly consumed cereals (wheat, maize and rice). Freshly harvested wheat, maize and rice grains were stored at 10, 25 and 45 ℃ for six months. A gradual decline in the level of moisture took place at 25 and 45 ℃ while there was no change in moisture contents during storage of cereal grains at 10 ℃ after six month storage. A significant decrease in pH and increase in titrable acidity was observed during storage of the cereal grains at 25 and 45 ℃. The total soluble sugars in rice, maize and wheat decreased at 45 ℃ storage and increased at 25 and 10 ℃. Protein and starch digestibilities of cereal grains were significantly affected at 25 and 45 ℃, where as they remained unchanged at 10 ℃. No significant change in nutritional quality was observed during storage of cereal grains at 10 ℃. In view of these facts, it is suggested that cereal grains (wheat, maize and rice) should not be stored above 25 ℃ in order to minimize nutrient losses during storage.

Sorghum grain stored in traditional underground pits was sampled from seven districts of Hararghe, eastern Ethiopia, representing lowland, intermediate and highland zones, from February to August 2001, and was analyzed at the International Livestock Research Institute (ILRI) for changes in chemical composition over time by Dejene *et al.* (2006). Samples were also taken from a replicated above ground bin and pit storage experiment at Alemaya University campus at 2-month intervals from March 2000 to August 2001 and analyzed in a similar manner. The effect of geographic location on chemical composition was significant, but there were differences in the sorghum varieties grown. The organic matter (OM) content of grain samples from pits in the lowlands was lower than those from the highlands. The crude protein (CP) and OM contents of samples from the seven districts did not change in 7–9 storage months. The OM content decreased and the CP slightly increased over time in samples from soil pits without any lining material on Alemaya University campus. The OM content decreased from 97.8 to 91.6 per cent; and CP increased from 10.1 to 11.2 per cent in these samples over a 17-month period. Soluble carbohydrate (SCHO) content significantly decreased over time in samples from the districts (from 2.4 to 1.2 per cent by 7 months) and in samples from soil pits on campus (from 2.4 to 1.9 % after 7 months and to 0.97% after 17 months). There was no significant change in the organic matter, CP and SCHO contents in samples taken from the cemented above ground bin, cement- and dung-lined pits at the Alemaya campus, all of which were lined with polythene sheeting.

Zhou *et al.* (2007) studied the effect of storage temperature on cooking behavior of rice. The differences in properties of residual cooking water and the textural profile of cooked rice grain following storage at 4 °C and 37 °C were examined. The higher temperature storage led to greater water uptake, reduced pH and turbidity of residual cooking liquid. The solid content in the residual cooking water also significantly ($p < 0.01$) decreased following storage at 37 °C compared to 4°C storage. Textural profile of the cooked rice grain also differed for rice grains under the two storage temperatures. Hardness increased ($p < 0.01$) and adhesiveness reduced ($p < 0.01$) following storage at 37 °C compared to 4 °C. Moreover, analysis of the hot-water soluble fraction suggested that storage at 37 °C decreased the leaching of starch components, particularly amylose. The cooked rice grains were also visualized using scanning electron microscopy, and the cooked rice following storage at 4 °C showed smoother surfaces than that of the cooked rice following storage at 37°C.

Tulyathan and Leeharatanaluk (2007) investigated how storage affects the quality of Khao Dawk Mali 105 (KDML 105) rice by monitoring the amount of 2-acetyl-1-pyrroline (2AP) over a period of 8 months. The pasting properties of KDML 105 following storage of up to 8 months showed a significant time effect at $p \le 0.05$. Breakdown viscosity was 51 per cent after 8 months storage while setback viscosity and hardness increased during storage. The amount of 2AP decreased to 7 per cent at 8 months while hardness increased proportionately. The number of high molecular weight protein bands increased as rice was aged for 5 and 8 months. In vitro digestibility of starch in fresh and 1-year aged rice was not significantly different.

Changes in physicochemical and sensory-properties of irradiated rice during storage was investigated by Sirisoontaralak and Noomhorm (2007). Milled aromatic rice (KDML-105) was g-irradiated at doses of 0, 0.2, 0.5 and 1.0 kGy. Changes in physicochemical and sensory properties were recorded during subsequent storage in polyethylene bags at ambient temperature for 1 year. Similar trends were observed in both irradiated and non-irradiated samples. Insignificant changes in yellowness and total solids in cooking water were observed during storage of irradiated rice compared with those of naturally-aged rice. Irradiated rice showed less increase in Rapid Visco Analyzer (RVA) setback, greater reduction of RVA breakdown, and softer texture than non-irradiated rice. It also had a softer but slimy texture, off odour and inferior taste compared with the non-irradiated sample. Based on overall acceptability to panelists preferring fresh rice, nonirradiated rice could be stored for more than 1 year while rice irradiated at 0.2, 0.5 and 1.0 kGy had shelf lives of 9, 7 and 2 months, respectively.

Changes in seed quality parameter of three wheat varieties during one year storage at four different storage conditions were studied by Strelec *et al.* (2010). Applied storage conditions adversely affected quality changes in wheat seeds during one year storage. The most pronounced changes were observed for seeds kept at 40°C, RH = 45 per cent , followed by seeds stored at 25°C, RH = 45 per cent , while seeds kept at 4°C, RH = 45 per cent or at warehouse conditions mostly showed minimal or statistically non significant changes. Elevated temperature of seed storage caused a significant decrease of starch content, hectoliter weight, and wet gluten content, accompanied with increase in flour acidity, and fluctuating in Zeleny sedimentation value. The intensities of observed changes showed strong dependence on wheat variety.

Kapoor *et al.* (2011) studied physiological changes during accelerated ageing like germination percentage, moisture content, seedling vigour and vigour index and biochemical changes like reducing sugars and soluble proteins in five rice varieties (Sugandha-4, Sugandha-5, Pusa-1, Saket-4 and Saket-370). For accelerated ageing seeds were exposed to 45℃ temperature and 100 per cent relative humidity (RH) for 24, 48, 72 and 96 h. The results of seed viability in aged seeds of all the varieties showed high germination percentage (>80%). Accelerated ageing treatments in rice varieties resulted in significant declination in germination percentage from 90 to 41.2 percent. Prolongation of ageing led to deterioration of both germinability and seed viability. Ageing resulted in significant increase in moisture content.

Effects of packaging materials, storage temperatures and time on physicochemical properties of organic hulled red fragrant rice cv. Hom Daeng were investigated by Tananuwong and Malila (2011). The samples were vacuum-packed in oriented polypropylene/aluminium/linear low-density polyethylene or nylon/linear low-density polyethylene pouches and stored at ambient temperature or 15° C for up to 12 months. Results from differential scanning calorimetry indicated that onset and peak temperature of gelatinisation of the aged rice samples increased after the 6th month while enthalpy of gelatinisation initially increased and then decreased after the 8th month. Measurements from the Rapid Visco Analyzer revealed that peak viscosity and breakdown of the rice pastes increased within the first 2 months, then decreased after the 6th month, whereas setback gradually increased during storage. Swelling power, at 70 and 90° C, of the aged samples, tended to decrease after the 4th month. Lower storage temperature retarded those changes while packaging materials did not influence the changes. Changes in thermal and pasting properties of the aged samples were reversed after adding 2-mercaptoethanol. Hence, an increase in disulphide linkages of oryzenin during storage could play a crucial role in altering those properties. Sensory evaluation indicated a significant increase in hardness of the cooked rice prepared from the longer-aged samples (p>0.05). However, the cooked rice samples, deriving from the samples stored at ambient temperature for up to 12 months, were still acceptable for Thai consumers.

2.3 Hydrothermal treatment to the cereals

Otegbyo *et al.* (2001) studied two varieties of local rice in paddy form. The rice were c divided in two, one half was processes by parboiling, drying and milling the other half was processed by drying and milling. The results of showed that parboiling affected the physic-chemical qualities of the rice varieties. There were differences in the physical dimension, appearance, colour, water absorption, cooking time, amylase, protein, fat and carbohydrate contents of the parboiled and non-parboiled samples. Varietal differences also exist between the rice samples. Parboiling reduced the breakage, fat, protein and amylase content of the rice while the cooking time, water uptake and thiamine contents were increased. It can therefore be inferred that parboiling which has been the means of processing rice in Nigeria can be a way of improving vitamin content and milling properties of rice and should attract the interest of food technologies and food processors to rice and should attract the interest of food technologists and food processors to develop the rice industry.

Miah *et al*. (2002a) investigated the effect of soaking time on the quality of parboiled rice. The paddy was soaked in water at 25 and 80 ℃ for 15, 30, 45, 60 and 120 min. The soaked paddy was steamed, dried, stored and milled. With increasing soaking time a significant increase in water absorption and milling and head rice yield (hence reduction in broken rice) was observed. A significant difference in milling yield, at the 1 per cent level, was obtained between the raw rice control and the hot soaked parboiled samples. A large reduction in fissured grain was observed after soaking.

Miah *et al*. (2002b) studied the effect of hot soaking time on degree of starch gelatinization. A differential scanning calorimetric study was done on raw and parboiled rice to determine the degree of gelatinization. Unparboiled rice absorbed the highest amount of endothermic heat, the enthalpy change gradually decreasing with increasing hot soaking time. The highest degree of gelatinization was achieved when the paddy was soaked for 120 min at 80℃. With increasing degree of gelatinization, the yield point in a compression test also increased. During the parboiling process internal fissures were healed, resulting in higher head rice yield during milling.

Differential scanning calorimetry (DSC) was used by Islam *et al.* (2002) to determine the thermal properties of parboiled rice, and these properties, i.e. gelatinization parameters, namely, peak temperature (Tp) and residual gelatinization enthalpy (ΔH) were evaluated. The Tp increased and ΔH decreased with increase in the severity of heat treatment during the parboiling process. The physical property of color value correlated positively with the Tp and the degree of starch gelatinization correlated positively with the hardness of the parboiled rice. The Tp, which represents half the conversion temperature of the sample melting, is believed to be a suitable indicator to identify the severity of heat treatment in the parboiling process. The quantitative *T*p values of 77.4 to 79.2℃ corresponding to the processing conditions of 90℃-30 min and 100℃-15 min are viewed as an index for better quality of the rice. The thermal properties thus can be utilized to understand the cooking behavior of parboiled rice.

Sujatha *et al.* (2004) studied the physicochemical properties and cooking qualities of brown and polished, raw and parboiled rice of both local (Kayame) and high-yielding (Jaya) varieties cultivated in Dakshina Kannada. Forty-eight rice samples of Jaya (hybrid) and Kayame (local) varieties cultivated in Dakshina Kannada were collected during different seasons (Enel, Suggi and Kolake) and stages of parboiling (brown raw rice, polished raw rice, brown parboiled rice, polished parboiled rice) over a two years period. When analyzed, they showed significant variation in total carbohydrate, total proteins, total fat, reducing sugar, crude fiber, amylose content, length/breadth ratio, 1000 kernel weight, energy content and swelling number between the varieties, seasons and stages of processing. Between varieties, Jaya was found to be of better quality for the above parameters. Samples of both varieties collected during the rainy season ("Enel" crop) had a higher percentage of chemical constituents than paddy grown in dry seasons (i.e., "Kolake" and 'Suggi' crops).

Roy *et al.* (2004) conducted laboratory scale studies to determine temperature distribution in the traditional parboiling process using a rice cooker. A sample holder with a wire-mesh bottom was used to keep the sample from the hot water. The material temperature and the qualities of parboiled rice (hardness, color, lightness and head rice yield) were determined for different layers. The thickness of each layer was about 20 mm. The temperature distribution in this parboiling process (pre-steaming and steaming) was found to be uneven. The change of material temperature was faster for the first (bottom layer; beneath which steam started to penetrate the paddy mass), next was the second (middle) and last was the third (top) layer. The greater the thickness of the material, the lower was the material temperature. The hardness and the head rice yield were found to be the highest for the first, with the second and third layers following in that order; this might be affected by the material temperature. Difference in color intensity and lightness value was insignificant among the layers. The hardness, color intensity and lightness value were about 70 N, 24, and 57, respectively, corresponding to the maximum head rice yield (67 %, first layer) which is considered to be the suitable quality of parboiled rice.

Heinemann *et al.* (2005) compared the chemical composition of commercial samples of brown, parboiled brown, parboiled milled and milled rice, and the contribution of each mineral to the Recommended Dietary Allowance (RDA). The chemical composition was determined according to official methods and an inductively coupled plasma-based technique was used to analyze the minerals. The results showed protein (Nx5.7) and crude fat contents in all rice forms similar to literature data with some differences in ash contents, mainly between milled samples. Parboiled milled rice showed 18 per cent ash enrichment in comparison with milled rice, and higher contents of K and P. Lower contents of Mn, Ca and Zn were observed, even though contents of other nutritionally important elements were basically similar to milled rice. The brown rice analysed showed concentrations of P, Mn and Na lower than those reported in literature, indicating the usefulness of selecting nutritionally promising varieties for commercial production. Se, Mn, Cu and Zn, reaching 35 per cent of the RDA, depending on the element and the form of rice, presented the highest nutritional contribution. Macro elements, which are the most affected by parboiling and milling, showed a low contribution to the RDA in all forms of rice.

Adebowale *et al*. (2005) investigated the effect of hydrothermal treatments on the properties of Finger millet starch. Finger millet was modified by heat-moisture treatment, HMT at 100° C, 16 h; 20 per cent moisture level (MHT-20), 25 per cent moisture level (MHT-25) and 30 per cent moisture level (MHT 30) and annealed, ANN at 50 8C for 48 h (MAN). Results of the pasting characteristics showed that MNS and MAN were indicative of type 'B'starch which is characteristic of normal cereal starches, while HMT starches were Type 'C' which were characteristics of cross-linked or legume starches. MNS belonged to the type 'A' pattern of cereal starches. X-ray diffractometry studies (XRD) show that MNS gave strong peaks centered at 23.5, 20.3, 18.2, 17.15, and 15.15 A°, while HMT and ANN starches retained the typical 'A' pattern. Scanning electron microscopy (SEM) studies show that the shape and surface characteristics of the starches were irregular, polygonal-shaped granules, with less than 1 per cent cavity or ruptured granules. Modification did not affect the appearance. All the starches swell as the temperature increased in the order MNS>MAN>MHT-20>MHT-25>MHT-30, and solubilized at different rate in the following order: MHT-30>MHT-20>MHT- 25>MAN>MNS.

Bello *et al.* (2006), used factorial design to determine the effects of hydrothermal process conditions on parboiled rice quality. The effect of temperature, heating time and tempering on head rice yield (HRY), translucence index (TI) and rupture force (RF) of milled grain was investigated. The effect of tempering and cooking time on texture profile analysis (TPA) of cooked parboiled rice was also studied. The quality indexes increased with tempering. A significant effect of heating time on RF and TI indexes was observed, while temperature affected mainly RF and TI quality indexes. The optimum conditions included tempering after soaking (24 h at 25 ℃) and heating at 85 ℃ (174.4 min) or 93.7 ℃ (45 min). The rice presented intermediate values of textural properties between raw and traditional parboiled rice. It means less hard than traditional parboiled rice and less sticky than raw rice.

The effects of the soaking and steaming steps in rice parboiling on color changes and the levels of reducing sugars in rice were studied by Lamberts *et al*, (2006). Brown rice was soaked to different moisture contents (MC, 15, 20, 25, and 30%). The *L*, a*, b** color parameters of the Commission Internationale de L'Eclairage (CIE 1976) indicated that during soaking, red and yellow bran pigments diffused from the bran into the endosperm. The increase in brightness brought about by soaking rice was attributed to migration of rice compounds (e.g., lipids) from the inner to the outer bran layers (rice surface). The levels of reducing sugars in brown and milled soaked rice samples increased with increasing brown rice MC after soaking. Total color difference (ΔE) between parboiled and nonparboiled rice increased with, increasing MC after soaking and depended on the intensity of the steaming conditions as reflected in the degree of starch gelatinization. Parboiling affected yellowness, more than redness in mildly steamed brown rice and most in intermediately steamed brown rice. Severe steaming of brown rice affected redness more than yellowness. All three parboiling conditions equally affected the yellow color more than the red color in milled rice. Linear regression analyses indicated that parboiling had a larger effect on ΔE of milled parboiled rice than of brown parboiled rice.

Changes in physicochemical properties of parboiled brown rice during heat treatment was studied by Parnsakhorn and Noomhorm (2008). Thai rice varieties with high amylose content (Chainat 1, Supanburi 1) and low amylose content (Koa Dok Mali 105) were used to produce parboiled brown rice. In this study brown rice with the initial moisture content of 13±1 per cent (w.b.) was soaked at two different initial soaking temperatures of 70 and 80^{o} C. The soaking time was 1h, 2h, 3h and 4h, followed by steaming at temperature of 100^{o}C for 10, 15 and 20 min. The samples were then shade dried at 30±1℃ and 60±5 per cent RH to a final moisture content of 13±1 per cent (w.b.). Physicochemical properties were determined and sensory analysis was performed for selected processing conditions. Head rice yield, yellowness (b-value), whiteness, hardness, water absorption, vitamin E and vitamin B_2 were measured and compared with those of commercial parboiled paddy. Results revealed that the head rice yield, color (b-value), cooking time and hardness of parboiled brown rice were decreased whereas whiteness and water absorption were increased compared with commercial parboiled paddy. Qualitatively, parboiled brown rice showed intermediate values between milled rice and commercial parboiled paddy. Sensory analysis revealed high acceptance of cooked parboiled brown rice from the panelists. However, presence of vitamin B_2 decreased and vitamin E disappeared after parboiling process on brown rice. Head rice yield was lower for parboiled brown rice when compared to that of parboiled paddy but greater than the head rice yield of non-parboiled rice.

Ibukun (2008) studied the effect of prolonged parboiling duration on proximate composition of rice.. Result indicated that there was a decrease in vital constituents such as proteins, and mineral elements as a result of prolonged parboiling duration. Longer the duration of parboiling periods lead to greater losses in nutritive value. Comparing these effects at 30, 45, 60 and 90 min, greater loss was recorded at 90 min with a loss of 32.5 per cent in crude protein, calcium 13.3 per cent, iron 16.66 per cent, sodium 5.76 per cent and potassium 2.31 per cent. The longer the parboiling duration the higher the percentage of breakages of paddy rice during milling. Variations observed in the result of proximate analysis carried out on parboiled rice obtained from different rice farmers indicated that there is no unique method of processing in operational, which can regulate the quality of rice in this locality. Rice parboiled at not more than 30 - 40 min will still produce the best quality product.

Sareepuang *et al.* (2008) studied effects of soaking temperature on cooking quality, physicochemical properties of fragrant rice which was quite fragile and kept for a long period of time. He concluded that overall soaking at 50℃ for 3 hr prior to steaming and drying was found to provide the most desirable quality of parboiled rice in terms of nutritional quality and sensory properties.

Chukwu and Oesh (2009) studied the response of nutritional values of rice (*Oryza sativa*) to different parboiling temperatures. Standard laboratory conditions, instruments and methods of AOAC (Association of Official Analytical Chemists) nutritional guidelines were used to obtain the proximate compositions of unparboiled rice and rice that was steam-parboiled at 80, 100 and 120ºC. The results showed that parboiling leads to variation in the nutritional contents of rice as demonstrated for protein content which shows a decrease from 6.61 to 5.29 per cent after the parboiling operation. The results obtained for vitamins A and C also showed decrease in values after parboiling at different temperatures of 80, 100 and 120ºC. It was concluded that parboiling rice adversely affects some of the nutritional contents of the product.

An experiment was conducted to study changes in carbohydrates, proteins and lipids of finger millet after hydrothermal processing by Dharmaraj and Malleshi (2011). Finger millet was soaked, steamed and dried to prepare hydrothermally processed millet, followed by decortication to prepare decorticated millet. The physicochemical properties and carbohydrate, protein and lipid profiles of control and processed millet were determined. The carbohydrates were fractionated to amlypectin and amylose equivalent fractions using gel permeation chromatography. The non-starch polysaccharides were isolated and their alditol acetyl derivatives were characterized by gas chromatography (GC). The proteins were extracted using different solvents and the total proteins were fractionated using SDS-PAGE. The ether extractable lipids were esterified and fractionated through GC. Hydrothermal processing decreased the amylopectin fraction and increased the amylose equivalent portion of the starch. Decortication further lowered the first fraction and increased the second fraction. A decrease in cold, hot water soluble and hemicellulose-B fractions and an increase in pectic polysaccharides, hemicellulose-A and cellulosic fractions were observed as a result of hydrothermal processing. Decortication significantly reduced the total non-starch polysaccharides specifically the cellulose fraction. Hydrothermal processing decreased the overall extractability of proteins by 50 per cent but decortication increased it to 80 per cent . It was observed that hydrothermal treatment did not change the gross nutrients composition of finger millet but for their profile. Decortication of hydrothermally processed millet caused significant changes in the nutrient contents and also in their profiles.

2.4 Value added products from Little millet

Ethnic foods like *mudde happala* and fermented food *paddu* and novel food such as biscuits, *chakali* and *laddoos* were made out of small millets were selected for evaluation of nutritional and technological opportunities for better utilization in the market as compared to other products already existing in the market. Products had excellent taste and were accepted by both rural and urban consumers across Karnataka state and which have entered the entrepreneurial activities of women Self Help Groups (SHGs) as home based food processing activity. The evaluation of ethnic and novel foods of millets as compared to standard ones revealed that the sensory scores of all the quality parameters were higher for the standard recipes as compared to those made with millets (Yenagi *et al.*, 2010).

Kotagi *et al.* (2011b) studied development, consumer acceptability and quality evaluation of millet chocoflakes. Little millet was sorted by sedimentation. Then subjected to partial gelatinization in steamer under pressure (20-24lbs/psi). Air cooling was done to surface dryness and passed under roller (0.25cm) to make the flakes. The rolled flakes were dried under sun and extruded in screw extruder, extruded flakes were toasted. Flakes were coated with milk and dark chocolate on double boiling system. All the sensory scores were more than 8 that mean product is very good. Millet chocoflakes scored 8.25 for the overall acceptability. Acceptability index was 90.91. Millet chocoflakes provides 1.58g of protein, 5.59g of fat 18.87g of carbohydrates, 0.09g of ash, 2.89g of dietary fiber and 151 K cal of energy per serving.

Chimmad *et al.* (2011) developed little millet cookies by replacing refined wheat flour at various levels. Results of sensory evaluation revealed that replacement of 40 per cent refined wheat flour was most acceptable. The cookies (100g) provided 494 K cal energy, 5.3g of protein, 22g of fat, 66g of carbohydrates, 2.75mg iron and 36.35mg calcium. Fiber content of the little millet cookies was higher (1.61g) in comparison with control cookies (0.15g).

The ready eat sports food mix was developed by Roopa *et al.* (2011) with little millet, soy bean, skim milk powder and sugar. The ready to eat mix provided 15 per cent of protein and yielded to many recipes. It provided 262 mg of calcium and 4.69 mg of iron per 100g. The consumption of sports food as prevent meal increased the physical endurance capacity of sports persons by 2-5 per cent when substituted with routinely consumed pre event meal. Neverthless, when formulated food consumed as pre event meal elicited 14-34 per cent improvement over fasting conditions.

The suitability of little millet (*Panicum sumatrense*) for the preparation of *Anaras* was studied by Ninganagoudar *et al*., (2012) as value addition. *Anaras* was prepared by different types of rice (Bold and Fine) and little millet (White and Black) flour and evaluated for product quality. Organoleptic scores of Anaras prepared from rice varieties ranged from 7.1-8.3 whereas product prepared from two types of little millet ranged from 3.6-6.2. Mean organoleptic scores of *Anaras* prepared with bold rice was higher and lower for both millet varieties.

A trial was conducted to prepare and evaluate the quality of ready to eat little millet (*Panicum miliare*) flakes. The flakes were rich source of dietary fiber (22.40%), iron (32.23 mg%), protein (7.51%), ash (0.45 mg%) and fair source of fat (0.44%) and carbohydrates (59.10%). Glycemic index of the millet flakes was 52.11, ranging from 41.57 to 61.80 among ten healthy normal volunteers. The acceptability of flakes tested in the form of avalakki, a traditional breakfast of north Karnataka, revealed very good acceptability with a mean total score of 36.50 and acceptability index of 81.11 on a nine point hedonic scale. The flakes were bright yellow and attractive (7.30), taste was well accepted (7.20), texture was soft and chewable (7.30) and aroma was very good (7.20). (Kotagi *et al.,* 2013)

2.5 Health benefits of millets

Itagi, (2003) conducted study on Development and evaluation of millet based composite food for diabetics II. Little millet and foxtail millet flour mix and grain mix were developed specially for the diabetic patients and evaluated for glycaemic index and its effect on glucose and cholesterol level of the diabetic patients compared with control. The glycaemic index of the mixes ranged from 54.39 to 64.51. Grain mix rice prepared from both millets was having lower glycaemic index followed by grain rice. Composite flour pancake was having higher glycaemic index. However, all the products had low glyacaemic indices. Fasting glucose, triglyglyceride and total cholesterol had reduced after the feeding trial and the HDL cholesterol had a positive effect that is HDL cholesterol level increased by 5.33 percent in case of foxtail millet composite food and 2.29 per cent in case of little millet composite food. The same trend was observed in the case of non diabetic volunteers during experiment. HDL cholesterol increased by 5.70 by foxtail composite food and 8.47 by little millet composite food. The developed products helped to reduce the fasting glucose and improve the blood lipid profiles.

Impact of long term feeding of millet based breakfast foods on the nutritional status of adolescent girls was studied (Anon, 2008). The school going girls were selected for the study. They were given millet based breakfast like *bisibelebath, khichadi, upama* and *paddu*. Their heamoglobin analysis and anthropometric measurements were done before and after the feeding trial and compared with control group. The results revealed that supplementation of millet based breakfast improved their height, weight and their heamoglobin level significantly.

Intervention studies on millets in school feeding programme and its impact on nutritional status of rural/urban school children was conducted. In this study the rice was replaced by the foxtail millet rice. Haemoglobin level was assessed before and after the feeding trial and compared to the control group. Mean haemoglobin level of children significantly increased after the feeding foxtail millet when compared to rice (Anon, 2011).

Meghana *et al.* (2011) studied effect of supplementation of ragi based snacks on nutritional status of children. Two hundred and ten children of age between 10 -11 years were selected for the study. Children were given the millet based snacks developed by Defence Food Research Laboratory Mysore. The snacks given were sweetened millet mix, spiced millet mix and millet sweet cookies. Their plasma ferritin, heamoglobin and serum calcium levels were assessed. The results showed that Plasma ferritin level significantly increased by 22ng/ml in boys and 12 ng/ml in girls. The improvement in the anaemia profile was evident to shift of children to the normal haemoglobin level from other groups. Serum calcium level was seen to be improved by 1mg/dl.

Jali *et al.,* 2011 studied efficacy of value added therapeutic foods in management of diabetes in selected human volunteers. Three hundred volunteer subjects who were visiting to the hospital were selected with Type 2 Diabetis mellitus and were assigned millet based diabetic food developed by the UAS Dharwad. Changes in glycaemic control and lipid profiles were recorded. All blood parameters namely HbA1c, Fasting glucose, insulin concentrations, total cholesterol, VLDL cholesterol and triglyceride were reduced significantly. It was interesting that some of the people in the group moved to normal condition after feeding millet based food.

2.6 Development of bread with other ingredients

López *et al.* (2004) used rice flour, corn and cassava starch in several formulations aiming to find a flour mixture to replace wheat flour in the production of free-gluten white bread. Production parameters were evaluated through sensory analysis. The resulting breads were evaluated taking into account physical parameters (crumb appearance, specific volume and moisture) and sensorial parameters (flavor, appearance, crumb texture, crust color and satisfaction). Regarding flavor and moisture, breads prepared with the three different ingredients were not statistically different at 5 per cent probability by the Tuckey test. However, they differed significantly regarding the specific volume, crumb texture, crust color, degree of satisfaction and external appearance. Breads prepared with rice flour resulted in a softer product, presenting a better consistency with small alveoli homogeneously distributed. As far as crumb texture was concerned, corn starch bread presented larger alveoli, while cassava starch resulted in bread with expandable and gummy crumb, with granulation without alveoli, and undesirable sensorial characteristics. A mixture of flours, composed by 45 per cent rice flour, 35 per cent corn starch and 20 per cent cassava starch presented good results originating bread with crumb formed by uniform and well distributed cells, and pleasant flavor and appearance.

Edema *et al.* (2005) examined the functional properties of three different flours/meals and two blends of maize meal and soybean-flour (ratios 9:1 and 8:2, maize:soybean) were carried out. Properties examined included amylose content, bulk density, dispersibility, swelling power, water absorption capacity and viscoelastic properties. The effect of the different flour/meal samples on the properties of sour maize bread were evaluated by baking bread samples with the different flours/meals using a mixed starter culture of *Lactobacillus plantarum* and *Saccharomyces cerevisiae*. All flour/meal samples differed, sometimes significantly ($p > 0.05$) in their functional properties. Significant positive correlations existed among the functional properties of the flours at the 1 per cent level (2-tailed). The maize meal/soy flour blends MSA (maize meal and soybean flour mixed in ratio 9:1) and MSB (maize meal and soybean flour mixed in ratio 8:2) did not differ significantly from each other in functional properties except for amylose content. MSA was adjudged the best flour blend for sour maize bread production as its bread had the highest score for overall acceptability (6.1) and other sensory parameters evaluated.

Shittu *et al.* (2007) investigated the effect of baking temperature and time on some physical properties of bread from composite flour made by mixing cassava and wheat flour at ratio of 10:90 (w/w). A central composite rotatable experimental design was used while the baking temperature and time investigated ranged from 190 to 240 °C and 20 to 40 min, respectively. Loaf volume, weight and specific volume varied significantly ($p < 0.001$) from 440 to 920 cm^3, 162 to 183 g and 3.31 to 5.32 cm^3/g, respectively. The tristimulus color parameters such as L* (lightness) and brownness index (BI) of the crust varied significantly ($p < 0.01$) from 31 to 72 and 68 to 123, respectively. Moreover, Fresh crumb moisture, density, porosity and softness as well as the dried crumb hardness were also significantly ($p < 0.01$) affected by both the baking temperature and time with values ranging from 34 per cent to 39 per cent , 0.16 to 0.20 g/cm^3, 0.69 to 0.80, 13.00 to 18.05 mm and 0.90 to 2.05 kg, respectively.

Baking technology for tasty bread with high wholemeal oat content and good texture was developed by Flander *et al.* (2007). Bread was baked with a straight baking process using whole grain oat (51/100 g flour) and white wheat (49/100 g four). The effects of gluten and water content, dough mixing time, proofing temperature and time, and baking conditions on bread quality were investigated using response surface methodology with a central composite design. Response variables measured were specific volume, instrumental crumb hardness, and sensory texture, mouthfeel, and flavour. The concentration and molecular weight distribution of β -glucan were analysed both from the flours and the bread. Light microscopy was used to locate β -glucan in the bread. Proofing conditions, gluten, and water content had a major effect on specific volume and hardness of the oat bread. The sensory crumb properties were mainly affected by ingredients, whereas processing conditions exhibited their main effects on crust properties and richness of the crumb flavour. β-glucan content of oat bread was 1.3/100 g bread. The proportion of the highest molecular weight fraction of β-glucan was decreased as compared with the original β-glucan content of oat/wheat flour.

Eddy, (2007) studied the performance of 10, 20 and 30 per cent cassava composite bread, carried out by evaluating the colour, aroma, texture, acceptability and buying preference. The samples were served to semi-trained panelists. The result showed that bread baked with 10 and 20 per cent composite flour were not significantly different in all sensory attributes, acceptability and readiness to buy from the control. However, bread baked from 30 per cent composite flour showed low mean scores to all the attributes. There was a tendency for bread baked with 10 and 20 per cent composite flour to be rated higher than the control especially in flavour, acceptability and desire to buy. Uniformity in the scores between all labeled and unlabelled samples was also observed. Values obtained for proximate composition of cassava composite bread samples were comparable to those obtained for whole wheat bread. Adoption of wheat/cassava flour for bread making is advocated in this work as an alternative to 100 per cent wheat.

The feasibility of partially replacing wheat flour with plantain flour in bread and biscuit making were investigated by Mepba *et al.* (2007). The wheat flour (WF) was substituted by plantain four at levels of 5, 10, 20 and 30 per cent and 0, 50, 60, 70, 80 90 and 100 per cent for bread and biscuit making, respectively. No significant difference was observed in the nutrient contents of control (wheat bread) and composite bread at 5 per cent level of plantain addition. The specific loaf volume decreased significantly with increased plantain content of blends. Sensory panel rating (80.20%) of the 10 per cent plantain flour content of composite bread was not significantly different from the score (83.80%) of the 5 per cent level of WF substitution but was significantly different from a score of 88.40 per cent for the control (Wheat-bread) ($P \leq 0.05$). Technically, organoleptically acceptable breads were formulated from wheat-plantain composite flours using up to 80:20 (w/w) per cent ratios of wheat: plantain flour as maximum acceptable levels of substitution for breads and biscuits, respectively.

Olaoye *et al.* (2006) used of soy flour (SF) and plantain flour (PF) substitution in wheat flour (WF), from 0 to 15 per cent each, for the production of bread was investigated by. The proximate analysis, sensory evaluation and aerobic plate count (APC) of the bread samples were determined. The crude protein, crude fiber, ether extract and ash contents of the soy supplemented breads (SSBs) increased with progressive increase in the proportion of soy flour, with the 15 per cent SSB having highest values of 8.39, 0.14, 2.46 and 1.17 per cent , respectively, while lowest values were recorded for the whole wheat bread (WWB). The carbohydrate content was observed to decrease with corresponding increase in the percentage of soy flour in SSBs. The sensory evaluation shows that no significant differences were observed between the WWB and the 5 per cent SSB in the sensory attributes of aroma, internal texture, taste and general acceptability ($p \geq 0.05$), but differences were significant in crust, shape and appearance. The ash content increased with progressive increase in the proportion of the PF, the highest value (0.95 per cent) was recorded for the 15 per cent PSB. There were no significant differences ($p \geq 0.05$) between the WWB and the PSBs up to 10 per cent PF substitution in all the sensory attributes tested; crust, taste, aroma, shape, internal texture, appearance and general acceptability.

Rosales-Juárez *et al.* (2008) studied the effect of adding defatted flour of germinated (32 °C, 72 h) or non-germinated soybean at different dry protein ratios (0, 0.5, 1.0, 1.5%) to wheat flour on: water absorption (WA), maximum consistency time (MCT), dough stability (S), maximum resistance to extension (Rmax), and dough extensibility (L). Baking tests (straight-dough procedure) were also performed to evaluate the effect of this addition on bread characteristics: loaf volume, texture (firmness, compression force, resilience), color (L*, a*, b*), crumb– grain structure (cell density, mean cell area, shape factor), and consumer acceptance (sensory analysis). Addition of both kinds of soybean flours increased the values of farinographic parameters (WA, MCT, S), although they did not have significant effects ($p \geq 0.05$) on extensographic properties (Rmax, L). Loaf volume and crumb color were improved as soy flour addition was increased, whereas crust color was not affected ($p>0.05$). Texture analysis showed that the addition of soy flour produced breads similar or better than the control, whereas the addition of GSF produced a coarser crumb grain. No detectable differences were found among samples during the sensorial analysis. Germinated soybean flour was better to improve dough bread making properties.

Holtekjølen *et al.* (2008) made breads by replacing 40 per cent of wheat flour with barley flour. The incorporation of barley increased the antioxidant properties of the breads compared to the control bread. Furthermore, these properties proved to be dependent on the variety of barley as well as the extraction rate of the flour. The amount of free phenolics (TPC-S) decreased during the baking process, while the amount of bound phenolics increased (TPC-IS). At the same time, the measured antioxidant activities (FRAP-S and FRAP-IS) were relatively stable during the baking process. A sensory evaluation showed differences in sensory attributes, depending on the barley variety, and there was a good consistency between the sensory evaluation and the amount of phenolics.

Malomo *et al.* (2011) assessed the quality of bread produced from breadfruit and breadnut-wheat composite flour. Six blends were prepared by homogenously mixing breadfruit and breadnut flours with wheat flour in the percentage proportions: 5:95, 10:90, 15:85 (BF: WF and BFN: WF) and later used to bake bread. The results of the proximate composition showed that the protein content of the breadfruit and breadnut flours are 3.35 and 3.62 mg/100 g; fat, 0.51 and 1.85 mg/100 g; ash, 2.69 and 1.24 mg/100 g; fibre, 3.67 and 4.52 mg/100 g; carbohydrate, 73.50 and 62.17 mg/100 g respectively and the protein content of the bread samples ranged from 10.66 to 11.96 mg/100 g; fat, 4.13-5.62 mg/100 g; ash, 1.67-2.10 mg/100 g; moisture 35.51- 39.06 mg/100 g; carbohydrate, 42.22-46.93 mg/100 g; energy value, 261.40-274.17 Kcal/100 g. The rheological study of composite flour samples had 9.50-10.50 mg/100 g of protein content; water absorption capacity, 62.90-72.30per cent ; dough development time, 1.50- 1.75 min; dough stability time, 7.50-12.00 min. Bread samples had sodium, 257.68-885.32 mg/100 g; calcium, 32.05-112.59 mg/100 g; potassium, 92.88-404.49 mg/100 g; iron, 0.32-4.14 mg/100 g. The bread loaf weights ranged from 550 to 600 g; loaf volume, 1229.01-1886.03 cm^3 and specific loaf volume, 2.08- 3.39 cm^3/g. There is no significant difference in the crust colour, crumb holes, stability, elasticity, firmness, shape regularity and appearance of the samples. No panelist showed a total dislike for the taste of any of the samples.

2.7 Introduction of millets in to Public distribution system:

A pilot study was conducted in Ananathpur, Andhra Pradesh to introduce millet in the public distribution system (Anon, 2010). Three decades back, 75 per cent of the cultivated land was under millet crops in Anantapur district. It was drastically reduced and reasons for fall in cultivation and consumption could be attributed to: More emphasis on rice for ensuring food security as part of Public Distribution System (PDS), The launching of Rs.2/ kg rice scheme in 1984 by the then Government of Andhra Pradesh, Centralized nature of the PDS design, Government support to groundnut crop in terms of subsidies. The easy availability of ready to cook, low cost rice influenced the consumption pattern in the rural areas. This in turn influenced the cropping pattern from millet based subsistence farming to groundnut based monocropping. Aim was to target of 10-20 per cent of the food grains substituted with nutritious millets ragi and sadda (jowar) to ensure multifarious benefits. An intensive campaign to reach the people in all the 20 habitations was planned through various means. The assurance to the farmers of farm gate procurement and advance announcement of minimum support price resulted in farmers taking up cultivation of Ragi and Sadda in their irrigated fields. Production of Ragi increased 3 times in Gorantlavari palli and other nearby villages due to the assured market support for supplying to the PDS. Nearly 40 tons of ragi was procured from the farmers.

MATERIAL AND METHODS

The present investigation was undertaken during the year 2011-2013 in the Department of Food Science and Nutrition, College of Rural Home Science, University of Agricultural Sciences, Dharwad, Karnataka. The study was carried out to evaluate little millet varieties for nutritional and processing qualities, to study physico-chemical, processing and nutritional quality changes in little millet during storage and hydrothermal treatment and to develop value added products from little millet through different technologies. The flow diagram of research design is given in Fig 1.The material used and methodology employed in carrying out the study is described in this chapter.

3.1 Evaluation of little millet varieties

3.1.1 Procurement of the little millet varieties

The two local varieties namely *Malli savi* and *Kari savi* and three high yielding varieties namely Sukshema, JK-8 and CO(Sa)-4 were procured from the farmers of Timmapur, Haveri District grown during 2011-2012. They were then dehusked by conventional method in emery mill. Decorticated grains were separated from the husk through winnowing. The grains were packed in polythene bags stored for further study. All the estimations were carried out in triplicates.

3.1.2 Physical characteristics of little millet varieties

The various physical characteristics like thousand grain weight, thousand grain volume, bulk density, length, breadth and LB ratio was studied for both whole grains and decorticated grains using standardized methods. The methods are outlined below.

3.1.2.1 Thousand grain weight of whole and milled grains

Weight of randomly selected thousand grains was recorded in grams using electronic balance with a sensitivity of 0.01 mg (Mishra and Gupta, 1995).

3.1.2.2 Thousand grain volume whole and milled grains

Thousand randomly selected grains were dropped in a measuring cylinder containing known volume of distilled water. The difference in volume was recorded in ml (Mishra and Gupta, 1995).

3.1.2.3 Grain density

Grain density was calculated using the formula:

$$\text{Grain density} = \frac{\text{Grain weight (g)}}{\text{Grain volume (ml)}}$$

The Grain density was expressed as g per ml (Mishra and Gupta, 1995).

3.1.2.4 Length (mm), breadth (mm) and L/B ratio whole and milled grains

The average length and breadth of the randomly picked ten grains were measured in mm with a help of vernier calipers. The length/breadth ratio was obtained by dividing the length of a single grain by the corresponding breadth to determine the size and shape (Graham, 2002).

3.1.2.5 Hardness of the grains

Texture was analyzed by using texture analyzer (Instron model 4502). Textural analysis of control and treatment breads, as force required to compress 50% of the original height of the little millet grain of 2.0-mm thickness was done using Instron texture analyzer. The individual grains were tested under the compression mode 20 mm diameter compression probes. A crosshead speed of 1.5 mm/min was used to record the maximum force expressed as the hardness of the grains in Newtons (N). All textural measurements were done for 5 times.

3.1.2.6 Colour of the milled grains

Colour determinations were carried out for little millet grains using a Minolta colorimeter (Minolta CR- 400, Konica Minolta Sensing, Inc., Osaka, Japan), and results were expressed in accordance with the Hunter Lab colour scale. The parameters determined were L (L=0 [black] and L=100 [white]), a (−a=greenness and +a=redness), b (−b=blueness and +b=yellowness).

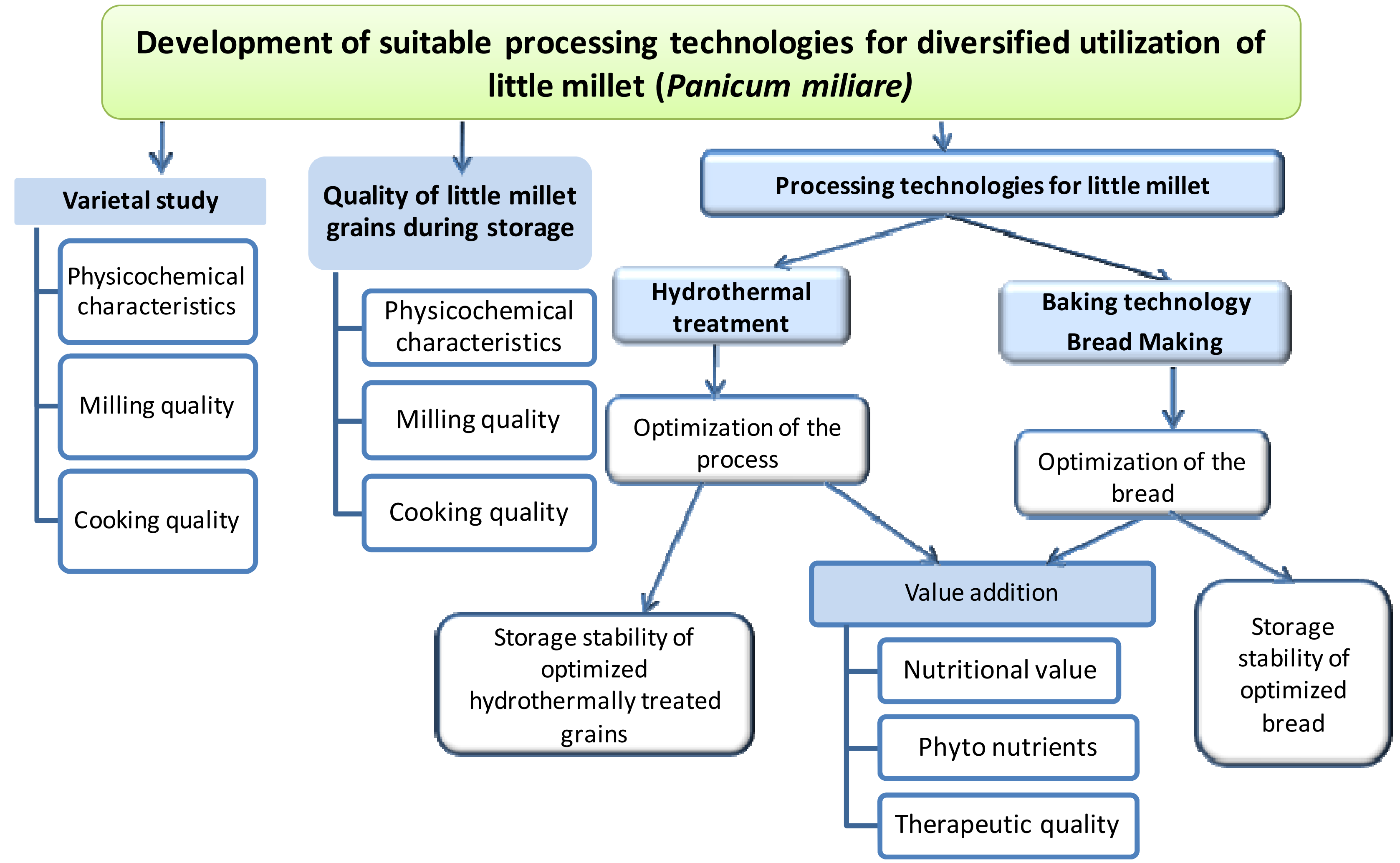


Fig. 1. Research design

3.1.3 Milling quality of little millet varieties

The three varieties namely *Malli savi* (local cultivar), Sukshema and JK-8 (high yielding varieties) were subjected to milling study.

3.1.3.1 Dehulling quality of little millet varieties

For each dehulling test samples (100 g each) were cleaned before passing through rubber roller mill (developed by McGill University, Canada and UAS Dharwad, India, IDRC millet project,). Hulled grains, unhulled grains and husk were separated and quantified.

3.1.3.2 Decortication of little millet varieties

Preliminary trials were conducted to optimize decortication of grains in laboratory scale rice polisher (Indosaw, limited, Oswa Industries, Ambala, Hyderabad). Then all the varieties were decorticated for 12 sec to remove bran. The head rice was separated from brokens and bran. The head rice yield (HRY) consisted of rice three-fourth in size to whole kernel. The per cent head rice yield calculated as whole milled grains respect to dehulled grains, the average value of triplicates was calculated. Per cent brokens were calculated as broken grains with size less than $3/4^{th}$ of the whole milled grains with respect to dehulled grains.

3.1.4 Chemical analysis

Preparation of sample

Decorticated little millet grains were powdered in a pestle and mortar to a fine particle size of 150 µm. Powdered samples were defatted before the analysis and were dried in a hot air oven at 60℃ powdered.

3.1.4.1 Proximate composition

3.1.4.1.1 Estimation of Moisture

Moisture was determined by taking about 10g of powdered sample in petri dish and dried in an oven at 105^0C till the weight of the petri dish with its content was constant. Each time before weighing, the petri dish was cooled in desiccators. Moisture content of the sample was expressed in g/100g of sample (Anon, 1995).

$$\text{Moisture content (\%)} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Weight of the sample}} \times 100$$

3.1.4.1.2 Estimation of Protein

For the digestion of samples the Kelplus- Classic Dx(Pelican equipments) digestion unit was used. The distillation was carried out in Kelplus- Classic Dx(Pelican equipments) automatically. The protein content of the dried sample was estimated as per cent total nitrogen by the Micro-kjeldahl method (Anon, 1995). Detailed procedure is given in Appendix I.

3.1.4.1.3 Estimation of Fat

Fat was estimated as crude ether extract of the dry material. The dry sample (5g) was weighed accurately into a thimble and plugged with cotton. The thimble was then placed in a soxhlet apparatus and extracted with anhydrous ether for about 3h. The ether was then evaporated and the flask with the residue dried in an oven at 80-100° C, cooled in a dessicator and weighed (Anon, 1995) (Appendix II).

3.1.4.1.4 Estimation of crude fibre

Fat free sample was hydrolyzed with acid and subsequently with alkali and the residue obtained after final filtration was weighed, incinerated, cooled and weighed again. The loss in weight is the crude fibre content (Sadashivam and Manikam, 2008) (Appendix III).

3.1.4.1.5 Estimation of ash

Total ash was estimated by taking about 5g of the sample (fat free) into a crucible. The crucible was placed on a clay pipe triangle and heated followed by heating in a muffle furnace for about four to five hours at about 600ºC. It was then cooled and weighed. This was repeated till two consecutive weights were same and the ash was almost white or greyish white in colour.

3.1.4.6 Carbohydrate by difference method

The carbohydrate content was calculated by deducting the sum of the value of moisture, protein, fat, ash and crude fiber from 100.

3.1.4.2 Estimation of total phenols by Folin Ciocalteau Reagent

Powdered samples were defatted before the analysis and were dried in a hot air oven at 60℃. Total phenol estimation was carried out with the Folin-Ciocalteau reagent. Phenols react with phosphomolybdic acid in Folin-Ciocalteau reagent in alkaline medium and produce blue coloured complex (molybdenum blue) (Sadashivam and Manikam, 2008) (Appendix IV).

3.1.4.3 Estimation of phytates

The estimation of phytic acid was based on the principle that the phytate is extracted with trichloroacetic acid and precipitated as ferric salt. The iron content of the precipitate was determined colorimetrically and the phytate phosphorous content calculated from this value assuming a constant Fe : 6 molecular ratios in the precipitate. Phytates were estimated as phytic and the phytate phosphorus was obtained (Sadashivam and Manikam, 2008) (Appendix V).

3.1.4.4 Micronutrients (mg/100g)

The trace elements (iron, zinc, copper and manganese) were estimated by wet digestion using triacid mixture. A known aliquot of test sample was suitably diluted and micronutrients in the test sample (Cu, Mn, Zn and Fe) were determined using Atomic Absorption Spectrophotometer (model :AAS GBS Avanta) (Appendix VI).

3.1.5 Cooking quality

3.1.5.1 Cooking time (minutes)

A known quantity of rice grains were dropped in boiling water and cooking time was noted by pressing the cooked grain between the glass slides and the time taken for disappearance of opaque core of millet rice grain was taken as cooking time.

3.1.5.2 Cooked weight and volume

A 5 g millet rice grains were taken and cooked in excess water for cooking time. The weight of cooked rice was recorded. Volume of cooked rice was measured in measuring cylinder.

3.1.5.3 Leached solids

Solid loss was determined by drying an aliquot of cooking water in a petri dish at 110℃ in a hot air oven until completely dried.

3.1.6 Organoleptic evaluation of little millet rice

Rice prepared by little millet varieties were evaluated for organoleptic characters like appearance colour, texture, taste/flavour and over all acceptability by scoring method using nine point hedonic scale by a panel of semi-trained judges(Appendix VII).

3.2 Quality changes in little millet during storage

3.2.1 Procurement of little millet grain

The local variety *Malli savi* was selected for the storage study. Immediately after harvesting of grains during the month of July 2011 were collected from farmer of Timmapur, Haveri District. The grains were de-stoned and cleaned. Each 2 kg of grains were packed in gunny bags and stored at room temperature for further study. The samples were removed randomly every six months up to 18 months and analyzed for processing, physical, chemical and nutritional qualities.

3.2.2 Physical characteristics

The grains were observed under compound microscope at every draw of the sample to observe any infestation. The procedures for the physical characteristics of stored little millet were followed as given in 3.1.2.

3. 2. 2.1 Particle size distribution

Hundred grams of stored decorticated grains at every draw was taken and passed through different meshes of BSS standards from 60, 100, 150, 200, 240 and 300 with sieve opening of 0.250, 0.152, 0.077, 0.066, 0.104, and 0.055mm respectively. The sample was passed from bigger to smaller mesh size. The sample above the sieve was weighed and recorded.

3.2.3 Milling quality

For each milling test samples (250g each) were taken. Dehulling quality was done as mentioned in 3.1.3.1 and decortication was done as mentioned in 3.1.3.2.

3.2.4 Chemical analysis of stored decorticated little millet grains

The procedures followed as given in 3.1.4.

3.2. 5 *In vitro* protein digestibility (IVPD)

The *in vitro* protein digestibility was determined by enzymatic method (Mouliswar *et al.*, 1993) (Appendix VIII).

3.2.6 *In vitro* starch digestibility (IVSD)

The *in vitro* starch digestibility was determined by enzymatic method (Mouliswar *et al.*, 1993) (Appendix IX).

3.2.7 Carbohydrate profile

3.2.7.1 Starch (%)

Starch content was estimated by anthrone reagent method. Starch was hydrolyzed into simple sugars by dilute acids and the quantity of simple sugars measured colorimetrically (Sadashivam and Manikam, 2008) (Appendix X).

3.2.7.2 Amylose content

Total amylose was estimated by following the method of Soubhagya and Bhattacharya (1979) 100 mg sample of was taken in a 100 ml volumetric flask, dispersed in 1 ml of alcohol followed by 10 ml of 1 N NaOH, left for overnight made the volume up to 100 ml from distilled water. From this extract 2.5 ml was taken, 20 ml of distilled water added and then added 3 drops of phenolphthalein indicator, which turned pink. Then added 0.1 N HCl, till it became colourless. Then added 1 ml of 0.2 per cent iodine solution. The purple-blue was read at 590 nm. Amylopectin was calculated by subtracting total amylose from 100.

3.2.2.3 Soluble amylose

Hundred miligram of sample, was dispersed in 50ml water was heated in a water bath for 20 minutes and filtered. The filtrate was estimated similar to total amylose.

$$\text{Soluble amylose content (\% dry bases)} = \frac{R}{A} \times \frac{a}{r} \times \frac{1\ \text{ml}}{5\ \text{ml}} \times 100 = \frac{R}{A} \times \frac{a}{r} \times 20$$

Where,

R – Reading of rice flour extract

A – Reducing of standard amylose solution

a – Amount of standard amylose weighed (mg)

r – Amount of rice powder weighed taken (mg)

3.2.2. 4. Dietary fiber content of stored decorticated grains

The soluble, insoluble and total dietary fiber fractions were analyzed by enzymatic method. Defatted foods were gelatinized, proteins and starch were removed by enzymatic digestion. The residue was filtered and washed and quantified gravimetrically for insoluble fiber.

The soluble fiber was estimated from the filtrate obtained after enzymatic digestion of protein and carbohydrate of defatted food which is precipitated and estimated gravimetrically (Anon, 1995) (Appendix XI). The soluble, insoluble and total dietary fiber content was calculated.

3. 2.5 Cooking quality

3.2.5.1 Cooking time (minutes)

The procedure followed as given in 3.1.6.1

3.2.5.2 Swelling power and per cent solubility

The swelling power and per cent solubility was determined according to the method used by Schoch (1964).

500 mg (W_1) of sample was added to a centrifuge tube, weight of centrifuge tube and test sample was noted (W_2). After addition of 20 ml (V_E) distilled water, the centrifuge tube was placed in the water bath at 100℃ for 20-30 min till the contents were cooked. Then it was centrifuged at 5000 rpm for 10 min. The supernatant was transferred to a test tube and the inner side of the centrifuge tube was dried well and weighed (W_3). The swelling of flour was calculated as follows.

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

For per cent solubility, weight of dried moisture dish was noted (W_4) and after pouring 10 ml aliquot (V_A) in a dish, dried at 110℃ for 4-5 h. The moisture dish was cooled and weighed (W_5).

$$\text{Solubility (\%)} = \frac{(W_5\text{-}W_4)\, V_E}{V_A} \times \frac{100}{W_1}$$

3.2.5. 3 Soluble protein

Soluble protein was estimated by Lowry's method (Sadashivam and Manikam 2008) (Appendix XII).

3.2.6 Sensory evaluation

Rice prepared by little millet drawn at six month interval was evaluated for organoleptic characters like appearance colour, texture, taste/flavour and over all acceptability by scoring method using nine point hedonic scale by a panel of 15 semi-trained judges (Appendix VII).

3.3 Hydrothermal treatment to little millet

3.3.1 Procurement of the sample

The local variety of little millet, *Malli savi* was procured from the farmer of Timmapur village, Karnataka. The grains were cleaned in destoner, packed in polythene bags and stored in ambient condition for further study.

3.3.2 Optimization of hydrothermal treatment

3.3.2.1 Soaking condition

Samples weighing 100 g of little millet whole grains were soaked in 3 volumes of hot water in precision hot water bath for 3 and 4 h for initial soaking temperatures of 60, 70 and 80 ℃ and then drained in colander. The soaked grain was cooled to room temperature.

3.3.2.2 Steaming Condition

The second step of the hydrothermal treatment was steaming to improve rice moisture and to gelatinize the starch. Steaming was done using an autoclave (Scientek Services, Bangalore) at 100° and 110° C for 15, 20 and 25 min.

3.3.2.3 Drying condition

The steamed little millet was dried on trays at 60℃ in drier for 8-10 h until they reach moisture content of 9 percent. After drying the samples were stored in airtight polythene bags for moisture equilibration and hardness stabilization.

Table 1: Hydrothermal treatments for little millet grains

Treatment	Experimental conditions			
	Soaking process		Steaming process	
	Initial temperature (℃)	Time (h)	Temperature (℃)	Time (min)
T_1	60	3	100	15
T_2	60	3	100	20
T_3	60	3	100	25
T_4	60	3	110	15
T_5	60	3	110	20
T_6	60	3	110	25
T_7	60	4	100	15
T_8	60	4	100	20
T_9	60	4	100	25
T_{10}	60	4	110	15
T_{11}	60	4	110	20
T_{12}	60	4	110	25
T_{13}	70	3	100	15
T_{14}	70	3	100	20
T_{15}	70	3	100	25
T_{16}	70	3	110	15
T_{17}	70	3	110	20
T_{18}	70	3	110	25
T_{19}	70	4	100	15
T_{20}	70	4	100	20
T_{21}	70	4	100	25
T_{22}	70	4	110	15
T_{23}	70	4	110	20
T_{24}	70	4	110	25
T_{25}	80	3	100	15
T_{26}	80	3	100	20
T_{27}	80	3	100	25
T_{28}	80	3	110	15
T_{29}	80	3	110	20
T_{30}	80	3	110	25
T_{31}	80	4	100	15
T_{32}	80	4	100	20
T_{33}	80	4	100	25
T_{34}	80	4	110	15
T_{35}	80	4	110	20
T_{36}	80	4	110	25

The effects of initial soaking temperature, soaking time and steaming condition on milling quality were investigated. Three initial soaking temperatures (60, 70, 80 °C), two soaking times (3 and 4h) , three steaming times (15, 20 and 25 min) and two steaming temperatures (100 and 110 °C) were evaluated. Hence, thirty six treatment combinations were tested as shown in Table 1.

3.3.3 Milling quality

After hydrothermal treatment the grains were passed through rubber roller mill (developed by McGill University, Canada and UAS Dharwad, India, IDRC millet project-2010-2013). Dehulled grains were subjected to polishing in laboratory scale rice polisher (Indosaw limited, Oswa Industries, Ambala Hyderabad) for 12 sec to remove 6 per cent bran. The head rice were separated from brokens and bran. The head rice yield consisted of rice three-fourth in size to whole kernel. The per cent head rice yield (HRY) calculated as whole milled grains respect to hulled grains, the average value of triplicates was calculated. Per cent brokens were calculated as broken grains with size less than $3/4^{th}$ of the whole milled grains with respect to hulled grains.

3.3.4 Cooking quality

3.3.4.1 Cooking time

The procedure followed was as given in 3.1.6.1

3.3.4.2 Leached solids

The procedure followed was as given in 3.1.6.3

3.3.4.3 Water uptake

Hydrothermally treated little millet rice was cooked in excess water. One gram rice was cooked with 20 ml of water in a 100 ml beaker placed on an electric heater. Samples were removed at cooking time to weigh and calculated by equation.

$$\text{Water uptake \%} = \frac{\text{Weight of cooked rice (g)}}{\text{Weight of raw rice (g)}}$$

3.3.4 Colour

Colour of the grains was tested in spectrophotometer (Premier color scan, color matching software version 7.5) and results were expressed in accordance with the Hunter Lab colour scale. The parameters determined were L (L=0 [black] and L=100 [white]), a (−a=greenness and +a=redness), b (−b=blueness and +b=yellowness). The instrument was calibrated with a standard white plate. Each measurement was replicated 5 times.

3.3.5 Consumer acceptability

A score card was prepared for consumer acceptability. Grains of all the treatments were subjected to consumer acceptability. The consumers were asked to evaluate the sample for the appearance on visual bases. Score card is given in Appendix XIII. The optimized hydrothermally treated grains were taken for the further study.

3.3.6 Chemical analysis of hydrothermally treated little millet grains

Optimized hydrothermally treated grains were analyzed for the nutrient composition and compared with non treated little millet grain.

3.3.6.1 Proximate composition

The procedures followed as given in 3.1.4.1.

3.3.6.2 Estimation of total phenols by Folin Ciocalteau Reagent

The procedure followed was as given in 3.1.4.1.

3.3.6.3 Estimation of phytates

The procedure followed was as given in 3.1.4.3.

3.3.6.4 Micronutrients (mg/100g)

The procedure followed was as given in 3.1.4.4.

3.3.7 Bioavailability minerals

Bioavailable iron and zinc were analyzed by the method of equilibrium dialysis (Miller *et al,* 1981). In brief the food samples were first subjected to stimulated gastrointestinal digestion by adjusting the pH to 2.0, followed by addition of pepsin (3 ml of 16% pepsin in 0.2M HCl) and incubation in a shaker water bath at 37 °C for 2 h. Then the digest was frozen for 90 min to stop the reaction. The frozen digest was thawed and an aliquot of the digest (20 ml) was tested for its titrable acidity by adding 5 ml of pancreatin-bile extract mixture (4g of pancreatin and 25 g bile extract in 1 L of 0.1 M $NaHCO_3$) against 0.2M NaOH until pH 7.5 was attained. The remaining digest was transferred into the dialysis tubes (molecular cut-off 10 kDa) and subjected to simulated intestinal digestion by placing the dialysis tubes in Erlenmeyer flasks containing 25 ml $NaHCO_3$ (equivalent to moles of NaOH determined by titrable acidity). The flasks along with the tubes were incubated in a shaker water bath at 37ºC for 30 min (until the pH of the solution in the flask changes to 5.0), and to the contents of the flask, pancreatin-bile extract mixture was added and shaken for another 2 h (until the pH reached 7.0). The dialysate from the tube was carefully transferred to graduated tube and the volume was measured and its zinc and iron, contents were estimated by Atomic Absorption Spectroscopic method.

3.3.8 Carbohydrate profile

The procedures followed were as given in 3.2.7

3.3. 9 *In vitro* protein digestibility (IVPD)

The procedure followed was as given in 3.2.5

3.3.10 *In vitro* starch digestibility (IVPD)

The procedure followed was as given in 3.2.6

3.3.10 Sensory evolution

Rice prepared by hydrothermally treated little millet was evaluated for organoleptic characters like appearance colour, texture, taste, flavour and over all acceptability with compare to raw little millet by scoring method using nine point hedonic scale by a panel of semi-trained judges. (Appendix XIV)

3.3.11 Sorption isotherm determination of hydrothermally treated grains

Saturated salt solutions (Table 2) were used to obtain different relative humidity (RH %) combinations of 11, 22, 32, 44, 56, 64, 75, 86 and 92 having water activity (a_w) values of 0.11, 0.22, 0.32, 0.44, 0.56, 0.64, 0.75, 0.86 and 0.92 respectively (Rockland 1960). All the chemicals used were analytical grade (AR). The saturated solutions were placed in different desiccators. Prior to keeping samples, samples were conditioned to 65 RH (%) at 27 °C. The initial moisture content (IMC) of the samples was determined in triplicate using gravimetric method. Five grams of hydrothermally treated little millet grain and untreated grains were taken petri plates and in duplicates exposed different RHs (%) which were built up in desiccators. The desiccators were kept at room temperature. Moisture sorption isotherms of little millet grains were determined gravimetrically in which weight was monitored continuously within a standard static system of thermally stabilized conditions. The samples were weighed periodically at every 2-3 days till they attained constant weight or onset of mould growth or which ever occurred earlier.

3.4 Hydrothermal and baking technology for development of therapeutic foods from little millet

To diversify the utilization of little millet value addition was done using hydrothermal and baking technology. The nutritional composition of hydrothermally treated grains per serving were computed and compared to raw little millet grains.

The breads were prepared with different proportion of little millet and per cent of millet incorporation was standardized.

Table 2 : Saturated salt solutions and their relative humidity

Salts	RH (%)
Lithium chloride (LiCl)	11
Potassium acetate (CH_3COOK)	22
Magnesium chloride ($MgCl_2$)	32
Potassium carbonate (K_2CO_3)	44
Sodium bromide (NaBr)	56
Sodium nitrate ($NaNO_2$)	64
Sodium chloride (NaCl)	75
Potassium chromate (K_2CrO_4)	86
Potassium nitrate (KNO_3)	92

3.4.1 Procurement of the ingredients

The study was conducted at McGill University, Macdonald Campus, Montreal Canada. Little millet grains were obtained from UAS Dharwad, India. The grains were milled to fine flour. Unbleached refined wheat flour, traditional yeast and all other ingredients were obtained from the local market.

3.4.2 Bread making

The standard bread recipe was collected from Bakery Unit, UAS, Dharwad and it was modified. Baking trials were carried out under laboratory conditions to optimize baking conditions prior to the actual experiments. The little millet breads were developed by replacing wheat flour by 10, 30 and 50 per cent. Bread recipe is given in Appendix XV.

3.4.3 Physical characteristics of breads

The bread loaves were packed in polyethylene bags and analyzed for physical dimensions.

3.4.3.1 Loaf weight

Bread loaves were weighed 20 min after baking, using a laboratory weighing scale and the readings recorded in grams.

3.4.3.2 Loaf volume

The loaf volume was determined using millet seed displacement method. Little millet grains were loaded into an empty box with calibrated mark until it reached the marked level and unloaded back. The bread sample was put into the box and the measured sorghum was loaded back again. The remaining sorghum grains left outside the box was measured using measuring cylinder and recorded as loaf volume in cm^3.

3.4.3.3 Height, Length and Breadth

Height, Length and Breadth of the bread loaves were measured by measuring scale.

3.4.3.4 Specific volume

Specific volume was calculated as volume to mass ratio (cm^3/g)

$$\text{Specific volume} = \frac{\text{Loaf volume (cm}^3\text{)}}{\text{Loaf weight (g)}}$$

3.4.3.5 Bread crumb texture

Texture was analyzed using texture analyzer (Instron model 4502). Textural analysis of control and treatment breads was studied as force required to compress 50 per cent of the original height of the bread slices of 25-mm in thickness. The individual bread slices were tested under the compression mode using 20mm diameter compression probe. A crosshead speed of 12.5 mm/min was used to record the maximum force expressed as the hardness of the bread in Newtons (N). All textural measurements were done in triplicates. Cohesiveness and adhesiveness were calculated using texture profile analysis graph. Cohesiveness is defined as "the ratio of the positive force area during the second compression portion to that during the first compression (Area2/Areal), excluding the areas under the decompression portion in each cycle". Adhesiveness is defined as "the negative force area for the first bite, representing the work necessary to pull the plunger away from the food sample".

3.4.3.6 Bread crumb and crust colour

Colour determinations were carried out on bread crumb and crust using a Minolta colorimeter (Minolta CR- 400, Konica Minolta Sensing, Inc., Osaka, Japan), and results were expressed in accordance with the Hunter Lab colour space. The parameters determined were L (L=0 [black] and L=100 [white]), a (−a=greenness and +a=redness), b (−b=blueness and +b=yellowness).

3.4.4 Sensory evaluation

Sensory evaluation to study appearance, crust color, crumb color, aroma, taste and overall acceptability was carried out the next day by a panel of 20 semi-trained judges on a 9-point hedonic scale (Appendix XVI).

3.4.5 Chemical composition

Chemical composition of optimized little millet bread was analyzed and the values were compared to wheat bread.

3.4.5.1 Proximate composition

The procedures followed as given in 3.1.4.1.

3.4.5.2 Dietary fibre content

The procedures followed as given in 3.2.2. 4.

3.4.5.3 Micronutrients (mg/100g)

The procedure followed was as given in 3.1.4.4.

3.4.6 Bioavailability minerals

The procedure followed was as given in 3.5.7.

3.4.7 Storage quality of little millet incorporated bread

The breads were stored in polythene covers, drawn every day and evaluated for moisture content, free fatty acid content and subjected to sensory analysis until mold growth was observed. The procedures are given below.

3.4.7.1 Moisture content

The procedure followed as given in 3.1.4.1.1

3.4.7.1 Free fatty acid content

Free fatty acids were estimated by using standard procedure given by Sadashivam and Manikam (2008). The detailed procedure given in Appendix XVII.

3.4.7.2 Sensory evaluation

The score card was developed. Little millet incorporated bread with compared to wheat bread was evaluated for organoleptic characters like appearance colour, texture, taste, flavour and over all acceptability by scoring method using nine point hedonic scale by a panel of 15 semi-trained judges (Appendix XVIII).

3.4.8 Nutrient composition of the bread per serving (50 g)

According to Food and Drug Administration (FDA) serving size of bread is 50 g. The nutrient composition of millet bread per serving was computed and compared to wheat bread.

3.5 Statistical analysis

Analysis of variance (ANOVA) was applied to test the difference in processing and nutritional changes during storage and hydrothermal treatment. One way ANOVA was applied to test the significance of organoleptic characters of value added products. 't' test was applied to test significance between nutritional quality optimized food products. Critical difference (CD) was used to test the significance between the samples. All the analysis were done using SPSS software (version 16.0).

EXPERIMENTAL RESULTS

India is the largest producer of small millets which are often referred to as coarse cereals. Because of their nutritional superiority they also referred as 'nutritious grains' or nutri millets. Little millet (*Panicum miliare*) is one of the coarse cereals consumed in the form of rice. There is traditional practice to use it as fasting food in most of the northern states of India. In the present study little millet varieties were evaluated for nutritional and processing qualities, studied physico-chemical, processing and nutritional quality changes in little millet during storage and hydrothermal treatment and developed value added products from little millet through different technologies. In the present chapter, the research findings have been presented after subjecting the data to appropriate statistical analysis.

4.1 Evaluation of little millet varieties

4.1.1 Physical characteristics

Physical characteristics of whole little millet grains are presented in Table 3. The whole little millet grains were olive green to blackish green in color (Plate 1). The grains were spherical to oval in shape.

4.1.1.1 Length and breadth

The length and breadth of the whole little millet grains was ranged from 2.30 to 2.50mm and 1.43 to 1.63 mm respectively. It was found that Sukshema and *Malli savi* grains were longer and JK-8 and *Kari savi* were shorter in length. There was significant difference ($p > 0.05$) observed for length of whole grains. Sukshema had higher breadth and *Kari savi* had lower breadth. However there was no significance ($p > 0.05$) observed for breadth. L/B ratio of whole little millet grains ranged from 1.41 to 1.60. *Kari savi* had higher and CO(Sa)-4 had lower L/B ratio. Significance difference was observed for ($p > 0.05$) L/B ratio.

4.1.1.2 Thousand grain weight and volume

Thousand grain weight and volume were recorded for whole grains and results are presented in Table 3. The mean thousand grain weight of whole grain was 2.53g. The thousand grain weight was ranged from 2.04 to 2.97 g. The volume of thousand grains ranged from 1.35 to 2.13 ml for whole grains. The *Malli savi* variety was having higher thousand grain weight and volume for whole grains where as *Kari savi* was having lower weight and volume. The bulk density of whole grain ranged from 1.39 to 1.64. Higher density(g/ml) was found for CO(Sa)-4 variety and least was found for *Malli savi* (Table 3).

4.1.2 Milling quality

Malli savi, Sukshema and CO(Sa)-4 varieties were studied for the milling quality. The results of de-hulling quality are presented in the Table 4. The mean hulled grain was 78.89 per cent and the husk ranged from 15.00 to16.33 per cent. Unhulled grains ranged from 4.00 to 6.30 per cent. There was significant difference ($p \geq 0.05$) observed for the hulled grains. The husk found to be high in Sukshema and CO(Sa)-4 (16.33%) and found to be low in local cultivar *Malli savi*.

The decortication results are presented in Table 5. Head rice yield ranged from 81.33 to 84.19 per cent, where *Malli savi* variety had higher head rice (84.19), higher bran percentage (5.81%), lesser broken percentage (9.86 %). Sukshema was found to have lower head rice yield. However there was no significant difference ($p \geq 0.05$) found for head rice yield. The broken grains ranged from 9.86 to 12.89 per cent. The maximum per cent of brokens (9.86 %) were found in Sukshema variety. There was significant difference ($p \geq 0.05$) observed for brokens. The bran per cent ranged from 5.54 to 5.81. The mean bran yield was 5.69 per cent. The bran was found to be high in *Malli savi* (5.81%) and low in CO(Sa)-4 (5.54 %). However there was no significant difference ($p \geq 0.05$) found for bran per cent.

4.1.3 Physical characteristics of decorticated little millet grains

Physical characteristics of decorticated little millet grains are presented in Table 6. The decorticated grains were creamy white to off white color. The grains were spherical to oval in shape (Plate 2).

Table 3: Physical characteristics of little millet varieties

Varieties	Length (L)(mm)	Breadth (B) (mm)	L/B ratio	1000 kernel Weight (g)	1000 kernel Volume (ml)	1000 kernel Density (g/ml)
Malli savi	2.42^{a}	1.60a	1.51^{b}	2.97^{a}	2.13^{a}	1.39^{c}
Kari savi	2.30^{b}	1.43^{b}	1.60^{a}	2.04^{d}	1.35^{d}	1.51^{b}
Sukshema	2.48^{a}	1.63^{a}	1.52^{b}	2.88^{b}	1.83^{b}	1.57^{a}
CO(Sa)-4	2.28^{b}	1.62^{a}	1.41^{c}	2.63^{b}	1.60^{c}	1.64^{a}
JK-8	2.47^{a}	1.62^{a}	1.53^{b}	2.14^{c}	1.40^{d}	1.52^{b}
SEm±	0.03	0.07	0.05	0.61	0.05	0.56
CD	0.08*	NS	0.11*	0.32*	0.21*	0.09*

*significant at 5% level NS- non significant

Values with the same letters in the same column are not significantly different

Table 4 : De-hulling of little millet varieties (%)

Varieties	Hulled grains	Husk	Unhulled grains
Malli savi	78.70^{a}	15.00^{b}	6.30^{a}
Sukshema	78.30^{a}	16.33^{a}	5.33^{b}
CO(Sa)4	79.67^{a}	16.33^{a}	4.00^{c}
SEm±	3.06	0.66	0.56
CD	NS	0.08*	0.83*

*significant at 5% level NS- non significant

Values with the same letters in the same column are not significantly different

Table 5: Decortication of little millet varieties (%)

Varieties	Head rice yield	Broken grains	Bran
Malli savi	84.19^{a}	9.86^{b}	5.81^{a}
Sukshema	81.33^{a}	12.89^{a}	5.73^{a}
CO(Sa)-4	82.40^{a}	12.15^{a}	5.54^{a}
SEm±	3.03	4.73	2.30
CD	NS	1.23*	NS

*significant at 5% level NS- non significant

Values with the same letters in the same column are not significantly different

Malli Savi

Kari Savi

JK-8

Sukshema

Co(Sa)-4

Pate 1 . Local and high yielding varieties of little millet

Malli Savi

Kari Savi

JK-8

Sukshema

Co(Sa)-4

Plate 2. Decorticated little millet varieties

Table 6: Physical characteristics of decorticated little millet varieties

Varieties	Length (L) (mm)	Breadth (B) (mm)	L/B ratio	1000 kernel		
				Weight (g)	Volume (ml)	Density (g/ml)
Malli savi	1.55[a]	1.80[a]	1.16[ab]	2.17[a]	1.70[a]	1.27[b]
Kari savi	1.36[b]	1.65[b]	1.22[a]	1.50[c]	1.10[c]	1.36[a]
Sukshema	1.55[a]	1.72[ab]	1.11[b]	2.19[a]	1.67[a]	1.32[ab]
CO(Sa)-4	1.56[a]	1.78[a]	1.14[ab]	2.07[b]	1.50[b]	1.38[a]
JK-8	1.53[a]	1.78[a]	1.17[ab]	2.06[b]	1.47[b]	1.40[a]
SEm±	0.04	0.06	0.07	0.65	0.61	0.45
CD	0.06*	NS	NS	0.07	0.08*	0.05*

*significant at 5% level   NS- non significant
Values with the same letters in the same column are not significantly different

Table 7: Nutrient composition of little millet grains (g/100g)

Varieties	Moisture	Protein	Fat	Ash	Crude fibre	Carbohydrate
Malli savi	9.61[a]	8.58[a]	3.32[c]	2.30[bc]	3.50[a]	72.69[b]
Kari savi	9.38[ab]	7.97[d]	4.25[a]	1.87[d]	2.80[b]	73.97[a]
Sukshema	9.51[ab]	7.66[c]	4.46[a]	2.62[a]	3.40[a]	72.35[ab]
CO(Sa)-4	8.83[c]	7.77[c]	3.63[b]	2.18[c]	3.40[a]	74.17[a]
JK-8	9.28[b]	8.31[b]	3.50b[c]	2.43[ab]	3.50[a]	72.93[ab]
SEm±	0.23	0.82	0.37	0.09	0.004	0.076
CD	0.45*	0.20*	0.68*	0.17*	0.12*	1.2*

*significant at 5% level
Values with the same letters in the same column are not significantly different

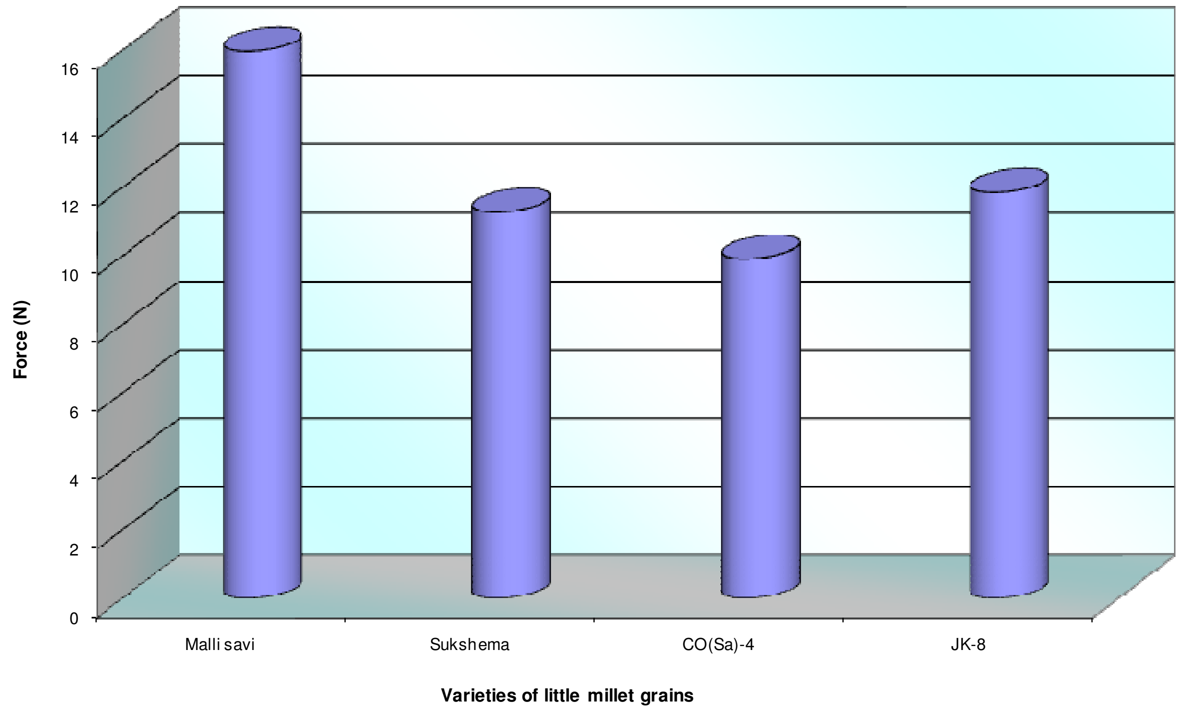


Fig. 2. Hardnes of the decorticated little millet varieties

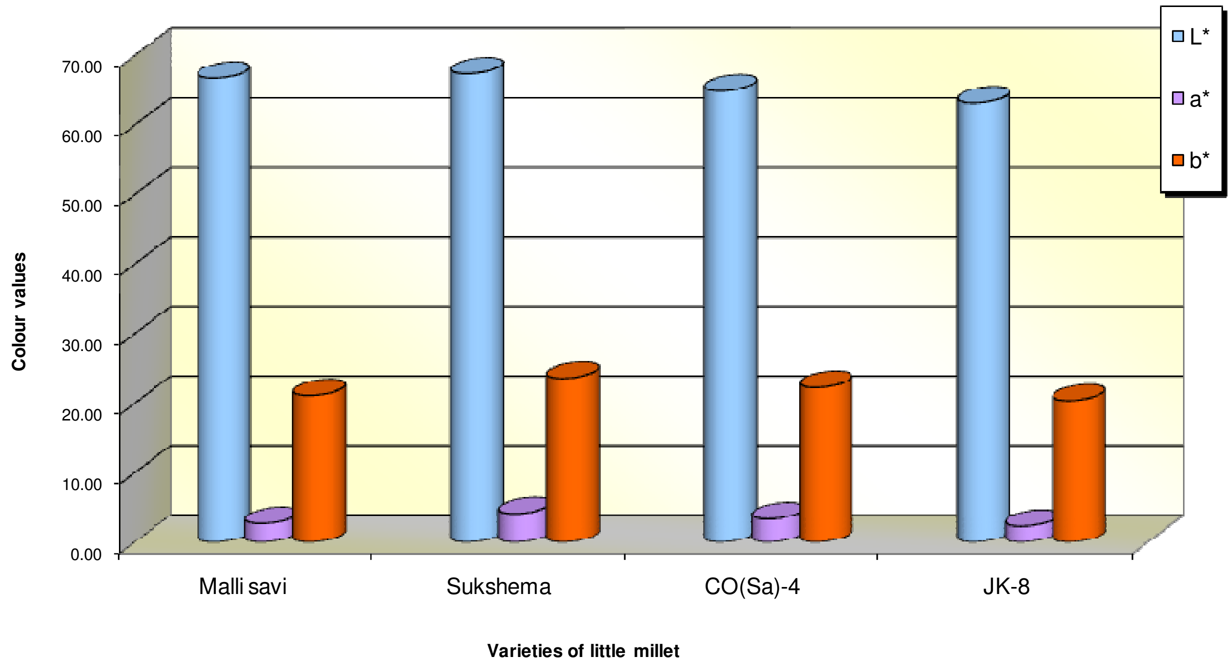


Fig. 3. Colour values for the decorticated little millet varieties

Fig 3. Colour values for the decorticated little millet varieties

4.1.3.1 Length and breadth

The length and breadth of decorticated little millet grains ranged from 1.65 to 1.80 mm, 1.36 to 1.56 mm respectively. It was found that Sukshema and *Malli savi* grains were longer and JK-8 and *Kari savi* were shorter in length. There was no significant difference (p>0.05) for breadth and L/B ratio. The L/B ratio ranged from 1.11 to 1.22. *Kari savi* had higher L/B ratio and Sukshema had lower L/B ratio. *Malli savi* variety was broader in size compared to other varieties (Table 6). Significant difference (p>0.05) observed for length.

4.1.3.2 Thousand grain weight and volume

Thousand grain weight and volume were recorded for decorticated grains and results are presented in Table 6. The mean thousand grain weight was 2.00g. The thousand grain weight and volume ranged from 1.50 to 2.17g and 1.10 to 1.70 ml respectively. *Malli savi* variety had higher thousand grain weight (2.19g) and volume (1.70 ml). *Kari savi* had lower weight and volume. The bulk density of decorticated grains ranged from 1.27 to 1.40g/ml. Higher density was observed for JK-8 and lower density was observed for *Malli savi*. Significant difference (p>0.05) observed for thousand grain weight, volume and density.

4.1.3.3 Hardness and colour

Hardness of the grains was significantly different (p>0.05) between the varieties. Hardness of grains ranged from 9.91 to 15.97 N (Fig. 2). *Malli savi* was the hardest (15.97N) followed by JK-8 (11.85N). CO(Sa)-4 had lower hardness value.

'L' value for the millet grains ranged from 63.21 to 67.38 (Fig. 3). Sukshema variety had highest 'L' value and JK-8 had least values. Maximum of 4.09 and 23.57 and minimum of 2.30 and 20.40 of 'a' and 'b' values recorded for the varieties respectively. Sukshema variety was high in 'a' and 'b' value and JK-8 variety was found to be low in 'a' and 'b' value. There was significant difference (p≥ 0.05) among the varieties for colour values. Sukshema and *Malli savi* variety of little millet grains were lighter in color compared to other varieties.

4.1.4 Chemical composition

4.1.4.1 Proximate composition

The proximate composition of little millet varieties is presented in Table 7. The moisture content ranged from 7.83 to 8.61 per cent. The moisture content was high in *Malli savi* variety (8.61%) followed by Sukshema and *Kari savi* and low in CO(Sa)-4 variety. The protein content ranged from 7.66 to 8.58 per cent. Protein content was found to be high in *Malli savi* variety and found to be low in Sukshema. The fat content in millet varieties ranged from 3.32 to 4.46 per cent. The highest fat was found in Sukshema variety followed by *Kari savi* and lowest was found in *Malli savi.* There was significant difference observed in fat content.

The crude fiber content ranged from 2.80 to 3.50 per cent. The *Kari savi* had low crude fiber compared to all other varieties. The carbohydrate content ranged from 72.35 to 73.97 per cent. The carbohydrate was found to be high in *Kari savi* and low in Sukshema. Ash content ranged from1.87 per cent in *Kari savi* to 2.62 per cent in Sukshema variety. The highest ash content was observed in Sukshema variety. There was significant difference (p>0.05) between all the little millet varieties with regard to proximate principles (moisture, fat, ash, protein and crude fiber) except for the carbohydrate content.

4.1.4.2 Phyto-nutrient composition

The phyto nutrients like phytic acid and total phenols were analyzed and results are presented in Table 8. The total phenol content in the millet varieties ranged from 90.90 to 94.50 mg/100. The Sukshema variety was found to be high in phenol content and JK-8 was found to be low in phenol content. Local cultivar *Malli savi* contained 93.60 mg/100g of phenols. The phytic acid content ranged from 2.74 to 5.09 g/100g. The highest phytic acid content was found in CO (Sa)-4 (5.09 g) and was low in *Malli savi (*2.74 g). There was significant difference (p>0.05) between all the varieties of little millet for total phenols and phytic acid.

Table 8: Phyto- nutrient composition of little millet grains

Varieties	Phytic acid (g/100g)	Phenols (mg/100g)
Malli savi	2.74^{d}	93.6^{a}
Kari savi	4.19^{b}	92.8^{b}
Sukshema	5.22^{a}	94.6^{a}
CO(Sa)-4	5.09^{a}	92.0^{b}
JK-8	3.15^{c}	90.9^{c}
SEm±	0.022	0.66
CD	0.86*	1.3*

*significant at 5% level
Values with the same letters in the same column are not significantly different

Table 9: Trace mineral content of little millet grains (mg/100g)

Varieties	Fe	Zn	Cu	Mn
Malli savi	8.91^{c}	1.66^{ab}	0.74^{ab}	1.24^{b}
Kari savi	7.96^{d}	1.76^{a}	0.67^{bc}	1.75^{a}
Sukshema	12.39^{a}	1.73^{a}	0.59^{c}	1.22^{b}
CO(Sa) -4	11.90^{b}	1.59^{b}	0.83^{a}	1.32^{b}
JK-8	7.20^{e}	1.34^{c}	0.44^{d}	1.22^{b}
SEm±	0.90	0.067	0.054	0.96
CD	0.06*	0.16*	0.06*	0.40*

*significant at 5% level   NS- non significant
Values with the same letters in the same column are not significantly different ($p>0.05$)

Table 10: Cooking quality characteristics of little millet varieties

Varieties	Cooking time(min)	Cooked weight (g)	Cooked volume (ml)	Leached out solids (%)
Malli savi	8.27^{b}	6.50^{a}	6.43^{a}	9.81^{c}
Kari savi	8.0^{b}	5.46^{b}	5.13^{c}	11.91^{a}
Sukshema	9.13^{a}	6.33^{a}	6.07^{ab}	9.51^{c}
CO(Sa)-4	7.1^{c}	6.17^{a}	5.83^{b}	10.36^{ab}
JK-8	7.37^{c}	5.54^{b}	5.20^{bc}	11.16^{ab}
SEm±	1.03	2.04	1.76	1.22
CD	0.87*	1.23*	0.98*	0.89*

*significant at 5% level
Values with the same letters in the same column are not significantly different (p>0.05)

Table 11: Mean sensory scores of the cooked little millet rice varieties

Varieties	Appearance	Texture	Colour	Flavour	Taste	Overall acceptability
Malli savi	6.7^{a}	6.7^{a}	6.9^{a}	7.1^{a}	7.0^{a}	6.8^{a}
Kari Savi	6.3^{a}	6.3^{a}	6.4^{a}	6.9^{a}	6.6^{a}	6.4^{a}
Sukshema	6.4^{a}	7.0^{a}	6.5^{a}	7.1^{a}	6.9^{a}	6.8^{a}
CO(Sa)-4	6.5^{a}	6.8^{a}	7.0^{a}	6.7^{a}	6.6^{a}	6.7^{a}
JK-8	6.2^{a}	6.4^{a}	6.7^{a}	6.4^{a}	6.8^{a}	6.5^{a}
SEm±	0.07	0.24	0.55	0.89	1.23	0.93
CD	NS	NS	NS	NS	NS	NS

NS- non significant at 5% level
Values with the same letters in the same column are not significantly different (p>0.05)

Plate 3. Storage of little millet grains at ambient temperature (25 ± 2.0º C)

Table 12: Physical characteristics of stored little millet grains

Storage duration (months)	1000 Kernel		
	Weight (g)	Volume(ml)	Density(g/ml)
0	2.70±0.01	1.77±0.03	1.52±0.01
6	2.60±0.05	1.62±0.02	1.60±0.02
12	2.58±0.06	1.62±0.03	1.59±0.03
18	2.56±0.02	1.55±0.13	1.69±0.06
SEm±	0.03	0.04	0.02
CD	0.09*	0.13*	NS

*significant at 5% level NS- non significant

Table 13: Changes in the quality de-hulling of stored little millet grains (%)

Storage duration (months)	Moisture Content	Hulled grains	Unhulled grains	Husk
0	10.66±0.08	81.47±0.61	2.44±0.20	15.94±0.19
6	9.63±0.30	81.00±0.26	2.20 ±0.12	16.40±0.40
12	9.43±0.04	80.80±0.63	2.10±0.18	16.45±0.20
18	8.39±0.18	80.27±0.23	2.03±0.06	16.60±0.13
SEm±	0.10	0.29	0.46	0.23
CD	0.69*	NS	0..14*	NS

*significant at 5% level NS- non significant

Table 14: Changes in decortication of stored little millet grains (%)

Storage duration (months)	Head rice yield	Brokens	Bran
0	71.20±0.54	16.48±0.55	11.71±0.43
6	74.42±0.41	14.23±0.54	11.17±0.34
12	77.75±0.34	12.51±0.36	9.84±0.12
18	79.11±0.39	11.98±0.19	9.14±0.46
SEm±	0.24	0.25	0.21
CD	1.06*	1.08*	0.98*

*significant at 5% level

4.1.4.3 Micronutrient composition

Micronutrient contents of little millet grains is presented in Table 9. There was significant difference ($p>0.05$) found between the micronutrient contents of the varieties. The iron content of the grains ranged from 7.20 to 12.39 mg/100. Zinc, copper and manganese content ranged from 1.34 - 1.76mg/100g, 0.44 - 0.83mg/100g and 1.22- 1.75 mg/100g respectively.

4.1.5 Cooking quality

Varietal difference in cooking quality of little millet rice is presented in Table 10. The cooking time in five varieties varied significantly ($p>0.05$) and it ranged from 7.10 to 9.13min. The maximum cooking time was observed in Sukshema (9.13min) followed by *Malli savi* variety (8.27min). Where minimum time was taken by CO(Sa)-4 (7.1min). The cooked weight ranged from 5.46 to 6.50g. *Malli savi* variety had higher cooked weight (6.50g). *Kari savi* had lower cooked weight. The cooked volume ranged from 5.13 to 6.43 ml. Per cent leached solids ranged from 9.51 to 11.91. There was no significant difference found for leached solids of the little millet varieties. *Kari savi* had higher per cent of leached solids.

4.1.6 Sensory evaluation

Scores for the sensory evaluation of cooked little millet rice for different varieties is presented in the Table 11. Appearance scores ranged from 6.20 to 6.70, texture scores ranged from 6.30 to 7.00, colour scores ranged from 6.40 to 7.00, flavor score ranged from 6.40 to 7.10 and taste scores ranged from 6.60 to 7.00. The scores for overall acceptability ranged from 6.40 to 6.80. There was no significant difference ($p>0.05$) in sensory characters in the five varieties of little millet cooked rice.

4.2 Changes during storage of little millet

Little millet grains were stored for 18 months in gunny bags (Plate 3). They were assessed for processing and nutritional quality at 6 months interval. The results are briefed below.

4.2.1 Physical properties of stored whole little millet grains

4.2.1.1 Thousand grain weight and volume of whole grains

At every drawn of the sample the grains were observed under microscope which revealed that there was no appearance of infestation as well microbial growth. Physical properties *viz.*, thousand grain weight, volume and density for the whole grains during storage are presented in Table 12. The thousand grain weight of stored grains ranged from 2.56 to 2.70 g with mean of 2.59 g. The thousand grain weight was high in fresh sample (2.70 g) and was low in 18 months stored sample (2.56 g). A significant decrease was observed for thousand grain weight during storage.

The thousand grain volume of stored grains ranged from 1.55 to 1.77 ml with mean of 1.61 ml. The thousand grain volume of fresh sample was 1.77 ml which was comparatively higher than other samples. The thousand grain volume was low in 18 months stored sample. The significant ($p\geq0.05$) decrease was observed for thousand grain volume during storage. A minimum of 1.52 g/ml and a maximum of 1.69g/ml of density were recorded for stored grains. The maximum density was observed for 18 months stored sample. A minimum density was recorded for fresh sample. However there was no significant difference between the mean values of density.

4.2.2 Moisture content of whole grains

The moisture content of whole grains is depicted in Table 13. Fresh little millet grains had 10.66 per cent of moisture. The moisture content decreased during storage period, it ranged from 8.39 to 10.66 per cent. The decrease of moisture content was significant ($p>0.05$) during storage.

4.2.3 De-hulling quality of stored little millet grains

De-hulling quality of stored little millet grains is presented in the Table 13. The per cent de-hulling of fresh sample was 81.47. The per cent hulled grains ranged from 80.27-81.47 during storage period of 18 months. The de-hulling percentage increased with storage.

The per cent of unhulled grains decreased from 2.03 to 2.44 during storage period. The per cent husk of fresh sample was15.94. The per cent recovery of husk was also increased from 15.94 – 16.80 during storage. However there was no significant difference observed for per cent recovery of hulled grains and unhulled grains

4.2.4 Decortication quality of stored little millet grains

The data of head rice yield, per cent brokens and bran recovery during storage is presented in Table 14. Initially Head rice yield (HRY) was 71.20 per cent with 16.48 per cent brokens and 11.71 per cent bran. The head rice yield ranged from 71.20-79.11 per cent during storage. HRY per cent increased as the storage period increased. HRY per cent was minimum at fresh and maximum for 18 months stored sample. There was significant ($p>0.05$) increase in HRY during storage.

The per cent brokens ranged from 11.98 to 16.48 and it was maximum for fresh sample and found to be minimum at 18 months stored sample. It decreased with storage period. The per cent bran ranged from 9.14 to 11.71. Bran content was high in fresh sample and found to be low in 18 months stored sample. Bran content decreased with increase in storage period. There was significant ($p>0.05$) decrease observed for per cent brokens and per cent bran during storage.

4.2.5 Physical characteristics of stored decorticated little millet grains

4.2.5.1 Thousand grain weight and volume of decorticated millet grains

Physical characteristics of milled grains during storage are presented in Table 15. A maximum of 2.16 and minimum of 2.08 for thousand grain weight was recorded. The maximum thousand grain weight was found in 6 months stored sample and minimum was found in 18 months stored sample. There was no significant difference ($p\geq 0.05$) found in the thousand grain weight. The thousand grain volume ranged from 1.58 to 1.63 ml. The highest volume was recorded for 6 months stored sample and lowest was observed for fresh sample. There was no significant difference ($p\geq 0.05$) observed for volume. Data on density revealed that the maximum density was found in fresh sample (1.34g/ml) and minimum was observed in 12 and 18 months samples (1.29g/ml). No significant difference ($p\geq 0.05$) was observed for the density.

4.2.5.2 Length. Breadth and L/B ratio of decorticated millet grains

The variations in the length, breadth and L/B ratio of decorticated little millet grains are presented in Table 15. The length of stored grains ranged from 1.62 to 1.73 mm. The maximum length was observed in fresh sample and minimum was observed in 18 months stored sample. A maximum breadth of 1.54 mm in fresh sample and minimum of 1.43 mm in 18 months stored sample was observed. During storage there was significant difference ($p\geq 0.05$) observed for length and breadth of sample. L/B ratio ranged from 1.13 to 1.15 mm. There was no significant difference observed for L/B ratio for stored samples.

4.2.6 Particle size distribution of decorticated stored little millet grains

Particle size distribution of decorticated stored little millet grains is presented in Table 16. Flour of stored decorticated grains was subjected to particle size analysis. Particle size distribution was more in the sieve opening of 0.077 mm. As the storage duration increased the flour particle size was bigger. The per cent particle size distribution was higher in the sieve opening of 0.150 mm.

4.2.7 Chemical composition

4.2.7.1 Proximate composition of decorticated stored little millet grains

Proximate composition of decorticated stored grains was studied and the data is presented in the Table 17. Moisture content of the fresh sample was 10.59 per cent. The moisture content of 6, 12 and 18 months was 9.50, 9.32 and 8.56 respectively. During storage the moisture content decreased to 8.56 per cent. The decrease was significant ($p\geq 0.05$) during storage periods.

The fat content of initial sample was 3.62 per cent. It ranged from 3.56 to 3.62 per cent. However there was no significant difference ($p\geq 0.05$) for fat content during storage.

The initial protein, ash, and crude fiber contents were 7.81, 1.97 and 2.37 g /100g respectively. The increase in all the nutrients was observed during storage. Carbohydrate content was ranged from 73.64 to 74.68 per cent. However the significant ($p\geq 0.05$) increase observed for protein content. There was no significant difference ($p\geq 0.05$) in carbohydrate ash and crude fiber content during storage period of 18 months.

4.2.7.2 Phyto-nutrient content of decorticated stored little millet grains

The change in phyto nutrient content of decorticated stored little millet is presented in the Table 18. Total phenol and phytic acid contents in the initial sample were 96.70 mg/100g and 3.05

Table 15: Changes in physical characteristics of stored decorticated little millet grains

Storage duration (months)	1000 kernel			Length (L) (mm)	Breadth (B) (mm)	LB ratio
	Weight (g)	Volume (ml)	Density (g/ml)			
0	2.13±0.02	1.58±0.03	1.34±0.01	1.73±0.07	1.54±0.05	1.13±0.04
6	2.16±0.01	1.63±0.01	1.29±0.03	1.70±0.06	1.48±0.05	1.15±0.05
12	2.09±0.02	1.62±0.03	1.30±0.03	1.65±0.07	1.45±0.04	1.14±0.06
18	2.08±0.03	1.61±0.01	1.29±0.02	1.62±0.07	1.43±0.04	1.14±0.06
SEm±	0.00	0.00	0.00	0.04	0.03	0.03
CD	NS	NS	NS	NS	NS	NS

NS- non significant

Table 16 : Changes in particle size distribution of flour of little millet grains (%) during storage.

BSS standards	Sieve opening (mm)	Storage duration(months)			
		0	6	12	18
60	0.250	14.28	19.11	21.17	17.62
100	0.150	27.92	23.11	28.62	54.34
150	0.104	14.65	13.93	21.11	21.70
200	0.077	34.14	33.01	26.66	4.92
240	0.066	6.35	6.12	2.16	1.24
300	0.055	2.66	4.71	0.29	0.19

Table 17: Changes in proximate composition of decorticated little millet grains (g/100g) during storage

Storage duration (months)	Moisture	Fat	Protein	Ash	Crude fiber	Carbohydrate
0	10.59±0.09	3.62±0.11	7.81±0.10	1.97±0.04	2.37±0.01	73.64±0.10
6	9.50±0.05	3.56±0.11	8.44±0.11	1.99±0.02	2.40±0.01	74.11±0.09
12	9.32±0.11	3.57±0.05	8.57±0.10	2.03±0.06	2.41±0.06	74.10±0.045
18	8.65±0.01	3.58±0.03	8.64±0.02	2.02±0.01	2.43±0.05	74.68±0.072
SEm±	0.04	0.05	0.19	0.02	0.02	0.45
CD	0.43*	NS	0.94*	NS	NS	NS

*significant at 5% level   NS- non significant

Table 18: Changes in phyto-nutrient content of stored decorticated little millet grains

Storage duration (months)	Total phenols (mg/100g)	Phytic acid (g/100g)
0	96.70±0.11	3.05±0.01
6	106.60±0.54	3.17±0.04
12	116.10±0.24	3.29±0.06
18	137.40±0.09	3.42±0.04
SEm±	21.80	0.03
CD	8.90*	0.35*

*significant at 5% level

g/100g respectively. The phenol content ranged from 96.70 to 137.40 mg/100 and phytic acid content ranged from 3.05 to 3.42 g/100g. The maximum phenols and phytic acid content were found in the 18 months stored sample and least values were observed in fresh sample. There was significant ($p \geq 0.05$) increase observed in both total phenols and phytic acid content during storage.

4.2.7.3 *In vitro* protein digestibility (IVPD) of decorticated stored little millet grains

Per cent *in vitro* protein digestibility (IVPD) is presented in Table 19. IVPD was ranged from 63.03 to 71.00 per cent. The highest value was found in the fresh sample (71.00%) and lowest was found in 18 months stored sample (63.03%). Significant ($p \geq 0.05$) decline was observed in IVPD during the storage.

4.2.7.4 *In vitro* starch digestibility (IVSD) of decorticated stored little millet grains

Data on *in vitro* starch digestibility (IVSD) is presented in Table 19. The maximum IVSD was observed in the fresh sample at all intervals (ranged from 61.57 to 94.44 mg glucose/g) and minimum was found in the 18 m stored sample (ranged from 63.03 to 74.86 mg glucose/g). During storage IVSD ranged from 51.28 to 83.81 mg glucose/g and minimum was observed for 18 months samples ranged from 63.03 to 74.86 mg glucose/g. The IVSD at 30 min, 60 min, 90 min and 120 min ranged from 51.58 - 61.57, 64.04 - 58.07, 77.37 – 63.23 and 93.78 – 74.86 mg glucose/g respectively. The maximum digestibility was observed at 120 min with respective of storage periods. There was significant ($p \geq 0.05$) decrease observed in IVSD during storage period at all the intervals

4.2.7.5 Carbohydrate composition of stored little millet grains

The carbohydrate composition is presented in Table 20. A minimum of 75.80 and maximum of 76.25 per cent of total starch was observed in the samples. There was no significant ($p \geq 0.05$) difference observed in the starch content during storage periods.

Amylose, amylopectin and soluble amylose content of decorticared stored little millet is presented in Table 20. Data revealed that amylose, amylopectin and soluble amylose ranged from 14.08 to 15.16 per cent, 84.84 to 85.92 per cent and 6.65 to 8.90 per cent respectively. A maximum amylose (15.16 %) was observed in the fresh sample and lowest (14.08 %) was observed in 18 months stored sample. There was significant ($p \geq 0.05$) decrease observed in amylose and soluble amylose content of the grains during storage.

4.2.7.6 Dietary fiber content

Per cent dietary fiber content of stored decorticated little millet grains was presented in the Table 21. A maximum soluble fiber (2.70%) was observed in fresh sample and a minimum was observed for 18 months stored sample (2.33%). Insoluble dietary fiber ranged from 5.45 to 6.05 per cent. Total dietary fiber content ranged from 8.15 to 8.43 per cent. Soluble dietary fiber decreased significantly during storage period but insoluble fiber and total dietary fiber increased during storage period. There was significant difference ($p \geq 0.05$) observed for soluble, insoluble and total dietary fiber.

4.2.8 Cooking quality of stored grains

Cooking quality of stored decorticated grains is presented in Table 22(Plate 4). A minimum of 8.34 min and maximum of 10.52 min of cooking time (Table 22) was recorded for storage samples. The maximum cooking time was observed in 18 months stored sample. There was significant ($p \geq 0.05$) increase in cooking time was observed as the storage period increased.

Data on swelling power, solubility and soluble proteins during storage are presented in the Table 22. Swelling power ranged from 6.80 to 7.66 per cent. The solubility index ranged from 12.57 to 15.10 and soluble protein ranged from 7.28 to 8.57 g/100g. There was significant ($p \geq 0.05$) decline observed in swelling power, solubility and soluble proteins during storage period. The maximum values observed for fresh and minimum for 18 months stored sample.

4.2.9 Sensory evaluation of little millet rice during storage

Sensory evaluation of cooked millet rice during storage was carried out. The data is presented in Table 23. As the storage period increased the rice was whiter and grainy in nature. At fresh the cooked millet rice was massy. Scores for the appearance, texture and overall acceptability ranged from 7.70 to 6.70, 6.30 to 7.50 and 6.80 to 7.60 respectively. Highest value was observed for 18 months stored sample and lowest was observed for the fresh sample.

Table 19: Changes in *in vitro* protein and starch digestibility of decorticated little millet grains during storage

Storage duration (months)	*In vitro* protein digestibility (%)	*In vitro* starch digestibility (mg glucose /min)			
		30 min	60 min	90 min	120 min
0	71.0±3.0	61.57±1.37	64.04±0.81	77.37±1.54	94.44±1.26
6	69.67±2.08	58.45±0.77	61.29±0.96	72.97±0.50	83.81±0.41
12	63.83±1.26	55.77±0.67	59.13±0.81	65.47±0.64	77.153±0.86
18	63.03±1.32	51.28±1.93	58.07±1.43	63.23±1.10	74.86±0.70
SEm±	1.16	0.64	0.57	0.52	1.11
CD	2.32*	1.72*	1.54*	1.54*	2.26*

*significant at 5% level NS- non significant

Table 20: Changes in carbohydrate composition of decorticated little millet grains during storage (%)

Storage duration (months)	Total starch	Amylose	Amylopectin	Soluble amylose
0	75.80±0.28	15.16±0.19	84.84±0.19	8.90±0.10
6	76.03±0.21	14.62±0.13	85.38±0.13	8.25±0.08
12	76.23±0.34	14.11±0.11	85.89±0.11	7.13±0.32
18	76.25±0.19	14.08±0.07	85.92±0.07	6.65±0.13
SEm±	0.13	0.24	0.24	0.11
CD	NS	1.05*	1.05*	0.70*

*significant at 5% level NS- non significant

Table 21: Changes in dietary fiber content of decorticated little millet grains (g/100g) during storage

Storage duration (months)	Soluble dietary fiber	Insoluble dietary fiber	Total dietary fiber
0	2.70±0.14	5.45±0.07	8.15±0.21
6	2.54±0.03	5.68±0.06	8.22±0.03
12	2.43±0.04	5.90±0.14	8.34±0.18
18	2.33±0.02	6.05±0.07	8.43±0.05
SEm±	0.03	0.03	0.05
CD	0.36*	0.38*	0.08*

*significant at 5% level   NS- non significant

Table 22: Changes in cooking quality characteristics of stored decorticated grains during storage

Storage duration (months)	Cooking time (min)	Swelling power (g/g)	Solubility (%)	Soluble proteins (%)
0	8.34±0.10	7.66±0.13	15.10±0.17	8.57±0.12
6	8.92±0.13	7.24±0.11	14.37±0.32	8.17±0.06
12	10.14±0.02	7.00±0.09	13.67±0.29	7.61±0.09
18	10.52±0.06	6.80±0.07	12.57±0.81	7.28±0.04
SEm±	0.05	0.06	0.27	0.47
CD	0.47*	0.52*	1.12*	1.23*

*significant at 5% level   NS- non significan

Fresh

18 months stored

Plate 4. Cooked little millet rice during storage

Table 23: Mean sensory scores of cooked little millet rice during storage

Storage duration (months)	Appearance	Texture	Colour	Flavour	Taste	Overall acceptability
0	6.7±0.47b	6.3±1.20b	7.0±0.88b	7.1±0.92a	6.9±1.14a	6.8±0.70a
6	6.3±1.24b	6.8±1.31ab	7.5±0.71ab	7.0±0.97a	6.9±0.94a	7.0±1.03ab
12	7.8±0.97a	7.5±1.16a	7.9±0.77a	7.1±1.14a	7.4±0.94a	7.5±1.02a
18	7.7±0.57a	7.5±0.71a	7.8±0.73a	7.2±0.94a	7.5±0.92a	7.6±0.70a
SEm±	0.51	0.64	0.44	0.57	0.57	0.51
CD	1.53*	1.72*	1.43*	1.62NS	1.62NS	1.53*

*significant at 5% level NS- non significant

Table 24 : Effect of hydrothermal treatment conditions on head rice yield and broken grains (%)

Treatment	Head rice yield	Broken
T_1	80.91	9.03
T_2	81.82	8.49
T_3	77.54	7.22
T_4	85.03	4.70
T_5	86.78	6.77
T_6	81.32	1.72
T_7	94.13	4.77
T_8	87.18	3.13
T_9	93.96	2.92
T_{10}	94.85	1.45
T_{11}	85.94	5.94
T_{12}	94.99	0.92
T_{13}	94.49	11.54
T_{14}	72.67	8.17
T_{15}	88.90	3.89
T_{16}	90.61	0.61
T_{17}	92.40	0.99
T_{18}	88.50	2.47
T_{19}	89.18	1.37
T_{20}	90.99	4.15
T_{21}	77.80	1.46
T_{22}	85.11	1.81
T_{23}	93.55	2.59
T_{24}	86.59	4.71
T_{25}	91.92	2.35
T_{26}	90.26	1.78
T_{27}	91.52	1.06
T_{28}	86.41	1.99
T_{29}	85.75	4.29
T_{30}	87.36	7.70
T_{31}	87.70	1.02
T_{32}	90.17	1.00
T_{33}	92.43	2.54
T_{34}	90.38	3.50
T_{35}	95.62	3.79
T_{36}	82.33	9.00
Untreated grains	75.30	13.31
SEm±	181.89	21.73
CD	5.33*	2.56*

*significant at 5% level

The scores for the colour ranged from 7.00 to 7.90. Scores for colour was maximum for 12 months stored sample and minimum was observed for fresh sample. The data revealed that there was significant difference ($p \geq 0.05$) observed in cooked millet rice for the characteristics like appearance, texture, colour, and overall acceptability. There was no significant difference ($p \geq 0.05$) observed for flavor and taste during storage.

4.3 Hydrothermal treatment of little millet

4.3.1 Optimization of hydrothermal treatment

Hydrothermal treatment for little millet was optimized by considering the milling quality, colour intensity, cooking quality and consumer acceptability. The results are presented below

4.3.1.1 Milling quality of hydrothermally treated little millet grains

4.3.1.1.1 Head rice yield

Table 24 presents the head rice yield and broken percentage of hydrothermally treated grains during milling. In this study the effects of three initial soaking temperatures of 60, 70 and 80º C for 3-4 h and various steaming time (15, 20 and 25 min) and steaming temperature (100 and 110 º C) on head rice was observed.

It was observed that the head rice yield varied from 72.67 per cent to 95.62 per cent for all the treatments. The head rice yield increased from 87.35 to 89.69 per cent with increase in soaking temperature from 60 to 80ºC. The head rice yield increased from 86.80 to 89.61 per cent with increase in soaking time of 3 to 4 h. The head rice yield increased from 87.42 to 88.98 per cent with increase in steaming temperature from 100 -110^0 C (Appendix XX). There was not much difference was observed in head rice yield with steaming time. At lower soaking temperature (60ºC) the results showed fluctuation in head rice yield. It showed that there was significant ($p \geq 0.05$) effect of treatments on head rice yield (Fig. 4).

4.3.1.1.2 Per cent broken

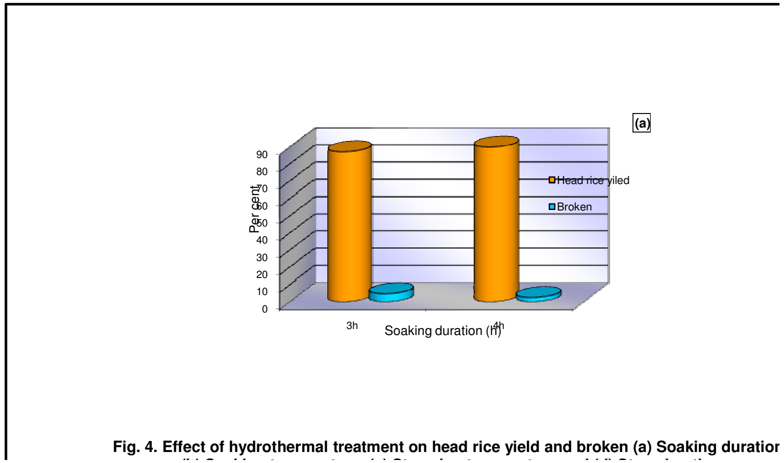
From the Table 24 it was observed that, the broken per cent ranged from 0.61 to 11.54 per cent. The broken per cent decreased from 4.71 to 3.12 with the increase in time of soaking (3- 4 h) and with increase in the soaking temperature the broken per cent decreased to 3.34 from 4.76. With increase in steaming temperature there was decrease in broken per cent from 4.22 to 3.61 per cent and with increase in steaming time there was decrease in broken per cent from 4.26 to 3.80(Fig. 4)(Appendix XXI). There was significant ($p \geq 0.05$) difference observed for the broken per cent with all the treatments.

4.3.1.2 Colour of the hydrothermally treated grains

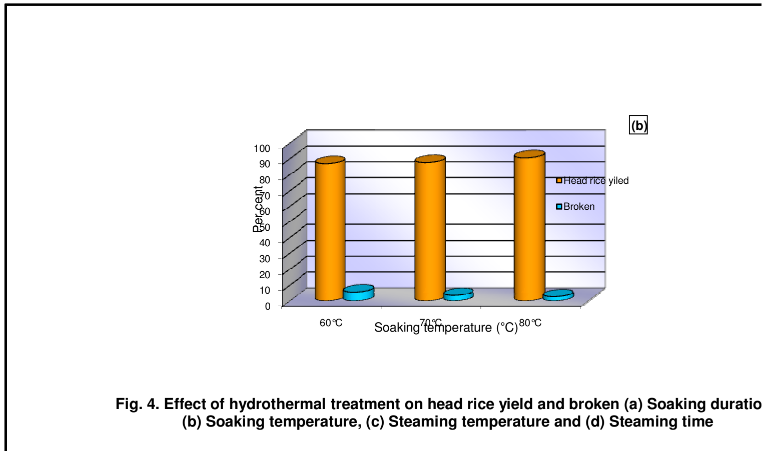
Table 25 show the effects of hydrothermal treatments on the colour value under different soaking and steaming conditions (Plate 5). The 'L' value of the grains decreased from 59.28 to 58.17 with the increase in soaking time. With increase in soaking temperature the whiteness decreased to 58.58 from 58.72 with increase in steaming temperature whiteness reduced to 56.63 from 60.81 (Appendix XXII). 'a' value of the colour ranged from 4.22 to 5.99. The 'a' value increased with severity of hydrothermal treatments. With increase in soaking temperature 'a' value increased from 4.84 to 5.28. With increase in steaming temperature 'a' value increased from 4.64 to 5.34. There was not much change observed with soaking time and steaming time for 'a' value (Appendix XXIII). Similarly the 'b' value ranged from 17.68 to 20.51. With severity of hydrothermal treatment the 'b' value increased from 19.44 to 19.62 with steaming time. 'b' value decreased with soaking temperature, steaming temperature and soaking time from 19.73 to 19.48, 19.84 to 19.08 and from 19.51 to 19.41 respectively(Appendix XXIV). There was lot of fluctuations observed during hydrothermal treatments for the colour values. It was found that there was significant ($p \geq 0.05$) effect of hydrothermal treatments on the 'L' 'a' & 'b' value of the colour.

4.3.1.3 Cooking quality of hydrothermally treated grains

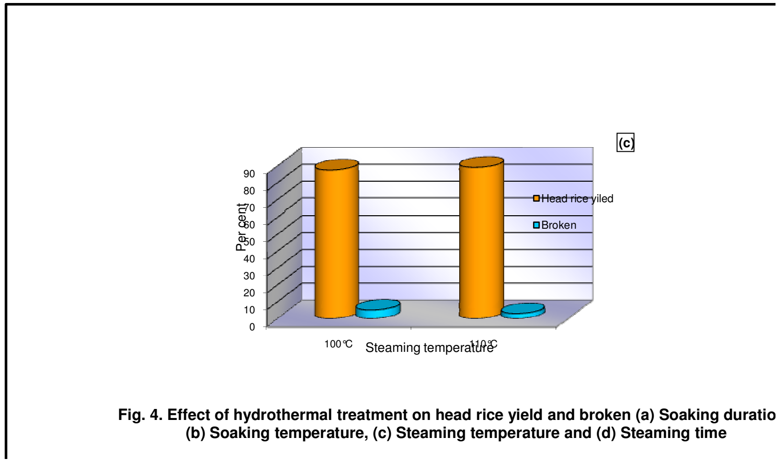
Table 26 shows the cooking quality of the hydrothermally treated grains varied from 15.00 to 28.73 min. There was significant ($p \geq 0.05$) increase observed with severity of hydrothermal treatment. With increase in soaking temperature from 60-80^0 C the cooking time increased from 15.41 to 24.40 min and with increase in soaking time cooking time increased to 20.82 from 19.09 min. With increase in steaming temperature cooking time increased from 18.55 to 21.36 min and with increase in steaming time it increased from 19.54 to 20.87 min (Appendix XXV). There were fluctuations observed between the treatments.



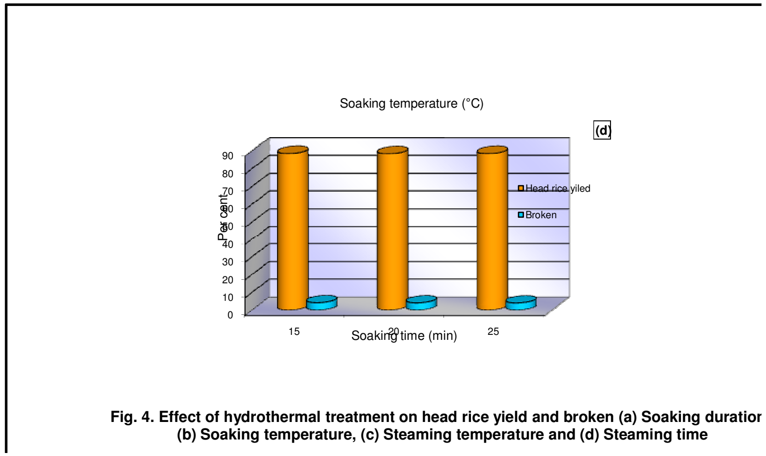
Soaking duration (h)



Soaking temperature (C)



Steaming temperature



Soaking time (min)

Fig 4. Effect of hydrothermal treatment on head rice yield and broken a) Soaking duration, b) Soaking temperature, c) Steaming temperature, and d) Steaming time.

Table 25: Effect of hydrothermal treatment conditions on color value

Treatment	L*	a*	b*
T_1	63.95	4.35	20.01
T_2	62.76	4.70	20.28
T_3	61.79	4.57	20.47
T_4	56.43	5.69	19.61
T_5	57.99	5.29	19.32
T_6	56.38	5.25	18.58
T_7	61.58	4.25	20.16
T_8	61.52	4.43	19.72
T_9	60.17	4.79	20.09
T_{10}	59.26	4.61	19.69
T_{11}	54.53	5.47	18.92
T_{12}	58.56	4.78	19.92
T_{13}	59.53	4.36	19.82
T_{14}	62.44	4.22	18.65
T_{15}	54.22	4.23	19.31
T_{16}	63.86	5.42	17.79
T_{17}	55.51	5.56	19.49
T_{18}	55.98	5.53	19.64
T_{19}	56.49	5.10	19.02
T_{20}	59.65	4.69	19.37
T_{21}	60.00	4.78	19.59
T_{22}	55.71	5.33	19.60
T_{23}	55.58	5.02	19.30
T_{24}	57.87	4.99	18.54
T_{25}	63.62	4.74	19.98
T_{26}	63.64	4.66	20.22
T_{27}	61.01	4.90	20.51
T_{28}	54.81	5.99	19.79
T_{29}	55.80	5.67	18.91
T_{30}	55.71	5.82	18.90
T_{31}	62.04	5.01	20.14
T_{32}	60.08	4.65	19.59
T_{33}	59.60	5.26	20.24
T_{34}	54.77	5.50	17.68
T_{35}	55.02	5.72	18.22
T_{36}	56.90	5.43	19.63
Untreated grains	72.25	3.18	17.87
SEm±	35.62	43.54	13.56
CD	2.12*	3.01*	1.98*

*significant at 5% level

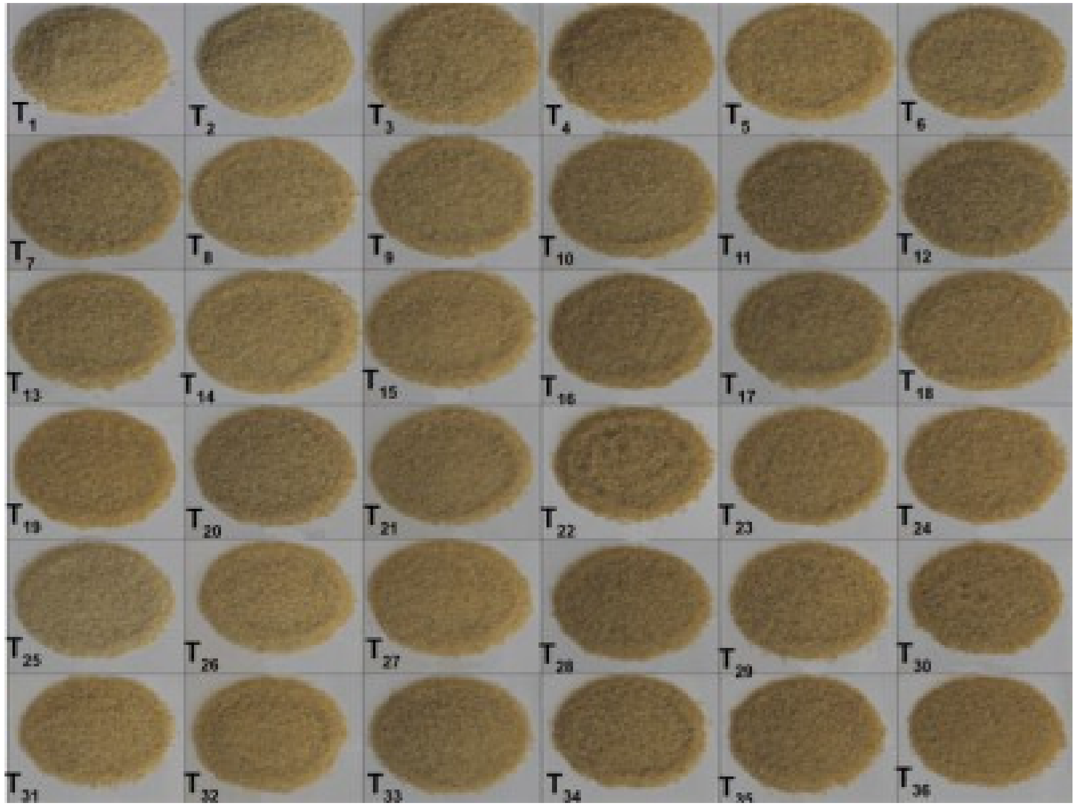


Plate 5. Hydrothermally treated little millet grains of different treatments

Table 26: Effect of hydrothermal treatment on cooking quality of little millet grains

Treatments	Cooking time	Leached out solids (%)	Water uptake(g/g)
T_1	15.47	11.20	4.77
T_2	14.77	10.67	4.70
T_3	16.10	10.10	5.18
T_4	15.13	7.27	3.92
T_5	16.20	6.60	4.01
T_6	15.00	6.53	4.75
T_7	15.00	7.50	5.13
T_8	15.16	8.43	5.42
T_9	15.78	9.33	5.59
T_{10}	15.34	8.07	4.77
T_{11}	15.32	6.37	4.81
T_{12}	15.65	6.90	4.94
T_{13}	15.65	10.67	5.45
T_{14}	16.33	10.80	5.55
T_{15}	17.10	9.93	5.61
T_{16}	18.40	6.03	3.62
T_{17}	19.67	4.90	4.31
T_{18}	23.17	4.77	4.49
T_{19}	17.63	9.17	4.32
T_{20}	18.27	9.63	4.68
T_{21}	19.10	9.97	4.99
T_{22}	24.10	8.90	3.28
T_{23}	25.67	7.03	3.67
T_{24}	26.67	5.77	4.24
T_{25}	23.30	11.13	4.13
T_{26}	23.83	11.70	4.14
T_{27}	23.15	9.77	4.90
T_{28}	22.20	8.40	4.96
T_{29}	23.23	6.43	5.36
T_{30}	25.96	5.20	5.25
T_{31}	22.58	11.67	4.48
T_{32}	19.32	11.53	4.57
T_{33}	24.35	10.33	4.66
T_{34}	28.73	7.13	3.61
T_{35}	27.56	5.40	3.84
T_{36}	28.21	4.83	4.10
Untreated grains	12.33	9.98	4.83
SEm±	68.64	34.76	22.54
CD	3.2*	3.24*	2.13*

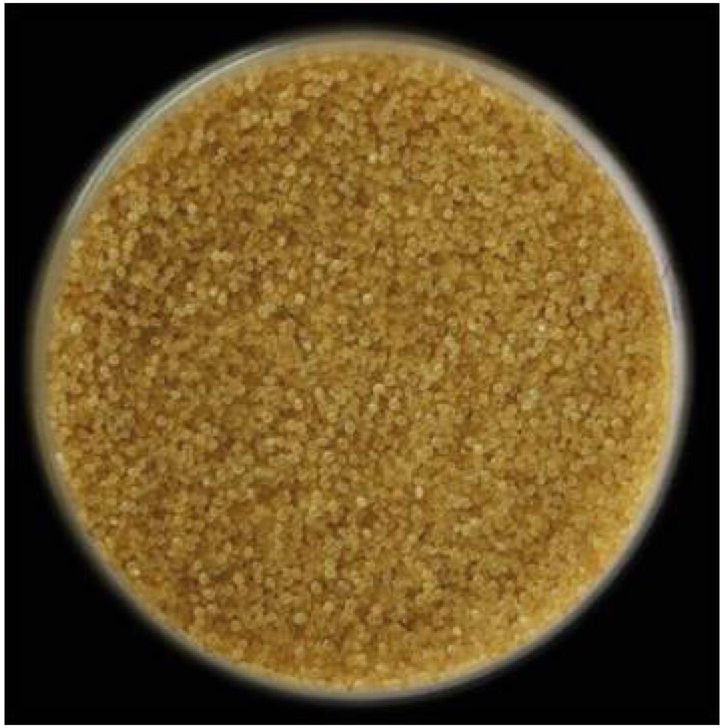
*significant at 5% level

Table 27: Consumer acceptability scores for hydrothermally treated grains

Treatment	Consumer acceptability scores
T_1	70
T_2	78
T_3	73
T_4	89
T_5	68
T_6	59
T_7	55
T_8	106
T_9	62
T_{10}	74
T_{11}	56
T_{12}	78
T_{13}	67
T_{14}	107
T_{15}	102
T_{16}	79
T_{17}	108
T_{18}	79
T_{19}	81
T_{20}	73
T_{21}	112
T_{22}	74
T_{23}	80
T_{24}	73
T_{25}	72
T_{26}	74
T_{27}	86
T_{28}	82
T_{29}	69
T_{30}	76
T_{31}	67
T_{32}	84
T_{33}	104
T_{34}	69
T_{35}	70
T_{36}	79
SEm±	64.86
CD	13.33*

*significant at 5% level

Raw little millet grains



Hydrothermally treated little millet grains

Plate 6. Optimized hydrothermally treated little millet grains in comparison to raw little millet grains

Table 28: Nutrient composition of hydrothermally treated little millet grains

Nutrients g/100	Raw little millet	Hydrothermally treated little millet	't'value
Moisture	9.32	9.43	NS
Protein	8.57	9.69	25.16*
Fat	3.57	3.35	NS
Ash	2.51	1.33	13.81*
Crude fiber	2.41	2.57	NS
Carbohydrate	74.1	73.41	4.41*

*significant at 5% level NS- non significant

Table 29: Phyto nutrient content of the hydrothermally treated little millet grains

Phyto nutrients	Raw little millet	Hydrothermally treated little millet	't'value
Total phenols (mg/100g)	116.10	239.40	25.33*
Phytic acid (g/100g)	3.29	4.25	15.70*

*significant at 5% level NS- non significant

Table 30: Trace mineral content of the hydrothermally treated little millet grains

Minerals (mg%)	Raw little millet	Hydrothermally treated little millet	't'value
Fe	8.91	7.47	18.49*
Zn	1.67	1.48	2.33*
Cu	0.75	0.15	9.39*
Mn	1.20	1.22	NS
Iron bioavailability (%)	5.05	12.45	79.77*
Zinc	13.17	25.00	84.79*

*significant at 5% level NS- non significant

Table 31 : Carbohydrate profile (%) and soluble protein (%) hydrothermally treated grains

Carbohydrates	Raw little millet	Hydrothermally treated little millet	‘t’value
Starch	76.03	73.45	16.21*
Amylose	14.62	14.95	8.67*
Amylopectin	85.38	85.05	8.67*
Total dietary fiber	8.34	11.4	47.15*
Insoluble dietary fiber	5.90	7.9	24.49*
Soluble dietary fiber	2.43	3.5	17.93*
Soluble amylose	7.20	6.90	2.89*
Soluble protein	7.62	7.40	3.01*

*significant at 5% level

Table 32: *In vitro* protein and carbohydrate digestibility of hydrothermally treated grains

Sample	*In vitro* protein digestibility (%)	*In vitro* starch digestibility (mg glucose /min)			
		30	60 min	90 min	120 min
Raw little millet	63.83	55.77	59.13	65.47	77.15
Hydrothermally treated little millet	62.20	49.50	51.28	56.04	68.78
‘t’value	NS	5.03*	0.40*	3.42*	2.31*

*significant at 5% level   NS- non significant

Table 33: Sensory evaluation of hydrothermally treated little millet rice grains

Sensory attributes	Raw millet rice	Hydrothermally treated millet rice	‘t’value
Appearance	7.80	8.10	NS
Texture	7.50	8.10	NS
Colour	7.90	8.00	NS
Flavour	7.10	7.90	0.076*
Taste	7.40	8.20	0.744*
Overall Acceptability	7.50	8.20	0.563*

*significant at 5% level   NS- non significant

Raw little millet grains

Hydrothermally treated little millet grains

Plate7. Cooked rice of hydrothermally treated millet rice in comparison to raw millet rice

The per cent leached solids ranged from 4.77 per cent to 11.70 per cent. The per cent leached out solids increased with increased in soaking temperature from 100 to 110^0 C and decreased with soaking time, steaming time and soaking temperature (Appendix XXVI).

Water uptake of different hydrothermal treatment ranged from 3.28 to 5.61 g/g. It decreased with severity of hydrothermal treatment. Water uptake of the grains at initial soaking temperature 60^{0}C was 4.43 decreased to 3.77 g/g at 80^{0}C. It was 4.69 g/g at 100^{0}C steaming temperature decreased to 3.53 g/g at 110 ^{0} C. With increase in steaming time 15 to 25 min the water uptake decreased from 4.20 to 3.99 g/g (Appendix XXVII). It was observed that hydrothermal treatments significantly ($p \geq 0.05$) affected the cooking quality.

4.3.1.4 Consumer acceptability of the hydrothermally treated grains

Consumer acceptability scores on the basis of colour and appearance are presented in the Table 27. The scores ranged from 55 to 112. The maximum score was for grains of treatment T_{21} (soaking at 70^0 C for 4 h and steaming for 100 °C for 25 min) and followed by grains of treatment T_{17} (soaking at 70^0 C for 3 h and steaming for 110 ° C for 20 min). The minimum score was for treatment T_7 (soaking at 70 ° C for 3 h and steaming for 100 ° C for 15 min). There was significant ($p \geq 0.05$) difference between the treatments.

From the above tables it was observed that hydrothermal treatments have significant effect on the quality of the grains. When the grains were subjected to consumer acceptability the four treatments (T_{21}, $T_{17,}$ T_{14} and T_8) got the highest scores. However there was no significant differences ($p > 0.05$) between the scores of these four treatments. When all other parameters considered the treatment with initial soaking temperature of 70^{0}C for 3 h and steaming at 110^0 C for 20 min was found to be optimum with 92.08 per cent head rice yield, 0.99 per cent broken, 17.66 min of cooking time, with 4.90 per cent leached solids and 3.30 g/g of water uptake (Plate 6). The treatment improved milling efficiency by increasing milling yield and reduced breakage.

4.3.2 Chemical composition of optimized hydrothermally treated little millet

4.3.2.1 Proximate composition

Nutrient composition of hydrothermally treated little millet compared to raw millet is present in Table 28. The moisture content of the hydrothermally treated grain was higher (9.43%) than the raw millet (9.32 %). However there was no significant difference ($p \geq 0.05$) between moisture content of the sample.

The protein content found to be high in the hydrothermally treated sample (9.69%) compared to raw millet (8.57%). There was significant difference ($p \geq 0.05$) in the protein content of the hydrothermally treated grains.

The fat content of hydrothermally treated grains (3.35%) was slightly decreased compare to raw grains (3.57%). The ash content decreased after hydrothermal treatment from 2.51 to 1.33 per cent. The crude fiber content of hydrothermally treated grains increased after hydrothermal treatment from 2.41 to 2.57 per cent. The carbohydrate content ranged from 72.41 to 74.1 per cent. However there was no significant difference ($p \geq 0.05$) found for fat and crude fiber content. But there was significant difference ($p \geq 0.05$) observed between the means for carbohydrate content.

4.3.2.2 Phyto nutrient composition

Phyto nutrient content of the hydrothermally treated grains is presented in the Table 29. The total phenols and phytic acid content increased after hydrothermal treatment. The phenol content increased from 116.10 to 239.40 mg/100g. The phytic acid content increased from 3.29 (raw grains) to 4.25 g/100g. There was a significant difference ($p \geq 0.05$) observed in the phyto nutrient content of the grains.

4.3.2.3 Mineral composition

Mineral composition of the hydrothermally treated grains is presented in Table 30. From the table it was observed that total mineral content reduced from 2.51 to 1.33 per cent. The iron and zinc content of hydrothermally treated grains decreased from 8.91 mg to 7.47 mg and 1.67 to 1.48 mg respectively. There was significant ($p \geq 0.05$) decrease observed for iron and zinc content. Magnesium content increased from 1.20 to 1.22 mg which was not significant. The copper content significantly decreased from 0.75 to 0.15 mg.

4.3.2.4 Per cent zinc and iron bioavailability

Per cent zinc and iron bioavailability was analyzed for hydrothermally treated grains and results are presented in Table 30. Per cent iron bioavailability increased after hydrothermal treatment from 5.05 to 12.45 and zinc bio availability increased from 13.17 to 25.00 per cent. There was significant ($p \geq 0.05$) increase observed for per cent iron and zinc bioavailability after hydrothermal treatment.

4.3.2.4 Carbohydrate profile

Carbohydrate profile of the hydrothermally treated grains is presented in the Table 31. The starch content of the hydrothermally treated grains decreased from 76.03 to 73.45 per cent. The amylose content of hydrothermally treated grains and raw grains was 14.95 and 14.62 per cent respectively. However there was slight increase in amylose content. The amylopection content decreased from 85.38 to 85.05 per cent. There was significant difference ($p \geq 0.05$) observed in starch content. But there was no significant difference ($p \geq 0.05$) observed in amylose and amylopectin content.

4.3.2.5 *In vitro* protein and carbohydrate digestibility

In vitro protein and carbohydrate digestibility is presented in Table 32. Protein digestibility after hydrothermal treatment decreased from 63.83 to 62.20 per cent. However there was no significant difference observed for protein digestibility. *In vitro* starch digestibility was higher in hydrothermally treated grains compared raw grains for 30, 60 and 90 min. It decreased from 55.77 to 49.50 mg glucose/min at 30 min, 59.13 to 51.28 at 60 min and 64.47 to 56.04 mg glucose/min for 90 min for hydrothermally treated grains. At 120 min starch digestibility was decreased from 77.15 to 68.78 mg glucose/min. Significant difference ($p \geq 0.05$) was observed *in vitro* starch digestibility.

4.3.3 Sensory evaluation

Sensory evaluation of hydrothermally treated little millet cooked rice is presented in Table 33 (Plate 7). From the table it is evident that hydrothermally treated millet scored higher scores compared to raw millet. Score for appearance for hydrothermally treated millet was 8.10, whereas for raw millet rice it was 7.80. The texture, colour, flavour and taste scores for hydrothermally treated millet rice was 8.10, 8.00, 7.90 and 8.20 respectively and for raw millet rice 7.50, 7.90, 7.10 and 7.40 respectively. The overall acceptability score for hydrothermally treated rice was 8.20 which was higher compared raw rice (7.50). There was no significant difference ($p \geq 0.05$) found for appearance, texture and colour. However, there was significant difference observed for flavour, taste and overall acceptability.

4.3.4 Sorption behavior of hydrothermally treated grains

The initial moisture content of hydrothermally treated grain and untreated grain was 8.55 and 8.43 per cent respectively. The sorption behaviour of the grains is presented in Fig. 5. It indicates that the moisture content decreased at lower RH (%) (11, 22 and 32). Above 44 RH (%) the moisture content started increasing. At 56 and 64 RH (%) the moisture content did not vary much it stayed almost constant. Above 75 RH (%) the moisture content started increasing rapidly. At 92 RH (%) the moisture content increased by 90 per cent. The time to reach equilibrium was about 20-25 days for the samples. At 92 RH (%) mold growth was detected by inspection at the end of 12th and 14th day in hydrothermally treated and untreated grains respectively. The critical moisture content was observed between 44 and 56 RH(%) for raw grains and between 56 and 64 RH (%) for hydrothermally treated grains. It indicates that hydrothermally treated grains can safely store below 64 RH (%). Table shows the equilibrium moisture content at different RH (%). The equilibrium moisture content ranged from 3.74 to 16.35 per cent and 3.67 and 18.15 per cent for raw and hydrothermally treated grains respectively. The equilibrium moisture content at particular RH is given in Table 34.

4.4 Hydrothermal and baking technology for development of therapeutic foods from little millet

4.4.1 Nutritional composition of hydrothermally treated little millet grain per serving (30 g)

Nutritional composition of hydrothermally treated little millet grain per serving (30 g) is given in Table 35. Hydrothermally treated grain provides 2.91g of protein, 1.01g of fat, 0.40g of ash, 0.77 g crude fiber, 22.02 g of carbohydrate and 109 Kcal of energy per serving (30g). The raw grains provides 2.57 g of protein, 1.07g of fat, 0.75 g of ash, 0.72 g of crude fiber, 22.23 g of carbohydrate and 109 Kcal of energy. Hydrothermally treated grains had more (3.42g) total dietary fiber than raw grains (2.50g). Soluble and insoluble dietary fiber were high (1.05 and 2.37g) in hydrothermally

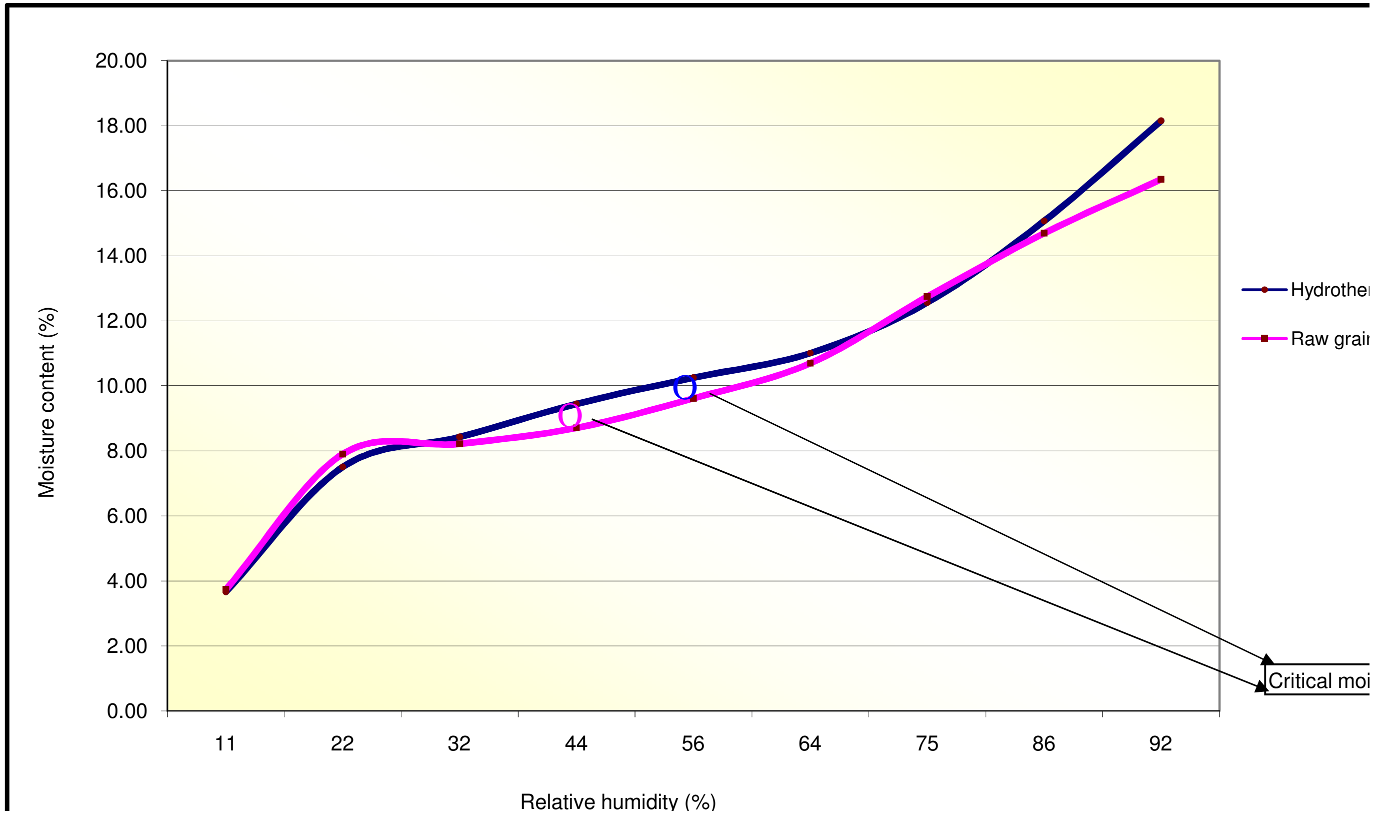


Fig 5. Moisture content of little millet grains at different relative humidity

Table 34: Equilibrium moisture content (%) of hydrothermally treated grains at different RH (%)

Relative humidity (%)	Raw grains	Hydrothermally treated grains
11	3.74	3.67
22	8.38	7.51
32	8.22	8.43
44	8.71	9.45
56	10.02	9.53
64	10.70	11.20
75	12.74	12.57
86	14.70	15.08
92	16.35	18.15

Table 35: Nutrient composition* of hydrothermally treated little millet grains (per serving, 30 g) for one serving

Nutrients /30g	Raw little millet	Hydrothermally treated little millet	% enhancement
Moisture (g)	2.80	2.83	1.07
Protein (g)	2.57	2.91	13.23
Fat (g)	1.07	1.01	-5.61
Ash (g)	0.75	0.40	-46.67
Crude fiber(g)	0.72	0.77	6.94
Carbohydrate(g)	22.23	22.02	-0.94
Energy Kcal	109	109	0.00
Starch(g)	22.81	22.04	-3.38
Total dietary fiber (g)	2.50	3.42	36.80
Insoluble dietary fiber (g)	1.77	2.37	33.90
Soluble dietary fiber (g)	0.73	1.05	43.84
Fe(mg)	2.67	2.24	-16.10
Zn(mg)	0.50	0.44	-12.00
Cu(mg)	0.23	0.05	-78.26
Mn(mg)	0.36	0.37	2.78
Iron bioavailability (%)	1.52	3.74	146.05
Zinc bioavailability (%)	3.95	7.50	89.87
Total phenols (mg/100g)	34.8	71.8	106.32
Phytic acid (g/100g)	0.99	1.28	29.29

*computed values

treated grains than raw grains (0.73 and 1.77g). The iron, zinc, copper and manganese contents of raw and hydrothermally treated little millet grains were 2.67 and 2.27 mg, 0.50 and 0.44 mg, 0.23 and 0.05 mg and 0.36 and 0.37 mg respectively. Even though the mineral contents are high in raw grains the per cent bio availability of zinc (7.50) and iron (3.74) were higher in hydrothermally treated grains. The phenol and phytic acid content in raw and hydrothermally treated grains were 34.80 and 71.58 mg and 0.99 and 1.28 g respectively.

4.4.2 Bread making

Bread was prepared by incorporating little millet from zero, 10, 30 and 50 per cent. The bread was evaluated for physical, nutritional and sensory quality. The results are presented below.

4.4.2.1 Physical dimensions of the bread

Physical dimensions of the millet incorporated breads are presented in Table 36. Weight of the breads ranged from 111.60 to 116.30 g. The wheat bread had higher mass (116.30g) and the 50 per cent incorporated bread had lower mass (111.60 g). As the per cent of millet flour increased, the weight of the bread decreased. There was significant difference ($p \geq 0.05$) observed for weight of the breads

The height of the breads ranged from 4.20 to 6.70 cm. The wheat bread had more height (6.70 cm) and the 50 per cent incorporated bread had lower height (4.20).The height of the bread decreased with an increase in millet proportion. There was no significant difference ($p \geq 0.05$) between wheat and 10 per cent incorporated bread. But there was significant ($p \geq 0.05$) decrease observed for 30 and 50 per cent incorporated bread (Plate 9 and 10).

Length and breadth of the wheat bread were 11.73 and 5.87 cm respectively. Length of the breads varied from 11.53 to 11.73 cm. Breadth of the breads varied from 5.60 to 5.87cm. The wheat bread had higher length and breadth however, there was no significant difference ($p \geq 0.05$) observed for length and breadth of the breads as the same baking moulds were used.

Loaf volume ranged from 284.03 to 461.28 cm^3 (Plate 8). The wheat bread had higher loaf volume and the 50 per cent incorporated millet bread showed lower loaf volume. Specific volume ranged from 2.51 to 4.05 cm^3/g. The maximum specific volume was found for wheat bread and minimum was found for 50 per cent incorporated bread. As the millet flour level increased the volume and specific volume decreased significantly ($p \geq 0.05$).

4.4.2.2 Colour of the breads

4.4.2.2.1 Crust colour

Bread colour varied with the proportion of millet present (Table 37). ‘L’ values of crust ranged from 40.73 to 72.10. ‘L’ value of the crust was found to be high in 50 per cent incorporated bread was low in 10 per cent incorporated bread. ‘a’ value for the crust ranged from 1.27 to 16.62 maximum was found in 30 per cent incorporated bread and minimum was found in 50 per cent incorporated bread. 'b' value ranged from 26.69 to 35.67. It was found maximum in wheat bread and minimum was observed in 50 per cent incorporated bread. “a” and “b” values were found to be significantly different ($p \geq 0.05$) when compared to the wheat bread (Plate 8).

4.4.2.2.2 Crumb colour

‘L’ values of crumb ranged from 64.28 to 72.71. ‘L’ value was maximum for wheat bread and was minimum for 50 per cent incorporated bread (Table 37). The ‘L’ value decreased with increase in millet proportion. ‘a’ value ranged from -2.43 to -1.18. It was higher in 50 per cent incorporated bread and was low in wheat bread. ‘b’ value ranged from 12.88 to 15.08. ‘b; value was high in 50 per cent incorporated bread and was found low in 30 per cent incorporated bread. Wheat bread had a whiter crumb than the experimental millet breads (Plate 10). There was significant difference ($p \geq 0.05$) observed for crumb colour.

4.4.2.3 Texture analysis

The texture analysis values of millet breads in contrast with the whole-wheat bread are given in Table 38. The hardness of the bread ranged from 1.76 to 5.67 N. The hardness values of the millet breads were higher when compared to wheat bread. The higher hardness value was found for 50 per cent incorporated bread and wheat bread had lower hardness. Hardness value for millet bread increased with the increase in millet proportion. There was significant difference ($p \geq 0.05$) observed for the hardness of the breads. Cohesiveness values ranged from 0.13 to 0.05. Maximum cohesiveness was observed for 10 per cent incorporated bread and minimum was observed for 30 per cent bread. Adhesiveness was ranged from 5.67 to 8.00 mJ.

Table 36: Physical dimensions of the little millet incorporated breads

Little Millet flour: refined flour	Mass (g)	Height (cm)	Length (cm)	Breadth (cm)	Volume (Cm^3)	Specific volume
0:100	116.30 ^{a}	6.70 ^{a}	11.73^{a}	5.87^{a}	461.28a	4.05a
10:90	115.64 ^{ab}	6.63^{a}	11.53^{b}	5.60^{b}	446.06ab	3.99a
30:70	113.34^{bc}	5.60^{b}	11.67^{ab}	5.73^{ab}	401.31b	3.47b
50:50	111.6^{c}	4.20^{c}	11.70^{ab}	5.73^{ab}	284.03c	2.51c
SEm±	0.55	0.13	0.04	0.04	0.11	6.45
CD	1.59*	0.77*	0.43*	0.43*	0.71*	5.45*

Values with the same letters in the same column are not significantly different (p>0.05)
*significant at 5% level

Table 37: Crumb and crust color of the millet incorporated breads

Little Millet flour: refined flour	Crust color			Crumb color		
	L	a	b	L	A	B
0:100	53.56b	14.26b	35.67a	72.71a	-2.43c	13.52b
10:90	40.73d	16.17a	27.92b	67.26b	-2.01bc	13.84ab
30:70	46.23c	16.62a	32.88a	64.28c	-1.63ab	12.88b
50:50	72.10a	1.27c	26.69 b	67.33b	-1.18a	15.08 a
SEm±	0.49	0.29	0.69	0.46	0.16	0.30
CD	1.50*	1.16*	1.79*	1.45*	0.85*	1.17*

Values with the same letters in the same column are not significantly different (p>0.05)
*significant at 5% level

Wheat bread 10% 30% 50%

Plate 8. Dorsal view of bread loaves of different proportion of little millet

Wheat bread **10%** **30%** **50%**

Plate 9. Front view of bread loaves of different proportion of little millet

Table 38: Textural properties of the millet incorporated breads

Little Millet flour: refined flour	Hardness	Cohesiveness	Adhesiveness
0:100	1.76d	0.096a	5.67a
10:90	2.59c	0.126a	8.00a
30:70	3.53b	0.049a	6.00a
50:50	5.67a	0.099a	7.00a
SEm±	0.14	0.04	0.53
CD	0.81*	NS	NS

Values with the same letters in the same column are not significantly different ($p>0.05$)
*significant at 5% level   NS- non significant

Table 39: Mean sensory scores of the millet incorporated breads

Per cent of millet	Appearance	Texture	Crust color	Crumb color	Flavor	Taste	Overall acceptability
0	8.10a	7.68a	8.10a	7.68a	7.42a	7.26a	7.84a
10	7.79a	7.73a	7.52a	7.63a	7.31a	7.57a	7.68a
30	6.68b	7.31ab	7.05ab	7.21ab	7.37a	7.21a	7.21ab
50	6.26b	6.36a	6.15b	6.26b	6.58a	6.68a	6.31b
SEm±	0.29	0.31	0.30	0.31	0.26	0.30	0.27
CD	1.07*	1.11*	1.10*	1.12*	NS	NS	1.04*

Values with the same letters in the same column are not significantly different ($p>0.05$)
*significant at 5% level   NS- non significant

Table 40: Nutrient composition of the little millet bread

Nutrients g /100g	Wheat bread	Little millet bread	't'value
Moisture	32.87	30.26	NS
Fat	5.23	4.95	NS
Protein	12.39	11.95	23.20*
Ash	2.01	2.25	14.56*
Crude Fiber	0.49	0.55	2.43*
Carbohydrate	47.17	50.01	21.34*
Insoluble dietary fiber	4.29	5.04	13.87*
Soluble dietary fiber	2.07	2.56	25.34*
Total dietary fiber	6.36	7.60	37.89*

*significant at 5% level NS- non significant

Table 41: Mineral composition of the bread

Minerals (mg/100g)	Wheat bread	Little millet bread	't'value
Iron	2.30	4.47	45.10*
Copper	0.46	0.59	12.09*
Zinc	0.25	0.43	12.34*
Phosphorus	0.40	0.51	52.22*
Manganese	0.14	1.38	14.23*
Sodium	114.6	109.1	NS
Potassium	26.50	27.60	NS

*significant at 5% level NS- non significant

Maximum adhesiveness was observed for 10 per cent incorporated bread and minimum was observed for wheat bread. However there was no significant difference ($p \geq 0.05$) observed for cohesiveness and adhesiveness of the bread.

4.4.2.4 Sensory evaluation

The mean sensory scores are given in Table 39. The appearance scores ranged from 6.26 to 8.10. The scores for texture ranged from 6.36 to 7.68. The scores for crust and crumb colour ranged from 6.15 to 8.10 and 6.26 to 7.68 respectively. Flavor scores ranged from 6.58 to 7.42. The wheat bread scored highest scores for appearance, texture, colour and flavor and 50 per cent incorporated bread scored low for these characteristics. The 30 per cent incorporated bread scored high for taste (7.57) and 50 per cent incorporated bread scored low for taste 6.68. The overall acceptability scores ranged from 6.31 to 7.84. The wheat scores maximum and 50 per cent incorporated bread scored minimum. The 10 and 30 per cent incorporated bread scored 7.21 and 7.68 respectively. There was significant difference ($p \geq 0.05$) was observed foe appearance, texture, colour and overall acceptability. It indicates that millet can be incorporated up to 30 per cent without affecting the sensory quality of the bread. Sensory evaluation revealed that there was no significant difference ($p \geq 0.05$) found between the wheat and the millet breads prepared with 10 and 30 per cent millet incorporation.

4.4.3 Nutrient composition

4.4.3.1Proximate composition

The optimized bread with 30 per cent little millet flour incorporation was selected for the further study. The nutritional composition (per 100 g) of little millet bread with 30 per cent incorporation compared to 100 per cent wheat bread is presented in Table 40. Moisture content of the wheat and millet bread was 32.88 and 30.26 respectively. There was no significant difference ($p \geq 0.05$) observed for moisture. The fat content (5.23 g) and protein (12.39g) content were high in wheat bread than the millet bread. The ash (2.25g) and crude fiber (0.55g) content were high in millet bread compared to wheat bread. Significant difference ($p \geq 0.05$) was observed for fat, ash, protein and crude fiber for the breads.

4.4.3.2 Dietary fiber content (per 100g)

The total dietary fiber content of wheat bread was 6.76 g and millet bread was 7.60 g (Table 40). Insoluble dietary fiber was maximum in millet bread (5.04g) and found to be minimum in wheat bread (4.69g). Soluble dietary fiber was maximum in millet bread (2.56 g) and minimum in wheat bread (2.07 g). There was significant difference ($p \geq 0.05$) observed for the dietary fiber content of the millet and wheat bread.

4.4.3.3 Micronutrient composition

The mineral composition of the breads is presented in Table 41. Little millet bread with 30 per cent incorporation had higher values for iron, copper, phosphorus, zinc, potassium except sodium content compared to the wheat bread. Iron, copper, phosphorus, zinc, potassium and sodium content in millet bread were 4.47, 0.59, 0.43, 0.51, 27.60 and 109.10 mg respectively. Significant difference ($p \geq 0.05$) observed for mineral composition.

4.4.3.4 Bioavailability of minerals

The per cent bioavailability of iron and zinc in wheat and millet bread were given in Table 42. It depicts that per cent bioavailability of iron and zinc was higher in wheat bread compared to millet. The per cent iron bioavailability was maximum (28.85%) in wheat bread and was minimum (21.16 %) in millet bread. The per cent zinc bioavailability was maximum (47.62%) in wheat bread and minimum (29.12%) in millet bread. Significant difference ($p \geq 0.05$) was observed for per cent zinc and iron bioavailability.

4.4.4 Storage of breads

Storage stability of the little millet incorporated bread was studied by testing moisture content, free fatty acids and sensory evaluation. The results are presented here.

4.4.4.1 Moisture content

The moisture content of the bread during storage is presented in Table 43. The moisture content of millet and wheat bread at fresh was 30.13 and 35.58 respectively. The moisture content decreased from 30.13 to 22.42 per cent in little millet bread and in wheat bread reduced from 35.58 to 23.00 per cent. Mold growth was on 4th day in wheat bread and on 5th day in millet bread.

Table 42: Bioavailability of iron and zinc of Little millet incorporated bread (%)

Bioavailability (%)	Wheat bread	Little millet bread	't'value
Iron	28.85	21.16	33.87*
Zinc	47.62	29.17	44.56*

*significant at 5% level

Table 43: Changes in Moisture and free fatty acid contents of little millet incorporated bread during storage

Days	Moisture (%)		Free fatty acid content (mg KOH/100g acid)	
	Wheat bread	Little millet bread	Wheat bread	Little millet bread
1	35.58	30.13	5.38	5.67
2	29.50	27.61	7.75	6.56
3	27.79	25.40	8.56	8.23
4	23.00#	22.91	10.89	8.84
5	--	22.42#	--	9.22

Mold growth was observed

Table 44: Changes in Sensory evaluation of Little millet incorporated bread during storage

Days	1		2		3		4	
Sample	Wheat bread	Little millet bread	Wheat bread	Little millet bread	Wheat bread	Little millet bread	Wheat bread	Little millet bread
Appearance	8.00	8.10	8.00	7.90	7.30	7.60	ND	6.90
Texture	7.40	8.10	7.30	7.60	6.40	6.80	ND	6.30
Crust Colour	7.80	7.80	7.80	7.50	7.00	7.20	ND	6.70
Crumb colour	7.80	7.80	7.60	7.30	6.80	7.00	ND	6.90
Flavour	7.30	7.90	7.30	7.60	6.00	7.00	ND	6.70
Taste	7.40	8.00	7.30	7.60	6.00	6.80	ND	6.10
Overall acceptability	7.70	8.20	7.60	7.80	6.40	7.00	ND	6.60

ND –Not determined mold growth observed

Table 45: Nutrient composition# of the Little Millet incorporated breads for per serving (50 g)

Nutrients (g)	Wheat bread	Little millet bread
Fat	1.83	1.73
Protein	4.34	4.18
Ash	0.70	0.79
Crude Fiber	0.17	0.19
Carbohydrate	27.96	28.10
Insoluble dietary fiber	1.64	1.76
Soluble dietary fiber	0.72	0.90
Total dietary fiber	2.37	2.66
Energy (K Cal)	146	128
Iron (mg)	1.15	2.24
Copper (mg)	0.23	0.30
Zinc (mg)	0.13	0.22
Phosphorus (mg)	0.20	0.26

computed values

4.4.4.2 Free fatty acid content

Free fatty acid content of the bread during storage is presented in Table 43. Free fatty acid content increased significantly during storage in both the breads. Free fatty acid content in little millet bread ranged from 5.67 to 9.22 mg KOH/ 100g and in wheat bread ranged from 5.38 to 10.89 mg /100 KOH. The free fatty acid content was higher in wheat bread when compared to little millet bread. The wheat bread got fungus on 4th day itself. The little millet bread got fungus on the 5th day. The little millet bread had more shelf life than wheat bread.

4.4.4.3 Organoleptic evaluation

The sensory scores of little millet bread and wheat bread during storage are presented in Table 44. The sensory scores for overall acceptability at 1st day for little millet bread was 8.2 and for wheat bread was 7.7. Scores for the appearance decreased from 8.1 to 6.9 for little millet and 8 to 7.3 for wheat bread. The texture scores decreased from 8.1 to 6.3 and 7.4 to 6.4 for little millet and wheat bread respectively. The crust scores ranged 7.8 to 6.7 for little millet bread 7.8 to 7.0 for wheat bread. The crumb color scores ranged 7.8-6.9 for little millet bread. 7.8 to 6.8 for wheat bread. Scores for taste ranged from 7.9 to 6.7 for millet bread and 7.4-6.0 for wheat bread and 7.7 to 6.4 for wheat bread. Thus, the little millet bread was highly acceptable compared wheat bread during storage.

4.4.5 Nutrient composition of the bread per serving (50 g)

Nutrient composition of per serving (50 g) of bread is given in Table 45. It indicates that the millet bread had higher values for ash (0.79 g), crude fiber (0.19), carbohydrate (28.10 g) and total dietary fiber content (2.66 g) compared to wheat bread. Wheat bread showed higher values for fat (1.83 g), protein (4.34 g) and energy (146 K cal). For 1000 K cal millet bread provides 21.11 g of dietary fiber which fulfills one day requirement of dietary fiber. Millet bread provides higher iron (2.24 mg), zinc (0.22 mg), copper (0.30 mg) and phosphorus (0.26 mg) compared to wheat bread.

DISCUSSION

The present investigation entitled "Storage quality of little millet (*Panicum miliare*) and diversification of utilization of little millet through hydrothermal and baking technologies" was carried with objectives to evaluate local and high yielding varieties for physico-chemical and nutritional qualities, to study the changes in physico-chemical, processing and nutritional qualities during storage and hydrothermal treatment and to develop value added products of little millet through different technologies. The results are discussed below.

5.1 Storage of little millet grains

Storage of food grains is inevitable both in times of deficit and surplus production. This single component in the chain of post harvest handling of the grains is responsible for losses of the order of 7 per cent which has a far reaching effect on the rural economy owing to 70 per cent of total food grain production being stored at the level of farmers. All farmers store food grains (52-84%) for their own consumption, 64 to 94 per cent for seed and 48 to 90 per cent for future sale and the quantity stored for the above purpose varied from 22 to 71 per cent of the total production. Storage of the grains and other agricultural products is necessary to provide consistent supply with demand to provide surplus storage to carry on over supplies in the years of low production and to adjust and maintain quality consistent with the intended use of the products.

Cereal grains constitute a major source of foods and raw materials for industrial processing. Chemical changes, some of which have profound effect on nutritive values are continuously taking place in all grains under storage conditions. Unfavorable storage condition can result in the complete spoilage of the grain stored for feed and food purposes within few days. Therefore a primary objective in the storage of grain and its products should be, to control the conditions of storage, that the deteriorative changes are minimized.

In recent days millets are getting more importance because of their health benefits. The scientists are also interested in deriving more data on millets. Decade by decade the production and consumption has declined. The people's diet is lacking in millets. It is known that millets can be stored for 100 years as they are resistant to pest and insects. They are usually stored in jute bags or earthen pots.

Now a days food technologists, and nutritionists are exploring the possibilities of millets in developing therapeutic foods as these are rich in fibre, minerals and also phyto nutrients. Many clinical studies have been conducted to know the effect of millets on diabetes and weight control where millet proved beneficial (Itagi, 2003 and Ushakumari and Malleshi, 2007).

Even though lot of interest is taken in value addition, the production of millets is not up to the mark. The industries are having very keen interest in use of millets in their production as millets are healthier and nutri-rich. Products can be developed from millets which are equally good as rice and wheat products. To promote the millets as well as to fulfill the industrial requirement the storage quality of millet is essential.

Little millet (*Panicum miliare*) is one of the important nutri cereals grown in South Asia and African countries. It has wide adoption and is grown under diverse situations of soil temperature, rainfall and from mean sea level to an altitude of 2100 meters. By virtue of its composition, little millet is comparable to wheat and rice with respect to its nutritive value. It can be a good food to human beings of all ages and at all stages of life. Little millet is one of the smaller millets grown in Northern Karnataka. However there is decline in the production as well as consumption of little millet in recent years. It is reliable catch crop in view of its earliness and resistance to adverse agro climatic condition. The straw is good fodder for cattle. In the form of rice this millet is very popular in Northern part of India specially consumed during festivals as fasting food. In spite of superior nutritive value of grains, their use is limited. The problem of pests and diseases in small millets is negligible. Being eco-friendly crops, they are suitable for fragile and vulnerable ecosystems and regarded as preferred crops for sustainable and green agriculture. Cultivated rice is typically consumed as cooked rice with only a small amount being used to make ingredients for processed food. This pattern of usage results in the need to store rice over varying periods. Storage results in numerous changes in rice chemical & physical property and these changes impact rice cooking and eating quality. The texture of the cooked rice grain has been shown to describe the ultimate acceptance of rice by consumers when consumed as the whole grains. As rice aged, texture of the cooked rice grain become harder and less sticky than cooked fresh rice and the aged rice showed increased volume expansion and water absorption during the cooking process. In this connection it is interesting to compare the effects of storage on millets as they are becoming more popularized as health grains for management of diabetes and other metabolic disorders. Similar to rice, little millet is also consumed as cooked rice. There is a need to store the grains for future use. Hence the study was undertaken to know the changes in physicochemical, nutritional and processing qualities during storage of little millet.

Initially experiments on varieties of little millet were conducted. The varieties local cultivars (*Malli savi* and *Kari savi*) and high yielding varieties Sukshema, COSa-(4) and JK-8 were selected. They were evaluated for the physico-chemical, nutritional and processing qualities.

In the present study the varieties of little millet differed in colour. The whole little millet varieties were olive green to blackish green in colour (Plate 1). The decorticated grains were creamy white to off white colour (Plate 2). The grains were spherical to oval shape. The length and breadth of the whole little millet grains were ranged from 2.3 mm to 2.5 mm, 1.4 mm to 1.6mm respectively (Table 3 and 6). It was found that Sukshema and *Malli savi* grains were longer and JK-8 and *Kari savi* were shorter in length. The same trend was seen in decorticated grains also. *Malli savi* variety was broader in size compared to other varieties.

Among the varieties under study the thousand kernel weight and volume of grains varied significantly. The mean thousand kernel weight was 2.53g and 2.00 g for whole and decorticated grain respectively (Table 3). Similar results were reported by Hadimani and Malleshi (1993) for whole little millet grains. The mean volume of thousand grains was 1.67 ml and 1.48 ml for whole grains and decorticated grains respectively. The *Malli savi* variety had significant higher thousand kernel weight for both whole grains (2.97 g) and decorticated grains (2.19g) and *Kari savi* was having lower weight and volume as its size is smaller. The bulk density of whole grains and decorticated grains ranged from 1.39 to 1.64 and 1.27 to 1.40 g/ml respectively (Table 3 and 6). There was significant difference ($P \geq 0.05$) observed for breadth, length, thousand kernel weight, volume and density. Similar results were reported by Hadimani and Malleshi (1993), Ninganagoudar *et al.* (2012) and Kotagi (2011a) for decorticated little millet grains.

The three varieties *Malli savi*, Sukshema and CO(Sa)-4 were studied for the milling quality. The mean hulled grains were 78.89 per cent and the husk was ranged from 15.00 to 16.33 per cent (Table 4). Hadimani and Malleshi (1993) reported that the mean milled grains were 77.00 per cent in little millet. Head rice yield in the present study ranged from 81.33 to 84.19 per cent where *Malli savi* variety was higher in bran percentage and lesser in broken grains (Table 5).

Hardness of the grains varied significantly among the varieties. *Malli savi* (local cultivar) was found to be harder compared to other grains. Sukshema was found to be having lower hardness. Hardness of the grains ranged from 9.408 to 15.966 N (Fig 2). Sukshema and *Malli savi* variety of little millet grains were lighter in colour compared to other varieties. 'a' and 'b' value of colour were higher in Sukshema variety and were low in JK-8 variety (Fig 3). The colour values were significantly differed ($P \geq 0.05$) among the varieties. Sukshema was found to be yellowish in colour. In the present study the wide variation in physical characteristics of varieties of the same species may be due to the influence of genetic and agronomical factors.

Kotagi *et al.,* (2011a) reported that decorticated little millet contains 7.45 g of protein, 1.49 g of fat, 64.87 per cent of carbohydrate, 0.39 g of total minerals, 15.80 g of dietary fiber and 303 Kcal of energy per 100 g. In the present study proximate composition of varieties significantly varied among the local cultivars and high yielding varieties of little millet. The local cultivar *Malli savi* was found to be superior in most of the characters (Table 7). The moisture content was high in *Malli savi* Variety (8.61 %) followed by Sukshema and *Kari savi* and low in CO(Sa)-4 variety. Protein content was found to be high in *Malli savi* variety. Which was ranged from 8.66 to 9.58 per cent and found to be low in Sukshema protein may influence the texture quality of the grains. Kulkarni *et al.* (1992) reported that protein content of little millet grains was 9.70g/100g. The fat content of little millet varieties ranged from 2.32 to 3.46 per cent. Sukshema was found to be having higher fat content. Kulkarni *et al.* (1992) were reported that fat content of little millet grains was 3.54g/100g. The similar results were observed in the present study. There was no significant difference found between varieties for crude fiber and carbohydrate content. Ash content ranged from 1.87 per cent to 2.62 per cent. The highest ash content was in Sukshema and lowest was found in *Kari savi* (1.87%). The results of the present study are in agreement with the earlier reports (Gopalan *et al*, 2007 and Padulosi *et al*, 2009)

There was significant difference between all the varieties of millet for phenols and phytic acid (Table 8). The phenol content ranged from 90.90 to 94.60 mg (%). They phytic acid ranged from 2.74

to 5.22 g/100 g. The Sukshema variety was found to be high in both phytic acid and phenols. Sridevi *et al.* (2011) reported that polyphenol content of whole little millet grains was 148.53 mg/100g and phytic acid content 1.49 g/100g. Kundgol *et al.* (2013) reported that polyphenol content of decorticated little millet grains ranged from 49.47 t0 90.73 mg/100g and the phytic acid content ranged from 1.44 to 1.53 g/100g. In the present study the results for phytic acid and phenols were slightly higher than the reported values may be due to genetic variations and ecological factors of species. Trace element compositions of little millet varieties were studied and results were presented in Table 9. The iron content of the grains ranged from 7.20 in JK-8 to 12.39 mg/100 in Sukshema. There was significant difference observed for mineral composition among the varieties. Ash content of the present study is similar to the results reported by Geervani and Eggun (1989) and Gopalan *et al*, (2007).

Varietal difference in cooking quality of little millet rice was observed (Table 10). The cooking time in 5 varieties varied significantly ($p \geq 0.05$). It ranged from 7.10 min to 9.13 min. Cooking time may be related to hardness of the grains. The cooked weight ranges from 5.46 to 6.50 g. *Malli savi* had higher cooked weight (6.50g) it indicates that it absorbs more water compared to other varieties. It can be related to the hardness of the grain. *Kari savi* was found to be having lower cooked weight may be due to its smaller size. Similar trend was observed in the cooked volume. The cooked volume ranged from 5.13 to 6.43 ml. No significant difference was found leached solids among the little millet varieties. It ranged from 9.50 per cent to 11.91 per cent *Kari savi* was found to be higher per cent of leached solids. Varietal differences for the quality characters were observed in Kodo millet (Kulkarni and Naik, 2000) and Barnyard millet (Veena *et al,* 2005).

Sensory evaluation report revealed that there was significant difference ($P \geq 0.05$) among the varieties (Table 11). However the local variety *Malli savi* got higher score for the sensory attributes. The scores for the overall acceptability ranged from 6.4 to 6.8. There was no dominant character observed among the sensory quality of little millet varieties.

The varietal study confirmed that the local cultivar *Malli savi* was superior in most of the characters. Among all the varieties Sukshema (high yielding variety) was comparable to *Malli savi* with respect to nutritional, physico-chemical and milling qualities.

The grains of *Malli savi* were harder, and which increased the milling efficiency compared to other varieties. Inherent characteristics of local cultivars can be considered by breeder to develop and improve the high yielding varieties. The functional characters can be considered for the development healthier foods. The local variety *Malli savi* was selected for further studies.

The grains were procured from farmer of Haveri district, de-stoned and cleaned. The each 2 kg of grains were packed in gunny bags and stored at ambient temperature. Sample were studied for physico-chemical, nutritional and processing qualities at fresh and sample drawn at the interval of 6 months up to 18 months. The temperature and relative humidity data during study recorded is presented in the Appendix XIX.

Physical characteristics of whole little millet grains are presented Table 12. Thousand kernel weight, 1000 kernel volume and density of fresh sample were 2.70 g and 1.77 ml and 1.52 g/ml respectively. As storage period increased the thousand kernel weight decreased by 4.47 per cent during storage. The thousand kernel volume of whole grains decreases during storing by 16.44 per cent at 18 months. There was significant difference ($p \geq 0.05$) observed for thousand kernel weight and volume. The thousand kernel volume of 6 months, 12 months and 18 months was 1.62 ml, 1.62 ml and 1.52 ml respectively. There was no significant difference ($p \geq 0.05$) observed between 6 months stored and 12 months stored. However there was significant ($p \geq 0.05$) decrease in the thousand kernel weight and volume. The density of whole grains was significantly ($p \geq 0.05$) varied during storage. The density increased in 18 months stored sample. The decrease in the weight and volume is due to loss of moisture content during storage (Table 12).

The moisture content of whole grains ranged from 8.39 to 10.66 per cent. The moisture content of fresh millet was 10.66 per cent (Table 13). There was significant ($P \geq 0.05$) decrease observed during storage. The per cent decrease was 9.66 per cent, 11.53 per cent and 21.9 per cent during 6, 12 and 18 months respectively. The moisture content of whole grains decreased with storage period.

Dehulling per cent of grains during storage ranged from 80.27 per cent - 81.47 per cent (Table 13). At fresh the hulling per cent of grains was 80.27 per cent, unhulled grains was 2.44 per cent and husk recovery was 15.94 per cent. The hulled grains per cent increased with increase in storage duration. The unhulled grains decreased with increase in storage duration. However there was no significant difference (p≥0.05) for hulled and husk percentage. There was significant decrease (p≥ 0.05) observed for unhulled grains. The unhulled grains reduced by 18, 31, and 33 per cent during 6, 12 and 18 months respectively. It showed that storage of grains improves the efficiency of dehulling. Husk per cent ranged from 15.94 to 16.60 during storage. The husk per cent was found to be high in 18 months stored sample and was low at fresh sample (15.94 %). Improved dehulling efficiency is due to change in chemical composition and formation of complex structure with protein and starch or starch with lipid (Table 17).

The results of decortication of the dehulled grains revealed that the head rice yield increased significantly from 71.20 to 79.11 per cent during storage of 18 months by gradual decrease in the breakage (Table 14). It indicates the storage improved milling efficiency and reduces the broken per cent. It may be due the grains become harder. The grain becomes compact due to loss of moisture content. Pearce *et al,* (2001) reported that rough rice drying condition and storage moisture and storage temperature influenced head rice yield. Head rice yield of all lots increased during the first 3 months of storage.

Physical characteristics of stored decorticated little millet grains was studied. The similar trend as in whole grains was observed for decorticated grains also. The thousand kernel weight decreased from 2.16 g to 2.08g (Table 15). The thousand kernel volume decreased to 1.58 from 1.63 ml. The decrease in thousand kernel weight and volume may be due to the loss of moisture content during storage. Length and breadth of the fresh sample was 1.73 and 1.54 mm respectively. The length and breadth of the grains also decreases with increase in storage period. The LB ratio ranges from 1.13 to 1.15. Gujral and Kumar (2003) reported that the increase in length to breadth ratio is due to lesser decrease in length of rice compared to breadth upon polishing. 1000 kernel weight and volume of decorticated grains were lower than that of whole grains. Brown rice from IR-8 Govinda and Saurabh had 1000 kernel weight of 24.20, 18.05, and 14.31 g which was lowered to 22.09, 16.79 and 13.16 g respectively. The present study results are in same trend.

The milled millet was subjected to sieve analysis during storage to know the particle size distribution (Table 16). The fresh and 6 months samples found to be having more particles with size of 0.077mm followed by. 0.152 mm. At 12 months sample found to be having more particles with size of 0.152 and is equally distributed to 0.251 and 0.104 mm of size. At 18 months 54.34 per cent particles having size of 0.152 mm. Results revealed that as the storage increases the particle size will be increased during storage period thus it indicates that grains become harder during storage.

The moisture content of whole grains and decorticated grains reduced from 10.66 to 8.39 and 10.59 to 8.65 per cent respectively (Table 13 and 17). The decrease in moisture content may be due to variation in the temperature and relative humidity in the environment during storage (Appendix XIX). Rehman (2006) observed the gradual decline in moisture content during storage of rice, maize and wheat. The moisture content of rice, maize and wheat grains decreased by 23.14 to 32.00 and 20.00 per cent at 25 ºC and 36.70, 48.80 and 27.57 per cent at 45 ºC per cent after six months of storage respectively. The observations of present study are in consistent with the findings of Thulyathan and Leeharatanluk (2004) who reported moisture content of KDML 105 rice during storage reduced from 12.30 to 11.71 per cent at 18 months of storage. Similar trend was observed in the present study. Fat, protein, ash, crude fiber and carbohydrate content at fresh were 3.62, 7.81, 1.97, 2.37 and 73.64 respectively. The fat content does not vary much during storage and there is no significant difference (p ≥ 0.05) observed (Table 17). The increase in the proximate composition observed during storage. However significant change was observed for protein. This may be due to decline in moisture content during storage. McDonough *et al.* (2004) reported that amounts of soluble proteins decreased and insoluble proteins increased because of increased protein interactions possibly disulfide bonds. Slight decrease in fat was observed it may be due to hydrolysis of lipids to produce free fatty acids or the oxidation of fat to produce hydro peroxides. There was no significant difference (p ≥0.05) was observed in ash, crude fiber and carbohydrate content during storage do not vary much.

The change in phyto nutrients and total phenols were also observed during storage (Table 18). The phenol content drastically increased during storage of grains and similar trend was observed for phytic acid content. The increase in the phenol content may be due to release of bound phenolics by enzymatic and non enzymatic reaction (Zhou *et al*, 2001). Chandrasekar and Shahidi *et al,* (2011) reported that little millet contains 5.77 (mmol FAE/g defatted meal) of free phenols, 1.37 of esterified phenol, 2.48 etherified and 9.64 insoluble bound phenol. Pradeep and Guha (2011) reported the native little millet contains 429.90 (mg/100g) of total phenolics (gallic acid equivalents).

Changes in *in vitro* protein digestibility and *in vitro* starch digestibility (IVSD) during storage was assessed (Table 19). The *in vitro* protein digestibility (IVPD) before was 71.00 per cent and IVSD was 61.57, 64.04, 77.37 and 94.44 at 30, 60, 90 and 120 min respectively. The IVPD and IVSD decreased during storage period. IVPD decreased significantly ($p \geq 0.05$) from 71.00 to 63.03 per cent. IVSD decreased significantly ($p \geq 0.05$) from 61.57 to 51.28, 64.04 to 58.07, 77.37 to 63.23, and 94.44 to 74.86 mg/glucose/min at 30, 60, 90 and 120 min respectively. Decreases in protein and starch digestibility could be result of maillard reactions, during which free amino groups of protein and carbonyl groups of reducing sugars from complex intermediate compounds by interacting with each other during storage. These complex compounds might have inhibited the activity of protolytic and amylolytic enzymes which ultimately caused distinct reductions in protein and starch digestibility (Rehman *et al.,* 2002). Zhou *et al,* (2001) reported that during storage there will be reduction in the activity of α-amylase and β-amylase. This may be resulted in lower starch digestibility. Rehman *et al.,* (2006) reported that protein and starch digestibility of cereal grains were significantly affected at 25 and 45^{0}C. On storage of for 6 months at 45^{0}C, protein digestibility's by 13.00, 15.60 and 17.60 per cent in rice maize and wheat grains respectively. Decreases in protein digestibility's were only 8.69, 9.09, and 9.45 per cent after 6 months of storage of rice maize and wheat grains respectively at 25^{0}C. Decreases in the starch digestibility were 17.10, 20.70 and 17.70 per cent at 45^{0}C and 12.90, 13.81, 11.30 per cent at 25^0 C after 6 months of storage of rice, maize and wheat respectively.

Total starch content at fresh state of little millet was 75.80 per cent which was increased to 76.25 per cent during storage (Table 20). The amylose and amylopectin content at fresh were 15.16 and 84.84 per cent respectively. The amylose content slightly decreased with in storage period and amylopectin content slightly increased. There was significant difference ($P \geq 0.05$) observed for amylose and amylopectin content. Soluble amylose content at fresh was 8.90 per cent and it decreased to 6.65 per cent during storage. McDonough *et al.* (2004) observed the soluble amylose content of sorghum, sorghum meal, whole maize decrease with increase in the storage period. Soluble, insoluble and total dietary fiber in fresh millet was 2.70, 5.45 and 8.151 per cent respectively. Soluble, insoluble and total dietary fiber increased with storage period may due to formation of complex carbohydrates during storage which are resistance to enzymatic digestion (Table 21).

Storage increased cooking time by 2 min (Table 22). The swelling power and solubility decreased with storage period by 11.66 and 20.12 per cent respectively. The increase in cooking time is attributed to increased hardness and changes in other functional properties (Table 22). The increase hardness during storage may be due to the formation of amylose lipid complexes as observed in the ageing of rice which made the aged rice harder and less prone to disintegration (Zhou *et al.* 2001).

Soluble proteins at fresh were 8.57 per cent. It decreased from 8.57 to 7.28 per cent during storage of millet (Table 22). The decrease in soluble proteins during ageing may be accompanied by denaturation of protein, elevated super oxides dismutase activity and lack of ATP (Gujral and Kumar, 2003). Zhou *et al.* (2001) reported that the protein content did not change during although its general solubility was reduced with decrease in the albumin. During storage the lower molecular peptides decreased and higher molecular weight peptides increased in grains.

Sensory evaluation of millet rice revealed that as the storage period increased the rice was more acceptable with respect to appearance, texture, colour and overall acceptability (Table 23). As the storage period increases rice become less sticky and harder and it was granular in nature. This is due the decrease water uptake and leached solids. This improved the textural quality of cooked rice as shown in the Plate 4. The improvement in the textural quality of stored rice may be due to complex formation of protein and starch. The binding between rice protein and starch is known to affect the stickiness of cooked rice. The binding decreases during storage, especially at high storage temperatures (Thulyathan and Leeharatanluk, 2001). Meullenet *et al,* (1999) reported the storage duration significantly affect the texture and flavor notes. Zhou *et al,* (2001) reported that, the storage time, temperature and duration influence the texture of cooked milled rice. The texture of the cooked aged rice was harder and less sticky than cooked freshly harvested. The results are consistent with the reported results.

5.2 Hydrothermal treatment to little millet

Little millet (*Panicum miliare*) is one of the staple foods in millet growing areas of Northern Karnataka. The farmers are least interested to grow the little millet as there are no suitable post harvest technologies for cleaning and grading of millets. Little millet grains are conventionally milled in the existing emery flour mills with higher per cent of breakage and admixture of bran. Traditional milling technologies are laborious and energy and time consuming especially it is drudgery on women. Hence rural and urban consumers are not showing inclination for utilization millet in their regular diet. The main objective of the hydrothermal treatment is to reduce the levels of breakage as there is high breakage was observed in the milled grains which are milled in the existing emery mill for flour. As nutritious grains, Government is interested to distribute millets under public distribution system for sustainable food security. But cleaning, grading and milling breakage are the major constraints to be addressed immediately. Hydrothermal treatment is processing technology applied to improve the milling efficiency in rice (Miah *et al*, 2002b). In similar direction it was planned to improve little millet rice quality such as milling yields, nutritional value and resistance to spoilage by insects and moulds for enhanced consumption.

In the present study hydrothermal treatment was optimized for soaking hours, temperature, steaming temperature and steaming time (Table 1). The treated grains were evaluated for milling quality, physical appearance, cooking quality and consumer acceptability. The hydrothermally treated millet grains at optimum processing condition were further studied for nutritional, therapeutic value and for storage stability.

The per cent head rice yield during different hydrothermal treatments ranged from 72.67 to 95.62 per cent (Table 24). The result showed that hydrothermal treatment improved the head rice from 72.25 to 95.62 per cent and reduced the broken from 11.52 to 0.61 per cent. It was observed that per cent head rice yield increased at the suitable soaking and steaming conditions (Appendix XX). The head rice yield increased with soaking temperature and time and also with steaming temperature and time. The improvement in the head rice yield may be due to gelatinization process, which brings strong structure and denaturation of protein by diffusing into inter granular space of starch. Which further increases the binding effect and thus improves the better for milling quality (Parnsakhorn and Noomhorm, 2008). However at higher temperature (80° C)of soaking, higher soaking time (4 h) and with higher steaming temperature (110° C) and steaming time (25 min) breakage increased by 2 per cent (Appendix XXI). This may be due to severe deformation of the grain that losses the exuded the endosperm while absorbing excessive moisture which led to reduced milled yield (Parnsakhorn and Noomhorm, 2008). Therefore longer duration of soaking and steaming are not suitable for hydrothermal treatment of millet.

The colour values of hydrothermally treated little millet grains revealed that there was significant difference between ‘L’ ‘a’ and ‘b’ values of colour. ‘L’ whiteness of the hydrothermal treatment significantly decreased (Table 25). The ‘L’ values decreased with increased soaking and steaming conditions (Appendix XXII). The ‘a’ and ‘b’ values also decreased with severity of hydrothermal treatments (Appendix XXIII and XXIV). Changing in b value of hydrothermally treated brown rice was mainly caused by Maillard type non enzymatic browning (Kimura *et al,* 1993). Parnsakhorn and Noomhorm (2008) also reported that temperature and period of soaking and steaming significantly influenced the whiteness of the hydrothermally treated rice. Regarding ‘b’ value of the hydrothermally treated millet grains, it was not only affected by steaming time, but also affected by soaking temperature. At a given soaking time, higher soaking temperature gave higher ‘b’ value. Thus increasing soaking temperature and time resulted in higher yellowness. Normally discolouration of hydrothermally treated rice directly related to the market value because in most countries consumers do not accept dark coloured hydrothermally treated rice.

Cooking time, leached out solids and water uptake varied with all different treatments hydrothermal treatment conditions (Table 26). Cooking time increased with increase in severity of hydrothermal treatment. The grains become harder as soaking temperature, time and steaming temperature and time increased (Appendix XXV). Because of the hardness the cooking time increased. The increase in the cooking time is related to the hardness of the grains which increases with severity of the hydrothermal treatment treatments (Table 25). The re-association of gelatinized starch after hydrothermal treatment may play key role in the hardening and also the thermal degradation of starch occurs during heat treatment could be an additional contributor to the changes in texture of the grain (Manful *et. al.,* 2008).

Water absorption reduced upon increasing soaking time for 3-4 h and steaming time 15 min to 25 min (Appendix XXVII). Leached solids decreased with increase in soaking time and steaming time (Appendix XXVI). Decrease in water absorption and leached solids of hydrothermally treated millet might be due to starch granules modified by heating and hydrothermal treatment process. Therefore the storage structure was obtained and difficult for water penetration into kernel. The similar trend was observed for KDML 105 rice by Parnsakhorn and Noomhorm (2008).

Colour of rice was main factor which decides the price of grains. In the present study consumer acceptability of hydrothermally treated grains was evaluated for colour and appearance (Table 27) (Plate 5). According to the consumer acceptability, the four treatments got the highest scores mainly, soaked for 4 hrs soaking 70^0C and 100^0C steaming for and 20 min, (T21) 70^0C initial soaking temperature for 3 hr (T17) 110^0C. Steaming for 20 min (T14) 60^0C 4 hr 100^0C steaming for 20 min (T8). Sensory scores of little millet treated at severe hydrothermal treatments were significantly lower. This may be due to the increased darkness of hydrothermally treated grains. Increased darkness is due to contribution of pigments to coloration of parboiled rice is supported by the fact that some nutrients from the bran compounds leached out during hydrothermal treatment to the endosperm (Islam *et al.,* 2002). Therefore the poor qualities of hydrothermally treated rice occurred due to high heat treatments during three main steps of hydrothermal treatment process (soaking, steaming and drying) can be improved by hydrothermal treatment at low heat treatments. The level of broken is more important commercially than the milling yield as rice with low levels of broken usually sells at a premium price (Manful *et al.* 2008).

There are very few reports in the literature about acceptability and consumer attitude towards parboiled rice. For its special nutritional and functional characteristics, parboiled rice can be considered a value-added product and, therefore, deserves more attention of industries, researchers and nutrition professionals. Heinemann *et al,* (2006) reported that less than 10 per cent of local consumers purchase parboiled rice. By the attitude it was concluded that the majority of the consumers do not reject the parboiled rice solely based on its sensory properties, but for not being familiar with it and so, unaware of its characteristics and advantages. By the sensory evaluation it was observed that parboiled rice can be well accepted when tasted, in a comparable level to milled rice. Thus, from a general view, a possible reason for the locally restricted acquisition of parboiled rice, despite its advantage of easy preparation and nutritional claim, could be the strong presence of milled rice in the Brazilian food habits. These findings corroborate the need for marketing efforts that would efficiently inform consumer about characteristics of parboiled rice, its nutritional value and its convenience. This information might contribute to increase parboiled rice consumption and consequently, bringing some nutritional benefits to the population.

Head rice yield, broken, colour values, cooking time, solid loss, water uptake and consumer acceptability were the parameters considered for optimizing the hydrothermal treatment of little millet. It was observed that initial soaking temperature 70° C for 3 h at 110° C steaming for 20 min was found to be optimum for little millet grains with 92.08 per cent head rice yield and 0.99 per cent broken (Plate 6).

Optimized hydrothermal treated little millet grains were analyzed for changes during hydrothermal treatment for proximate composition, phyto nutrients, mineral composition, carbohydrate profile, in vitro protein and starch digestibility and evaluated for sensory quality comparison with raw little millet.

The hydrothermally treated rice showed superior quality compared to raw millet. Moisture content and crude fiber and fat content does not vary significantly. Protein content is the most important criterion quality since cereals are the main source of protein. Protein content varies much with environmental and cultural practices. In the present study protein content of hydrothermally treated grains increased significantly ($P > 0.05$) compared to raw millet 13 per cent(Table 28). Sujatha *et al* (2004) also reported that JBRR rice Enel (summer) crop has 9.46 per cent protein which increased to 10.40 per cent during hydrothermal treatment. Total Minerals content reduced to 1.33 from 2.51 per cent. This may be due to the leaching of mineral content from the endosperm during soaking and steaming (Dharmaraj and Malleshi, 2010).

Sujatha *et al.* (2004) reported a gradual decrease of total carbohydrate content in the grain collected during dry seasons for rice sample, carbohydrate is a source of energy for the synthesis of lipids and protein. It decreases in the dry season. In the present study carbohydrate content of hydrothermally treated grain (73.41%) decreased significantly compared to raw millet rice (74.10%) (Table 28).

Phenols and phytic acid increased during hydrothermal treatment (Table 29). The phenols and phytic acid content increased double times than the raw rice. The phenol content increased from 11.61 to 23.94 mg/100g. The phytic acid content increased from 3.29 to 4.25 mg/100g. It may be because during soaking and steaming the phenol and phytic acid content from the seed coat entered in to the endosperm. The seed coat is the richer source of phyto-nutrients. Pradeep and Guha (2011) reported that the processing steaming process enhanced phenolic contents in little millet compared to native. Kawassaki *et al,* (2011) observed that the insoluble phenolic components showed in average slight increase after the rice parboiling probably due to polymerization and complexation of reactions.

Mineral composition of the hydrothermally treated millet and raw millet was studied (Table 30). The total ash content of hydrothermally treated was decreased significantly ($P \geq 0.05$). This may be attributed to the lower contents of iron, Zn and Cu after hydrothermal treatment. But when bioavailability of iron and zinc was assessed it showed that per cent bioavailability of iron and zinc was significantly higher in the hydrothermally treated rice (Table 30). Hydrothermal treatment enhanced the bioavailability of minerals.

Carbohydrate profile of hydrothermally treated rice was compared to raw millet (Table 31) results revealed that starch content of hydrothermally treated rice was found to be low. It may be due to reduction in total carbohydrate content. In the present study Amylopectin content decreased after hydrothermal treatment significantly ($p > 0.05$). Total amylose content increased. Gelatinization of starch during hydrothermal treatment may have attribution to increase in amylose content. Dharmaraj and Malleshi (2011) observed that increase in amylose content of hydrothermally processed finger millet.

Total dietary fiber content of hydrothermally treated grains increased after hydrothermal treatment. It is due to increase in SDF and IDF. Dharmaraj and Malleshi (2011) observed that increase soluble dietary fiber after hydrothermal treatment. The increase insoluble dietary fiber may be due to formation of resistant starch during hydrothermal treatment process. Mangala *et al,* (1999) reported that hydrothermal treatment results in significant changes in milled rice starch. Over 90 per cent of rice endosperm becomes gelatinized and only part of it re-associates as resistant starch upon cooling and also revealed that resistant starch is higher in hydrothermally treated rice comparative to the native rice.

During hydrothermal processing, structure modifications and/ or rupture of starch molecules can occur. These fragments can combine with other molecules, creating new compounds resistant to enzymatic digestion (Englyst, 1989, Theander *et al.,* 1989). In this way, it is reasonable to assume that hydrothermal processing may create complexes that render starch resistant to digestion. Formation of RS Type III during process may consequently increases dietary fiber content (Walter, *et al.,* 2005)

A significant decrease in IVPD and IVSD was observed in hydrothermally treated millet (Table 32). Decrease in IVPD and IVSD may be due decrease in activity of alpha amylase and beta amylase. The increase in phenol and phytic content may inhibit the digestion of starch and protein. Serna *et al.* (1995) reported that PER reduced after hydrothermal treatment of sorghum. Devi *et al.* (1997) reported that parboiling of rice resulted decrease in IVPD by 13.4 per cent in rice. It may due to upon parboiling, the unbound lipid and free fatty acids in milled rice decreased where as lipids bound to starch and protein and free phenolic acid increase there by reducing the extractability of proteins in the grains resulting in reduction in protein digestibility of parboiled rice (Kato *et al.,* 1983). Walter *et al.* (2005) reported that resistant starch content of parboiled rice was higher (3.8%) compared to white rice (1.5 %) and also the digestibility of starch decreased due to hydrothermal processing from 82.4 to 73.9 per cent. It may be due to after certain heat-moisture treatments of starch (like hydrothermal processing) resistant starch(RS) type III can be formed (Eerlingen and Delcour, 1995) and that digestible starch values were lower for hydrothermally treated millet.

Sensory evaluation of hydrothermally treated little millet revealed (Table 33) that hydrothermally treated millet scored higher scores compared to raw millet. Score for appearance for hydrothermally treated millet was 8.1. The overall acceptability scores for hydrothermally treated rice was 8.2 which was higher compared raw rice (7.5). There was no significant difference news found for appearance, texture, colour. However, there was significant difference observed for flavour, taste and overall acceptability. The hydrothermally treated rice was more acceptable than the raw millet rice is due to improved nutrient composition (Table 28, 29, and 31), flavour and texture (Plate 7).

Sorption behaviour of hydrothermally treated little millet was studied. Relative Humidity (RH) of the product is more important than moisture content. Sorption isotherm is a sigmoid (type II) graph of the moisture content of the product as functioning the RH at a single temperature. The relationship can relate to a product adsorbing or desorbing moisture and it varies for different products mainly because of differences in chemical composition. Storage of products becomes hazardous in conditions represented by the final curved portion of the isotherm. Which begins between 75 and 80 relative humidities (%). Above 75 RH (%) moulds will develop rapidly during storage. For products such as grain the safe - moisture content is usually accepted as that in equilibrium with 70 RH (%) or less and the chances of deterioration through development of micro organisms and subsequent heating are considerably reduced. The moisture content in equilibrium with 70 RH (%) relatively varies with different products (Christensen, 1982).

Knowledge of the moisture sorption characteristics is crucial for shelf life predictions and determination of critical moisture and water activity for acceptability of products that deteriorate mainly by moisture gain and are important in drying, packaging and storage. The ability to predict the moisture content during storage under a variety of conditions can reduce the cost and the cycle time of product development and shelf life estimation. In the present study from curve of sorption behavior (Fig 5) it can be seen that above 70% RH the moisture content increased rapidly. The 70 RH (%) hydrothermally treated grains and In case untreated grains the safe moisture and RH was 10.02 and 60 RH (%). At 92 RH (%) mold growth was detected by inspection at the end of 12^{th} and 14^{th} day in hydrothermally treated and untreated grains respectively. At 86 RH (%) mold growth was detected by inspection at the end of 16^{th} and 20^{th} day in hydrothermally treated and untreated grains respectively. The hydrothermally treated grains can be stored safely below the 70 RH (%). The non treated grains should be stored below 60 RH (%). This information is useful for storage, transportation of millet grains. Suitable packaging materials can also be selected for storage of hydrothermally treated grains beyond 70 RH(%). Daniel *et al,*(2012) reported that commercial hybrid Maize (*Zea mays* L) seeds can be stored safely below 55 RH(%). Siripatrawan and Jantawat (2006) reported that the Jasmine rice crackers can be stored safely at 0.60 water activity (a_w =%RH/100).

5.3 Hydrothermal and baking technology for development therapeutic foods from little millet

5.3.1 Nutritional composition of hydrothermally treated grains

The nutritional composition of little millet grains were enhanced with nutrients after the hydrothermal treatment. Protein, dietary fiber, phyto nutrients, and bioavailability of minerals. Several studies have proved that the dietary fiber has important role in management of diabetes and cardiovascular disease. It has protective effect against a range of diseases, as constipation, diverticular disease, large bowel cancer, diabetes, coronary heart disease, obesity and gall stones. IDF shortens bowel transit time, increases faecal bulk and renders faeces softer. SDF delays gastric emptying slows glucose absorption, lowers serum cholesterol level and helps to reduce the risk of heart attack. Increased intake of legumes is recommended for diabetes because their beneficial effect in reducing post-prandial glycaemia (Chopra *et al*., 2009). The effects are related to the source of fibre (from cotyledon or hull) are dose related and depend on the form in which it is ingested. Recommended dietary allowance of dietary fibre is 25-30g/day. Scientific research must be undertaken to substantiate the potential long term health effect of legume fibre ingestion on health, in both normal individuals and subjects suffering from disorders. Fundamental knowledge of behaviour of fibre fractions in complex food systems is still required in order to be able to propose ingredients and adaptations to the formulations for appetizing foods with good nutritional properties.

The concepts of food are changing from a previous emphasis on survival, hunger satisfaction, absence of adverse effects on health, and health maintenance to a current emphasis on the use of nutraceutical foods which promise to promote better health and well-being, thus helping to reduce the risk of chronic illnesses such as cardiovascular diseases, some cancers and obesity. Phenols and phytic acid act as antioxidants which are nutraceuticals present in millet. Antioxidants are micronutrients that have gained interest in recent years due to their ability to neutralize the actions of free radicals. Free radicals are potentially harmful products generated during a number of natural processes in the body and associated with ageing of cells and tissues. Failure to remove active oxygen compounds, over a long term, can lead to cardiovascular disease, cancer, diabetes, arthritis and various neurodegenerative disorders. Hence the recent research on development of healthy foods focuses on antioxidant properties.

From the study it was observed that hydrothermal treatment enhanced the nutrition profile with respect to protein, dietary fiber, phyto-nutrients and more bioavailable minerals than the raw millet (Table 35). Hydrothermally treated grain provides (per serving 30g) 13 per cent higher protein than the raw grain. Similarly there was increase in the total dietary fiber content by 36 per cent. Hydrothermally treated grain provides 3.42 g of TDF, 2.37 g of IDF and 1.05 g of SDF.

Hydrothermally treated grains also provide 106 per cent more phenols and 29 per cent phytic acid than the raw grains. The per cent bioavailability of iron and zinc in hydrothermally treated grain was 3.74 and 7.50 with respectively where in raw grains it was 1.52 and 3.95 respectively.

Bioavailability of iron and zinc increased by 2.22 and 3.55 per cent respectively in hydrothermal treated grains. By considering above facts the hydrothermally treated little millet grains can be recommended as therapeutic grains in the management of diabetes and cardiovascular diseases.

5.3.2 Development of little millet incorporated little millet incorporated bread

Bread is a bakery product priced for its taste, aroma and texture. It is a staple food prepared by baking dough of flour and water. Salt, fat and yeast, are common ingredients, in addition to a wide range of other ingredients, namely, milk, egg, sugar, spice, fruits, vegetables, nuts and seeds (Encyclopedia Britannica, 2006). The popularity of bakery products has contributed to increased demand for ready-to-eat, convenience food products, such as bread, biscuits and other pastry products (David, 2006). In recent years, the consumption of wheat bread has risen in many developing nations, including Nigeria, as a result of increasing population, urbanization and changing food habits (Onabolu *et al*.,1998; Oloye, 2006). Wheat is the grain of choice in bread preparation due to its high gluten content. There have been reports of bread made from flours of other cereal grains such as rye, maize, barley and oats; roots like cassava in combination with wheat flour. FAO reported that flour from indigenous raw materials could be added in proportions that will not affect the original and intended colour, flavour and the particle size of the product adversely. To this end, there have been several attempts at partial substitution of wheat flour with flour from readily available, cheap, indigenous ingredients like millets. Alternatives to wheat flour such as germinated and non germinated soy flour (Dominguez, *et al* 2008), malted fermented sorghum (Hugo *et al*, 2009) banana flour (Mepba *et al*, 2007) composite flours of wheat, plantain, soy beans (Olaoye, *et al,* 2006), maize, soybean flour blends (Edema, *et al* 2005), rice flour (Noomhorm and Bandola, 1994), rice flour, corn starch and cassava starch have been reported.

Little millet is nutritionally better compared to rice and wheat. The aim of the present study is to evaluate the possibility of substituting wheat flour with little millet flour for the preparation of bread and to improve the nutritional quality of the bread. Little millet is one of important minor cereals grown extensively in the tropics and staple food for the low income groups. Traditionally it is consumed in form of rice and fermented form *idli* and *paddu* in northern part of India it is specially consumed as fasting food during festival. Little millet comparable to other cereals it is considered as good source of dietary fiber, minerals, and also contains phyto chemicals such as phenolic acids, flavaonoids tannins and phytates. It also possesses low glycaemic value. Processing of little millet significantly improves the neutarceutical properties of little millet by increasing phenolic contents also its anti oxidant activity. The regular consumption of little millet can bring significant health benefits but urban dwellers view millet as poor man's food the lack of awareness of health benefits of millet consumption among general public its usage in under usage. Little millet by its unique grain properties positions itself as a valuable food grain, possess considerable opportunities for diversification of its food use through processing and value addition. Hence little millet is good source of fiber and neutraceuticals used in the food formulation to enrich bread and popularize for therapeutic benefits.

Standard wheat bread recipe was modified used in the study. Decorticated little millet flour was incorporated in the levels of 10, 30 and 50 per cent to optimize the level of incorporation without affecting the functional properties of bread and acceptability. Physical dimensions, specific volume, textural properties and colour of the bread were the quality parameters observed. The increased incorporation of millet flour from 0 to 50 per cent decreased significantly ($p>0.05$) the physical dimensions of bread with respect to height, weight volume and specific volume (Table 36) (Plate 8 and 9). Length and breadth did not vary. The per cent decrease in volume of bread at maximum level of incorporation was 39.04. Similarly Rai *et al.* (2011) also reported that loaf weight and height decreased with progressive increase in the proportion of non gluten flour such as maize meal and rice flour. Height of the bread decreased with increase in millet proportion it is mainly because of substitution of non gluten flours which has reduced the gluten content in dough.

Higher loaf weight and volume have positive economic effect on bread at the retail end. Therefore, loaf weight reduction during baking is an undesirable economic quality to the bakers as consumers often get attracted to bread loaf with higher weight and volume believing that it has more substance for the same price. The specific volume, which is the ratio of the two properties (volume/weight), has been generally adopted in the literature as a more reliable measure of loaf size. Loaf volume is affected by the quantity and quality of protein in the flour (Ragaee & Abdel-Aal, 2006) as well as proofing time (Zghal *et al.,* 2002). Whereas loaf weight is basically determined by the quantity of dough baked, the amount of moisture and carbon dioxide diffused out of the loaf during baking (Shittu *et al,* 2007). In the present study the significant decrease in the physical dimensions of the bread with increased incorporation of millet flour might be due to decrease in proportion of gluten content which is the important protein responsible for visco-elastic property of dough and to increase the volume of bread.

According to China Grain Products Research and Development Institute (CGPRDI) the specific volume of standard bread should be 6 cm^3 /g and should not be less than 3.5 cm^3 /g (Lin *et al*, 2009). In the present study specific volume of millet breads range from 2.51 to 3.99 cm3/g. Incorporation millet flour at 10 and 30 per cent level could attain the standard specific volume mentioned above (Table 36).

The results of crust and crumb colour of millets incorporated breads revealed that the crust colour varied significantly ($p>0.05$) with increase in the millet proportion (Table 37). The preferred bread crust colour is brown. In the present study "L" (whiteness) value of crust decreased with increase in millet flour proportion up to 30 per cent. At 50 per cent incorporation the crust did not turn to brown as other variations (Plate 7). Similar trend was also observed 'a' value and it was varied significantly ($p>0.05$) with proportion of little millet. There was also significant difference ($p>0.05$) between wheat and millet bread for 'b' value which depicts browning of bread. 'b' values were lower than wheat bread.

Crumb colour was also significantly varied ($p>0.05$) (Plate 10). For the crumb 'a' value increased and 'b' value decreased significantly ($p>0.05$) with increase in millet proportion. The results revealed that as the proportion of millet increased the colour of bread decreased. Siddiq *et al*, (2009) observed that defatted maize germ flour addition to wheat bread decreased 'L' and b value and increased 'a' value with increase in proportion.

The crumb texture of millet breads were also observed by using Texture Analyzer. Incorporation of millet flour at different level increased (1.76 to 5.67 N) hardness value of the bread with increased proportion (Table 38). However there is no significant difference found in cohesiveness and adhesiveness when compared to wheat bread. The main function of wheat gluten present in dough during dough mixing is to swell and hold water, forming cells with strong elastic walls which capture carbon dioxide formed during fermentation. In the study the increased hardness in millet incorporated bread may be due to lack of gluten network to capture the carbon-di-oxide formed during fermentation (Veluppillai *et al,* 2010). The bread texture is influenced amount of water in dough, different water retention capacities of wheat and other flours and any change in the protein content. Jyotsna *et al.* (2011) reported that the hardness increased, indicating a hard texture with the increase in the level of finger millet flour (up to 25%). Siddiq *et al,* (2009) reported that the texture parameters were greatly affected by the addition of defatted maize germ (DMG) flour in breads. The hardness values increased with increasing levels of DMG flour, from 32.84 N recorded for the control bread to 61.58 N in 20 g/100 g DMG bread. In present study same trend was observed the hardness value increased from 1.76 to 5.67 N. The addition of millet flour influenced the crumb structure by retaining more moisture thus increasing the hardness values of the bread and also modifying the quantity and quality of protein in the wheat–millet flour bread system. Additionally, high levels of millet flour addition led to lack of uniform crumb structure (Plate 9).

The mean sensory scores obtained for millet incorporated bread at different levels and wheat bread ranged between 6.31 and 7.84 (Table 39). The analysis of variance (ANOVA) showed that there was no significant difference ($p>0.05$) between wheat and millet breads with 10 and 30 per cent incorporation. Fifty per cent incorporated millet had slightly lower score when compare to other millet breads. Even quantitative analysis of bread through instruments also revealed lower acceptability of millet bread (50 %) for texture and colour. This is mainly because of increased hardness and less browning of crust during baking (Table 37, 38). Since there was no significant difference for the most of the sensory characteristics of millet bread with 10 and 30 per cent incorporation bread, because of the health benefits of incorporation of little millet at higher proportion without affecting the consumer acceptability the 30 per cent incorporation was considered as optimum level for enrichment of bread for therapeutic use. Similarly Veluppillai *et al*. (2010) reported that wheat flour substitution with 35 per cent malted rice flour was the best according to the physical and sensory quality of the bread. Rai *et al.* (2011) reported that 25 per cent replacement of wheat flour by rice flour was found to be more acceptable than control bread. Hence millet flour substitution at 30 per cent in baking bread make a good and acceptable sensory attributes with probably no significant differences from the wheat bread. Thirty per cent incorporated little millet bread was evaluated for its nutritional and shelf life.

The nutrient composition of 30 per cent little millet incorporated bread and wheat bread showed that ash, crude fiber, dietary fiber contents increased significantly with addition of millet (Table 40). The dietary fiber increased by 19 per cent of that wheat bread in the little millet bread. This could be probably due to the higher ash and dietary fiber content in the little millet compared to wheat (Gopalan *et al,* 2007, Anon, 2009, Padulosi *et al,* 2009). Whereas the protein content of little millet incorporated bread was significantly lower (11.95%) this could be due to lower protein content in the grain itself compared to wheat (Gopalan *et al.,* 2007 and Padulosi *et al,* 2009). Similar type of results were also observed by Jyotsna et al (2011) by incorporating finger millet flour increased ash content and lowered protein content in bread and muffins or mineral composition.

Little millet incorporated bread also showed higher values for iron, copper, manganese, zinc, and potassium (Table 41). The per cent increase in iron, zinc, copper and phosphorus was 94, 29, 70, and 28 respectively. The bioavailability of iron and zinc is significantly greater in wheat bread as compared to little millet bread. The decrease in the bioavailability of iron and zinc in little millet bread is due to the presence of higher per cent of dietary fiber and crude fiber (Table 42). However consumption of 100 g little millet bread provides more iron and zinc which in turn provides more bioavailable minerals. The study demonstrated that incorporation of millet enhances the dietary fiber and micro nutrients which are considered beneficial in management diabetes and cardiovascular disease.

Shelf life of the selected level of breads was studied. The moisture content of the breads decreased as the storage period increased (Table 43). It may be due loss of moisture content and dryness. Breads were analyzed for apparent spoilage by visual observation for mould growth under ambient temperature. The wheat bread got mould growth one day earlier than little millet bread. In little millet bread (30%) mould growth was seen at 5th day of storage. The moisture content of little millet bread decreased during storage and free fatty acid (mg KOH/100g) contents increased during storage in both breads. The free fatty acid contents increased more in wheat bread than the little millet bread. The sensory evaluation revealed that the little millet bread was acceptable up to 3rd day it became sour later. The wheat bread was acceptable up to 3rd day of storage. The scores were higher at initial and decreased during storage. The sensory scores were higher for little millet bread than wheat bread during storage. The shelf life of little millet bread was 4 days and shelf life of wheat bread was 3 days at ambient temperature (25 ± 2ºC). The storage stability of millet bread was better than wheat bread may be due higher per cent of phenols and phytic acid in the little millet (Table 8).

Nutrient composition of bread (per serving 50g) was computed. The little millet bread showed higher values for ash, crude fiber and dietary fiber content, which may be due little millet itself is good source of minerals, crude fiber and dietary fiber compared to wheat. Millet also showed higher values for the micronutrients like iron, zinc, copper and phosphorus. It may be due little millet is good source of micronutrients (Gopalan *et al,* 2007, Ushakumari and Malleshi, 2007). The millet bread can be recommended as therapeutic bread for the needy people.

Future line of the work

- To study acceptability and consumer attitude towards hydrothermally treated little millet grains.
- Physico chemical characteristics of hydrothermally treated cooked rice and alternative uses.
- Intervention studies on health benefits of hydrothermally treated rice and little millet bread.
- Market potentiality of value added products of little millet grains developed through novel technologies.

SUMMARY AND CONCLUSIONS

The present investigation entitled “Storage quality of little millet (*Panicum miliare*) and diversification of utilization of little millet through hydrothermal and baking technologies” was carried out in Department Food Science and Nutrition, College of Rural Home Science, UAS, Dharwad with objectives to evaluate local and high yielding varieties for physico-chemical and nutritional qualities, to study the changes in physico-chemical processing and nutritional qualities during ageing and hydrothermal treatment and to develop value added products of little millet through different technologies.

The little millet grains were procured from farmers of Timmapur village, Haveri District, Karnataka. The other ingredients were procured from local market. The milling experiments were conducted by using rubber roller mill (developed by McGill University, Canada and UAS Dharwad, India, IDRC millet project,) and laboratory rice polisher. The physico-chemical characteristics were assessed by using standard procedure. The little millet grains were stored in gunny bags at ambient temperature drawn at every six months studied for physico-chemical and processing changes. The hydrothermal treatment to the little millet grains was done using combination of soaking time (3- 4h), soaking temperature (60, 70 and 80° C) steaming time (15, 20, and 25 min) and steaming temperature (100 and 110° C). Drying was done drying oven at 60 ° C for 10 to 12 h. The process was optimized by milling quality, colour, cooking quality and consumer acceptability. The optimized grains were analyzed for physico-chemical, nutritional and functional properties by using standard procedures. Nutrients per serving (30 g) were computed. Sorption behavior of hydrothermally treated grains was studied using standard procedure. The millet incorporated bread was developed by using standard procedure of Bakery Unit, UAS, Dharwad, and then optimized the process by assessing physical dimensions, texture, colour and sensory evaluation. The optimized bread was analyzed for nutrients using standard procedure. Storage stability of little millet (30 %) bread was studied and with comparison was made to wheat bread.

The salient findings of the study are summarized below.

- *Malli savi* yielded higher Head rice yield and lesser broken compare to high yielding varieties. It was found that Sukshema and *Malli savi* grains were longer and JK-8 and *Kari savi* were shorter in length.
- The *Malli savi* variety was having higher thousand grain weight (2.97 and 2.19g) for both whole grains and decorticated grains. The mean volume of thousand grains was 1.67 ml and 1.48 ml for whole grains and decorticated grains respectively. *Malli savi* was the hardest (15.97N) followed by JK-8. *Malli savi* variety of little millet grains were lighter in color compared to other varieties.
- The moisture content was high in *Malli savi* variety (8.61%) followed by Sukshema and *Kari savi* and low in CO(Sa) 4 variety. Protein content was found to be high in *Malli savi* variety and found to be low in Sukshema. The highest fat was found in Sukshema variety followed by *Kari savi* and lowest was found in *Malli savi*.
- There was significant difference between all the varieties of little millet for phenols and phytic acid. There was significant difference found between the mineral compositions of the varieties. Significant varietal difference in cooking quality of little millet rice was observed. There was no significant difference in sensory characters in the five varieties of little millet cooked rice.
- The moisture content decreased during storage period, it ranged from 8.39 to 10.66 per cent. The decrease of moisture content was significant during storage.
- The per cent hulled grains ranged from 80.27-81.47 during storage period of 18 months. The de-hulling percentage increased with storage. Head rice yield per cent was minimum in fresh. Head rice yield per cent increased as the storage period increased. There was significant increase in head rice yield during storage.
- The thousand kernel weight was found to be high in fresh sample (2.70 g) and was low in 18 months stored sample (2.56 g). Similar trend was observed for decorticated grains. Significant difference was observed for length and breadth of sample. L/B ratio ranged from 1.15 mm to 1.13 mm. As the storage increased the particle size increased.
- The increase in all the nutrients was observed during storage. However the significant increase was observed for protein content, total phenols and phytic acid content during storage.
- Significant decline was observed in IVPD and IVSD during the storage. Significant decrease observed in amylose and soluble amylose content of the grains during storage. Soluble dietary fiber decreased significantly but insoluble fiber and total dietary fiber increased during storage period.

- A minimum of 8.34 min and maximum of 10.52 min of cooking time was recorded for storage samples of little millet. Significant decline was observed in swelling power, solubility and soluble proteins during storage period. The maximum values were observed at fresh and minimum values were observed in 18 months stored sample.
- Significant difference was observed in millet rice for the characteristics like appearance, texture, colour, and overall acceptability. There was no significant difference observed for flavor and taste during storage.
- It was observed that the head rice varied from 72.67 to 95.62 per cent for all the hydrothermal treatment.
- The head rice yield increased from 87.35 to 89.69 per cent with increase in soaking temperature from 60 to 80ºC. The head rice yield increased from 86.80 to 89.61 per cent with increase in soaking time of 3 to 4 h. The head rice yield increased from 87.42 to 88.98 per cent with increase in steaming temperature from 100 -110^{0} C.
- The broken per cent decreased with the increase in time of soaking (3-4 hrs), with increase in the soaking temperature, with increase in steaming temperature and with increase in steaming time. There was significant difference observed for the broken per cent.
- There was significant decrease in L* and a* value observed and significant increase in b* value was observed with the hydrothermal treatment.
- The cooking quality of the hydrothermally treated grains varied from 15.00 min to 28.73 min. The cooking time increased with increase in conditions of hydrothermal treatment.
- The leached solids ranged from 4.77 to 11-70 per cent. The per cent leached solids increased with increased in soaking temperature from 100^{0} to 110^{0} C and decreased with soaking time, steaming time and soaking temperature.
- Water uptake of different hydrothermal treatment ranged from 3.28 to 5.61 per cent water uptake decreased with severity of hydrothermal treatment.
- Consumer acceptability scores ranged from 55 to 112. The maximum score for grains of 70^{0} soaking for 4 h and steaming for 100^{0}C for 25 min and followed by grains of 70^{0} soaking for 3 h and steaming for 110^{0} for 15 min.
- When all other parameters considered the treatment with initial soaking temperature of 70^{0} C for 3 h and steaming at 110^{0} C for 20 min was found to be optimum.
- The moisture content of the hydrothermally treated millet was higher (9.63%) than the raw millet (9.32).The protein content found to be high in the hydrothermally treated sample (10.69%) compared to raw millet (8.57%). The fat content of hydrothermally treated grains (3.35%) was slightly decreased compared to raw grains (3.57%).
- The ash content decreased after hydrothermal treatment from 2.51 to 1.33 per cent. The crude fiber content of hydrothermally treated grains increased after hydrothermal treatment from 2.41 to 2.57 per cent. The carbohydrate content ranged from 72.41 to 74.10 per cent.
- The total phenols and phytic acid content increased after hydrothermal treatment. The phenol content increased from 116.10 to 239.40 mg. The phytic acid content increased from 1.29 g (raw grains) to 2.25 g. There was a significant difference observed in the phyto nutrient content of the grains.
- It was observed that total mineral content reduced from 2.51% to 1.33%.There was significant ($p>0.05$) decrease observed for iron and zinc content. Per cent iron bioavailability increased after hydrothermal treatment from 5.05 to 12.45% and zinc bio availability was increased from 13.17 per cent to 25.00 per cent.
- There was significant decrease in starch content of the hydrothermally treated grains from 76.03 to 73.45%. The amylose content of hydrothermally treated grains & raw grains was 14.95 and 14.62 per cent respectively.
- Protein digestibility after hydrothermal treatment decreased from 63.83 to 62.20%. However there was no significant difference observed for protein digestibility. Starch digestibility was significantly lower in hydrothermally treated grains compared raw grains.
- The overall acceptability score for hydrothermally treated rice was 8.2 which was higher compared to raw rice (7.5). There was no significant difference found for appearance, texture and colour. However, there was significant difference observed for flavour, taste and overall acceptability.
- The hydrothermally treated grains had better storage at less than 75 RH(%). The storage quality is better than raw grains.
- As the per cent of millet flour incorporation increased, the weight of the bread decreased. There was significant difference ($p>0.05$) observed for weight of the breads.

- The height of the breads ranged from 6.70 to 4.20 cm. The control bread was having more height (6.70 cm) and the 50 per cent incorporated bread was having lower height (4.20cm).
- Loaf volume ranged from 284.03 to 461.28 cm^3. Specific volume ranged from 2.51 to 4.05cm^3/g. As the millet flour level increased the volume and specific volume decreased significantly ($p>0.05$).
- 'L* , a* and b* value of crust and crumb varied significantly ($p>0.05$) with increase in millet flour proportion
- The hardness of the bread ranged from 1.76 to 5.67 N. The hardness values of the millet breads were higher when compared to wheat bread.
- There was no significant difference ($p>0.05$) observed for cohesiveness and adhesiveness of the bread.
- Sensory evaluation revealed that there was no significant difference found between the control and the millet breads prepared with 10 and 30 per cent millet incorporation.
- Moisture content of the wheat and millet bread was 32.88 and 30.26 respectively. There was significant difference ($p>0.05$) observed for fat, ash, protein and crude fiber for the breads.
- The total dietary fiber content of wheat bread was 6.76 g and millet bread was 7.60 g. There was significant difference ($p>0.05$) observed for the dietary fiber content of the millet and wheat bread.
- Little millet bread with 30 per cent incorporation showed high values for iron, copper, phosphorus, zinc, potassium except sodium content compared to the wheat bread.
- The per cent iron bioavailability was maximum (28.85%) in wheat bread and was minimum (21.16 %) in millet bread. The per cent zinc bioavailability was maximum (47.62%) was in wheat bread and was minimum (29.12%) in millet bread.
- As the storage period increased the bread became dried and the moisture content decreased. At 4^{th} and 5^{th} day fungus was developed in wheat and little millet bread.
- Free fatty acid content of initial day was 5.67 (mg KOH/100g) and as the storage days increased the free fatty acid content increased.

Conclusion

The study concludes that local cultivars possess superior nutritional and processing qualities. Varietal difference for nutrition and milling quality determines the specific end use of grains. Stored little millet grains of 18 months exhibited better milling and cooking qualities with enhanced nutritional benefits for better health. Hydrothermally treated little millet rice was translucent shiny, firm, fluffy and non sticky. These characteristics were preferred properties by the consumer. Hydrothermal treatment improved the nutritional profile and enhanced therapeutic property, processing quality and shelf life. These grains can be claimed nutritionally as therapeutic cereal for management of metabolic disorders. Bread is an excellent vehicle for addition of functional ingredient like little millet flour to increase the fibre and micronutrient content. These formulations can be easily adopted by the bakeries to value added health foods required for particular segment of the population who are health conscious and consider food as medicine. Millet flour at 30 per cent level of incorporation was optimum on the basis of bread making and organoleptic quality of bread. Shelf life of little millet bread was 4 days at room temperature (25±2º C).

REFERENCES

Adebowale, K.O., Afolabib, T.A. and Owolabi, B.I., 2005, Hydrothermal treatments of Finger millet (*Eleusine coracana*) starch. *Food Hydrocolloids*. **19**: 974–983.

Anonymous, 2008, Annu. Tech. Rep. (2007-08), Project on Empowering rural poor by strengthening their identity, income, opportunities and nutritional security through the improved use and marketing of neglected and underutilized species, Phase-II, MSSRF , Chennai.

Anonymous, 2010, Introducing millets into Public Distribution System (PDS): A Pilot project by WASSAN in Andhra Pradesh, www.dhan.org/Millet/docs/report/Introducing_millets_into_Public_Distribution_System.pdf, Accessed on 28/04/2012

Anonymous, 1983, *Annu. Rep.,* National Institute of Nutrition (ICMR), Hyderabad, pp. 1-4.

Anonymous, 1995, Official methods of Analysis, Association of Official Analytical Chemists,18th edition, Washington, DC.

Anonymous, 2009, Millet Network of India, Deccan Development Society, FIAN, India.

Anonymous, 2011, Annu. Tech. Rep (2010-11), Project on Empowering rural poor by strengthening their identity, income, opportunities and nutritional security through the improved use and marketing of neglected and underutilized species, Phase-II, MSSRF , Chennai.

Bello, M., Baeza, R. and Tolaba, M.P., 2006, Quality characteristics of milled and cooked rice affected by hydrothermal treatment. *J. Food Eng.,* **72**: 124–133.

Chandrasekara, A., Naczk, M. and Shahidi, F., 2012, Effect of processing on the antioxidant activity of millet grains. *Food Chem.*, **133**: 1–9.

Chethan, S. and Malleshi, N. G., 2007, Finger millet polyphenols: Characterization and their nutraceutical potential. *Am. J. Food Technol.*, **2**(7): 583-592.

Chimmad, B. V., Meghana, D. R., Naik, R. and Kamatar, M. Y., 2011, Formulation of sports food for physical endurance, *Proc. Nation. Symp. on Recapturing nutritious millets for health and management of diseases*, NAIP, UAS, Dharwad, pp-43.

Christensen, C. M. 1982, Storage of cereal grains and their products. 3rd edition, American Association of Cereal Chemists, Inc. St. Paul, MN, USA.

Chopra, H., Udipi, S. A. and Ghuge, P., 2009, Dietary fibre content of selected legumes: Varietal differences and effect of processing, *J. Food. Sci. Technol.,* 46 (3): 266-268.

Chukwu, O. and Oseh, J. F., 2009, Response of nutritional contents of rice (*Oryza sativa*) to parboiling temperatures. *Am. Eurasian J. Sustain. Agric.,* **3**(3): 381-387.

Daniel, I. O, Oyekale, K. O., Ajala, M. O., Sanni, L. O.,Okelana, M A., Adetumbi, J. A., Akintobi, D. A. C., and Adebisi, M. A., 2012, Moisture sorption in commercial hybrid maize (*Zea mays* L.) seeds during storage at ambient tropical conditions. *Res. J. Seed Sci.*, **5**(1):32-37

Daniels, M. J., Marks, B. P., Siebenmorgen,T. J., Macnew, R. W. and Meullenet, J. F., 1998, Effects of long-grain rough rice storage history on end-use quality. *J. Food Sci.,* **63**(5):832-835.

David, M.O., 2006, Nigeria, No 1 market for U.S. Wheat; Potential for other grains and feeds, USAID, Foreign Agric. Serv. Bull., pp. 1-2.

Dejene, M., Yuen, J. and Sigvald, R., 2006, Effects of storage methods, storage time and different agro-ecological zones on chemical components of stored sorghum grain in Hararghe. *Ethiopia J. Stored Prod. Res.*, **42**: 445-456.

Devi, K., Geervani, P. and Sumathi, S., 1997, Changes in solubility and in *vitro* digestibility of rice proteins subjected to heat processing, *J. Food Sci. Technol.*, **34**(4): 345-347.

Dharmaraj, U. and Malleshi, N.G., 2010, Changes in carbohydrates, proteins and lipids of finger millet after hydrothermal processing. *LWT -Food Sci. Tech.*, **30**: 1-7.

Dominguez, G. C., Juarez, M. R., Mendoza, G., Guel, E. C. L., Baustista, F. L., Perez, J. C., Lopez, G. C. and Rebollo, R. F., 2008, Changes on dough rheological characteristics and bread quality as a result of the addition of germinated and non germinated soy bean flour. *Food Bioprocess. Technol.*, **1**(2): 152–160.

Eddy, N. O., Udofia, P. G. and Eyo, D., 2007, Sensory evaluation of wheat/cassava composite bread and effect of label information on acceptance and preference. *African J. Biotech.,* **6** (20):2415-2418.

Edema, M. O., Sanni, L. O. and Sanni, A. I., 2005, Evaluation of maize soybean flour blends for sour maize bread production in Nigeria. *African J. Biotech.*, **4**(9): 911–918.

Eerlingen, R.C., Delcour, J.A., 1995. Formation, analysis, structure and properties of type III enzyme resistant starch. *J. Cereal Sci.,* **22**:129–138.

Encyclopaedia Britannica, 2006, Bread Britannica Concise Encyclopedia Britannica, Inc, www.britannicaencyclopediainc.com

Englyst, H., 1989. Classification and measurement of plant polysaccharides. *Animal Feed Science and Technology*, **23**:27–42.

Flander, L., Salmenkallio-Marttila, M., Suortti, T. and Autio, K., 2007, Optimization of ingredients and baking process for improved wholemeal oat bread quality, *LWT- Food Sci. Tech.,* **40**: 860–870.

Geervani, P and Eggum, B. O., 1989, Nutrient composition and protein quality of minor millets, *Plant Foods for Human Nutr.*, **29**: 201-208.

Gopalan, C., Ramasastri, B.V. and Balaubramanian, S.C., 2007, Nutritive value of Indian foods. National Institute of Nutrition, ICMR, Hyderabad.

Graham, R., 2002, A proposal for IRRI to establish a grain quality and Nutrition Research Center, *IRRI Discussion Paper Series,* 44, pp15.

Gujral, H. S., and Kumar, V., 2003, Effect of accelerated ageing on the physicochemical and textural characteristics of brown and milled rice, *J. Food Eng.,* **59**: 117-121.

Hadimani, N.A., and Malleshi, N.G., 1993, Studies on milling, physico-chemical properties, nutrient composition and dietary fibre content of millets. *J. Food Sci. and Tech.,* **30** : 45-52.

Heinemann, R. J. B., Behrens, J. H. and Lanfer-Marquez, U. M., 2006, A study on the acceptability and consumer attitude towards parboiled rice. *International J. Food Sci. Technol.*, **41**: 627–634.

Heinemann, R. J. B., Fagundes, P. L., Pinto, E. A., Penteado, M. V. C. and Lanfer-Marquez, U.M., 2005, Comparative study of nutrient composition of commercial brown, parboiled and milled rice from Brazil. *J. Food Composition Analysis,* **18**: 287–296.

Holtekjølen, A. K., Bævre, A.B., Rødbotten, M., Berg, H. and Knutsen, S. H., 2008, Antioxidant properties and sensory profiles of breads containing barley flour, *Food Chem.,* **110**: 414–421.

Hugo, L. F., Rooney, L. W. and Taylor, J. R. N., 2009, Bread making with malted and fermented sorghum. http://www.afripro.org.uk/ papers/Paper19 Hugo.pdf.

Ibukun, E. O., 2008, Effect of prolonged parboiling duration on proximate composition of rice. *Scientific Res. Essay*, **3**(7):323-325.

Islam, R. M., Shimizu, N. Kimura, T., 2002, Effect of Processing Conditions on Thermal Properties of Parboiled Rice. *Food Sci. Tech. Res.,* **8**(2): 131–136.

Itagi, S. K, 2003, Development and evaluation of millet based composite food for diabetics II, *Ph.D thesis*, Univ. Agric. Sci., Dharwad, Karnataka.

Jali, M. V., Hiremath, M. B., Sankpal, S., Kamatar, M. Y. and Naik, R., 2011, Efficacy of value added therapeutic foods in the mangement of diabetes in selected human volunteers, *Proc. Nation. Symp. on Recapturing nutritious millets for health and management of diseases*, NAIP, UAS, Dharwad, pp.31.

Jyotsna, R., Soumya, C., Indrani, D. and Venkateswararao, G., 2011, Effect of replacement of wheat flour with finger millet flour *(Eleusine corcana)* on the batter microscopy, rheology and quality characteristics of muffins. *J. Texture Studies,* **42:** 478–489.

Kapoor, N., Arya, A., Siddiqui, A. M., Kumar, H. and Amir, A., 2011, Physiological and biochemical changes during seed deterioration in aged seeds of rice (*Oryza sativa* L.). *American J. Plant Physiol.,* **6**(1): 28-35.

Kato, H., Ohta, T., Tsugita, T. and Hosaka, Y., 1983, Effect of parboiling on texture and flavor components of cooked rice. J Agric. Food Chem., **31**:818-823(Cited in: Devi, K., Geervani, P. and Sumathi, S., 1997)

Kawassaki, F., Mikaro, A. S., Massaretto, I. L., Noldin, J. A. and Marquez, U. M., 2011, Correlation between phenolic compounds and antioxidant activity in brown rice before and after parboiling, AACC International Annual meeting October 16-19, 2011, Palm Springs, California, USA http://www.aaccnet.org/meetings/Documents/2011Abstracts/p11ma110.html.

Kimura, T., Bhattacharya, K.R. and Ali, S.Z., 1993, Discoloration characteristics of rice during parboiling (I): Effect of processing conditions on the color intensity of parboiled rice. *J. Soc. Agric. Structures*, **24**: 23–30.

Kotagi, K., 2011a, Little millet (*Panicum miliare*) flakes: development, value addition, quality evaluation, consumer acceptability and commercialization, *Ph.D. Thesis*, Univ. Agric. Sci., Dharwad, Karnataka.

Kotagi, K., Chimmad, B., Naik, R. and Bharati, P., 2011b, Millet choco flakes: development, consumer acceptability and quality evaluation, *Proc. Nation. Symp. on Recapturing nutritious millets for health and management of diseases*, NAIP, UAS, Dharwad (India), December16-17, 2011, pp.33.

Kotagi, K., Chimmad, B., Itagi, S. and Bharati, P., 2013, Glycemic index and quality evaluation of ready to cook little millet (*Panicum miliare*) flakes, *Proc international workshop on Small millet research in value addition*, IDRC, UAS, Dharwad (India), February 8-9, 2013, pp. 94.

Kulkarni, L.R., Naik, R.K. and Katarki, P.A, 1992, Chemical composition of minor millets. *Karnataka J. Agric. Sci.,* **5** (3) : 255-258.

Kulkarni, L.R. and Naik, R. K., 1999, Chemical composition and protein quality of Italian millet. *Karnataka J. Agric. Sci.,* **12** : 164-167.

Kulkarni, L. R. and Naik, R. K., 2000, Nutritive value, protein quality and organoleptic quality of kodo millet (*Paspalum scorbiculatum*). *Karnataka J. Agric. Sci.,* **13**(1) : 125-129.

Kundgol, N.G., Kasturiba, B., Malagi, U. and Naik, R.K., 2013, Antioxidant activity of little millet landraces grown in three different districts of Karnataka, *Proc international workshop on Small millet research in value addition*, IDRC, UAS, Dharwad (India), February 8-9, 2013, pp. 91.

Lamberts, L., De Bie, E., Derycke,V., Veraverbeke, W.S., De Man, W. and Delcour, J. A., 2006, Effect of processing conditions on color change of brown and milled parboiled rice. *Cereal Chem*., **83**(1):80–85.

Lin, L., Liu, H., Yu,Y., Lin, S. and Mau, J., 2009, Quality and antioxidant property of buckwheat enhanced wheat bread. *Food Chem.,* **37**: 461-467.

López, A. C. B., Pereira, A. J.G. and Junqueira, R. G., 2004, Flour mixture of rice flour, corn and cassava starch in the production of gluten-free white bread. *Brazilian Arch. Biol. Tech.*, **47**(1):63-70.

Lorenz, K., 1983, Tannin and phytate content of Proso Millets *(Panicum miliaceum). Cereal Chem.,* **60**(6): 424-426.

Malleshi, N. G., 2002, Nutritional qualities of millets and Pseudocereals. *Short-term Processing and Value Course on Addition to Nutritious Millets,* CFTRI, Mysore, pp. 17-27.

Malomo, S. A., Eleyinmi, A. F. and Fashakin, J. B., 2011, Chemical composition, rheological properties and bread making potentials of composite flours from breadfruit, breadnut and wheat, *African J. Food Sci.,* **5**(7): 400– 410.

Manful, J.T, Grimm, C.C, Gayin, J and Coker, R.D, 2008, Effect of variable parboiling on crystallinity of rice samples. *Cereal Chem*, **85**: 92–95.

Mangala, S. L., Malleshi, N.G., Mahadevamma and Tharanathan, R.N., 1999, Resistant starch free differently processed rice and ragi (Finger millet). *European Food Res. Technol.,* **209**: 32-37.

McDonough, C.M., Floyd, C.D., Waniska, R.D. and Rooney, L.W., 2004, Effect of accelerated aging on maize, sorghum, and sorghum meal, *J. Cereal Sci.,* **39**: 351–361.

Meghana, D.R., Saraswathi, G. and Premavalli, K. S., 2011, Effect of supplementation of Ragi based Snacks on nutritional Status of children, *Proc. Nation. Symp. on Recapturing nutritious millets for health and management of diseases*, NAIP, UAS, Dharwad, , December 16-17, 2011, pp. 34.

Mepba, H., Eboh, L., Nwaojigwa, S. U., 2007, Chemical composition, functional and baking properties of wheat-plantain composite flours. *African J. Food Agric. Nutr. Dev.*, 7(1): 1–22.

Meullenet, J. F., Marks, B. P., Griffin, K. and Daniels, M. J., 1999, Effects of rough rice drying and storage conditions on sensory profiles of cooked rice. *Cereal Chem.*, **76**(4):483-486.

Miah, M.A.K., Haque, A., Douglass, M.P. and Clarke, B. 2002a, Parboiling of rice. Part I: Effect of hot soaking time on quality of milled rice. International *J. Food Sci. Technol.*, **37**: 527–537.

Miah, M. A. K., Haque, A., Douglass, M. P. and Clarke, B., 2002b, Parboiling of rice (II): Effect of hot soaking time on the degree of starch gelatinization. *Int. J. Food Sci. Tech.,* **37**: 539–545.

Miller, J. D., Schricker, B. R., Rasmussen, R. R. and Campen, J. V., 1981, An *in vitro* method for estimation of iron availability from meals. *American J. Clin. Nutr.*, **34**: 2248-2256.

Mishra, B. K. and Gupta, R. K., 1995, Protocol for evaluation of wheat quality. *Technical Bulletin No. 3,* Directorate of Wheat Research, Karnal, India.

Mogra, R., Bhatnagar, V. and Choudhry, M., 1998, Proximate principles and mineral composition of foxtail millets. *Proc. Nutr. Soc. India, Annu. Meet.*, Nov. 26-28, Hyderabad, p. 59.

Mouliswar, P., Kurien, S., Daniel, V.A., Malleshi, N.G. and Venkatarao, S., 1993, *In vitro* digestibility of protein and starch as energy food and its bulk reduction. *J. Food Sci. Technol.,* **30**: 36-39.

Ninganagoudar, G. S., Yenagi, N. B. and Prashanti, K. S., 2012, Evaluation of *Anaras* prepared from different types of rice and little millet *(Panicum sumatrense*) flours. *Karnataka J. Agric. Sci.,* **25**(4): 503-505.

Noomhorm, A. and Bandola, D. C., 1994, Effect of rice variety, rice flour concentration and enzyme levels on composite bread quality. *J. Sci. Food Agric.*, **64**(4): 433–440.

Ohno, T. and Ohisa, N., 2005, Studies on textural and chemical changes in aged rice grains. *Food Sci. Technol. Res.*, **11**(4): 385-389.

Ojha, R., 2010, Prevalence of Malnutrition in India: A Disturbing Phenomenon, *Cyber Literature*, 3(2): 37-44

Olaoye, O. A., Onilude, A. A. and Idowu, O. A., 2006, Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. *African J. Biotech*, **5**(11): 1102–1106.

Onabolu, A., Abass, A, and Bokannga, M.,1998, New Food product from cassava. IITA, Ibadan, pp. 40.

Otegbayo, B. O., Osamuel, F. and Fashakin, J. B., 2001, Effect of parboiling on physico-chemical qualities of two local rice varieties in Nigeria. *J. Food Tech. Africa,* **6**(4): 130-132.

Padulosi, S., Mal, B., BalRavi, S., Gowda, J., Gowda, K.T.K., Shantkumar, G., Yenagi, N. and Dutta, M., 2009, Food security and climate Change: Role of plant genetics resources of minor millets, *Indian J. Plant Genet. Resource,* **22**(1):1-16

Parnsakhorn, S. and Noomhorm A., 2008, Changes in physicochemical properties of parboiledbrown rice during heat treatment. *Agric. Engineering Int. the CIGR E-journal.,* **10**: 1-20.

Patindol, J., Wanga, Y. and Janeb, J., 2005, Structure-functionality changes in starch following rough rice storage. *Starch/Stärke*, **57**: 197–207.

Pearce, M. D., Marks, B. P. and Meullenet, J. F., 2001, Effects of postharvest parameters on functional changes during rough rice storage. *Cereal Chem*, **78**(3): 354-357.

Perdon, A.A., Siebenmorgen, T.J., Buescher, R.W. and Gbur, E.E., 1999, Starch retrogradation and texture of cooked milled rice during storage. *J. Food Sci.,* **64**(5):828-832

Pradeep, S. R., and Guha, M., 2011, Effect of processing methods on the nutraceutical and antioxidant properties of little millet (*Panicum sumatrense*) extracts. *Food Chem.*, **126**: 1643-1647.

Ragaee, S. and Abdel-Aal, E. M., 2006, Pasting properties of starch and protein in selected cereals and quality of their products. *Food Chem*, **95**(1):9–18.

Rai, S, Amarjeet, K., Singh, B and Minhas K. S., 2011, Quality characteristics of bread produced from wheat, rice and maize flours. *J. Food Sci.*, **49**(6):786-789.

Rehman, Z. and Shah, W.H., 1999, Biochemical changes in wheat during storage at three temperatures. *Plant Foods for Human Nutrition,* **54**: 109–117.

Rehman, Z., Habib, F., and Zafar, S. L., 2002, Nutritional changes in maize (*Zea mays*) during storage at three temperatures. *Food Chem.,* **77**: 197–201.

Rehman, Z., 2006, Storage effect on nutritional quality of commonly consumed cereals. *Food Chem.*, **95**: 53-57.

Rockland, L.B., 1960, Saturated salt solutions for static control of relative humidity between 5^{o}C to 40 ^{o}C. *Analytical Chem.*, **32**:1375-1380.

Roopa, U., Kasturiba, B. and Naik, R., 2011, Formulation of sports food for physical endurance, *Proc. Nation. Symp. on Recapturing nutritious millets for health and management of diseases*, NAIP, UAS, Dharwad (India), December 16-17, 2011, pp. 43.

Rosales-Juárez, M., González-Mendoza, B., López-Guel, E. C., Lozano-Bautista, F., Chanona-Pérez, J., Gutiérrez-López, G. and & Farrera-Rebollo, R., Georgina Calderón-Domínguez, 2008, Changes on Dough Rheological Characteristics and Bread Quality as a Result of the Addition of Germinated and Non-Germinated Soybean Flour. *Food Bioprocess Technol.,* **1**: 152–160.

Roy, P., Shimizu, N. and Kimura, T., 2004, Effect of temperature distribution by traditional parboiling process on the quality of parboiled rice produced. *Food Sci. Tech. Res.,* **10**(3): 254-260.

Sadasivam, S. and Manikam, A., 2008, Biochemical Methods for Agricultural Sciences. Wiley Eastern Limited, New Delhi, India.

Sareepuang, K., Siriamornpun, S., Wiset, L. and. Meeso, N., 2008, Effect of Soaking Temperature on Physical, Chemical and Cooking Properties of Parboiled Fragrant Rice. *World J. Agric Sci.,* **4**(4): 409-415.

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

Serna-Saldivar, S. O., Clegg, C. and Rooney, L. W., 1994, Effects of Parboiling and Decortication on the Nutritional Value of Sorghum (*Sorghum bicolor* L. Moench) and Pearl Millet (*Pennisetum glaucum* L.) . *J. Cereal Sci.,* **19**: 83-89.

Sharma, B. R., Rao, K. V., Vittal, K. P. R. and Amarasinghe, U. A., 2006, Realizing the potential of rainfed agriculture in India, *Draft prepared for the IWMI-CPWF Project on Strategic Analyses of India's National River-Linking Project, Colombo, Sri Lanka: International Water Management Institute*..

Shittu, T.A, Raji, A.O. and Sanni, L.O., 2007, Bread from composite cassava-wheat flour: I. Effect of baking time and temperature on some physical properties of bread loaf, *Food Res. International,* **40**: 280–290.

Siddiq, M., Nasir, M., Ravi, R., Butt, M.S., Dolan, K. D and Harte, J. B, 2009, Effect of defatted maize germ flour addition on the physical and sensory quality of wheat bread, *LWT - Food Sci. Technol.*, **42** : 464–470.

Siripatrawan, U. and Jantawat, P., 2006, Determination of moisture sorption isotherms of jasmine rice crackers using BET and GAB Models. *Food Sci. Tech. Int.,* **12**(6):459–465.

Sirisoontaralak, P. and Noomhorm, A., 2007, Changes in physicochemical and sensory-properties of irradiated rice during storage. *J. Stored Products Research,* **43**: 282–289.

Sridevi., Nirmala, B.Y., Basavaraj., Hanchinal, R.R. and Basarkar, P.W., 2011, Antioxidant contents of whole grain cereals, millets and their milled fractions. *J. Dairying, Foods Home Sci.*, **30** (3): 191 – 196.

Sodhi, N.S., Singh, N., Arora, M. and Singh, J. 2003. Changes in physicochemical, thermal, cooking and textural properties of rice during aging. *Food Process. Pres.*, **27**: 387–400.

Soubhagya, C. M. and Bhattacharya, K. R., 1979, Simplified determination of amylase in milled rice. *Starch,* **31**(5) : 159-163.

Srivastava, S. and Batra, A., 1998, Popping qualities of minor millets and their relationship with grain physical properties. *J. Food Sci. and Tech.,* **35** (3): 265-267.

Strelec, I., Komlenic, K.D., Jurkovic,V., Jurkovic, Z. and Hardi, U.Z., 2010, Quality parameter changes in wheat varieties during storage at four different storage conditions. *Agriculturae Conspectus Scientificus*, **75**(3): 105-111.

Sujatha, S.J., Ahmad, R., and Bhat, R. P., 2004, Physicochemical properties and cooking qualities of two varieties of raw and parboiled rice cultivated in the coastal region of Dakshina Kannada, India. *Food Chem.,* **86**: 211–216.

Tananuwong, K. and Malila, Y., 2011, Changes in physicochemical properties of organic hulled rice during storage under different conditions. *Food Chem.*, **125**: 179–185.

Theander, O., Westerlund, E., Aman, P., Graham, H., 1989. Plant cell walls and monogastric diets. *Animal Feed Sci. Technol.*, **23**: 205–225.

Tulyathan, V. and Leeharatanaluk, B., 2007, Changes in quality of rice (*Oryza sativa L.*) Cv. Khao dawk Mali 105 during storage. *J. Food .Chem*, **31**: 415-425.

Ushakumari, S. R. and Malleshi, N. G., 2007, Small millets: Nutritional and technological advantages, *In: Food uses of small millets and avenues for further processing and value addition*, Ed. Krishnegowda, K. and Seetharam, All India Coordinated Small Millets Improvement Project, ICAR, UAS, Bangalore.

Veena, B., Chimmad, B. V. Naik, R. K. and Shantakumar, G., 2005, Physicochemical and nutritional studies in barnyard millet. *Karnataka J. Agric. Sci.,* **18**(1): 101-105.

Veluppillai, S., Nithyanantharajah, K., Vasantharuba, S., Balakumar, S. and Arasaratnam, V., 2010, Optimization of bread preparation from wheat flour and malted rice flour, *Rice Sci.*, **17**(1): 51–59.

Walter, M., Silva, L P. and Denardin, C. C., 2005, Rice and resistant starch: different content depending on chosen methodology. *J. Food Composition Analysis,* **18**(4):279-285.

Yenagi, N. B., Handigol, J. A., BalRavi, S., Mal, B. and Padulosi, S., 2010, Nutritional and technological advancements in the promotion of ethnic and novel foods using the genetic diversity of minor millets in India, *India J Plant Genet Resource*, **23**(1):81-86.

Zghal, M. C., Scanlon, M. G., and Sapirstein, H. D., 2002, Cellular structure of bread crumb and its influence on mechanical properties. *J. Cereal Chem.*, **36**: 167–176.

Zhou, Z., Robards, K., Helliwell, S., Blanchard, C. and Boxterb, G., 2001, Ageing of stored rice: changes in chemical and physical attributes, *J. Cereal Sci.,* **33:**1-15

Zhou, Z., Robards, K., Helliwell, S., Blanchard, C. and Boxterb, G., 2007, Effect of storage temperature on cooking behaviour of rice. *Food Chem.*, **105**: 491–497.

Zhou, Z., Robards, K., Helliwell, S., Blanchard, C., and Boxterb, G., 2003, Rice ageing I: Effect of changes in protein on starch behaviour, *Starch/ Strake*, **55**: 162-169.

APPENDIX I

Estimation of protein

Principle

Organic nitrogen digested with sulphuric acid in the presence of catalyst is converted to ammonium sulphate. Ammonium liberated by making the solution alkaline is distilled into a known volume of standard acid, which is then back titrated. Protein per cent was calculated by multiplying the nitrogen presented the factor 5.95.

Reagents :2% boric acid solution ; 40% NaOH (W/V) ; 0.1 N HCl ; Mixed indicator (methyl red (0.2%) and Bromocresol green (0.2%) in a 1:2 ratio (v/v); Digestion mixture(Anhydrous sodium sulphate and copper sulphate) ; Concentrated sulphuric acid (H_2SO_4).

Procedure

Digestion: 0.5 g of the sample was weighed into the digestion tubes of the Gerhardt digester in duplicate and two heaped spatulas each of sodium and copper sulphate were added to each tube. 25 ml of concentrated sulphuric was also added and samples digested until the contents of the tubes were sea green in color. Each of the digested materials was dissolved in distilled water and transferred into a 100 ml volumetric flask and then brought to the mark.

Distillation: 10ml of each sample was transferred into the distillation tube of the automatic Gerhardt unit and 20ml of 2 per cent boric acid to which was added 3-4 drops of the mixed indicator was placed in the collecting conical flask to trap the liberated ammonia. The unit was furnished with 40 per cent NaOH and distilled water to facilitate operation. Distillation was done for 5 minutes and the ammonia collected and trapped by the boric acid. In between the distillation of samples, the unit was rinsed with distilled water for 2.5 minutes. The boric acid turned from reddish pink to green as it collected the ammonia.

Titration: The green colored boric acid was titrated against the 0.1NHCl until its color turned to pink. A blank was run simultaneously. The titer values obtained were incorporated in the equation below to obtain the per cent nitrogen present in the sample which, in turn, was multiplied by the factor 6.25 to obtain the per cent protein.

$$\text{Per cent nitrogen (\% N)} = (V_a - V_b) \times 0.014 \times \frac{V_1}{V_2} \times \frac{100}{W}$$

Where:

VA = Titre value of sample
VB = Titre value of blank
V1 = Volume to which digested sample was made up (100 ml)
V2 = Volume to aliquot used in distillation
W = Weight of samples taken for digestion
% Protein = 5.95 X % Nitrogen.

Estimation of fat

Principle: The extraction of fat is done by using heating with the solvent using soxhlet apparatus in which fresh solvent continuously comes into contact with the material to be extracted over a relatively long period of time.

Procedure

Five gram of sample was weighed into a thimble and plugged with fat free cotton wool. The thimble was placed in the soxhlet apparatus attached to a pre-weighed flask and extracted for about 14-26 hours. Thereafter, the flask was retrieved from the apparatus with as little solvent in it as was possible. It was then transferred into an oven to evaporate the remaining solvent, leaving behind only the residue or extract. The flask was then cooled in desiccators after which it was weighed to estimate the fat.

$$\text{Fat content (g/100g sample)} = \frac{\text{Weight of ether extract}}{\text{Wt. of the sample (equivalent to fresh sample) taken}} \times 100$$

APPENDIX II

APPENDIX III

Estimation of crude fibre

Principle : During the acid and subsequent alkali treatment, oxidative hydrolytic degradation of the native cellulose and considerable degradation of lignin occur. The residue obtained after final filtration was weighed, incinerated, cooled and weighed again. The loss in weight gave the crude fibre content.

Materials: a. Sulphuric acid solution (0.255± 0.005 N): 1.25 g concentrated sulphuric acid diluted to 100 ml (concentration checked by titration). b. Sodium hydroxide solution (0.313±0.005 N): 1.25 g sodium hydroxide in 100ml distilled water (concentration checked with standard acid).

Procedure

1. Two gram of ground material was extracted with petroleum ether to remove fat.
2. The dried sample obtained was boiled with 200ml of sulphuric acid for 30 min with bumping chips.
3. It was then filtered with muslin cloth and washed with boiling water until the washings is no longer acidic.
4. It was boiled with 200 ml of sodium hydroxide solution for 30 min. It was then filtered through muslin cloth and washed with 25 ml of boiling 1.25% H_2SO_4, three 50ml portions of water and 25ml alcohol.
5. The residue was removed and transferred to ashing dish (preweighed dish W_1).
6. The residue was dried for 2 h at 130± 2^0C. The dish in the desiccators was cooled and weighed (W_2) and then ignited for 30 min at 600± 15^0 C. It was then cooled in a desiccator and reweighed (W_3).

$$\text{\% crude fibre in ground sample} = \frac{\text{Loss in weight on ignition } (W_2 - W_1) - (W_3 - W_1)}{\text{Weight of the sample}} \times 100$$

APPENDIX IV

Estimation of Polyphenols

Materials : 80% ethanol , Folin- Ciocalteau reagent , $Na_2 C0_3$,20%, Standard (100 mg Catechol in 100 ml water) .10 times diluted for a working standard.

Procedure

1. The sample 0.5 to 1g is weighed and ground with a pestle and mortar in 10 time volume of 80% ethanol.
2. The homogenate was centrifuged at 10,000 rpm for 20 min. The supernatant was saved. The residue was re-extracted with five times the volume of 80% ethanol, centrifuged and the supernatants pooled.
3. The supernatant was evaporated to dryness. The residue was dissolved in a known volume of distilled water (5 ml).
4. The different aliquots (0.2 -2 ml) was pipetted out into test tubes.
5. The volume was made upto 3 ml with water in each tube. 0.5 ml of Folin-Ciocalteau reagent is added.
6. After 3 min, 2 ml of 20% $Na_2 CO_3$ solution was added to each tube and mixed thoroughly.
7. The tubes were placed in boiling water for exactly 1 min, cooled and the absorbance measured at 650 nm against a reagent blank.
8. A standard curve was prepared using different concentrations of catechol.

Calculation

From the standard curve the concentration of phenols in the test samples is expressed as mg phenols/100g material.

APPENDIX IX

In vitro starch digestibility (IVSD)

Two per cent s lurry of the food material was cooked on a boiling water bath for 15 min. 30 ml of 0.2 M glycine - Hcl buffer (pH 2.2) containing 10 mg of pepsin of were added to 50 ml of slurry was neutralized with 0.2 N NaOH and the volume was made up to 100 ml. 5 ml of 0.05 M phosphate buffer (pH-6.9) containing 15 mg of pancreatin and 15 mg of amylase were added to 10 ml Aliquots and incubated for 2h at 37^0C. After 30 min the reaction was stopped by keeping the digest on boiling water both for 5 min. sample was drawn at intervals of 30, 60, 90, 120 min. Aliquots (0.5 ml) of the sample were mixed with 2 ml of dinitrosalicyclic acid reagent for determination of reducing sugar. The absorbance was measured at 550 nm and concentration of the sample was calculated from the standard were prepared using 0.24 - 1.2 mg/ml of glucose standard. The starch digestibility was expressed as mg of glucose released per g of sample.

APPENDIX V

Estimation of Phytic acid

Materials : 3% Trichloroacetic acid , 3% sodium sulphate in 3 % TCA , 1.5 N NaOH, 3.2 N HNO_3 , $FeCl_3$ solution (Dissolve 583 mg $FeCl_3$ in 100 ml of 3% TCA), 1.5 M Potassium thiocynate (KSCN) (29.15 g dissolved in 200 ml water), standard Fe $(N0_3)_3$ solution.

Procedure

1. Finely ground sample (40 mesh) estimated to contain 5-30 mg phytate P is weighed into a 125 ml Erlenmeyer flask. TCA 3% is extracted in 50 ml for 30 min with mechanical shaking or with occasional swirling by hand for 45 min.
2. The suspension was centrifuged and 10 ml of aliquot of the supernatant was transferred to 40 ml conical centrifuge tube. $FeCl_3$ solution 4 ml was added to the aliquot by blowing rapidly from the pipette.
3. The contents was heated in a boiling water bath for 45 min.(*One or two drops of sodium sulphate (3%) was added in 3% TCA and heating continued if the supernatant is not clear after 30 min).
4. After centrifuging for 10-15 min the clear supernatant is carefully decanted. The precipitate was washed twice by dispersing well in 20-25ml 3% TCA and heated in boiling water for 5-10 min and centrifuged. Washing with water was repeated.
5. The precipitate was dispersed in few ml of water and 3 ml 1.5 N NaOH was added with mixing.The volume was brought to 30 ml with water and heated in boiling water for 30 min.
6. It was filtered hot through a moderately retentive paper Whatman No. 2. The precipitate was washed with 60-70 ml hot water and the filtrate discarded.
7. The precipitate from the paper was dissolved with 40 ml hot 3.2 N HNO_3 into a 100ml volumetric flask. The paper was washed with several portions of water, collecting the washings in the same flask.
8. The flask was cooled and also the contents to room temperature and the volume diluted with water.
9. Five ml of the aliquot was transferred to another 100 ml volumetric flask and diluted to approximately 70 ml.
10. Twenty ml of 1.5 M KSCN was added and diluted to volume and the color read immediately (within a min) at 480nm.
11. Reagent blank was run with each set of samples.

Standard: $Fe(NO_3)_3$, 433 mg was weighed accurately and dissolved in 100 ml distilled water in a volumetric flask. The stock standard 2.5 ml is diluted and made upto 250ml in a volumetric flask. Working standard 2.5, 5, 10 ,15 and 20 ml is pipette out into a series of 100ml volumetric flasks and proceeded from step 9. The µg iron present in the test was found from the standard curve.

APPENDIX VI

Determination of Cu, Zn, Fe and Mn in grains

Principle: The sample is treated with a mixture of mineral acids (tri or diacid) and heated for more rapid decomposition. The volatile constituents disappear and non volatile mineral elements enter into solution. Heating is continued until digest is reduced to a few ml of clear white residue. The residue is dissolved in HCl (6N), filtered and made to known volume with distilled water for various elemental analysis.

Reagents : Triacid mixture: Mix 100ml of conc.HNO_3 10 ml of conc. H_2SO_4 and 40 ml of 60% $HClO_4$ or 30ml of 72% $HCl0_4$. (HNO_3 : H_2SO_4: $HClO_4$ in the ratio of 10:1:4 respectively)

Procedure : A. *Predigestion of sample with HNO_3*: Around 1g of the sample was transferred into 100ml conical flask and the samples, wetted with 10 ml of conc. HNO_3 and allowed to stand overnight. The content was then gently heated on a hot plate till the volume of the contents was reduced to 4 ml or less and then cooled. B. *Digestion with triacid mixture* : 5ml of triacid mixture was added and kept on hot sand bath until evolution of dense white fumes subside leaving about 3 ml of colourless solution in the conical flasks which on cooling gives white residue. C. *Preparation of grain test solution*: 5ml of 6N HCl is added to the residue, the contents swirled and transferred to 100 ml volumetric flasks by filtering through Whatman No.42 filter paper. The procedure was repeated 3-4 times with additional quantity of 6 N HCl until all the residue is filtered. The conical flask is rinsed distilled water and the contents transferred to volumetric flasks. The volume is made upto 100ml with distilled water washing of the residue on the filter paper. The flask is stoppered and preserved for elemental analysis.The instrument is set to zero with blank .The working standards of element to be determined to AAS is fed to calibrate the instrument. The plant digest is fed and absorbance/concentration of the element recorded.

$$\text{Total (minerals,ppm)} = \frac{\text{Volume made after digestion}}{\text{Weight of plant sample used for digestion}} \times \text{ppm from the instrument or graph.}$$

$$\text{\% Fe, Cu, Zn or Mn in plant sample} = \frac{\text{ppm}}{10000}$$

APPENDIX VII

SCORE CARD FOR THE SENSORY EVALUATION OF MILLET RICE

Name: Date:

Instructions:

Please evaluate each of the following samples using scoring system given below. Write the preferred number score in the column as per evaluation. Rinse your mouth in between evaluating each sample.

Sample	Appearance	Texture	Colour	Flavour	Taste	Overall acceptability
A						
B						
C						
D						

Scoring system:-

9-like extremely 6-like slightly: 3-dislike moderately:

8-like very much: 5-neither like nor dislike: 2-dislike very much:

7-like moderately: 4-dislike slightly: 1-dislike extremely:

Comments:

Signature

APPENDIX VIII

In vitro protein digestibility (IVPD)

Slurried samples containing 100 mg of protein were shaken with 12.5 mg of pepsin in 50ml of 0/N Hcl at 37^0C for 3 h. The neutralization was done by 0.5 N NaOH by using pH meter. After neutralization 6 mg of pancreatin dissolved in 25 ml of phosphate buffer (pH-8.0) was added to it and the digestion continued for 24 h and 37^0C. Then the volume was made up to 100 ml and aliquot (50 ml) was treated with 10% TCA overnight to precipitate the proteins. The suspensions were centrifuged (6000x g for 40 min) and residue was assayed for protein.

APPENDIX X

Estimation of starch by anthrone reagent method

Starch is hydrolyzed into simple sugars by dilute acids and the quantity of simple sugars is measured colorimetrically.

Principle : The sample is treated with 80% alcohol to remove sugars and then starch is extracted with perchloric acid. In hot acidic medium starch is hydrolysed to glucose and dehydrated to hydroxymethyl furfural.this compound forms a green colored product called anthrone.

Materials : a) Anthrone : 200mg anthrone is dissolved in 100ml of ice cold 95% sulphuric acid, b) 80% ethanol. c) 52% perchloric acid. d) Standard glucose: Stock- 100 mg in 100ml water. e) Working standard- 10ml of stock diluted to 100ml with water.

Procedure

1. The sample (0.1-0.5 g) was homogenized in hot 80% ethanol to remove sugars centrifuged and the residue was retained. The residue was washed repeatedly with hot 80% ethanol till the washings do not give color with anthrone reagent. The residue is dried well over a water bath.
2. To the residue 5 ml of water and 6.5 ml of 52% perchloric acid was added.
3. It was extracted at 0^0 C for 20 min centrifuged and the supernatant was saved.
4. The extraction was repeated using fresh perchloric acid. The supernatants was centrifuged and pooled and the volume is made upto 100 ml.
5. The supernatant 0.1 or 0.2 ml is pipetted out and the volume made upto 1 ml with water.
6. The standards was prepared by taking 0.2, 0.4.0.6, 0.8 and 1 ml of the working standard and the volume made upto 1 ml in each tube with water.
7. Four ml of anthrone reagent was added to each tube and heated for eight minutes in a boiling water bath. After cooling rapidly the intensity of green to dark green color at 630nm was read.

APPENDIX XI

Estimation of Insoluble dietary fibre (AOAC 1995)

Reagents : 95% Ethanol ii. 78% Ethanol iii. 0.08M Phosphate Buffer iv. pH 6.0 , v. 0.275 N NaOH vi. 0.325 N HCl vii. α- Amylase heat stable solution viii. Protease solution: suspended 50 g protease in 1 ml phosphate Buffer pH 6.0 ix. Amyloglucosidase solution

Determination: Homogenized and dried sample (0.3 to 0.5 mm) is taken. 1 g of duplicate sample was weighed accurate to 0.1 mg into 500 ml beakers. Heat stable α- amylase solution (0.1 ml) was added. The beakers was covered with aluminium foil and placed in boiling water bath. It was ensured that the contents of the beaker reach 100^0 C and incubated for 15 min at this temperature. The solution was cooled to room temperature and the pH adjusted to 7.5 with NaOH solution.

Protease solution 0.1 ml was added to each beaker. The beaker was covered with aluminium foil and incubated for 30 min at 60^0C with continuous agitation. The crucible was weighed with a fritted disc containing 1 g celite to constant weight. The celite in the crucible was made into a bed using a stream of 78% ethanol and applying suction. The suction was maintained and the precipitate was transferred quantitatively from enzyme digest to crucible using filtration module.

The residue was washed successively with 3 times 20 ml portions of 78% ethanol, two 10 ml portions of 95% ethanol and two 10 ml portions of acetone. The crucible containing residue is dried overnight at 100^0C in hot air oven, cooled in desicator and weighed to nearest 0.1 mg. The crucible and celite weight was substracted from the above to obtain the insoluble dietary fibre residue (IDF residue). The residue was analysed from one sample of set of duplicates for protein by kjeldahl method using N x 6.25 as conversion factor and subtracted from the IDF residue value. The second residue sample was incinerated for 5 h at 525℃, cooled in desiccator and weighed to nearest 0.1 mg and subtracted from the IDF residue value.

Insoluble dietary fibre = IDF residue – (Protein + ash).

Estimation of Soluble dietary fibre

Sample preparation: Similar to insoluble fibre followed.

Determination: The digestion steps followed with α-amylase, protease and amylo glucosidase and quantitatively transfered the digest and collected the filtrate. Four volumes of pre-heated (60ºC) 95% ethanol is added and allowed the precipitation to complete for 60 min. It is filtered through an accurately weighed crucible with celite. The procedure given under insoluble fibre was followed to obtain soluble dietary fibre (SDF) residue. Duplicate samples run similarly were analysed for protein and ash.

Soluble dietary fibre = weight of SDF residue - (protein+ash)

Total dietary fibre is the sum of insoluble and soluble dietary fibres.

APPENDIX XII

Soluble protein

Principle: The blue colour developed by the reduction of the phosphomolybdic-phospotungstic components in the Folin-Ciocalteau reagent by the amino acids and tryptophan present in the protein plus the colour developed by the biuret reaction of the protein with the alkaline cupric tartrate are measured.

- Reagents
  - 2% sodium carbonate in 0.1 N NaOH(Reagent A),
  - 0.5 % copper sulphate (Reagent B)
  - Alkaline copper solution :Mix 50 ML of A and 1 mL of B prior to use (Reagent C)
  - Folin-Ciocalteau reagent (Reagent D)
  - Protein stock solution (stock standard): Weigh accurately 50 mg of bovine serum albumin (Fraction V) and dissolve in distilled water and make up to 50 mL in a standard flask.
  - Working reagent: Dilute 10 mL of the stock solution to 50 ml with distilled water in standard flask one mL of this contains 200 μg protein.
- Extraction of protein sample

Extraction is usually carried out with buffers of distilled water. Weigh 500 mg of the sample and grind well with a pestle and mortar in 5-10 mL of the buffer. Centrifuge and use the supernatant for estimation.

- Estimation of protein
  1. Pipette out 0.2, 0.4, 0.6, 0.8 and 1 mL of the working standard in to a series of test tubes
  2. Pippette out 0.1 mL and 0.2mL of the sample extract in two other test tubes.
  3. Make up the volume to 1 mL in all the test tubes. A tube with 1 mL of water serves as the blank
  4. Add 5 mL of reagent C to each tube including the balnk. Mix well and allow to satnd for 10 min.
  5. Then add o.5 mL of reagent D, mix well and incubate at room temperature in the dark for 30 min. blue colou is developed
  6. Take readings at 660 nm
  7. Draw a standard graph and calculate the amount of protein in the sample

APPENDIX XIII

Score card for the colour and physical appearance of the parboiled little millet grains

Name: Date:

Instructions: Please evaluate each of the following samples using scoring system given below. Tick the preferred number score in the column as per evaluation.

Sample Code	Treatment	1	2	3	4	5
GDH	1					
NDE	2					
KJD	3					
OSA	4					
HFS	5					
GHT	6					
FYM	7					
HFJ	8					
UED	9					
JDS	10					
NCM	11					
TRK	12					
SNM	13					
IUE	14					
WAJ	15					
JDK	16					
PLJ	17					
UJQ	18					
GHA	19					
IDE	20					
IED	21					
ISD	22					
HGD	23					
RHW	24					
RHT	25					
IEJ	26					
IJS	27					
THU	28					
OKA	29					
YUL	30					
SHR	31					
OEL	32					
IDJ	33					
ETS	34					
JKS	35					
HJK	36					

Scores; 5- Excellent, 4-Very good, 3- Good, 2-Fair , 1- Poor

APPENDIX XIV

Score card for the sensory evaluation of hydrothermally treated cooked little millet rice

Name: Date:

Instructions:

Please evaluate each of the following samples using scoring system given below. Write the preferred number score in the column as per evaluation. Rinse your mouth in between evaluating each sample.

Sample	Appearance	Texture	Colour	Flavour	Taste	Overall acceptability
Raw millet rice						
Hydrothermally treated millet rice						

Scoring system:-

9-like extremely	6-like slightly:	3-dislike moderately:
8-like very much:	5-neither like nor dislike:	2-dislike very much:
7-like moderately:	4-dislike slightly:	1-dislike extremely:

Comments:

Signature

APPENDIX XIX

Relative humidity and temperature record during storage period from August 2011 to February 2013

Month-Year	Max. Temp	Min. Temp	RH Max	RH Min	Mean RH
May-11	34.7	21.3	86.4	36.8	61.6
Jun-11	27.5	21.3	93.1	74.5	83.8
Jul-11	26.9	20.6	94.3	77.3	85.8
Aug-11	26.7	20.7	94.2	78.7	86.7
Sep-11	28.9	21.0	92.0	66.8	79.5
Oct-11	29.9	19.5	89.4	57.7	66.4
Nov-11	29.8	15.8	73.2	38.6	55.9
Dec-11	29.5	13.7	73.1	39.2	68.6
Jan-12	29.8	13.9	73.8	40.2	57.0
Feb-12	33.0	16.1	53.6	27.7	54.2
Mar-12	35.8	18.5	61.7	19.7	40.7
Apr-12	35.7	21.2	73.8	38.1	56.0
May-12	35.7	21.5	71.8	49.4	60.6
Jun-12	30.2	21.2	82.0	67.8	74.9
Jul-12	27.3	20.8	88.0	81.4	84.7
Aug-12	27.2	20.5	88.9	80.7	79.7
Sep-12	28.2	19.7	85.1	79.8	82.5
Oct-12	29.7	18.2	72.0	56.4	64.2
Nov-12	28.4	16.0	70.5	51.6	61.0
Dec-12	30.3	15.0	69.4	43.9	57.1
Jan-13	31.2	14.6	60.5	30.1	45.3
Feb-13	32.6	16.6	62.3	36.6	49.4
Mar-13	35.3	19.3	65.1	28.9	47.0
Apr-13	36.7	20.2	63.7	33.7	48.7
May-13	37.8	22.0	74.7	60.0	67.3

APPENDIX XV

Preparation of bread

Recipe of Bakery Unit UAS, Dharwad

Ingredients

Flour -1000gm, Yeast-15gm, Water-600ml,Sugar- 40gm, Salt-20gm, Vanaspati-20gm

Method

1. Disintegrate yeast into 100ml of luke warm water with little sugar and rest aside for 10 minutes.
2. Dissolve salt and sugar in the remaining water and strain through filter cloth
3. Sieve the flour on the working table and make a depression in the centre
4. Add salt and sugar water in the centre of the depression and mix roughly
5. Add the ferment and knead to a soft and smooth dough
6. Knead in vanaspati
7. Rest the dough under thick cloth for an hour (till it becomes double in size)
8. Divide into 400 gm or (desired size) pieces mould longer than bread i.e., about 35 to 45 cm. (15 inch) apply egg/ milk/ water wash.
9. Place it on a greased tray/ special mould (which are longer than bread mould and shorter in width and height)
10. Proof till the desired volume achieved (i.e., about 30-45 min)
11. Bake at 400 degree Fahrenheit for 30 min.
12. The baked loaf is allowed to cool until it acquired room temperature about (3-4 hrs)
13. Slice it arrange each slice on baking tray separately and dry in oven at 90 degree Fahrenheit for about 2 hrs.

Modified Bread Recipe

For the control bread, 250 g of wheat flour, 3g of yeast, 15 g of sugar, 12.5 g of fat, 4 g of salt and 170 ml water were used. Yeast was allowed to rise with some amount of sugar in warm water for ten minutes prior to incorporation in the flour. The flour was mixed thoroughly with all the other ingredients. A Kitchen Aid brand kneading machine was used to prepare the dough. The dough was kneaded until it leaved the sides of the vessel. The dough was allowed to first proofing in an oil smeared vessel for 2 hours at room temperature and then the dough was separated into parts weighing around 130g and put into the baking bread moulds (12 x 4.5 x 5.5 cm), where the dough was allowed to rest for the second proofing for an hour. The breads were then baked at 220^0 C for 15-20 min and cooled. The little millet breads were developed by replacing wheat flour by 10, 30 and 50 per cent.

APPENDIX XVI

SCORE CARD FOR THE SENSORY EVALUATION OF MILLET BREAD

Name: Date:

Instructions:

Please evaluate each of the following samples using scoring system given below. Write the preferred number score in the column as per evaluation. Rinse your mouth in between evaluating each sample.

Sample	Appearance	Texture	Colour		Flavour	Taste	Overall acceptability
			Crust	Crumb			

Scoring system:-

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:

Comments:

Signature

APPENDIX XVII

Free fatty acid value

50 gm of the sample was extracted for fat using 1:1 chloroform: methanol mix and kept overnight for extraction. The extracted sample which contain 2-3g of fat was dissolve in 50 ml of neutral solvent (25 ml ether, 25 ml 95% alcohol and 1 ml of 1% phenolpthelein indicator and neutralised by 0.1 N KOH) and to it a few drops of phenolphthalein indicator was added and titrate against 0.1 N KOH till a pink colour which persist for 15 seconds is obtained. (Sadasivam and Manickam, 2008)

$$\text{Acid value} = \frac{\text{Titre value x N of KOH x 56.1}}{\text{Weight of the sample (g)}}$$

APPENDIX XVIII

Score card for sensory evaluation of millet bread during storage

Name: Date:

Instructions:

Please evaluate each of the following samples using scoring system given below. Write the preferred number score in the column as per evaluation. Rinse your mouth in between evaluating each sample.

Duration		1 day		2 day		3 day		4 day		5 day	
Sample		A	B	A	B	A	B	A	B	A	B
Appearance											
Texture											
Colour	Crust										
	Crumb										
Flavour											
Taste											
Overall acceptability											

Scoring system:-

9-like extremely 6-like slightly: 3-dislike moderately:

8-like very much: 5-neither like nor dislike: 2-dislike very much:

7-like moderately: 4-dislike slightly: 1-dislike extremely:

Comments:

Signature

APPENDIX XX

Effect of hydrothermal treatments on head rice yield (%)

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	80.91	81.82	77.54	80.09	94.13	87.18	93.96	91.76	87.52	84.50	85.75	85.92
	110	85.03	86.78	85.09	85.63	94.85	85.94	94.99	91.93	89.94	86.36	90.04	88.78
	Mean	82.97	84.30	81.32	82.86	94.49	86.56	94.48	91.84	88.73	85.43	87.90	87.35
70	100	94.49	72.67	88.90	85.35	89.18	90.99	77.80	85.99	91.84	81.83	83.35	85.67
	110	90.61	92.40	88.50	90.50	85.11	93.55	86.59	88.42	87.86	92.98	87.55	89.46
	Mean	92.55	82.54	88.70	87.93	87.15	92.27	82.20	87.20	89.85	87.40	85.45	87.57
80	100	91.92	90.26	91.52	91.23	87.70	90.17	92.43	90.10	89.81	90.22	91.98	90.67
	110	90.83	85.75	87.36	87.98	90.38	95.62	82.33	89.44	90.61	90.69	84.85	88.71
	Mean	91.38	88.01	89.44	89.61	89.04	92.90	87.38	89.77	90.21	90.45	88.41	89.69
Total Mean	100	89.11	81.58	85.99	85.56	90.34	89.45	88.06	89.28	89.72	85.52	87.03	87.42
	110	88.82	88.31	86.98	88.04	90.11	91.70	87.97	89.93	89.47	90.01	87.48	88.98
	Mean	88.97	84.95	86.49	86.80	90.23	90.58	88.02	89.61	89.60	87.76	87.25	88.20

APPENDIX XXI

Effect of hydrothermal treatments on broken grains (%)

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4							
		Steaming Time (min)				Steaming Time (min)				Mean			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	9.03	8.49	7.22	8.25	4.77	3.13	2.92	3.61	6.90	5.81	5.07	5.93
	110	4.70	6.77	1.72	4.40	1.45	5.94	0.92	2.77	3.08	6.36	1.32	3.58
	Mean	6.87	7.63	4.47	6.32	3.11	4.54	1.92	3.19	4.99	6.08	3.20	4.76
70	100	11.54	8.17	3.89	7.87	1.37	4.15	1.46	2.33	6.46	6.16	2.68	5.10
	110	0.61	0.99	2.47	1.36	1.81	2.59	4.71	3.04	1.21	1.79	3.59	2.20
	Mean	6.08	4.58	3.18	4.61	1.59	3.37	3.09	2.68	3.83	3.98	3.13	3.65
80	100	2.35	1.78	1.06	1.73	1.02	1.00	2.54	1.52	1.69	1.39	1.80	1.63
	110	1.99	4.29	7.70	4.66	3.50	3.79	9.00	5.43	2.75	4.04	8.35	5.05
	Mean	2.17	3.04	4.38	3.20	2.26	2.40	5.77	3.48	2.22	2.72	5.08	3.34
Total Mean	100	7.64	6.15	4.06	5.95	2.39	2.76	2.31	2.48	5.01	4.45	3.18	4.22
	110	2.43	4.02	3.96	3.47	2.25	4.11	4.88	3.75	2.34	4.06	4.42	3.61
	Mean	5.04	5.08	4.01	4.71	2.32	3.43	3.59	3.12	3.68	4.26	3.80	3.91

APPENDIX XXII

Effect of hydrothermal treatments on 'L' value

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	63.95	62.76	62.83	63.18	61.52	60.17	61.09	60.93	62.74	61.47	61.96	62.05
	110	56.43	57.99	56.93	57.12	54.53	58.56	57.45	56.85	55.48	58.28	57.19	56.98
	Mean	60.19	60.38	59.88	60.15	58.03	59.37	59.27	58.89	59.11	59.87	59.58	59.52
70	100	59.53	62.44	54.22	58.73	56.49	59.65	60.00	58.71	58.01	61.05	57.11	58.72
	110	63.86	55.51	55.98	58.45	55.71	55.58	57.87	56.39	59.79	55.55	56.93	57.42
	Mean	61.70	58.98	55.10	58.59	56.10	57.62	58.94	57.55	58.90	58.30	57.02	58.07
80	100	63.62	63.63	61.00	62.75	62.04	60.08	59.60	60.57	62.83	61.86	60.30	61.66
	110	54.81	55.80	55.71	55.44	54.77	55.02	56.90	55.56	54.79	55.41	56.31	55.50
	Mean	59.22	59.72	58.36	59.10	58.41	57.55	58.25	58.07	58.81	58.63	58.30	58.58
Total Mean	100	62.37	62.94	59.35	61.55	60.02	59.97	60.23	60.07	61.19	61.46	59.79	60.81
	110	58.37	56.43	56.21	57.00	55.00	56.39	57.41	56.27	56.69	56.41	56.81	56.63
	Mean	60.37	59.69	57.78	59.28	57.51	58.18	58.82	58.17	58.94	58.93	58.30	58.72

APPENDIX XXIII

Effect of hydrothermal treatments on ‘a’ value

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	4.34	4.70	4.57	4.54	4.24	4.42	4.79	4.48	4.29	4.56	4.68	4.51
	110	5.69	5.29	5.25	5.41	4.61	5.46	4.77	4.95	5.15	5.38	5.01	5.18
	Mean	5.02	5.00	4.91	4.97	4.43	4.94	4.78	4.72	4.72	4.97	4.85	4.84
70	100	4.35	4.22	4.22	4.26	5.10	4.69	4.77	4.85	4.73	4.46	4.50	4.56
	110	5.41	5.55	5.52	5.49	5.33	5.01	4.98	5.11	5.37	5.28	5.25	5.30
	Mean	4.88	4.89	4.87	4.88	5.22	4.85	4.88	4.98	5.05	4.87	4.87	4.93
80	100	4.74	4.66	4.89	4.76	5.00	4.64	5.26	4.97	4.87	4.65	5.08	4.87
	110	5.99	5.66	5.82	5.82	5.25	5.18	5.34	5.26	5.62	5.42	5.58	5.54
	Mean	5.37	5.16	5.36	5.29	5.13	4.91	5.30	5.11	5.25	5.04	5.33	5.20
Total Mean	100	4.48	4.53	4.56	4.52	4.78	4.58	4.94	4.77	4.63	4.56	4.75	4.64
	110	5.70	5.50	5.53	5.58	5.06	5.22	5.03	5.10	5.38	5.36	5.28	5.34
	Mean	5.09	5.01	5.05	5.05	4.92	4.90	4.99	4.94	5.00	4.96	5.02	4.99

APPENDIX XXIV

Effect of hydrothermal treatments on 'b' Value

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	20.01	20.28	20.47	20.25	20.16	19.72	20.09	19.99	20.09	20.00	20.28	20.12
	110	19.61	19.32	18.58	19.17	19.69	18.92	19.92	19.51	19.65	19.12	19.25	19.34
	Mean	19.81	19.80	19.53	19.71	19.93	19.32	20.01	19.75	19.87	19.56	19.77	19.73
70	100	19.82	18.65	19.31	19.26	19.01	19.36	19.58	19.32	19.42	19.01	19.45	19.29
	110	17.78	19.49	19.63	18.97	19.60	19.30	18.54	19.15	18.69	19.40	19.09	19.06
	Mean	18.80	19.07	19.47	19.11	19.31	19.33	19.06	19.23	19.05	19.20	19.27	19.17
80	100	19.98	20.22	20.50	20.23	20.14	19.59	20.23	19.99	20.06	19.91	20.37	20.11
	110	19.78	18.90	18.90	19.19	17.68	18.21	19.63	18.51	18.73	18.56	19.27	18.85
	Mean	19.88	19.56	19.70	19.71	18.91	18.90	19.93	19.25	19.40	19.23	19.82	19.48
Total Mean	100	19.94	19.72	20.09	19.92	19.77	19.56	19.97	19.76	19.85	19.64	20.03	19.84
	110	19.06	19.24	19.04	19.11	18.99	18.81	19.36	19.05	19.02	19.02	19.20	19.08
	Mean	19.50	19.48	19.57	19.51	19.38	19.18	19.67	19.41	19.44	19.33	19.62	19.46

APPENDIX XXV

Effect of hydrothermal treatments on cooking time (min)

Soaking Temperature (°C)	Steaming Temperature (°C)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	15.47	14.76	16.10	15.44	15.00	15.16	15.78	15.31	15.24	14.96	15.94	15.38
	110	15.13	16.20	15.00	15.44	15.34	15.32	15.62	15.43	15.24	15.76	15.31	15.44
	Mean	15.30	15.48	15.55	15.44	15.17	15.24	15.70	15.37	15.24	15.36	15.63	15.41
70	100	16.64	16.33	17.10	16.69	17.63	18.26	19.10	18.33	17.14	17.30	18.10	17.51
	110	18.40	17.66	23.16	19.74	24.10	25.66	26.66	25.47	21.25	21.66	24.91	22.61
	Mean	17.52	17.00	20.13	18.22	20.87	21.96	22.88	21.90	19.19	19.48	21.51	20.06
80	100	23.30	23.83	23.12	23.42	22.58	19.39	24.35	22.11	22.94	21.61	23.74	22.76
	110	22.20	23.23	25.95	23.79	28.73	27.56	28.50	28.26	25.47	25.40	27.23	26.03
	Mean	22.75	23.53	24.54	23.61	25.66	23.48	26.43	25.19	24.20	23.50	25.48	24.40
Total Mean	100	18.47	18.31	18.77	18.52	18.40	17.60	19.74	18.58	18.44	17.96	19.26	18.55
	110	18.58	19.03	21.37	19.66	22.72	22.85	23.59	23.05	20.65	20.94	22.48	21.36
	Mean	18.52	18.67	20.07	19.09	20.56	20.23	21.67	20.82	19.54	19.45	20.87	19.95

APPENDIX XXVI

Effect of hydrothermal treatments on leached solids (%)

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	10.53	9.78	10.10	10.14	9.50	2.43	9.33	7.09	10.02	6.11	9.72	8.61
	110	7.26	6.60	6.53	6.80	8.06	6.36	6.90	7.11	7.66	6.48	6.72	6.95
	Mean	8.90	8.19	8.32	8.47	8.78	4.40	8.12	7.10	8.84	6.29	8.22	7.78
70	100	10.66	10.80	9.93	10.46	9.16	12.63	9.96	10.58	9.91	11.72	9.95	10.52
	110	6.03	4.90	4.76	5.23	2.90	7.03	5.76	5.23	4.47	5.97	5.26	5.23
	Mean	8.35	7.85	7.35	7.85	6.03	9.83	7.86	7.91	7.19	8.84	7.60	7.88
80	100	11.13	11.70	9.76	10.86	11.66	11.53	10.33	11.17	11.40	11.62	10.05	11.02
	110	4.40	6.43	5.20	5.34	7.13	5.40	3.83	5.45	5.77	5.92	4.52	5.40
	Mean	7.77	9.07	7.48	8.10	9.40	8.47	7.08	8.31	8.58	8.77	7.28	8.21
Total Mean	100	10.77	10.76	9.93	10.49	10.11	8.86	9.87	9.61	10.44	9.81	9.90	10.05
	110	5.90	5.98	5.50	5.79	6.03	6.26	5.50	5.93	5.96	6.12	5.50	5.86
	Mean	8.34	8.37	7.71	8.14	8.07	7.56	7.69	7.77	8.20	7.97	7.70	7.96

APPENDIX XXVII

Effect of hydrothermal treatments on water uptake (g/g)

Soaking Temperature (℃)	Steaming Temperature (℃)	Soaking time (h)											
		3				4				Mean			
		Steaming Time (min)				Steaming Time (min)				Steaming Time (min)			
		15	20	25	Mean	15	20	25	Mean	15	20	25	Mean
60	100	4.76	4.69	5.18	4.88	5.13	5.41	3.92	4.82	4.95	5.05	4.55	4.85
	110	3.91	4.00	3.75	3.89	4.77	3.70	3.93	4.13	4.34	3.85	3.84	4.01
	Mean	4.34	4.35	4.47	4.38	4.95	4.56	3.93	4.48	4.64	4.45	4.20	4.43
70	100	5.44	5.54	5.21	5.40	4.31	4.68	4.49	4.49	4.88	5.11	4.85	4.95
	110	3.62	3.30	3.19	3.37	3.27	3.26	3.23	3.25	3.45	3.28	3.21	3.31
	Mean	4.53	4.42	4.20	4.38	3.79	3.97	3.86	3.87	4.16	4.20	4.03	4.13
80	100	4.12	4.14	3.90	4.05	4.48	4.47	4.56	4.50	4.30	4.31	4.23	4.28
	110	2.95	3.35	3.34	3.21	3.61	3.14	3.30	3.35	3.28	3.25	3.32	3.28
	Mean	3.54	3.75	3.62	3.63	4.05	3.81	3.93	3.93	3.79	3.78	3.78	3.78
Total Mean	100	4.77	4.79	4.76	4.78	4.64	4.85	4.32	4.61	4.71	4.82	4.54	4.69
	110	3.49	3.55	3.43	3.49	3.88	3.37	3.49	3.58	3.69	3.46	3.46	3.53
	Mean	4.13	4.17	4.10	4.13	4.26	4.11	3.91	4.09	4.20	4.14	4.00	4.11

STORAGE QUALITY OF LITTLE MILLET (Panicum miliare) AND DIVERSIFICATION OF UTILIZATION OF LITTLE MILLET THROUGH HYDROTHERMAL AND BAKING TECHNOLOGIES

MAMATA MANNURAMATH 2013 Dr. NIRMALA YENAGI

MAJOR ADVISOR

ABSTRACT

The study was undertaken to evaluate local cultivars (*Malli savi and Kari savi*) and high yielding varieties (Sukshema, COSa-(4) and JK-8) for physico-chemical and nutritional qualities and to develop of value added little millet products through hydrothermal and baking technologies. The local cultivar *Malli savi* was found to be superior followed by high yielding variety Sukshema. The storage of local cultivar of little millet for duration of 18 months exhibited better nutritional, milling and cooking qualities. The significant changes were observed for protein content, total dietary fiber total phenols and phytic acid content during storage. Significant decline was also observed for *in vitro* protein digestibility, *in vitro* starch digestibility, amylose, soluble amylose, swelling power, solubility and soluble proteins. The hydrothermal treatment with initial soaking temperature of 70^0 C for 3 hr and steaming at 110^0 C for 20 min was found to be optimum with improved head rice yield (92.39 %) with lower breakage (0.98%). Hydrothermally treated little millet rice was translucent shiny, firm, fluffy and non sticky. These characteristics were preferred properties by the consumer. Hydrothermal treatment improved the nutritional profile and enhanced therapeutic property, processing quality and shelf life. Incorporation of little millet at 10 and 30 per cent was organoleptically acceptable and enhanced the nutritional profile by increasing dietary fiber, iron, zinc, copper and phosphorus by 19, 94, 29, 70 and 28 per cent respectively. The study concludes that economic value of the local staple cereal can be enhanced through suitable technologies as therapeutic food and little millet has potential of designing basic functional food for better health.