# DEVELOPMENT AND STORAGE QUALITY OF FOXTAIL MILLET (*Setaria italica*) *LADDU*

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# DEVELOPMENT AND STORAGE QUALITY OF FOXTAIL MILLET (*Setaria italica*) *LADDU*

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**IN**

**FOOD SCIENCE AND NUTRITION**

**BY**

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# CERTIFICATE

This is to certify that the thesis entitled "DEVELOPMENT AND STORAGE QUALITY OF FOXTAIL MILLET (*Setaria italica) LADDU*" submitted by Miss K. V. SUDHA, for the degree of MASTER OF HOME SCIENCE in FOOD SCIENCE AND NUTRITION to the University of Agricultural Sciences, Dharwad is a record of research work carried out by her during the period of her study in this University, under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.

**DHARWAD**
**JULY, 2016**

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**DHARWAD**

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# 1. INTRODUCTION

Traditional food refers to foods that are passed through generations and also refers to foods consumed over the long-term duration of civilization that have been passed through generations. Traditional foods are the foods based on sound foundation of culture, custom, natural environment and consumed by people over long time. Traditional foods are developed through ages invented, modified, utilized and evolved to overcome the monotony in the diet. The traditional foods are carefully held and not quickly changed.

The traditional food of India has been widely appreciated for its fabulous use of locally grown crops. Indian traditional food is known for its large assortment like sweet, savoury and spicy traditional foods. The cooking style varies from region to region and is largely divided into south Indian and north Indian traditional foods. India is quite famous for its diverse traditional foods available in a large number of restaurants and hotel resorts, which is reminiscent of unity in diversity. In modern times Indian pallete has undergone a lot of change. In the last decade, as a result of globalisation, a lot of Indians have travelled to different parts of the world and vice versa there has been a massive influx of people of different nationalities in India. This has resulted in Indianisation of various international foods. Nowadays, in big metro cities one can find specialised food joints of traditional foods. The information regarding traditional foods would also help in the development of new food products for modern markets. Further, the significance of traditional foods is more appreciable when their nutritive value is known. In this regard, India has a rich treasure of traditional foods specifically prepared for festivals, rituals, and physiological conditions (Inamdar *et. al.,* 2005). The staple food in India includes wheat, rice and pulses with chana (bengal gram) being the most important one. Some examples of traditional snack products are *laddu, mysorepak, bhundi, bhujia, chakli, ghevar, khakhra, kachori, khaman, khandavi, pakora, bhaji* and so on.

With improvement in food technology, convenience food and ready to eat foods are emerging in market. Convenience foods have also been described as foods that have been created to "make them more appealing to the consumer." And they also save time. They are commercially prepared (often through processing) to optimize ease of consumption. Such food is usually ready to eat without further preparation. It may also be easily portable, have a long shelf life, or offer a combination of such convenient traits. Types of convenience foods can vary by country and geographic region. Convenience foods include ready-to-eat dry products, shelf-stable foods, prepared mixes and snack foods. Hence are gaining more popularity.

Millets are a group of small seeded species of cereal crops, widely grown around the world for food and fodder. The group includes millets such as foxtail (*Setaria italica*), little (*Panicum miliare*), kodo (*Paspalum scrobiculatum*), common (*Panicum miliaceum*), barnyard (*Echinochloa frumentacea*), pearl millet (*Pennisetum glaucum* L.) and finger (*Elusine coracana*) millets. Millets are being adjudged as miracle grains and potential future crops. Millet, when compared to cereals, have several desirable nutritional qualities. Millets are rich in vitamins, minerals, sulphur and containing amino acids. And they contain high amounts of fibre and low quantities of carbohydrates. Compared to staple cereals, millets have more protein, fat, calcium and phosphorus and hence are termed as “nutri-cereals”.

Foxtail millet (*Setaria italica*) is one such nutritious and important underutilized grain, grown in various parts of India. It grows well even under adverse agro climatic conditions. It is also called as *navane*. Among the millets, foxtail millet is a good source of protein (12.3 g/100 g) and dietary fibre (14 g/100 g). The carbohydrate content is low (60.9 g/100 g). Besides, it is rich in minerals (3 g/100 g) and phytochemicals (Gopalan *et al.,* 2010). Foxtail millet is a good source of ß carotene (126-191 µg/100 g, Goudar *et al*., 2011).

In India, different kinds of traditional foods, made from small millets, forms staple diet for many rural and urban households. Although foxtail millet like any other minor millet is nutritionally superior to cereals, yet its utilization is limited. The major factor discouraging its cultivation and consumption with improvement in living standard or urbanization is the drudgery associated with its processing, low economic gains and lack of awareness about their nutritional significance. They are mostly used in preparation of traditional dishes and hence they play an important role in the local food culture. Inamdar *et al.,* (2005) documented the typical regional festival sweet foods of North Karnataka, India wherein the *Tambittu* and *Hurakki holige* which are made from the Foxtail millet. For *Tambittu,* the foxtail millet is roasted, milled and *laddu* is prepared with jaggery (cardamom is the condiment added for enhancing the taste). For *Hurakki holige,* the Foxtail millet flour is kneaded with hot jaggery syrup as stuffed in the maida dough and deep fried as pan cake. However, there is a need to restore the lost interest in millets particularly foxtail millet that deserves recognition for its nutritional qualities and potential health benefits.

Traditional food products have the potential to contribute to poverty elimination through employment opportunities, household food security, improved diets and cultural identity. With changing consumption patterns, globalization of trade, increasing migration and urbanization and demographic changes, some of the traditional food products are being lost from the diet. The future for small-scale food processing and of traditional food products in particular is optimistic. The small-scale food processing sector is a thriving growth area with huge potential for further development. Through their impact on food and livelihood security, social and cultural well being, traditional food products are set to play an increasingly important role in food security, sustainable growth and poverty reduction in developing countries (Ali and Battcock, 2001). Incorporating the millets in traditional foods like *papads*, *chakali*, fermented breakfast food '*paddu*', novel foods like biscuits, *laddu* were prepared and proved to have a good scope for enhancing nutrition security, marketing and income generation of community members, particularly rural women. Value addition also showed to be a highly strategic intervention in the popularization of nutritionally and technologically rich local crops which are currently largely neglected and underutilized (Yenagi *et al*., 2010).

*Laddu* is an Indian sweet made from a mixture of flour, sugar, and shortening and other ingredients that vary by recipe, which is shaped into a ball. They are often served at festive or religious occasions. *Besan laddu* is a popular Indian sweet dish made of *besan* (chickpea flour or gram flour), sugar and ghee. *Besan* is roasted in ghee till golden brown appearance with nutty fragrance. Then sugar is added to it. Pistachio pieces are also mixed in this mixture optionally. Sweet balls are then made from this mixture. It has a long shelf life. It is often served at festivals, family events and religious occasions in India.

People are getting busy with their career and profession. So there is great demand for nutritious ready to eat foods. Value addition to existing foods with foxtail millet is a simple and feasible way of enhancing nutritional values of foods and in turn the health benefits. Hence the present investigation is aimed to develop the foxtail millet incorporated *laddu*. Foxtail millet *laddu* may have a good scope for enhancing nutrition security. It may also provide good opportunity for marketing and can be taken up as income generating activity. Hence the study was taken with the following objectives:

1. To study the physico-chemical and nutritional changes of millet flour during roasting
2. To analyze nutrient composition of foxtail millet *laddu*
3. To evaluate the shelf life of millet *laddu*
4. To study the consumer preference regarding millet *laddu.*

# 2. REVIEW OF LITERATURE

In India, different kinds of traditional foods are made from small millet grains. Number of technologies have been developed to enhance the utility and commercial value of these grains. Since people are becoming health conscious, they prefer nutritious ready to eat food products. The related literature pertaining to the study and other related factors are reviewed and presented under the following subtitles:-

2.1 Nutrient composition of millets

2.2 Nutrient composition of processed Foxtail millet

2.3 Nutrient composition and functional properties of chickpea

2.4 Functional properties of flours

2.5 Nutrient composition and storage study of developed foxtail millet based foods

2.6 Nutrient composition of developed nutritious *laddu*

2.7 Intervention studies based on nutritious *laddu*

2.8 Millet based nutritious *laddu*

## 2.1 NUTRIENT COMPOSITION OF MILLETS

Ravichandran (1991) analysed the proximate composition, mineral composition and phytate and oxalate contents. The average protein contents of common millet, finger millet and foxtail millet were 14.4, 9.8 and 15.9 per cent respectively. The crude fibre content of the millets ranged from 3.2 to 4.7 per cent. In general, the mineral contents were high compared with those of other common cereal grains. In particular, the high level of classification (0.24 %) in finger millet was noteworthy. The high contents of phytic acid (0.50 – 0.70 %) in millets present grounds for concern, in view of its interference with several minerals. The oxalate contents (21 – 29 mg/ 100 g dry weight) of the millets were low. Considerable between and within millet difference were observed with regard to most nutrients analysed.

Kulkarni *et al.* (1992) in Karnataka carried out a study on proximate composition of five millets *viz.*, proso, kodo, Italian, little and barnyard. Little millet recorded highest moisture content (11.58 g/100 g) followed by Italian millet (10.62 g/100 g), proso millet (10.61 g/100 g), kodo millet (10.1 g/100 g) and barnyard millet (9.89 g/100 g). The moisture content of only little millet varied significantly with the other millets screened. However, the moisture content observed was within the acceptable range (12 %). It was interesting to observe that there was no significant variation among millets with respect to protein content, though little millet recorded highest (9.70 %) and kodo millet the least (9. 12 %). The fat content of millets ranged from 2.64 to 4.91 per cent. Barnyard recorded highest fat content followed by little, kodo, italian and proso millets. Kodo millet recorded higher crude fibre compared to other minor millets studied. It recorded 6.33 % followed by little millet (5.73 %), proso millet (5.51 %), barnyard millet (5.35 %) and Italian millet (4.51 %). The ash content of millets ranged between 2.83 to 4.20 per cent.

Hadimani and Malleshi (1993) studied the milling characteristics, the milled fractions, chemical composition and dietary fibre content of Pearl millet and small millets. The milled grains were also evaluated for cooking quality. The yields of milled grains, bran and husk varied from 63.2 to

90.0 per cent, 5.0 to 11.0 per cent and 1.5 to 29.3 per cent respectively. Milled grains contained about 90 and 70 per cent of the grain protein and grain fat, respectively. The oil contents of the bran from pearl, finger and other small millets were 15, 3 and 23-27 per cent, respectively. The total dietary fibre contents of milled grains ranged from 9-16 per cent out of which 32-50 per cent was soluble dietary fibre. Milled millet grains cooked soft within a short period when added to boiling water. The Brabender visco-amylograms of milled millet flour indicated a gelatinisation temperature of about 75 + 2 ℃, peak viscosity of 220-560 BU, breakdown viscosity of 20-120 BU and cold paste viscosity of 340-1120 BU.

Kamara *et al*. (2009) examined the chemical composition and physicochemical properties of two varieties defatted foxtail millet flour grown in China. The seeds were obtained, milled and sieved to produce flour. The flours were tagged DFMFW and DFMFY for defatted foxtail millet flour white and defatted foxtail millet flour yellow, respectively. The protein contents of DFMFW and DFMFY were 11.92 and 11.39 g/100 g, respectively. DFMFY had higher mineral elements, ash and fat content than DFMFW. Essential amino acids were above the recommended amount by Food Agricultural organization/World Health Organization (FAO/WHO) for humans. The foxtail millet flours had molecular sizes below 14.4 kDa and above 97.0 kDa. They had similar solubility curves. Water binding capacity was in the range of 1.36 and 1.26 g $g^{-1}$, while oil absorption capacity ranged between 0.78 and 0.50 g $g^{-1}$ for both DFMFW and DFMFY, respectively. A low bulk density (0.27 and 0.23 g $mL^{-1}$) and was also low in total phenolic assay (0.56 and 0.72 mg $g^{-1}$) was observed for both DFMFW and DFMFY, respectively. Foam capacity was 13.36 mL for DFMFW and 12.32 mL DFMFY. Their infrared falls within (1600 and 600 $cm^{-1}$) and both samples possessed O-H and C-H compounds. Defatted foxtail millet flour could be used in food formulation with less fear of retrogradation.

Anju and Sarita (2010) study was undertaken to analyse the nutrient composition (%) of foxtail millet flour. Crude protein, crude fat, crude fibre, total ash and carbohydrate content ranged from 9.92, 4.71, 8.07, 2.89 and 65.95 mg/100 g respectively.

Millets are rich in vitamins, minerals, sulphur and containing amino acids. And they contain high amounts of fibre and low quantities of carbohydrates. Compared to staple cereals, millets have more protein, fat, calcium and phosphorus. Marked varietal differences in proximate composition of millets depends on the type of soil, area where the seeds are grown, genetic variability and processing aspects.

## 2.2 NUTRIENT COMPOSITION OF PROCESSED FOXTAIL MILLET

Antony *et al*. (1996) studied the effect of fermentation on the primary nutrients in foxtail millet. Fermentation by endogenous microflora increased the total soluble sugars and reducing sugars with a simultaneous decrease in the starch content. The protein extractability and albumin/globulin fractions were improved. The beneficial long-chain fatty acid profile of raw flour was retained. Acetic and butyric acid were the major short-chain fatty acids produced. Most of these changes occurred in the first 24 hr of fermentation.

Coulibaly and Chen (2011) conducted the study to assess the energetic compounds (protein, fat and carbohydrate), some vitamins, minerals, antioxidant capacity, phytase and amylase activity during the germination of foxtail millet. Germination has been found to increase nutritive qualities of foxtail millet. One day soaking and germination up to 8 days increased significantly soluble sugars (reducing and total sugars), amylase activity from the first day to third day and phytase activity from first day to seventh day. The proteins were not changing during germination. Vitamins and minerals increased, however fat content and total phenolic content decreased through germination. Germination of foxtail millet for three days allowed obtaining flour with high amylolytic activity, high DPPH scavenging activity and high concentration of minerals, thus it can be added to different flour to initiate starch degradation and reduce viscosity, to control the minerals balance in children diet.

Choudary *et al*. (2011) evaluated the nutritional composition of popped and malted indigenous millet of Assam. For better utilization of millets, two processing techniques, *viz*., popping and malting were standardized using two local varieties of foxtail millet (*Setaria italica*). In popped samples, crude fat and crude fibre contents were significantly lower than raw millet in both the yellow and purple varieties, while the carbohydrate and energy values were significantly higher. In malted samples, crude protein and fat contents were significantly lower than in raw millet in both the varieties, whereas the carbohydrate contents were higher. Starch digestibility was highest (42.4 %) in yellow popped samples and lowest in yellow malted samples (21.8 %). Protein digestibility was highest (13.2 %) in purple popped and lowest (2.4 %) in yellow malted samples.

Sharma *et al*. (2015) analysed the effects of independent variables [soaking time (ST), germination time (Gt) and temperature (GT)] on responses like antioxidant activity (AoxA), total phenolic contents (TPC) and flavonoid contents (TFC) by applying a central composite rotatable design. The results indicated that with increase in ST, Gt and GT, AoxA, TPC (free/bound) and TFC (free/bound) of foxtail millet increased significantly. The best combination of germination bioprocess variables for producing optimized germinated foxtail millet flour with the highest AoxA (90.5 %), TPC (45.67 mg gallic acid equivalent (GAE)/100 g sample) and TFC (30.52–43.96 mg RU/g sample) were found with soaking time of 15.84 min having germination temperature of 25 °C. The optimized germinated foxtail millet flour was nutritionally rich as it produced higher protein (14.32 g/100 g), dietary fibre (27.42 g/100 g), calcium (25.62 mg/kg), iron (54.23 mg/kg), magnesium (107.16 mg/kg) and sodium (69.45 mg/kg) per kg as compared to un-germinated foxtail millet flour.

Foxtail millet contains good amount of protein, fibre, ash, fat, carbohydrate and varied between cultivars due to genetic variability. Processing methods such as germination, malting, fermentation and popping enhanced the nutritive value and reduced antinutritional factors tannin, phytic acid, polyphenols and increased the bioavailability of micronutrients. The processed millet can be used in developing low cost dietary formulations.

## 2.3 NUTRIENT COMPOSITION AND FUNCTIONAL PROPERTIES OF CHICKPEA

Costa *et al*. (2006) studied the chemical composition and the contents of resistant starch and soluble and insoluble dietary fibre of pea (*Pisum sativum* L.), common bean (*Phaseolus vulgaris* L.), chickpea (*Cicer aretinum* L.) and lentil (*Lens culinaris* Med.) legumes. Raw and freeze-dried cooked samples were used, both in the form of flour. Protein values of the legumes ranged from 18.5 to 21.9 g/100 g for the raw grains and from 21.3 to 23.7 g/100 g for freeze-dried cooked legumes.

Chickpea stood out for the highest lipid content, the lowest insoluble fibre values, and soluble dietary fibre not detected. The average content of resistant starch found in the legumes did not differ statistically, being 2.23 ± 0.24 g/100 g for freeze-dried cooked legumes, and showing a slight reduction in comparison to the raw form.

Iqbal *et al*. (2006) studied the proximate composition, mineral constituents and amino acid profile of four important legumes (chickpea, lentil, cowpea and green pea) in order to evaluate their nutritional performance. Significant variations existed among the legumes with respect to their proximate composition, mineral constituent and amino acid profile. Lentil was found to be a good source of protein, while cowpea was good in ash among the grain legumes tested. All four types of legumes were also better suppliers of mineral matter, particularly potassium, phosphorus, calcium, copper, iron, and zinc. However, the concentrations of various mineral constituents was not in good nutritional balance. It was concluded that the four legumes tested were rich in lysine, leucine and arginine and can fulfil the essential amino acid requirement of human diet except for S-containing amino acids and tryptophan.

Daur *et al*. (2008) analysed the raw and processed (roasted and pressure-cooked) seeds of chickpea for nutritional and antinutritional qualities. A significant difference was seen between the proximate composition of raw and processed seeds. The seeds consist of 19.47-21.27 per cent proteins and 8.53-9.89 per cent fibre. Among the minerals, potassium was highest (725-1171 mg/100 g) followed by phosphorus (188.3-252.7 mg/100 g) and sodium (61.3-100.3 mg/100 g). Significant variation existed in some amino acid of raw and processed seeds or roasted and pressure-cooked seeds. The amino acids: arginine, histidine, isoleucine, leucine, lysine, aspartic acid, glutamic acid were higher in both roasted and pressure-cooked than whole egg protein. Essential amino acids excluding methionine and phenylalanine of all seeds type: raw, roasted and pressure cooked exceeded than FAO/WHO pattern. The amino acids: leucine, lysine, valine and tyrosine were recorded with lower amount in pressure-cooked seed compared to roasted seed. Polyphenol 153 mg/100 g was detected less in pressure-cooked seed compared to roasted and raw seeds (281.3 vs 315.9). In the study there was little loss of nutrients from raw to roasted chickpea seed compared to pressure-cooked.

Wang *et al*. (2010) investigated the effect of cooking on levels of nutrients and anti-nutritional factors in beans and chickpeas. Significant variation existed among the beans and chickpeas with respect to their crude protein, starch, soluble dietary fiber (SDF), insoluble dietary fiber (IDF), total dietary fiber (TDF), resistant starch (RS), trypsin inhibitor activity (TIA), mineral, phytic acid, tannin, sucrose and oligosaccharide (raffinose, stachyose and verbascose) contents. Cooking beans and chickpeas in water significantly increased protein, starch, SDF, IDF, TDF, Mn and P contents (on a dry weight basis), whereas reduced ash, K, Mg, TIA, tannin, sucrose and oligosaccharide contents were observed. Colored beans (black, cranberry, dark red kidney, pinto and small red bean) contained tannins, whereas little tannin in white-colored beans (great northern and white pea bean) and chickpeas (Desi and Kabuli type) was detected.

Chickpea flour is known for its binding property. It is good source of protein. Processing technologies of chickpea can be used in development of suitable products.

## 2.4 FUNCTIONAL PROPERTIES OF FLOURS

Narayana and Narasinga (1982) compared the nitrogen solubility, emulsification capacity, foam capacity, fat and water absorption capacity of raw and heat-processed winged bean flour with those of raw soy flour, both as a function of pH and NaCl concentration. Nitrogen solubility vs pH profile showed only one minimum, at pH 4.5. Heat processing of winged bean flour lowered nitrogen solubility. Water and fat absorption capacity of winged bean flour were 2.1 g/g and 1.4 g/g, respectively; those of raw soy flour were 3.1 g/g and 1.2 g/g. Heat processing increased water and fat absorption capacity of winged bean flour by 38 and 57 per cent respectively. Emulsification capacity of raw winged bean flour was higher than that of raw soy flour by about 30–60 per cent depending on the pH. Heat processing diminished emulsification and foam capacity of winged bean flour by about 35 and 18 per cent respectively. Incorporation of NaCl up to 0.4M improved emulsification capacity of winged bean flour and foam capacity up to 0.2 M.

Abbey and Ibeh (2006) determined the functional properties, gelation, water and oil absorption, emulsification, foaming and protein solubility of raw and heat processed cowpea flour. The effects of pH and NaCl concentration on some of these functional properties were also investigated. Protein solubility vs pH profile showed minimal solubility at pH 4. Water and oil absorption capacities of raw flour were 2.4 g/g and 2.9 g/g, respectively, while heat processed flour gave 3.6 g/g and 3.2 g/g, respectively. Addition of NaCl up to 0.4 per cent improved the emulsification capacity of raw flour while a decrease was observed in the heat processed flour after 0.2 per cent. Least gelation concentration of raw flour was found to be 16 per cent and heat processed flour, 18 per cent.

Ghavidel and Prakash (2006) studied the functional properties of flours derived from selected legumes, before and after dehulling of the germinated seeds. Ungerminated seeds were used as the control. The chosen legumes were green gram, cowpea, lentil and bengal gram. Dehulled samples had a higher protein solubility compared with germinated and control samples. The bulk densities of germinated and dehulled legume flours were lower compared to control. Germination increased water absorption capacities of legume flours from 1226, 1285, 974 and 1362 g $kg^{-1}$ to 1481, 1433, 1448 and 1517 g $kg^{-1}$ in green gram, cowpea, lentil and bengal gram, respectively. Fat absorption capacities increased in germinated samples (1130, 1242, 920 and 837 g $kg^{-1}$) as against 900, 993, 857 and 788 g $kg^{-1}$ at ambient conditions for green gram, cowpea, lentil and bengal gram, respectively. On dehulling, the fat absorption capacities of samples were reduced and the differences were statistically significant. The emulsification capacities of control samples ranged from 55 to 193 ml oil emulsified per gram of sample. On germination and dehulling, the emulsification capacities, activities and stabilities of samples increased significantly. There were increases in foaming capacities and reduction in foam stabilities of all the samples investigated on germination and dehulling. This indicated that germination and dehulling improved the functional properties of legumes.

Sathe and Salunkhe (2006) investigated the functional properties of the Great Northern bean (*Phaseolus vulgaris* L.) flour, albumins, globulins, protein concentrates, and protein isolates. Protein concentrates had the highest water and oil absorption capacity (5.93 and 4.12 g/g, respectively) among all the samples studied. Protein concentrates registered the highest emulsion capacity (72.6 g oil emulsified/g) while albumins had the highest emulsion stability (less than 5 ml separation of phase in 780 hr at room temperature of 21 °C). Foaming ability of the Great Northern bean proteins was fair. Foamability of the proteins was concentration dependent.

Sade (2009) investigated the effect of germination, roasting and fermentation on the proximate composition, antinutritional factors and functional properties of pearl millet. Pearl millet were subjected to the different processing methods; samples were dried and milled into fine flours, respectively. Standard methods were used to evaluate the flours for proximate composition, minerals, antinutritional factors and functional properties. The vis co-elastic property was determined using the Rapid Visco Analyzer (RVA). Germination and fermentation increased the crude protein content of pearl millet flour. The carbohydrate content decreased during fermentation, while germination and roasting significantly increased the carbohydrate level resulting in significant increase in the energy density of the flour. Processing had varied effects on the mineral composition of the flours, it also reduced the antinutritional factors. Processing significantly increased the water absorption capacity, oil absorption capacity, least gelation concentration and bulk density of the flours.

Ocheme *et al.* (2010) studied the effect of lime soaking and cooking on the functional, proximate, and antinutritional properties of millet flour. Flour samples were produced from soaked millet grains and cooked millet grains. Portions of millet grains were soaked in water and in 1 % lime solution for 24 hr and some were cooked for 30 minutes in both water and in 1 % lime solution. At the end of soaking and cooking, the grains were dried; milled; sieved with a 0.25 mesh screen; and packaged in white high density polyethylene bags. Cooking millet grains in lime solution prior to processing into flour resulted in a flour that contains significantly higher protein; ash; crude fibre; water absorption capacity; pH; emulsion capacity and stability; hygroscopicity; and swelling power; and significantly, lower fat; oil absorption capacity; tannin; trypsin inhibitor and hydrogen cyanide than flours obtained from untreated millet grains and millet grains cooked in water. Furthermore, flour obtained from millet grains soaked in lime solution contains significantly ($p<0.05$) higher water absorption capacity; hygroscopicity; and swelling power; and significantly lower protein; phytic acid; tannin; and trypsin inhibitor than flours obtained from untreated millet grains and millet grains soaked in water.

Adebowale and Maliki (2011) studied the changes in the chemical composition and functional properties of fermented seed flour of Pigeon pea, for 0, 1, 2, 3, 4 and 5 days. The differently fermented seeds were analyzed for proximate composition, calorific values and functional properties. Results showed that fermentation significantly increased the moisture, protein and ash contents of the seed while the crude fat, crude fibre and carbohydrate contents were noted to be decreased. However, water/oil absorption, bulk density, swelling capacity, foam capacity/ stability, viscosity and gelation power were significantly decreased.

Chandra and Samsher (2013) studied the functional properties of different flours, that is, wheat flour, rice flour, green gram flour and potato flour. The functional properties (swelling capacity, water absorption capacity, oil absorption capacity, emulsion activity and stability, foam capacity and stability, least gelation concentration, gelatinization temperature and bulk density) and moisture content of flours were evaluated. Wheat flour had highest moisture content and emulsion activity while rice flour observed lowest value for foam capacity. Potato flour had highest value of swelling capacity, water absorption capacity, oil absorption capacity and emulsion stability. Highest bulk density observed for rice flour while foam capacity; least gelatinization concentration and gelatinization temperature for green gram flour compared to others. Green gram flour and potato flour have good functional properties which enhance the nutritional quality of the value added products which processed by addition of them.

Processing of grains enhances the nutritional and functional properties and decreases the antinutritional factors. Hence, processed products have the scope in value addition.

## 2.5 NUTRIENT COMPOSITION AND STORAGE STUDY OF DEVELOPED FOXTAIL MILLET BASED FOODS

Thathola and Srivastava (2002) developed a weaning food based on malted foxtail millet flour (30 %), malted barnyard millet flour (30 %), roasted soybean flour (25 %) and skim milk powder (15 %). The mix contained 18.37 g protein and 398 kcal energy per 100 g. The nutrient composition of this unfortified weaning (UW) mix met the Prevention of Food Adulteration (PFA) standards, except in total ash. In order to meet the minor constituent requirements, the UW mix was fortified. The fortified weaning (FW) mix met PFA standards for various nutrients. The protein efficiency ratio of the UW mix was 2.25 against a casein control, for which a value of 2.50 was recorded. The nutrient composition, viscosity and sensory quality of the UW mix was compared with the marketed weaning mix, commercial infant formula. The viscosity of UW gruel was much lower (20 centipoise (cps)) than that of marketed weaning mix (7400 cps). The high alpha-amylase activity of 661 units in the UW mix was responsible for its low viscosity. The sensory quality of UW mix and marketed weaning mix did not differ significantly. Both of the gruels were liked moderately on the Hedonic Scale. The UW gruel met the acceptability criteria for weaning food. It could be stored in plastic airtight containers at room temperature for 4 months without any changes in sensory quality.

Anju and Sarita (2010) prepared biscuits based on foxtail millet and barnyard millet and to evaluate their sensory quality and acceptability, nutritional value and glycemic index by comparing with biscuits made from refined wheat flour. The biscuits made from millet were prepared using 45 per cent of millet flour and 55 per cent of refined wheat flour. All the three types of biscuits were found to be acceptable by a trained panel and diabetic subjects. The shelf life study indicated that the biscuits made from both types of millet flour can be successfully stored for a period of 60 days in a thermally sealed single polyethylene bag at room conditions. The millet flour and biscuits had higher content of crude fibre, total ash and total dietary fibre than refined wheat flour and biscuits. Biscuits from foxtail millet flour had the lowest GI of 50.8 compared to 68 for biscuits from barnyard millet flour and refined wheat flour. Thus, besides its traditional use in making *chapatti* and porridge, millet can be exploited for the development of low GI therapeutic food products like biscuits. Further studies are needed to determine long term effects of consumption of foxtail millet biscuits on blood lipid profile and glycosylated haemoglobin of diabetics and cardiovascular patients.

Deshpande and Poshadri (2011) developed Foxtail millet (*Setaria italica*) based ready-to-eat snack products using extrusion cooking. Composite flours were prepared using whole foxtail millet flour and other flours namely; rice flour, chick pea, amaranth seed flour and cow pea. Nutritional properties of the blends were analyzed and extrusion cooking was carried out using a twin screw extruder at optimised extrusion parameters namely temperature: 115 ˚C and 90 ℃ for two different heating zones, die diameter: 3 mm and screw speed: 400 rpm. The extrudate physical properties namely bulk density, piece density, expansion ratio and moisture retention were also analysed. The organoleptic qualities of extruded samples were analysed by panellists on a 9 point hedonic scale. The results indicated that composite flour (Foxtail millet; Amaranth; Rice; Bengal gram; Cow pea in the ratios of 60:05:05:20:10) could be used to produce quality extrudates with acceptable sensory properties.

Garwadhiremath (2011) developed foxtail millet based breakfast muffin and evaluated for its nutrient adequacy. The foxtail millet based muffin was standardized for optimum addition of foxtail millet flour to refined wheat flour, sugar, fat, egg and baking powder by varying quantity and evaluated organoleptically for acceptability of suitable proportion by semi-trained panellists. The developed muffin was enriched by addition of dehydrated papaya powder at different levels and assessed for proximate composition, trace elements and total carotene content. The developed millet muffin was tested for acceptability of consumers in comparison with refined wheat flour muffin. Standardization trials indicated that foxtail millet flour could be incorporated at 50 per cent and 5 per cent decrease in fat in the standard recipe and further enriched with 10 g of papaya powder, to yield acceptable breakfast muffin. Nutrient analysis revealed that, the moisture, protein, fat, ash, crude fibre and carbohydrate contents of refined flour breakfast muffin was 24.95, 12.87, 24.80, 0.67, 0.11 and 36.59 per cent respectively. Replacement of foxtail millet flour significantly increased the nutrient composition of breakfast muffin. Foxtail millet muffin was found superior nutritionally compared to refined wheat flour muffin as it increased the protein, crude fibre and mineral contents by 12.5, 90 and 28 per cent respectively. Copper zinc and iron contents increased by 34.5, 24.5 and 49.9 per cent respectively. Further enrichment of foxtail millet muffin with dehydrated papaya powder significantly increased the copper, zinc, and iron by 30, 5 and 41 per cent respectively. The total carotene content of refined wheat flour breakfast muffin was 124.60 µg/100 g, with incorporation of foxtail millet flour and enriched with papaya powder, the total carotene content increased by 93 % (291.36 µg/100 g.). The developed foxtail millet based breakfast muffin possessed the shelf life of 4 days. The enriched foxtail millet breakfast muffins were liked very much by the consumers.

Coulibaly *et al*. (2012) developed a breakfast food with a low glycemic index from a formulation based on the pre-treated foxtail millet and soybean. The pre-treatment applied to raw materials (germination of millet, pre-cooking or roasting soybeans) have helped to improve the functional properties of blends. Flours made from germinated millet have a low estimated glycemic index 35.39 and 34.49 respectively for GMRS and GMPCS. During storage periods, the pH of four blends decreased significantly. The FA (Fat Acidity) and IPV (Initial Peroxide Value) of all blends increase slightly during storage without reaching their standard values which were set at no more than 30 meq.g of iodide/Kg for FA and 3 mg of KOH/100 g for IPV. At room temperature the blends can be stored for 90 days without preservatives.

Pandey (2013) developed foxtail millet based value added vermicelli. Standardized by incorporating 50 per cent processed foxtail millet flour, 20 per cent black gram dhal flour and 1 per cent fenugreek seed powder. Developed vermicelli were evaluated for sensory, nutritional and storage quality. The overall sensory score for designed foxtail millet vermicelli was 7.6 in comparison to control which scored 8.4. The results indicated that foxtail millet vermicelli exhibited good cooking quality, percent solubility (30.67 %) and short cooking time (5.03 min). Cooking loss decreased significantly in both control and foxtail millet based vermicelli (8.84 – 6.74, 12.30 – 10.85 g/100 g, respectively) at the end of storage period. Nutrient analysis revealed that, the protein, fat, ash, crude fiber and carbohydrate contents of developed vermicelli was 14.32, 0.21, 1.42, 0.45 and 77.0 per cent respectively with high dietary fibre content (22.17 %; soluble- 4.90 % and insoluble-17.4 %). The developed foxtail millet vermicelli was acceptable and could be stored well beyond six months.

Balloli *et al*. (2014) developed foxtail millet based bread by incorporating foxtail millet flour at 10, 30 and 50 per cent level in the recipe. Height of the breads affected significantly at 50 per cent incorporation of foxtail millet flour. Value addition to breads with foxtail millet resulted in significant change in colour of both crust and crumb. Crumb colour changed from white to dull yellowish with increased incorporation of millet flour. The highest L value was found for 50 per cent (67.24) incorporated breads followed by control (53.56), 30 per cent (48.47) and 10 per cent (40.86). Compressive test of bread crumb showed significant difference between control and foxtail millet incorporated breads. Increase in foxtail millet resulted in increased hardness with harder crumb and grainy texture. Sensory evaluation scores revealed that the higher proportion of foxtail millet incorporation although decreased scores for colour, appearance and texture, the taste, flavour and overall acceptability improved and are on par with control bread. Thus, the study indicated the potentials of development of foxtail millet incorporated breads at 50 per cent level.

Ranganna *et al*. (2014) developed millets' based cold extruded products (vermicelli and pasta). Five small millets' (barnyard, foxtail, kodo, little and proso) were used in the study. Small millets flour, wheat and soy flours were used in the ratio of 50:40:10 for the development of cold extruded products. Vermicelli kheer and pasta masala were prepared from all the five millets and were subjected to sensory evaluation along with control (wheat based vermicelli). Sensory results showed that the millets kheer was more acceptable and foxtail millet kheer was better preferred followed by kodo and proso millet kheers. The millets pasta masalas were also very much acceptable compared to control. Among the millets, proso millet pasta masala was more preferred for its sensory attributes followed by kodo millet. Nutritional analysis of stored vermicelli showed not much variation in composition before and after storage irrespective of packaging material. Both the gauges of package (300 and 400 PE) were found suitable for storing vermicelli up to two months without affecting the quality.

Gautam (2014) developed foxtail millet based micronutrients rich ready-to-eat snack products using home-made extrusion cooking. Composite flour were prepared using processed Foxtail millet flour (FMF) and other processed flours namely; wheat flour (WF), and chick pea flour (CPF). Two homemade extruded products namely; namkeensev, seviyan were prepared with four treatments T0, T1, T2, & T3. The commonly consumed recipes were developed by incorporating 50, 75 and 100 per cent of best result malted composite flour (FMF+CPF+WF). The organoleptic qualities of these extruded samples were analyzed by panelists on a 9 point hedonic scale. The result indicate that the processed composite flour (FMF+CPF+WF) based products were significantly accepted at the level of 50 per cent incorporation followed by 75 and 100 per cent respectively.

Advances in post-harvest processing and value addition technologies have made it possible to process and prepare value added products acceptable to both rural and urban consumers. Processing and utilization of foxtail millet in product development have promising prospects with regard to nutrition, quality and health benefits and can be an alternative to cereals but its full scope and utilization is yet to be established.

## 2.6 NUTRIENT COMPOSITION OF DEVELOPED NUTRITIOUS *LADDU*

Kumari and Singh (2005) developed the *laddu* from maize of high quality protein due to having balanced amino acid composition commonly known as Quality *Protein* Maize in combination with ragi, green gram, gingelly seeds, amaranthus and jaggery was analysed for nutritional composition and tested for common acceptability. The percentage of moisture, ash, fat, crude fibre, crude protein, carbohydrate, sugar and starch was 6.9, 3.8, 6.4, 2.05, 16.2, 17.05, 2.4 and 45.5 respectively. Iron and calcium content was 13.23 mg/100g and 418.03 mg/100g, respectively. Acceptability score of food product was evaluated by 30 pregnant women by using 9 point hedonic scale. The score for different parameters such as colour, flavour, texture, taste and general acceptability were recorded. Scores for all parameters was above 6 which indicated the acceptance of the product.

Sood *et al.* (2009) developed protein and energy rich sweet balls (*ladoos*) by locally available food sources like amaranth, sesame, soybean and sugar. Sesame and soyabean supplemented sweet balls were found to be rich in protein (12.90-15.37 %), fat (18.32-24.49 %), calcium (541.8-739.4 mg/100 g) and iron (6.41-8.02 mg/l00 g.) Amaranth and soybean supplemented sweet balls were found to be rich in total carbohydrates (79.58-87.43 %) and potassium (210.359 mg/l00 g). Sensory evaluation of the developed products revealed that amaranth and sesame based soybean (15 %) supplemented sweet balls were most acceptable. From the results of the study it can be concluded that amaranth, sesame and soybean supplemented sweet balls can be prepared easily at home using locally available nutritious resources and can help in combating protein and energy malnutrition.

Verma *et al.* (2014) revealed that 20 per cent mushroom (oyster mushroom) fortified *laddus* contained high amount of protein and fibre, low fat and carbohydrate than control sample (*besan laddu)* and organoleptic evaluation of prepared *laddus* revealed that 15 per cent fortification of mushroom powder in *besan laddus* was liked very much. The fortified *laddus* had better quality with respect to nutritive value and organoleptic acceptability.

Jain *et al.* (2014) developed the *laddu* by incorporating the groundnut meal powder. Ground nut meal is the high protein by-product remaining after commercial extraction of peanut oil. Groundnut meal applications are limited because of typical high concentrations of aflatoxin. In the present study technology was developed to prepare protein rich powder from an oil extracted groundnut. To make the meal free from aflatoxin four treatments were employed *viz*. ether treatment, heat treatment, acid alkali treatment and homestead acid-alkali treatment. After each treatment, the powder was subjected to analysis of protein and aflatoxin and acceptability for sensory characteristics. A reduction ranged from 17.86 to 100 per cent of aflatoxin and 29.17 to 70.47 per cent of protein. A comparative evaluation of four powders indicated that homestead acid alkali treatment is free from aflatoxin and containing 10.09 gm of protein. This powder was incorporated in *besan laddu* at 35 and 50 per cent level. Acceptability was assessed on 9 point hedonic rating scale. The mean overall acceptability of reference, 35 per cent and 50 per cent incorporated *besan laddu* were 8.0 and 7.3 respectively, revealing that the developed powder is acceptable at moderate level. No significant difference was found between 35 and 50 per cent incorporated product. However, the 50 per cent incorporated product scored significantly lower than the reference, specifically for colour and appearance.

Dash *et al.* (2014) investigated the physico-chemical characteristics of 10 selected turmeric germplasm of South Western region of Bangladesh. The physico-chemical characters of 10 germplasm of turmeric species were studied. There was significant variation among the germplasms in relation to rhizome characteristics and organoleptic evaluation. Better performance of turmeric was found in germplasm No.1 in respect of total rhizome weight, rhizome length, rhizome width, rhizome height, pulp weight, pulp thickness, skin weight, skin thickness and percents of edible part. Turmeric germplasm No. 5 and germplasm No. 4 gave better performance in respect of pH (6.90) and vitamin C (5.70) content of rhizome pulp, respectively. The total soluble solids (13.67 %) found higher in germplasm No. 10 and titratable acidity (7.15 %) in germplasm No.1. Carotenoids (14.81 mg/100 g) found maximum in germplasm No. 2. Germplasm No. 9 and 7 was better in respect of anthocyanin (0.92 mg/100 gm) and flavonoids (7.67 gm.) content of turmeric pulp. The ingredients used for preparing the turmeric based *laddu* were sugar, ghee, bengal gram flour and cardamom powder. Turmeric *laddu* was successfully prepared by using 400 g sugar containing treatment consisting 300-500 g of sugar with 100 g variation in three treatments without changing other ingredient. All turmerics are not available year round in the country. So it is possible to preserve these rhizomes by development of product like *laddu,* to meet the nutritional requirement of people of the country.

Thimmappa (2015) critically studied the preparation of *Tirumala Srivari Laddu.* It has the history of 300 years. *Laddu* is the main offering (Prasadam) to the presiding deity. Pilgrims are offered two *laddus* at Rs. 20/- (subsidised rates). The ingredients used are the first Quality Rice, sugar, cashew nuts, cardamom, cow ghee, sugar candy, raisins (*kishmish*) and gram flour in optimised level. *Tirupati laddu* got the patent rights under the Geographical Indications of Goods Registration and Protection Act in 2009. The TTD (*Tirumala Tirupati Devasthanams*) had applied for GI with Chennai-based Geographical Indication Registry to avoid its black-marketing by hawkers and middlemen. Pilgrims about 87.6 % found the taste of *laddu* to be good.

Nutritious *laddu* can be prepared by incorporating some nutritious ingredients. There is a scope for incorporating the pulses, nuts, oilseeds, mushroom powder, turmeric *etc*.

## 2.7 INTERVENTION STUDIES BASED ON NUTRITIOUS *LADDU*

Nazni and Poongodi (2006) incorporated the processed papaya powder at a level of 15 per cent in standardized recipes such as rice flakes *ladoo,* wheat flour *ladoo* and besan *ladoo*. Organoleptically rice flakes *ladoo* was highly acceptable. Selected *ladoo* was used for supplementation for 90 days. Twenty students were selected whose serum vitamin A levels ranged between 0.7- 1.05 mmol/lit (20-30/dl). Selected students were divided into two groups. Group I as control and group II as experiment group. Each group consists of ten students each. There was significant increase in the serum vitamin A level and blood haemoglobin level, when rice flakes *ladoo* containing 15 per cent of papaya powder were supplemented for a period of 90 days in experimental group when compared to control group.

Barnwal *et al.* (2011) assessed the impact of supplementation of niger seed *laddoo* in anaemic adolescent girls aged 17-18 years studying in Government Girl's Schools and colleges in Azadnagar and Nawabganj area of Kanpur, Uttar Pradesh. The subjects were dewormed with a single dose of 400 mg albendazole tablet one week prior to supplementation. Thirty anaemic subjects were selected randomly for the study and divided in to two groups- experimental and control group (15 anaemic subjects in each group). Subjects in experimental group were supplemented daily with one serving (25 g) of niger seed *laddoo* for 75 days. No supplementation was given to anaemic subjects of control group. The prevalence of anaemia was found to be 50.19 per cent in adolescent girls. It was found that 49.41 per cent of the subjects had normal iron status as indicated by haemoglobin level. In the experimental group the mean haemoglobin value was found to increase from 9.50 ± 0.19 g/dl to 11.07 0.28 g/dl, ($p<0.001$) after 75 days of supplementation period, whereas in the control subjects the mean haemoglobin value was found to decrease from 10.55 ± 1.65g/dl to 9.70 ± 0.19 g/dl. A significant difference was found in the net change of mean haemoglobin values (-0.85 ± 0.10 and 1.57 ± 0.15 g/dL in the control and experimental subjects, respectively. The developed supplementary food *i.e.* niger seed *laddoo* was found to be acceptable and its efficacy as an iron supplement in combating mild to moderate iron deficiency anaemia is reflected.

Mulik and Salunkhe (2011) evaluated the effectiveness of 'Krishna Poshak mix' on nutritional status of Anganwadi children, evaluative approach was done with pre and post test control group design was used. Study was conducted on 54 Children admitted in Anganwadi at Malkapur village. The experimental group was given 'Krishna Poshak mix' *laddus* 50 g two *laddus* daily for one month. Whereas control group receives adlib ICDS supplementary diet for one month. The results show that the number of subjects in normal, mild, moderate and severe degree of malnutrition in experimental group 2, 16, 8 and 1 and in control group were 1, 20, 4 and 2 respectively. Experimental group Anganwadi children gained more weight pre & post-test with mean of 13.61 & 14.08 kg & mid arm circumference pre & post-test mean 14.90 & 15.14 cm after getting Krishna Poshak Mix *laddus* than control group weight pre & post-test mean 13.62 & 13.78 kgs & mid arm circumference pre and post-test mean 14.64 &14.74 cms. There was no statistically significant association between pre interventional assessment nutritional status score and socio-demographic variables.

Patil *et al.* (2014) assessed and intervened the strategies for control of anemia among adolescent girls in an urban slum of Karad, Dist. Satara, Maharashtra with an objective to find the prevalence of anemia among adolescent girls and to assess the impact of nutritional education, therapeutic intervention and supplementary intervention for the control of anemia amongst these girls. All the adolescent girls in the age group of 11-18 years were contacted and data collected regarding social and personal factors was collected along with hemoglobin (Hb) estimation. Out of the total 103 adolescent girls 88 (85.4 %) were anemic of which 52 (50.48 %) had mild anemia, 34 (33 %) moderate anemia and 2 (1.9 %) had severe anemia. Age match distribution was done of the 52 mildly anemic girls in Group 1, Group 2 and Group 3 in the age of 17 and 18 respectively. Interventions of nutritional education, distribution of iron and folic acid tablets and supplementary nutrition by giving iron rich preparations (in the form of *Laddus* which was given to consume for a period of one month. Twenty-five *laddus* were prepared from garden cress seeds (locally called as '*haliva*') 250 gms, dry coconut 500 gms and jaggery 750 gms which contained a total of 349 mg of iron. A *laddu* of 60 gms was prepared. One *laddu* contained 14 mg of iron. Girls were made to consume two *laddus* at a time considering the iron absorption among adolescent girls to be 2.4 mg/day and the recommended daily allowance of iron should be 28 mg/day) was done in the above three groups for a period of one month and Hb was rechecked. *It was* revealed homogeneity in age matched distribution of girls in 3 groups. There was significant rise in the Hb level in group 2 who received iron and folic acid tablets. No change in Hb level was seen in group 1and 3. But in some girls there was improvement in Hb levels however in some there was reduction in Hb level belonging to group 1 and 3. It was found that increasing age, mixed diet and supplementation of iron and folic acid were associated with improved Hb level irrespective of intervention in group 1 and 3.

Nutritious *laddu* can be supplemented to the children who are deficient in one or the other nutrient. Mineral and vitamin rich *laddus* were supplemented to the children and intervention study witnessed the improvement in their health status.

## 2.8 MILLET BASED NUTRITIOUS *LADDU*

Pathak *et al.* (2000) developed *laddu* (sweet balls) by using foxtail millet, fenugreek seeds and legumes in judicious combination, after suitable processing. Evaluation of product for glycemic response in five normal and five diabetic subjects showed hypoglycemic effects in terms of glycemic-index (GI). The GI, 23.52 was observed for *laddu* in normal. The *laddus* prepared were well acceptable by the subjects. The developed *laddu* may have an important role in dietary management for diabetic people and may cater for their needs on a large scale if commercialized.

Singh and Sehgal (2008) developed popped pearl millet based *ladoo*. Popping produces low bulk density and improves *in vitro* digestibility Two types of *ladoo* were prepared from popped pearl millet. In type I, roasted and dehulled chickpea and groundnut were also added to improve the nutritional quality, whereas type II of *ladoo* was prepared using 100 per cent popped pearl millet. It was revealed that type I popped pearl millet *ladoo* had significantly higher calcium, phosphorus and iron content. Higher polyphenol and phytic acid and lower *in vitro* protein and starch digestibility were also found in type I *ladoo*. Cellulose and lignin content was found to be more in type II *ladoo* compared to type I *ladoo*.

Naidu *et al.* (2013) designed a galactogogue and a nutritionally rich common food product - multigrain *ladoo,* made with varied kind of flours (bengal gram dhal, green gram dhal, black gram dhal, wheat flour, ragi flour and *rava*), nuts (almond, cashew nut and raisin), functional food "dink", artificial sweetener (sugar free tablet), cardamom powder and ghee. The product provides good amounts of biological proteins, functional property, vitamins and minerals and adequate fibre and has a good satiety value. Evaluation was done on sensory attributes like color, taste, texture, aroma and overall acceptability of the product.

Raj and Santhanam (2015) developed the foxtail millet *laddu.* Foxtail millet powder-250 g, milkmaid (sweetened condensed milk)-100 ml and jaggery - 75 g were used. The sweetened condensed milk was mixed with the powdered foxtail millet. Jaggery was melted and mixed with mixture. And then made into balls. Prepared foxtail millet based *laddu* were organolepticaly accepted.

Shunmukha and Kowsalya (2015) prepared convenience mix. For 100 g of convenience mix 65 g of malted millet flour (pearl millet, finger millet and jowar) was taken. To this, green gram (roasted and powdered), roasted Bengal gram (powdered) and groundnuts (roasted and powdered) were added in the ratio 20 g: 10 g: 5 g respectively to each of these malted millet flours to form the 100 g mix. It was observed that, the ash content ranged from 2.57 g, 2.85 g and 3.23 g respectively for pearl millet based mix, finger millet based mix and sorghum based mix. The moisture content of the mixes was in the range of 4.07 to 4.63 per cent. The sorghum based mix contains the highest energy content of 388.09 Kcal whereas the protein content of three mixes was in the range of 15.03 g to 16.35 g. The fat content of the pearl millet based mix was highest of 6.10 g. Pearl millet based mix contained iron of 7.78 g, zinc 3.01 g, phosphorus 335.17 mg/100 g. The finger millet based mix contained high calcium of 284.78 mg. From these convenience food mixes *ladoo* were developed with sugar/ jaggery and were highly acceptable.

Millets have the scope of incorporating in making the *laddu* which contribute to its nutritional composition.

# 3. MATERIAL AND METHODS

The present investigation on ‘Development and storage quality of foxtail millet (*Setaria italica*) *laddu* was carried out in the Department of Food Science and Nutrition, College of Rural Home Science, University of Agricultural Sciences, Dharwad during 2014-16. The research design carried out is presented in Fig. 1. A detailed procedure of standardisation of foxtail millet *laddu* for varied proportion of different ingredients of developed *laddu* are presented in this chapter. A detailed procedure of development of Foxtail millet *laddu* are given in the following sub headings.

3.1 Physico-chemical properties and nutritional composition of flours during roasting

3.2 Development of foxtail millet *laddu*

3.3 Physical parameters of developed foxtail millet *laddu*

3.4 Nutritional quality evaluation of developed foxtail millet *laddu*

3.5 Storage stability of foxtail millet *laddu*

3.6 Market potentiality, consumer acceptability and economic analysis of foxtail millet *laddu*

3.7 Statistical analysis

## Procurement of raw materials

The raw materials like foxtail millet, bengal gram dhal flour, ghee and sugar powder were purchased from the local market. The millet grains were washed, rinsed, shade dried and milled from the local commercial milling machine.

## 3.1 PHYSICO-CHEMICAL PROPERTIES AND NUTRITIONAL COMPOSITION OF FLOURS DURING ROASTING

The foxtail millet flour, bengal gram dhal flour and millet mix *i.e.* both raw and roasted were studied for the physico- chemical and the nutritional changes. Fifty gram of raw bengal gram dhal flour, raw foxtail millet and raw millet mix (25 g bengal gram dhal flour and 25 g foxtail millet flour) each were taken separately and roasted till the flour enhanced its aroma and flavour. Bengal gram dhal flour took twelve minutes to get roasted and foxtail millet flour took 10 mins to get roasted. However the millet mix took nine minutes to get roasted. Physico- chemical properties include colour, volume, bulk density, water absorption index, oil absorption index and swelling power and per cent solubility. Nutritional composition include moisture, protein, fat, crude fibre, ash and carbohydrate.

### 3.1.1 Colour of the flour

Chromatic component, L (lightness), a (redness) and b (yellowness) values of sample were measured using spectrophotometer (Colour lab + Premier colour scan).

### 3.1.2 Volume

Twenty grams of flour was measured and it was transferred to 100 ml measuring cylinder. Measuring cylinder was tapped 100 times and then volume was noted.

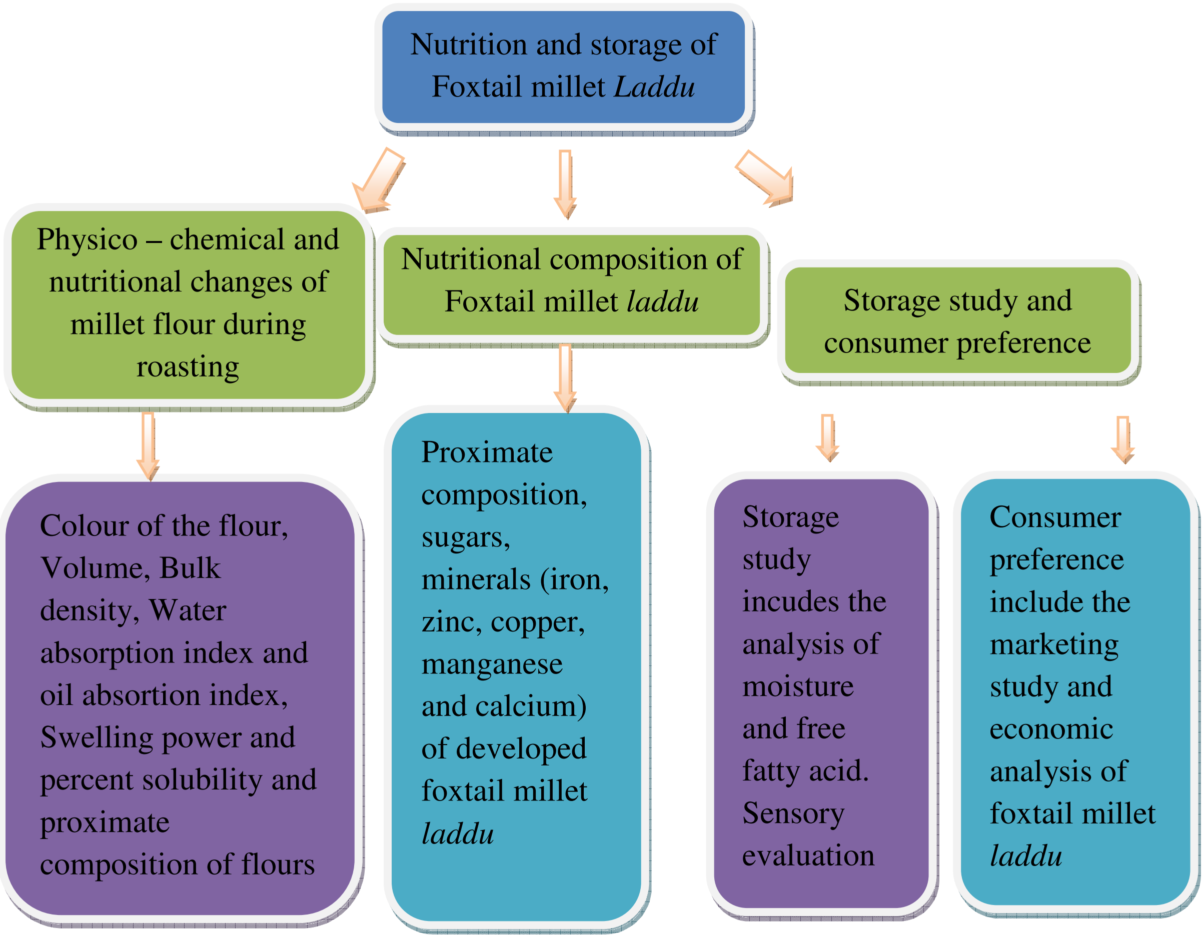


**Fig. 1. Research design**

### Bulk density

A 50 g flour sample was put into a 100 ml measuring cylinder and tapped to a constant volume. The bulk density (g/ cm-3) was calculated as weight of flour (g) divided by flour volume (cm3) (Okaka and Potter, 1979).

### 3.1.4 Water absorption index (WAI) and Oil absorption index (OAI)

WAI and OAI were determined according to the methods of Niba *et al.* (2001). Flour samples (1g) were suspended in 5 ml of water (for WAI) or vegetable oil (for OAI) in a centrifuge tube. The slurry was shaken on a platform tube rocker for 1 min. at room temperature and centrifuged at 3000 rpm for 10 min. The supernatant was decanted and discarded. The adhering drops of water were removed and reweighed WAI and OAI were expressed as the weight of sediment / initial weight of flour sample (g/g).

### 3.1.5 Swelling power and solubility

The swelling power and per cent solubility was determined according to the method used by Scotch (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 $^{o}$C for 20-30 min. till the contents were cooked. Then it was centrifuged at 5000 rpm for 10 min. The supernatant was transferred to a test tube and the inner side of the centrifuge tube was dried well and weighed ($W_3$). The swelling of flour was calculated as follows.

$$\text{Swelling power (g/g)} = \frac{W_3 - W_2}{W_1} \times 1$$

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$^{o}$ C for 4-5 hour. The moisture dish was cooled and weighed ($W_5$).

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

### 3.1.6 Moisture (%)

A known quantity of sample was weighed into previously weighed moisture cups and dried in a hot air oven at 98 to 100 ºC to a constant weight (AOAC 2005). Moisture content was calculated using the formula.

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

### 3.1.7 Protein

Nitrogen content of cookies was estimated in Kelplus dx of pelican make and crude protein content was calculated by multiplying with a factor 6.25 (AOAC 2005).

$$\text{Nitrogen (\%)} = \frac{14 \times \text{Normality of the acid} \times \text{Titre value}}{\text{Weight of the sample}} \times 100$$

### 3.1.8 Fat

Fat content was estimated in Socs plus apparatus SCS -2 model of pelican make. The total crude fat content was calculated using the formula (AOAC 2005).

$$\text{Fat Content (g/100g)} = \frac{\text{Weight of ether extract}}{\text{Weight of the sample}} \times 100$$

### 3.1.9 Crude fibre

Crude fibre was estimated by the acid alkali digestion method by using fibra plus instrument (Pelican equipments). Fat free sample was hydrolysed with sulphuric acid and sodium hydroxide. The residue obtained after digestion was dried in a crucible and its weight was recorded (We). The dried residue was then ashed in a muffle furnance at 600 $^{o}$C for three hours and its weight (Wa) was recorded (AOAC 2005).

$$\text{Crude fibre \%} = \frac{\text{We - Wa}}{\text{Weight of fat free sample (g)}} \times 100$$

### 3.1.10 Ash (%)

Samples of 5 g was weighed in a previously weighed silica crucible and charred to remove the organic matter. The process was continued till no more smoke emitted. The crucible with charred sample was ignited to ash in a muffel furnace at 600 ºC for 6 hours. The crucibles was allowed to cool in desiccator and weighed (Anon., 1990). Total mineral (ash) content is calculated employing the formula.

Weight of ash = Weight of crucible after igniting (g) – Weight of crucible (g)

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Weight of fat free sample}} \times 100$$

### 3.1.11 Total carbohydrate

The total carbohydrate content was calculated by the following formula.

Total carbohydrate = 100 - (% moisture + % fat + % protein + % ash)

Available Carbohydrate = 100 - (% moisture + % fat + % protein + % ash + % crude fibre).

## 3.2 DEVELOPMENT OF FOXTAIL MILLET *LADDU*

*Besan laddu* are popular sweet dish which often prepared and served during festivals and religious occasions. Standard recipe of *besan laddu* include bengal gram dhal flour (150 g), ghee (75 g), sugar powder (128 g) and the roasting time 45 minutes (Appendix I).

### **3.2.1** Optimization for the incorporation of foxtail millet flour

The suitability of foxtail millet flour in the preparation of *laddu* was studied by incorporating foxtail millet flour in standard recipe. Bengal gram dhal flour was replaced by foxtail millet flour at 25, 50, 75 and 100 per cent level in the standard recipe and all other ingredients were kept constant. Roasting time was kept constant 45 minutes.

A. Physical and descriptive qualities of *laddus* by varying proportion of bengal gram dhal flour to foxtail millet flour

The physical and descriptive qualities of *laddus* prepared by varying proportion of bengal gram dhal flour to foxtail millet flour at 25, 50, 75 and 100 per cent were done. The weight of the roasted flour with ghee and sugar, number of *laddus* prepared, weight and volume of each *laddu* were noted.

B. Sensory evaluation of the *laddu* prepared by incorporating the foxtail millet flour at 25 to 100 per cent level

Sensory qualities of the value added foxtail millet based *laddu* was conducted in comparison with *besan laddu,* control and developed foxtail millet *laddu*. A nine point hedonic scale was used, which describes sensory attributes *viz.,* appearance, colour, texture, taste and flavour on nine point scale (Appendix II). Sensory evaluation was done by a panel of 15 semi trained judges of Department of Food Science and Nutrition, College of Rural Home Science, UAS, Dharwad.

**3.2.2** Optimization for the addition of ghee

The highly accepted *laddu* had the ingredients, bengal gram dhal flour (50 %), foxtail millet flour (50 %), ghee (50 %) and time taken for roasting was 45 minutes. To this, level of ghee incorporation was studied by adding the ghee at 5 % variation *i.e.* 60, 55, 50, 45, and 40 per cent.

A. Physical and descriptive qualities of *laddus* prepared by varying quantity of ghee

The physical and descriptive qualities of *laddus* prepared by varying quantity of ghee to the optimised foxtail millet *laddu* (*i.e.* 50 per cent of foxtail millet flour and 50 per cent bengal gram dhal flour) were done. The weight of the roasted flour with ghee and sugar, number of *laddus* prepared, weight and volume of each *laddu* were noted.

B. Sensory evaluation of the *laddu* prepared by addition of ghee at 60 to 40 per cent level

The *laddu*s prepared by adding ghee at 5 per cent variation *i.e.* 60, 55, 50, 45 and 40 per cent were evaluated for sensory qualities. The procedure followed was as given 3.2.1.B.

3.2.3 Optimization for addition of sugar powder

The level of sugar powder incorporation in the highly accepted (by sensory evaluation) foxtail millet based *laddu* (after optimisation of ghee incorporation) was studied by adding the sugar powder at 5 % variation *i.e.* 95, 90, 85, 80 and 75 per cent.

A. Physical and descriptive qualities of *laddus* prepared by varying quantity of sugar powder

The physical and descriptive qualities of *laddus* prepared by varying quantity of sugar powder to the optimised foxtail millet *laddu* (*i.e.* 50 per cent of foxtail millet flour, 50 per cent bengal gram dhal flour and 45 per cent ghee) were done. The weight of the roasted flour with ghee and sugar, number of *laddus* prepared, weight and volume of each *laddu* were noted.

B. Sensory evaluation of the *laddu* prepared by addition of sugar powder at 95 to 75 per cent level

The *laddu*s prepared by adding sugar powder at 95 to 75 per cent level were evaluated for sensory qualities. The procedure followed was as given 3.2.1.B.

### 3.2.4 Optimization for the roasting time

The time required for roasting for *laddu* was done to the highly accepted (by sensory evaluation) foxtail millet based *laddu* (after optimisation of ghee and sugar powder incorporation) at 5 min variation *i.e.* 55, 50, 45, 40 and 35 min. It was mainly done to compare the colour after roasting with control.

A. Physical and descriptive qualities of *laddus* prepared by varying the roasting time

The physical and descriptive qualities of *laddus* prepared by varying the roasting time to the optimised foxtail millet *laddu* (*i.e.* 50 per cent of foxtail millet flour, 50 per cent bengal gram dhal flour, 45 per cent ghee and 75 per cent of sugar powder) were done. The weight of the roasted flour with ghee and sugar, number of *laddus* prepared, weight and volume of each *laddu* were noted

**B.** Sensory evaluation of the *laddu* prepared by varying the roasting time

Sensory evaluation of foxtail millet *laddu* with roasting time variation of 5 minutes *i.e.* 55, 50, 45, 40 and 35 minutes was carried out. The procedure followed was as given 3.2.1.B

## **3.3** PHYSICAL PARAMETERS OF DEVELOPED FOXTAIL MILLET *LADDU*

Physical parameters like colour, weight, volume and circumference of developed foxtail millet *laddu* were studied. Colour values were measured using spectrophotometer (3.1.1). Weight was measured using weighing balance. Volume of *laddu* was determined using seed displacement method. Mustard seeds were loaded into 100 ml beaker until it is full and it was unloaded back. The *laddu was* put into the beaker and the measured mustard seeds were loaded back again in the beaker. The remaining mustard seeds left outside the beaker were measured using the measuring cylinder and volume (ml) was noted. With the help of white coloured thread and the measuring scale, the circumference (cm) of *laddu* was noted.

## **3.4** NUTRITIONAL QUALITY EVALUATION OF DEVELOPED FOXTAIL MILLET *LADDU*

The foxtail millet *laddu* was developed with the ingredients bengal gram dhal flour (50 %), foxtail millet flour (50 %), ghee (45 %) and sugar powder (75 %). Time taken for roasting was 40 minutes.

### 3.4.1 PROXIMATE COMPOSITION OF DEVELOPED *LADDU*

Moisture, protein, fat, crude fibre, ash and carbohydrate content were analysed. The procedure followed was as given in 3.1.6 to 3.1.11.

### 3.4.2 Sugar

The total and reducing sugars were determined as per the procedure of Nelson Somogyi (Sadhasivam and Manikam, 2008). Non reducing sugar was computed by subtracting reducing sugar from total sugar.

$$\text{Non reducing sugar} = \text{Total sugar} - \text{reducing sugar} \times (0.95)$$

### 3.4.3 Iron, zinc, copper, manganese and calcium (mg/100g)

Iron, zinc, copper, manganese were determined by Atomic Absorption Spectroscopy method. Calcium was determined by precipitating it as calcium oxalate and titrating the solution of oxalate in dilute $H_2SO_4$ against standard $KMnO_4$ (Anon., 1990).

## **3.5** STORAGE STABILITY OF FOXTAIL MILLET *LADDU*

The control (*besan laddu*) and the developed foxtail millet *laddu* were prepared on large scale and stored in HDPE packets by sealing, at room temperature. *Laddu* samples were drawn every fifteen days and evaluated for changes in moisture content, free fatty acid content and sensory qualities. Score card developed for sensory evaluation of foxtail millet *laddu* during storage is given in (Appendix III).

### 3.5.1 Moisture content

The procedure followed was as given 3.1.7

### 3.5.2 Free fatty acid content

The amount of free fatty acid present gives the indication of age and quality of fat in foods. Standard (Sadasivam and Manickam, 2008) procedure was used to estimate the free fatty acid content of *laddu* samples during storage.

Reagents

1.1 % phenolphthalein in 95 % ethanol

2. 0.1 N potassium hydroxide

3. Neutral solvent: Mix 25 ml ether, 25 ml 95% alcohol and 1 ml of 1 % phenolphthalein solution and neutralise with N/10 alkali.

Procedure:

Dissolve 1-10 g of oil or melted fat in 50ml of the neutral solvent in a 250 ml conical flask. Add a few drops of phenolphthalein. Titrate the contents against 0.1 N potassium hydroxide. Shake constantly until a pink colour which persists for fifteen seconds is obtained.

$$\text{Acid value (mg KOH/g)} = \frac{\text{Titre value} \times \text{Normality of KOH} \times 56.1}{\text{Weight of the sample (g)}}$$

### 3.5.3 Sensory evaluation of *laddu* during storage

Score card developed for sensory evaluation of foxtail millet *laddu* and *besan laddu* during storage is given in Appendix III. The procedure followed was as given 3.2.1.B.

## **3.6** MARKET POTENTIALITY, CONSUMER ACCEPTABILITY AND ECONOMIC ANALYSIS OF FOXTAIL MILLET *LADDU*

Market potentiality, consumer acceptability and economic analysis of foxtail millet *laddu* was carried out.

### 3.6.1 Market survey

The availability of foxtail millet *laddu* in the Dharwad city was assessed by interviewing 40 randomly selected shopkeepers using the self-structured questionnaire. Questionnaire is given in (Appendix IV).

### 3.6.2 Market potentiality and consumer acceptability

Developed foxtail millet *laddu* were packed in HDPE covers and kept in the 10 shops. Each shop was provided with 10 packets of *laddu* both control (*Besan laddu*) and developed foxtail millet *laddu*. Each packet contain four *laddus* of 25gm each. Hence each packet weighed 100 gm. Feedback was taken from the shopkeepers about the millet *laddu* using self-structured questionnaire. Questionnaire is given in (Appendix V).

### 3.6.3 Economic analysis

Economic analysis of production of foxtail millet *laddu* was done by taking into consideration of fuel, labour, ingredients, packaging material label, transportation and milling charges.

## 3.7 STATISTICAL ANALYSIS

The results of the study need to analysed statistically to ascertain its significance. Hence, suitable statistical methods were used for the data in the present study. The results obtained in this study were analysed by the following statistical methods using SPSS statistical package (Version 16.0).

a. All the chemical analysis were performed in triplicate and the data was presented as mean ± SD.
*b.* The data was analysed by using one way ANOVA to test significant difference in physico-chemical parameters and proximate composition of flours and mean organoleptic scores for different trials tried for chemical of the *laddu.*
c. Paired 't' test was used to compare the sensory scores, physical parameters and nutrient composition of *besan* and foxtail millet *laddu.*
d. For storage study two way ANOVA was used to test significant difference in the quality attributes of millet *laddu*.
e. The consumer knowledge and preference was evaluated and expressed in terms of frequency and percentage.

# 4. EXPERIMENTAL RESULTS

Nutritionally superior foxtail millet was used in the development of *laddu.* The results of standardised procedure for the development of foxtail millet *laddu*, its nutrient composition of optimised millet *laddu*, storage quality and marketing potentiality are presented below.

## 4.1 PHYSICO-CHEMICAL PROPERTIES AND NUTRITIONAL COMPOSITION OF FLOURS DURING ROASTING

Physico-chemical properties and nutritional composition of flours were studied. Bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix (bengal gram dhal flour (25 g) and foxtail millet flour (25 g) and roasted millet mix were taken for the study. Physico chemical properties include colour, volume of flour, bulk density, water absorption capacity, oil absorption capacity, swelling power and per cent solubility. Nutritional composition include the proximate composition. The nutritional composition include the proximate composition *viz*., moisture, fat, protein, crude fibre, ash, carbohydrate and energy.

### 4.1.1 Physico-chemical properties of flours

Table 1 shows the volume of flours varied from 43.33 to 33.33 ml. The bengal gram dhal flour (raw) had the highest volume *i.e.* 43.33 ml followed by roasted bengal gram dhal flour (41.33 ml), millet mix (39.33 ml), roasted millet mix (37.33 ml), foxtail millet flour (35.33 ml) and roasted foxtail millet flour (33.33 ml). The volume of the flours decreased significantly ($p<0.01$) after roasting process. The bulk density of flours ranged from 0.56 g to 0.63 g/cm$^3$. The foxtail millet flour had the highest bulk density *i.e.* 0.63 g/cm$^3$ then followed by the roasted foxtail millet flour (0.62), millet mix (0.62), roasted millet mix (0.61), bengal gram dhal flour (0.58) and roasted bengal gram dhal flour (0.56). Bulk density also decreased with the roasting process. Water absorption index (WAI) of roasted foxtail millet flour was highest with 2.11 g/g whereas the raw foxtail millet flour had 1.57 g/g. WAI of bengal gram dhal flour was 1.08 which increased with roasting to 1.68 g/g. WAI of millet mix was 1.11 g/g which also increased with roasting to 1.62 g/g. Oil absorption index (OAI) of raw bengal gram dhal flour, foxtail millet flour and millet mix were 1.21, 1.02 and 1.01 g/g respectively. However, OAI increased with roasting i.e roasted bengal gram dhal flour (1.24 g/g), roasted foxtail millet flour (1.21 g/g) and roasted millet mix (1.21 g/g). Swelling power of bengal gram dhal flour was 3.74 g/g which increased with roasting to 5.85 g/g. Swelling power of millet mix was 5.34 g/g which increased with roasting to 5.58 g/g and swelling power of foxtail millet flour was 5.75 g/g which also increased with roasting to 6.17 g/g. Per cent solubility of bengal gram dhal flour (0.08), foxtail millet flour (0.07) and millet mix (0.09) increased with the roasting process *i.e.* 0.10, 0.12 and 0.14 per cent respectively. Statistical analysis showed that there was significant difference in volume, bulk density, WAI, OAI, swelling power and percent solubility ($p<0.01$).

Table 2 shows the colour values of flours. The values of ‘L’ of raw bengal gram dhal flour, foxtail millet flour and millet mix were 91.74, 87.36 and 90.23 respectively. The values of ‘L’ decreased with roasting of flours *i.e.* bengal gram dhal flour (83.93), foxtail millet flour (79.85) and millet mix (83.31) which indicates lightness decreased and darkness increased.

Table 1: Physico-chemical characteristics of raw and roasted flours

| Flour | Volume[#] (ml) | Bulk density ($g/cm^3$) | Water absorption index (g/g) | Oil absorption index (g/g) | Swelling power (g/g) | Per cent solubility (%) |
|---|---|---|---|---|---|---|
| A. Bengal gram dhal | | | | | | |
| Raw | $43.33^{a} \pm 0.57$ | $0.58^{d} \pm 0.03$ | $1.08^{f} \pm 0.02$ | $1.21^{b} \pm 0.18$ | $3.74^{e} \pm 0.17$ | $0.08^{c} \pm 0.01$ |
| Roasted | $41.33^{b} \pm 0.57$ | $0.56^{d} \pm 0.04$ | $1.68^{b} \pm 0.05$ | $1.24^{a} \pm 0.21$ | $5.85^{b} \pm 0.12$ | $0.10^{b} \pm 0.01$ |
| B. Foxtail millet | | | | | | |
| Raw | $35.33^{e} \pm 0.57$ | $0.63^{a} \pm 0.05$ | $1.57^{d} \pm 0.02$ | $1.02^{d} \pm 0.02$ | $5.75^{bc} \pm 0.05$ | $0.07^{c} \pm 0.02$ |
| Roasted | $33.33^{f} \pm 0.57$ | $0.62^{b} \pm 0.05$ | $2.11^{a} \pm 0.04$ | $1.21^{c} \pm 0.02$ | $6.17^{a} \pm 0.02$ | $0.12^{a} \pm 0.05$ |
| C. Millet mix | | | | | | |
| Raw | $39.33^{c} \pm 0.57$ | $0.62^{b} \pm 0.06$ | $1.11^{e} \pm 0.01$ | $1.01^{d} \pm 0.02$ | $5.34^{d} \pm 0.30$ | $0.09^{c} \pm 0.01$ |
| Roasted | $37.33^{d} \pm 0.57$ | $0.61^{c} \pm 0.04$ | $1.62^{c} \pm 0.02$ | $1.21^{b} \pm 0.19$ | $5.58^{cd} \pm 0.10$ | $0.14^{ab} \pm 0.05$ |
| F | 126.00** | 55.46** | 771.06** | 126.47** | 99.56** | 21.33** |
| SEm | 0.39 | 0.11 | 0.09 | 0.19 | 0.20 | 0.09 |
| CD | 1.02 | 0.07 | 0.05 | 0.25 | 0.28 | 0.05 |

** Significant at 0.01 %.

[#] For volume 50 g of flours (Bengal gram dhal and foxtail millet), millet mix (Bengal gram dhal 25 g and foxtail millet 25 g) was taken.

Each value is mean of three replications

Values with same superscript are not significantly different

**Table 2: Colour values of raw and roasted flours**

| Flour | L (lightness or darkness) | a (redness or yellow) | b (blue or green) |
|---|---|---|---|
| A. Bengal gram dhal | | | |
| Raw | 91.74[a] ± 0.56 | 1.31[d] ± 0.03 | 18.61[c] ± 0.03 |
| Roasted | 83.93[a] ± 0.05 | 3.92[a] ± 0.03 | 23.54[a] ± 0.05 |
| B. Foxtail millet | | | |
| Raw | 87.36[a] ± 0.06 | 1.41[c] ± 0.03 | 14.83[f] ± 0.04 |
| Roasted | 79.85[a] ± 0.05 | 3.85[a] ± 0.05 | 18.44[d] ± 0.05 |
| C. Millet mix[#] | | | |
| Raw | 90.23[a] ± 0.05 | 1.20[e] ± 0.05 | 17.80[e] ± 0.04 |
| Roasted | 83.31[a] ± 0.03 | 3.51[b] ± 0.07 | 20.54[b] ± 0.09 |
| F | 1.34 | 2368.41** | 8079.11** |
| SEm | 2.32 | 0.16 | 0.16 |
| CD | 35.19 | 0.17 | 0.17 |

** Significant at 0.01 %
[#] Millet mix (Bengal gram dhal 25 g and foxtail millet 25 g)
Each value is mean of three replications
Values with same superscript are not significantly different

The values of 'a' of raw bengal gram dhal flour, foxtail millet flour and millet mix were 1.31, 1.41 and 1.20 respectively. The values of 'a' increased with roasting of flours *i.e.* bengal gram dhal flour (3.92), foxtail millet flour (3.85) and millet mix (3.51) which indicates redness of flour increased. The values of 'b' of raw bengal gram dhal flour, foxtail millet flour and millet mix were 18.61, 14.83, 17.80 respectively. The values of 'b' increased with roasting of flours *i.e.* bengal gram dhal flour (23.54), foxtail millet flour (18.44) and millet mix (20.54). Statistical analysis showed that there was significant difference in values for 'a' and 'b' ($p<0.01$).

### 4.1.2 Nutritional composition of flours

Table 3 shows the proximate composition of flours. Moisture content of flours ranged from 8.74 to 0.77 per cent *i.e.* bengal gram dhal flour (8.74), roasted bengal gram dhal flour (1.20), foxtail millet flour (8.53), roasted foxtail millet flour (0.81), millet mix (8.59) and roasted millet mix (0.77). There was decrease in the moisture content after roasting of flours. The fat content of bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix and roasted millet mix were 4.80, 4.46, 4.29, 4.13, 4.59 and 4.19 g/100g respectively. Fat content decreased with the roasting of flours. Protein content of flours ranged from 11.46 to 20.90 g/100g *i.e.* bengal gram dhal flour (19.56), roasted bengal gram dhal flour (20.90), foxtail millet flour (13.01), roasted foxtail millet flour (11.46), millet mix (14.03) and roasted millet mix (12.58). There was increase in the protein content after roasting of flours. Crude fibre content of flours decreased with the roasting process in bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix and roasted millet mix *i.e.* 1.79, 0.93, 7.92, 7.13, 4.67 and 3.07 respectively. There was decrease in the ash content of flours after roasting *i.e.* bengal gram dhal flour (2.54), roasted bengal gram dhal flour (2.35), foxtail millet flour (2.78), roasted foxtail millet flour (2.64), millet mix (2.60) and roasted millet mix (2.16). Carbohydrate content also increased with the roasting in bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix and roasted millet mix *i.e.* 62.54, 70.15, 65.00, 72.28, 66.49 and 75.21 respectively. The energy also increased with roasting process *i.e.* bengal gram dhal flour (371.68), roasted bengal gram dhal flour (404.38), foxtail millet flour (344.50), roasted foxtail millet flour (378.41), millet mix (357.46) and roasted millet mix (394.92). Statistical analysis showed that there was significant difference in moisture, fat, protein, crude fibre, ash, carbohydrate and energy ($p<0.01$) between the different flours.

## 4.2 DEVELOPMENT OF FOXTAIL MILLET *LADDU*

The results of quality of foxtail millet based *laddu* optimised results of incorporation of foxtail millet flour, ghee and sugar powder are presented. The processing conditions like roasting time are also presented.

### 4.2.1 Optimization for the incorporation of foxtail millet flour

*Laddus* prepared by varying the addition of foxtail millet flour at 25, 50, 75 and 100 per cent to bengal gram dhal flour were evaluated for physical and organoleptic characters (Plate 1). And the other ingredients used were the ghee 75 g and sugar powder 128 g (Table 4 and 5).

**Table 3: Proximate composition of raw and roasted flours**

| Flours | Moisture (%) | Fat (g/100g) | Protein (g/100g) | Crude fibre (g/100g) | Ash (g/100g) | Carbohydrate (g/100g) | Energy (Kcal) |
|---|---|---|---|---|---|---|---|
| A. Bengal gram dhal | | | | | | | |
| Raw | 8.74$^{a}$ ± 0.05 | 4.80$^{a}$ ± 0.18 | 19.56$^{b}$ ± 0.70 | 1.79$^{e}$ ± 0.47 | 2.54$^{c}$ ± 0.02 | 62.54$^{e}$ ± 0.93 | 371.68$^{d}$ ± 1.89 |
| Roasted | 1.20$^{b}$ ± 0.26 | 4.46$^{bc}$ ± 0.04 | 20.90$^{a}$ ± 0.40 | 0.93$^{f}$ ± 0.05 | 2.35$^{d}$ ± 0.04 | 70.15$^{c}$ ± 0.48 | 404.38$^{a}$ ± 0.60 |
| B. Foxtail millet | | | | | | | |
| Raw | 8.53$^{a}$ ± 0.24 | 4.29$^{cd}$ ± 0.01 | 13.01$^{cd}$ ± 0.58 | 7.92$^{a}$ ± 0.06 | 2.78$^{a}$ ± 0.02 | 65.00$^{d}$ ± 0.64 | 344.50$^{f}$ ± 0.74 |
| Roasted | 0.81$^{c}$ ± 0.08 | 4.13$^{d}$ ± 0.15 | 11.46$^{e}$ ± 0.55 | 7.13$^{b}$ ± 0.04 | 2.64$^{b}$ ± 0.03 | 72.28$^{b}$ ± 0.50 | 378.41$^{c}$ ± 0.55 |
| C. Millet mix$^{\#}$ | | | | | | | |
| Raw | 8.59$^{a}$ ± 0.06 | 4.59$^{ab}$ ± 0.20 | 12.58$^{d}$ ± 0.59 | 4.67$^{c}$ ± 0.12 | 2.60$^{b}$ ± 0.02 | 66.49$^{d}$ ± 0.71 | 357.46$^{e}$ ± 0.70 |
| Roasted | 0.77$^{c}$ ± 0.02 | 4.19$^{d}$ ± 0.01 | 14.03$^{c}$ ± 0.61 | 3.07$^{d}$ ± 0.11 | 2.16$^{e}$ ± 0.04 | 75.21$^{a}$ ± 0.74 | 394.92$^{b}$ ± 0.65 |
| F | 2261.15** | 11.88** | 139.406** | 558.91** | 129.32** | 188.513** | 1584.97** |
| SEm | 0.19 | 0.16 | 0.39 | 0.23 | 0.16 | 0.43 | 0.51 |
| CD | 0.25 | 0.17 | 1.02 | 0.35 | 0.17 | 1.21 | 1.73 |

** Significant at 0.01%, $^{\#}$ Millet mix was taken in the ratio of 1:1 (Bengal gram dhal flour : foxtail millet flour), Each value is mean of three replications, Values with same superscript are not significantly different

**Table 4: Physical and descriptive qualities of *laddu*# prepared by varying proportion of foxtail millet flour to bengal gram dhal flour**

| Flour (%) Bengal gram dhal : Foxtail millet | Flour (gm) Bengal gram dhal : Foxtail millet | Weight of the roasted flour with ghee and sugar (g) | Mean weight of *laddu* (g) | Mean volume of *laddu* (ml) | Bulk density (g/cm$^3$) | Descriptive qualities of *laddu* | |
|---|---|---|---|---|---|---|---|
| | | | | | | Sensory attributes | *Laddu* binding property |
| 100 : 0 | 150 : 0 | 339.33 ± 0.57 | 33.40 ± 0.39 | 38.70 ± 1.08 | 0.86 | Golden brown, more sticky | Excellent |
| 75 : 25 | 113 : 37 | 337.33 ± 1.15 | 32.20 ± 0.25 | 39.10 ± 0.51 | 0.82 | Golden brown, moderate stickiness | Excellent |
| 50 : 50 | 75 : 75 | 335.66 ± 0.57 | 32.40 ± 0.39 | 37.90 ± 0.39 | 0.85 | Golden brown, less stickiness | Very good |
| 25 : 75 | 37 : 113 | 329.66 ± 0.57 | 31.50 ± 0.47 | 37.00 ± 0.47 | 0.85 | Golden brown, slightly grainy | Good |
| 0 : 100 | 0 : 150 | 314.66 ± 0.57 | 30.40 ± 0.45 | 35.80 ± 0.48 | 0.85 | Creamish white, more grainy | Poor |

Note: # *Laddus* prepared by 150 g of flour mix; Other ingredients: Ghee-75 g; Sugar powder-128 g; Roasting time- 45 min. Number of *laddus* prepared (in each flour variation): 10

Each value is mean of three replications

**Table 5: Mean organoleptic scores# of *laddu* prepared by varying proportion of foxtail millet flour to bengal gram dhal flour**

| Flour (%) Bengal gram dhal : Foxtail millet | Appearance | Colour | Texture | Taste | Flavour | Overall acceptability |
|---|---|---|---|---|---|---|
| 100 : 0 | $8.3^{a} \pm 0.48$ | $8.3^{ab} \pm 0.67$ | $8.4^{a} \pm 0.69$ | $8.5^{a} \pm 0.84$ | $8.2^{a} \pm 1.03$ | $8.6^{a} \pm 0.51$ |
| 75 : 25 | $8.5^{a} \pm 0.52$ | $8.6^{a} \pm 0.51$ | $8.3^{a} \pm 0.94$ | $8.5^{a} \pm 0.52$ | $8.0^{ab} \pm 0.94$ | $8.6^{a} \pm 0.51$ |
| 50 : 50 | $8.7^{a} \pm 0.48$ | $8.7^{a} \pm 0.48$ | $8.9^{a} \pm 0.31$ | 8.5a ± 0.52 | $8.6^{a} \pm 0.51$ | $8.7^{a} \pm 0.48$ |
| 25 : 75 | $7.3^{b} \pm 0.82$ | $7.4^{b} \pm 0.96$ | $7.2^{b} \pm 0.78$ | $7.4^{a} \pm 1.07$ | $7.0^{b} \pm 0.66$ | $7.4^{b} \pm 0.69$ |
| 0 : 100 | $4.9^{c} \pm 1.96$ | $5.1^{c} \pm 1.79$ | $5.2^{c} \pm 2.14$ | $5.5^{b} \pm 2.12$ | $5.6^{c} \pm 2.11$ | $5.3^{c} \pm 1.94$ |
| F | 23.28** | 22.02** | 16.22** | 12.34** | 10.14** | 20.28** |
| SEm | 0.21 | 0.21 | 0.22 | 0.22 | 0.23 | 0.21 |
| CD | 0.92 | 0.90 | 1.04 | 1.06 | 1.07 | 0.90 |

Note: #Mean of 10 panellists. Sensory scores were based on 9 point hedonic scale.
** Significant at 0.01 %
Each value is mean of three replications
Values with same superscript are not significantly different

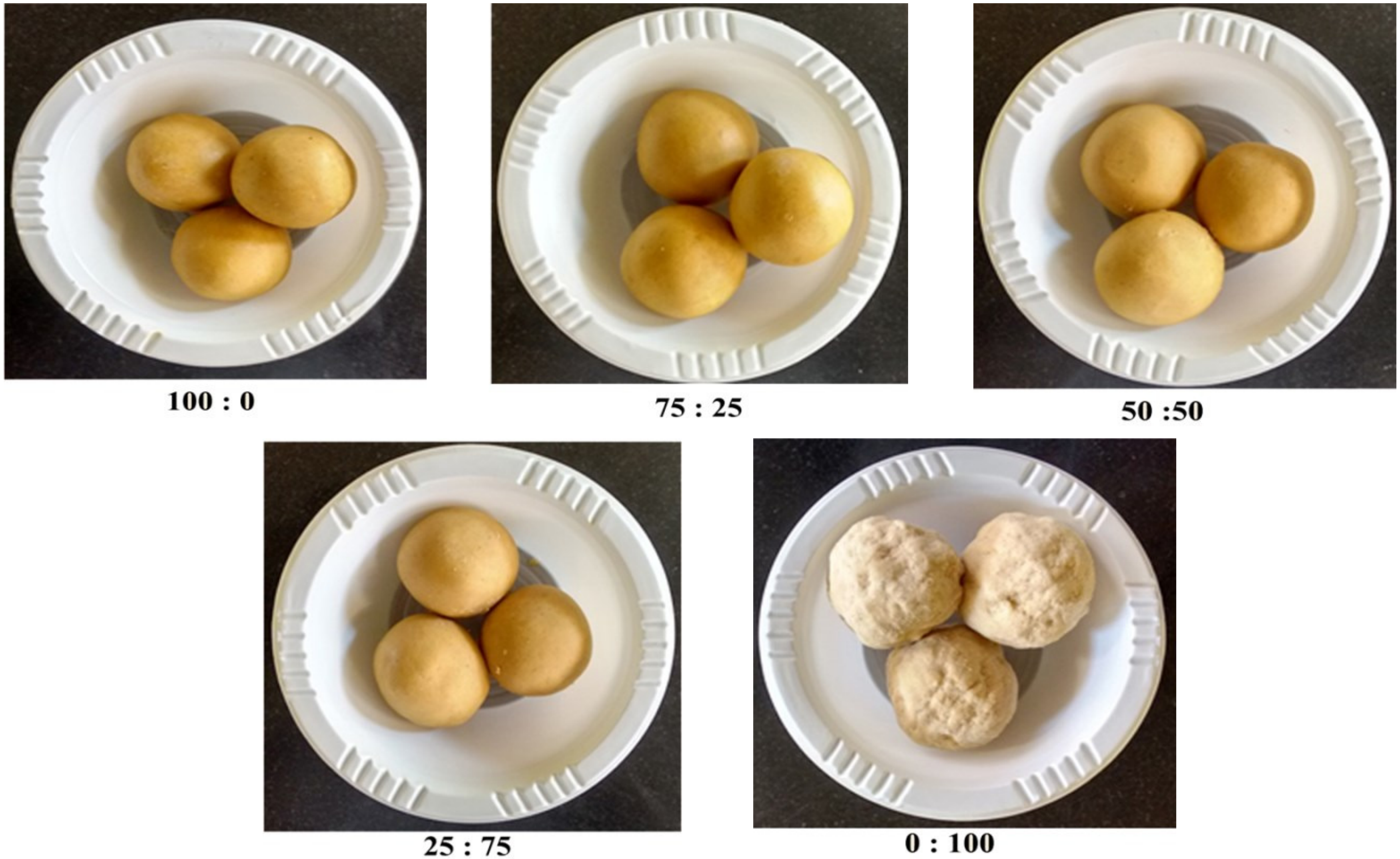


**Plate 1:** ***Laddus*** **prepared by varying the incorporation of foxtail millet flour (Bengal gram dhal flour: foxtail millet flour)**

Increased addition of foxtail millet flour from 25 to 100 per cent decreased the final weight of flour mix from 337.33 to 314.66 g. Increased addition of foxtail millet flour had increased the grainy texture and decreased the stickiness in *laddu. Laddu* prepared by addition of foxtail millet flour (upto 75 per cent) had attained the golden brown colour, but *laddu* prepared by 100 per cent of foxtail millet flour had the creamish white colour, was grainy and could not hold the shape for long time. And here the time of roasting was kept constant *i.e.* 45 minutes. The weight of each *laddu* decreased with incorporation of foxtail millet flour and therefore volume also.

Organoleptic evaluation revealed that *laddus* prepared from 50 per cent incorporated foxtail millet flour had the highest overall acceptability scores followed by 75:25, 100:0 and 25:75 level. From Table 4 it can be observed that the overall acceptable scores of 50:50 was not significant from control (100:0) and 75:25. However 25:75 and 0:100 were having significantly lower overall acceptable scores *viz.*, 7.4 and 5.3 respectively. The most acceptable *laddu* also had the highest scores for appearance (8.7), colour (8.7), texture (8.9), taste (8.5) and flavour (8.6). There was not much change in the organoleptic scores of *laddu* prepared by 100:0 and 75:25 proportions. *Laddu*s prepared with 100 per cent foxtail millet flour had the lowest scores for overall acceptability (5.3), appearance (4.9), colour (5.1), texture (5.2), taste (5.5) and flavour (5.6) and was significantly lower compared to all other formulations except in taste.

As the 50 per cent incorporated foxtail millet *laddu* had the highest overall acceptability score and all other parameters, it was considered as optimum level of incorporation.

### 4.2.2 Optimization for the addition of ghee

*Laddus* were prepared from 150 g of flour mix containing 1:1 proportion of bengal gram dhal flour (75 g) and foxtail millet flour (75 g), sugar powder (128 g), 45 minutes roasting time and with ghee variation from 90, 83, 75, 68 and 60 g of ghee (which accounts 60 % to 40 % variation) (Plate 2). From Table 6 it can be seen that, with increased ghee addition, there was increase in the weight of roasted flour mix that ranged from 328.66 to 349.33 g.

The descriptive qualities also affected the organoleptic characteristics. Increased addition of ghee (50-60 %) made roasting easy but the round shape of the *laddu* could not be retained. There was slight difficulty in the roasting in case of 45 per cent ghee addition. Roasting was very difficult in the 40 per cent incorporation of *laddu* was difficult to bind as well breaks easily (Table 6). Table 7 shows the overall acceptability score was highest (7.7) in 45 per cent ghee incorporated *laddu* and was significantly higher when compared to 40, 45, 50, 55 and 60 per cent ghee incorporation (6.4, 7.7, 6.4, 5.1, 1.8 respectively). For appearance, the score were 6.6, 8.2, 6.4, 6.4 and 2.5 for the incorporation 40, 45, 50, 55 and 60 per cent ghee. The scores for colour were 6.4, 7.7, 6.1, 5.6 and 1.9 for the incorporation 40, 45, 50, 55 and 60 per cent ghee. For incorporation of 40, 45, 50, 55 and 60 per cent ghee, the scores for texture were 6.4, 7.8, 6.4, 4.4 and 2.2. For taste, the score were 6.4, 7.8, 6.6, 5.2 and 1.6 for the incorporation 40, 45, 50, 55 and 60 per cent ghee. For incorporation of 40, 45, 50, 55 and 60 per cent ghee, the scores for flavour were 6.6, 7.8, 6.2, 4.8 and 1.5.

Hence, from table 6 and 7 it was observed that 68g (45 %) of ghee addition was optimal for development of foxtail millet based *laddu*.

**Table 6: Physical and descriptive qualities of *laddu*# prepared by varying quantity of ghee**

| Ghee (%) | Ghee (g) | Weight of the flour after roasting (g) | Mean weight of each *laddu* (g) | Mean volume of each *laddu* (ml) | Bulk density ($g/cm^3$) | Descriptive qualities of *laddu* |
|---|---|---|---|---|---|---|
| 40 | 60 | 328.66 ± 0.50 | 31.70 ± 0.25 | 37.15 ± 0.04 | 0.85 | Very difficult to roast, was difficult to bind, easily breaks |
| 45 | 68 | 332.66 ± 0.57 | 32.15 ± 0.24 | 37.65 ± 0.24 | 0.85 | Slight difficulty in roasting, good binding and retains the shape, breaks moderately |
| 50 | 75 | 335.66 ± 0.57 | 32.70 ± 0.25 | 38.20 ± 0.25 | 0.85 | Easy to roast, could not retain the shape |
| 55 | 83 | 346.33 ± 0.57 | 33.70 ± 0.25 | 39.70 ± 0.25 | 0.85 | Easy to roast, could not retain the shape |
| 60 | 90 | 349.33 ± 0.57 | 34.20 ± 0.25 | 40.20 ± 0.25 | 0.85 | Easy to roast, cannot retain round shape |

Note: # *Laddus* prepared by 75 g of bengal gram dhal flour and 75 g foxtail millet flour; Other ingredients: Sugar powder-128 g; Roasting time- 45 min.
Number of each *laddu*s prepared (in each ghee variation): 10
Each value is mean of three replications

**Table 7: Mean organoleptic scores[#] of *laddu* prepared by varying the quantity ghee**

| Ghee (%) | Appearance | Colour | Texture | Taste | Flavour | Overall acceptability |
|---|---|---|---|---|---|---|
| 40 | $6.6^{b} \pm 0.51$ | $6.4^{b} \pm 0.51$ | $6.4^{b} \pm 0.51$ | $6.4^{b} \pm 0.51$ | $6.6^{b} \pm 0.51$ | $6.4^{b} \pm 0.51$ |
| 45 | $8.2^{a} \pm 0.78$ | $7.7^{a} \pm 0.82$ | $7.8^{a} \pm 0.63$ | $7.8^{a} \pm 0.91$ | $7.8^{a} \pm 0.78$ | $7.7^{a} \pm 0.48$ |
| 50 | $6.4^{b} \pm 0.51$ | $6.1b^{c} \pm 0.99$ | $6.4^{b} \pm 0.51$ | $6.6^{b} \pm 0.51$ | $6.2^{b} \pm 0.63$ | $6.4^{b} \pm 0.51$ |
| 55 | $6.4^{b} \pm 0.51$ | $5.6^{c} \pm 0.96$ | $4.4^{c} \pm 0.96$ | $5.2^{c} \pm 1.39$ | $4.8^{c} \pm 0.91$ | $5.1^{c} \pm 0.99$ |
| 60 | $2.5^{c} \pm 0.70$ | $1.9^{d} \pm 0.73$ | $2.2^{d} \pm 1.03$ | $1.6^{d} \pm 0.84$ | $1.5^{d} \pm 0.70$ | $1.8^{d} \pm 0.63$ |
| F | 115.543** | 69.523** | 80.932** | 69.874** | 111.114** | 117.765** |
| SEm | 0.16 | 0.19 | 0.18 | 0.20 | 0.18 | 0.17 |
| CD | 0.55 | 0.74 | 0.69 | 0.81 | 0.65 | 0.59 |

Note: [#] Mean of 10 panellists. Sensory scores were based on 9 point hedonic scale.
** Significant at 0.01 %
Each value is mean of three replications
Values with same superscript are not significantly different


**Plate 2. *Laddus* prepared by varying the addition of ghee**

### 4.2.3 Optimization for addition of sugar powder

Bengal gram dhal flour and foxtail millet flour in 50:50 proportion with 68 g (45 %) of ghee and 45 minutes roasting time was used in preparation of *laddu* with varying quantity of sugar powder which ranged from 143 to 113 g (*i.e.* 95 to 75 % ) (Plate 3).

Table 8 presents that, with increased addition of sugar powder there was increase in the roasted flour mix weight that is ranged from 317.66 g to 347.66 g. The weight (31.25 g to 34.20 g) and volume (36.75 to 40.20 ml) of each *laddu* increased with increased addition of sugar powder. As there was increase in the addition of sugar powder, the flour mix resulted in powdery mixture which made fair handling of roasted mix. The sweetness increased with the addition of sugar powder and the *laddu* became lighter in colour. The prepared *laddu* were not acceptable till the 85 per cent addition because of more sweetness. Addition of 75 per cent sugar powder to the roasted flour (with ghee) were found to be acceptable.

The varied quantity of sugar powder addition also resulted in the difference of organoleptic characteristics (Table 9). The scores for overall acceptability, appearance, colour, texture and taste ranged from 6.3 to 8.2, 7.3 to 8.7, 7.2 to 8.8, 6.7 to 8.7, 7.1 to 8.5 and 7.0 to 8.8 respectively. With 113 g of sugar powder, the *laddus* had the highest overall acceptability (8.2), and also had the highest scores for appearance (8.7), colour (8.8), texture (8.7), taste (8.5) and flavour (8.8). The lowest scores of overall acceptability (6.3) was in *laddu* prepared with highest amount (143 g *i.e.* 95 %) of sugar. It also scored less in all the other parameters *i.e.* appearance (7.3), colour (7.2), texture (6.7), taste (7.1) and flavour (7.0). Statistical analysis showed that there was significant difference in scores for appearance, colour, texture, taste and overall acceptability among 95 to 75 per cent addition of sugar powder to foxtail millet flour *laddu* ($p<0.01$).

Addition of 113 g sugar powder was selected and considered as optimal level for development of foxtail millet based *laddu*.

### 4.2.4 Optimization for the roasting time

*Laddus* were prepared from 150 g flour mix containing 1:1 proportion of Bengal gram dhal flour and foxtail millet flour, ghee (68 g), sugar powder (113 g) and with roasting time variation from 35 to 55 minutes (Plate 4).

The descriptive qualities also affected the organoleptic characteristics. As the roasting time increased there was decrease in the weight of the flour mix (317.33 to 311.33 g). There was not much change in the weight and volume of *laddu* prepared. Increase in the roasting time resulted in the charring of the roasted flour mix and therefore the colour resulted was dark brown. However 40 minutes roasting time was found to be acceptable as the colour turned out golden yellow. But there was lightness in colour of *laddu* when roasted for 35 minutes (Table 10). Dough handling *i.e.* binding property was very good in 45 and 40 minutes roasting time. However it was good in 35 and 50 minutes roasting time. The scores for organoleptic characters varied with varied level of roasting time and the scores ranged for overall acceptability from 3.5 to 8.1, appearance from 3.3 to 8.5, colour from 3.5 to 8.4, texture from 3.5 to 8.0, and taste from 3.3 to 7.9 and flavour from 3.4 to 6.5. *Laddu*s prepared by roasting for 45 minutes had the highest overall acceptability scores (8.1) and it also had the highest scores for appearance (8.5), colour (8.4), texture (8.0), taste (7.9) and flavour (6.5). The *laddu*s prepared from the roasting time 55 and 50 minutes scored lowest for all the parameters (Table 11).

**Table 8: Physical and descriptive qualities of *laddu*# prepared by varying quantity of sugar powder**

| Sugar powder (%) | Sugar powder (g) | Weight of the flour after roasting (g) | Mean weight of each *laddu* (g) | Mean volume of each *laddu* (ml) | Bulk density (g/cm$^3$) | Descriptive qualities of *laddu* | |
|---|---|---|---|---|---|---|---|
| | | | | | | Sensory attributes | *Laddu* binding property |
| 75 | 113 | 317.66 ± 0.57 | 31.25 ± 0.26 | 36.75 ± 0.26 | 0.85 | Golden brown, tastes acceptable | Very good<br>No powdery mixture |
| 80 | 120 | 326.33 ± 0.57 | 31.70 ± 0.25 | 37.20 ± 0.25 | 0.85 | Golden brown, tastes acceptable | Fair<br>powdery mixture |
| 85 | 128 | 332.66 ± 0.57 | 32.70 ± 0.25 | 38.20 ± 0.25 | 0.85 | light golden brown, too sweet | Fair<br>powdery mixture |
| 90 | 135 | 339.66 ± 0.57 | 32.60 ± 0.77 | 38.30 ± 1.03 | 0.85 | light golden brown, too sweet | Fair<br>powdery mixture |
| 95 | 143 | 347.66 ± 0.57 | 34.20 ± 0.25 | 40.20 ± 0.25 | 0.85 | light golden brown, too sweet | Fair<br>powdery mixture |

Note: # *Laddus* prepared by 75 g of bengal gram dhal flour and 75 g foxtail millet flour; Other ingredients: Ghee 68 g; Roasting time- 45 min. Number of *laddus* prepared (in each ghee variation): 10

Each value is mean of three replications

**Table 9: Mean organoleptic scores# of *laddu* prepared by varying the quantity of sugar powder**

| Sugar powder (%) | Appearance | Colour | Texture | Taste | Flavour | Overall Acceptability |
|---|---|---|---|---|---|---|
| 75 | $8.7^{a} \pm 0.48$ | $8.8^{a} \pm 0.63$ | $8.7^{a} \pm 0.48$ | $8.5^{a} \pm 0.52$ | $8.8^{a} \pm 0.42$ | $8.2^{a} \pm 0.42$ |
| 80 | $7.9^{bc} \pm 0.73$ | $8.0^{ab} \pm 0.81$ | $7.5^{b} \pm 0.52$ | $7.8^{abc} \pm 1.13$ | $7.6^{bc} \pm 0.84$ | $7.4^{b} \pm 0.69$ |
| 85 | $8.1^{ab} \pm 0.73$ | $8.2^{a} \pm 0.78$ | $8.0^{b} \pm 1.15$ | $8.3^{ab} \pm 0.67$ | $8.2^{ab} \pm 0.63$ | $7.8^{b} \pm 0.91$ |
| 90 | $8.1^{ab} \pm 0.73$ | $8.1^{a} \pm 0.73$ | $7.6^{b} \pm 0.69$ | $7.6^{bc} \pm 0.84$ | $7.7^{bc} \pm 0.82$ | $7.5^{b} \pm 0.52$ |
| 95 | $7.3^{c} \pm 1.15$ | $7.2^{b} \pm 1.39$ | $6.7^{c} \pm 0.82$ | $7.1^{c} \pm 1.10$ | $7.0^{c} \pm 0.94$ | $6.3^{c} \pm 1.05$ |
| F | 3.92** | 3.91** | 8.88** | 3.96** | 8.01** | 13.79** |
| SEM | 0.18 | 0.20 | 0.18 | 0.19 | 0.18 | 0.18 |
| CD | 0.72 | 0.82 | 0.69 | 0.80 | 0.68 | 0.68 |

Note: #Mean of 10 panellists. Sensory scores were based on 9 point hedonic scale.
** Significant at 0.01 %
Each value is mean of three replications
Values with same superscript are not significantly different

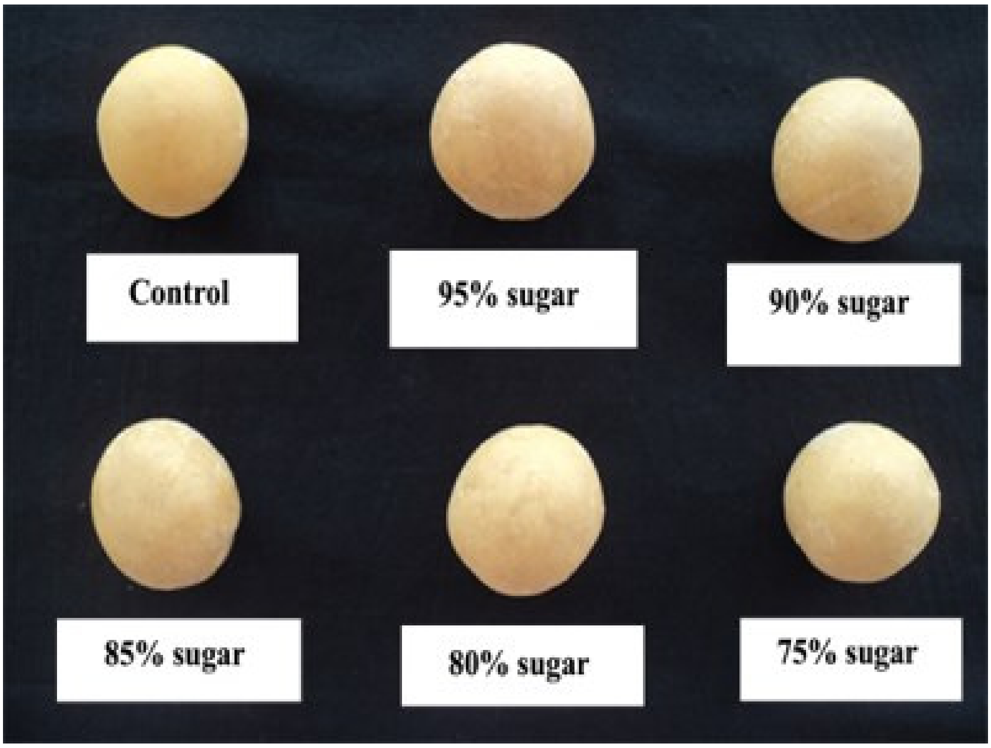


**Plate 3. *Laddus* prepared by varying the addition of sugar powder**

**Table 10: Physical and descriptive qualities of *laddu** prepared by varying the roasting time**

| Roasting time (min.) | Weight of the flour after roasting (g) | Mean weight of each *laddu* (g) | Mean volume of each *laddu* (ml) | Bulk density (g/cm$^3$) | Descriptive qualities of *laddu* | |
|---|---|---|---|---|---|---|
| | | | | | Sensory attributes | *Laddu* binding property |
| 35 | 319.00 ± 1.15 | 29.85 ± 0.62 | 34.95 ± 0.83 | 0.85 | Light yellowish | Good |
| 40 | 317.33 ± 1.15 | 29.90 ± 0.61 | 35.00 ± 0.81 | 0.85 | Golden brown (colour nearly matches the control) | Very Good |
| 45 | 315.00 ± 1.15 | 29.95 ± 0.59 | 35.05 ± 0.79 | 0.85 | Brownish | Very Good |
| 50 | 313.33 ± 1.15 | 29.95 ± 0.59 | 35.05 ± 0.79 | 0.85 | Dark brown, charred, | Good |
| 55 | 311.33 ± 1.15 | 29.80 ± 0.25 | 34.80 ± 0.25 | 0.85 | Dark brown, charred | Good |

Note:**Laddus* prepared by 75 g of bengal gram dhal flour and 75 g foxtail millet flour; Other ingredients: Ghee 68 g; Sugar powder-113 g.
Number of *laddus* prepared (in each roasting time variation): 10
Each value is mean of three replications

**Table 11: Mean organoleptic scores# of *laddu* prepared by varying the roasting time**

| Roasting time (min.) | Appearance | Colour | Texture | Taste | Flavour | Overall acceptability |
|---|---|---|---|---|---|---|
| 35 | $6.60^b \pm 0.51$ | $6.70^b \pm 0.48$ | $6.40^b \pm 0.51$ | $6.80^b \pm 0.42$ | $6.50^b \pm 0.52$ | $6.60^b \pm 0.51$ |
| 40 | $8.50^a \pm 0.52$ | $8.40^a \pm 0.51$ | $8.00^a \pm 0.81$ | $7.90^a \pm 0.73$ | $8.30^a \pm 0.48$ | $8.10^a \pm 0.56$ |
| 45 | $6.50^b \pm 0.52$ | $6.50^b \pm 0.52$ | $6.40^b \pm 0.51$ | $6.80^b \pm 0.42$ | $6.40^b \pm 0.51$ | $6.60^b \pm 0.51$ |
| 50 | $3.36^c \pm 0.52$ | $3.55^c \pm 0.69$ | $3.51^c \pm 0.48$ | $3.38^c \pm 0.52$ | $3.43^c \pm 0.84$ | $3.52^c \pm 0.51$ |
| 55 | $3.60^c \pm 0.51$ | $4.00^c \pm 0.66$ | $3.50^c \pm 0.70$ | $3.50^c \pm 0.52$ | $3.60^c \pm 0.84$ | $3.50^c \pm 0.52$ |
| F | 169.50** | 117.84** | 108.02** | 145.47** | 94.93** | 156.17** |
| SEm | 0.15 | 0.16 | 0.16 | 0.15 | 0.17 | 0.15 |
| CD | 0.47 | 0.52 | 0.56 | 0.48 | 0.59 | 0.47 |

Note: #Mean of 10 panellists. Sensory scores were based on 9 point hedonic scale.
** Significant at 0.01 %
Each value is mean of three replications
Values with same superscript are not significantly different


**Plate 4.** ***Laddus*** **prepared by varying the roasting time**

Hence, from table 10 and 11 can observe that roasting for 40 minutes found to be optimal for development of foxtail millet *laddu.*

### 4.2.5 Sensory scores of developed foxtail millet and *besan laddu*

The *Besan laddu* was prepared by 100 per cent bengal gram dhal flour (150 g), ghee 75 g (50 %), sugar powder 128 g (85 %) and the time taken for roasting was 45 minutes. The optimised foxtail millet based *laddu* was prepared by incorporating the foxtail millet flour (75 g) to bengal gram dhal flour (75 g), ghee (68 g) and sugar powder (113 g). The time taken for roasting was 40 minutes (Plate 5). The score was 8.5 for the colour, flavour and overall acceptability of foxtail millet *laddu*. However for appearance and taste the score was 8.4. For texture the score was 8.6. Overall acceptability score of *besan laddu* was 8.5. Texture (8.9) of *besan laddu* score higher and then followed by the flavour (8.6). And for appearance, colour, taste the score was 8.5. However, there was no significant difference between the foxtail millet *laddu* and *besan laddu* (Table 12).

## 4.3 PHYSICAL PARAMETERS AND NUTRIENT COMPOSITION OF FOXTAIL MILLET BASED *LADDU*

Physical parameters include the colour values, weight of the *laddu*, volume, circumference of the *laddu*. Nutrient composition of optimised foxtail millet based *laddu* was evaluated in comparison with *besan laddu.*

### 4.3.1 Physical parameters

From Table 13 it is observed that there was no significant difference in 'L' values of *laddu i.e. besan laddu* (53.56) and foxtail millet *laddu* (52.99). There was increase in the darkness with 50 per cent foxtail millet flour incorporated *laddu* however this was not significant. Value of 'a' were 13.14 and 14.32 for foxtail millet *laddu* and *besan laddu* respectively. Value of 'b' for foxtail millet *laddu* and *besan laddu* were 29.91 and 32.73 respectively. Weight of the foxtail millet *laddu* and *besan laddu* were 30.66g and 33.66g respectively. Volume of foxtail millet *laddu* was 36.13 and for *besan laddu* 39.66 ml. Circumference of foxtail millet *laddu* and *besan laddu* were 12.83 cm and 14.10 cm respectively. Statistical analysis showed that there was significant difference for colour 'a' and 'b' values, weight, volume and circumference in both the *laddus i.e. besan laddu* and optimised foxtail millet based *laddu.*

### 4.3.2 Proximate composition

The proximate composition of *besan laddu* and foxtail millet *laddu* are depicted in the Table 14. Fat and protein content were significantly higher in *besan laddu i.e.* 21.49 and 13.55 g/100g respectively when compared to foxtail millet *laddu*. The moisture content was higher in *besan laddu* (0.45%) when compared to foxtail millet *laddu* (0.25%). However, there was no significant difference. The energy content was significantly higher in *besan laddu* (499.61 Kcal) when compared to foxtail millet *laddu* (471.60 Kcal). Crude fibre (2.64), ash (1.11) and carbohydrate (66.85) content was higher in foxtail millet *laddu* when compared to *besan laddu* i.e 0.56, 0.90 and 62.99 respectively.

**Table 12: Sensory scores of *besan laddu* and developed foxtail millet *laddu***

| Parameters | *Besan laddu* | Foxtail millet *laddu* | *'t'* value |
|---|---|---|---|
| Appearance | 8.50 ± 0.52 | 8.40 ± 0.69 | $0.36^{NS}$ |
| Colour | 8.50 ± 0.52 | 8.50 ± 0.52 | $0.00^{NS}$ |
| Texture | 8.90 ± 0.31 | 8.60 ± 0.51 | $1.56^{NS}$ |
| Taste | 8.50 ± 0.70 | 8.40 ± 0.84 | $0.28^{NS}$ |
| Flavour | 8.60 ± 0.51 | 8.50 ± 0.52 | $0.42^{NS}$ |
| Overall acceptability | 8.50 ± 0.52 | 8.50 ± 0.52 | $0.00^{NS}$ |

NS – Non Significant

a. *Besan laddu*

b. Developed foxtail millet *laddu*

**Plate 5. *Besan laddu* and developed foxtail millet *laddu***

### 4.3.3 Sugar content

The sugar content *besan* and foxtail millet *laddu* is shown in the Table 15. The total sugars of foxtail millet *laddu* was higher 24.10 g as compared to *besan laddu* (21.79 g). Non reducing sugar present in foxtail millet *laddu* (22.91) and *besan laddu* (20.53g), in the contrary the reducing sugar was 1.33 and 1.25. However, there was no significant difference found in total sugar, reducing sugar and non reducing sugar in foxtail millet *laddu* and *besan laddu.*

### 4.3.4 Mineral content

The mineral content of foxtail millet *laddu* and *besan laddu* are depicted in the Table 16. The calcium and iron content of foxtail millet *laddu* were high 9.34 mg and 2.44 mg respectively compared to control *laddu* 8.27 mg and 2.44 mg respectively. However it was not significant. Copper was higher in foxtail millet *laddu* (0.81 mg/100 g) compared to *besan laddu* 0.05 mg/100 g but were not significant. Zinc and manganese were higher in *besan laddu* compared to foxtail millet *laddu.* However, difference were not significant.

## 4.4 STORAGE STABILITY OF FOXTAIL MILLET *LADDU*

The results of foxtail millet *laddu* evaluated for changes in moisture content, free fatty acid and organoleptic characteristics during storage period at ambient conditions in comparison with *besan laddu* packed in high density polyethylene (HDPE) covers are presented here (Plate 6).

### 4.4.1 Moisture content

The changes in moisture content (%) during storage of *besan laddu* and foxtail millet *laddu* depicted in Table 17*.* The moisture content increased in foxtail millet *laddu* and *besan laddu* as the storage period advanced. The initial moisture content in foxtail millet *laddu* was 0.27 % however it increased significantly after 30, 45, 60, 75 and 90 days of storage and it was 0.67, 0.75, 0.85, 1.12 and 1.44 % respectively.

### 4.4.2 Free fatty acid content

The changes in free fatty acid (mgKOH/g) during storage of *besan laddu* and foxtail millet *laddu* at ambient conditions were shown in the Table 18. With the increase in the storage period there was increase in FFA in both the *laddus*. The initial free fatty acid content in foxtail millet *laddu* was 2.88 mgKOH/g however it increased significantly after 30, 45, 60, 75 and 90 days when compared to initial free fatty acid content 5.31, 5.40, 7.49, 11.14 and 11.67 respectively. The initial free fatty acid content in *besan laddu* was 1.91 mg/KOH/g and significant increase in free fatty acid was observed after 30, 45, 60, 75 and 90 days *i.e.* 4.80, 5.03, 5.61, 9.96 and 10.40 respectively. Free fatty acid content of *besan laddu* was lower in all storage days when compared to foxtail millet *laddu* however it was not significant.

### 4.4.3 Organoleptic changes during changes

Effect of storage on appearance, colour, texture, taste, flavour and overall acceptability of *laddus* are shown in Table 19.

Effect of storage on appearance and colour of *besan laddu* and *foxtail millet laddu*

**Table 13: Physical parameters of *besan laddu* and developed foxtail millet *laddu***

| Parameters | *Besan laddu* | Foxtail millet *laddu* | 't' value |
|---|---|---|---|
| L# | 53.56 ± 0.35 | 52.99 ± 0.05 | 2.74$^{NS}$ |
| a# | 14.32 ± 0.23 | 13.14 ± 0.16 | 7.07** |
| b# | 32.73 ± 0.25 | 29.91 ± 0.08 | 18.04** |
| Weight (g) | 33.66 ± 0.28 | 30.66 ± 0.28 | 1.00** |
| Volume (ml) | 39.66 ± 0.28 | 36.13 ± 0.32 | 0.81** |
| Circumference (cm) | 14.10 ± 0.17 | 12.83 ± 0.15 | 0.69** |

NS –Non significant
** Significant at 0.01 %
# Colour values (L, a and b)
Each value is mean of three replications

**Table 14: Proximate Composition of *besan laddu* and foxtail millet *laddu***

| Nutrient (%) | *Besan laddu* | Foxtail millet *Laddu* | 't' value |
|---|---|---|---|
| Moisture | 0.45 ± 0.01 | 0.25 ± 0.04 | 6.90 |
| Fat | 21.49 ± 0.10 | 17.52 ± 0.46 | 14.51* |
| Protein | 13.55 ± 0.04 | 11.61 ± 0.23 | 14.25* |
| Crude Fibre | 0.56 ± 0.05 | 2.64 ± 0.03 | 55.00* |
| Ash | 0.90 ± 0.02 | 1.11 ± 0.02 | 12.15 |
| Carbohydrate | 62.99 ± 0.07 | 66.85 ± 0.40 | 16.40 |
| Energy (Kcal) | 499.61 ± 0.47 | 471.60 ± 2.33 | 20.3* |

*significant at 0.5 %
Each value is mean of three replications

**Table 15: Sugar content of *besan laddu* and foxtail millet *laddu***

| Sugars (%) | *Besan laddu* | Foxtail millet *laddu* | 't' value |
|---|---|---|---|
| Total sugar | 21.79 ± 5.87 | 24.10 ± 5.10 | $0.51^{NS}$ |
| Reducing sugar | 1.32 ± 0.34 | 1.25 ± 0.10 | $0.35^{NS}$ |
| Non reducing sugar | 20.53 ± 5.55 | 22. 91 ± 5.02 | $0.54^{NS}$ |

NS –Non significant
Each value is mean of three replications

On the first day the scores of appearance were 8.7 and 8.6 for *besan laddu* and foxtail millet *laddu.* However, it decreased after 90 days of storage, the scores decreased to 7.2 and 6.8 for *besan laddu* and foxtail millet *laddu* respectively*.* On the initial day, the colour of *besan laddu* and foxtail millet *laddu* scored 8.6 and 8.5 respectively. However, it decreased after 90 days of storage, the scores decreased to 7.3 and 6.5 for *besan laddu* and foxtail millet *laddu* respectively. However, there was significantly decrease in appearance and colour of *besan laddu* and foxtail millet *laddu* scores after 90 days.

Effect of storage on texture, taste and flavour of *besan laddu* and foxtail millet *laddu*

On the initial day, the texture for *besan laddu* and foxtail millet *laddu* scored 8.7 and 8.5 respectively. After 90 days of storage, the texture of *besan laddu* and foxtail millet *laddu* decreased to 5.6 and 5.8*. Besan laddu* and foxtail millet *laddu* scored 8.6. However, it decreased to 5 and 5.7 respectively. On the initial day, the flavour for *besan laddu* and foxtail millet *laddu* scored 8.5 and 8.4 respectively. After 90 days of storage, the texture of *besan laddu* and foxtail millet *laddu* decreased to 5 and 5.4 respectively. However, there was significantly decrease in texture, taste and flavour and of *besan laddu* and foxtail millet *laddu* scores after 90 days.

Effect of storage on overall acceptability of *laddus*

Table 19 presents the mean organoleptic scores for changes in overall acceptability of *besan laddu* and developed foxtail millet *laddu* during storage period. On the first day the scores were 8.7 and 8.5 for *besan laddu* and foxtail millet *laddu* and the scores decreased significantly after 90 days of storage, the scores decreased to 5.8 and 5.1 for *besan laddu* and foxtail millet *laddu.*

## 4.5 MARKET POTENTIALITY, CONSUMER ACCEPTABILITY AND ECONOMIC ANALYSIS OF FOXTAIL MILLET *LADDU*

To know the market potentiality and consumer acceptance of foxtail millet *laddu* survey was done. The availability of foxtail millet *laddu* in the Dharwad city was assessed by interviewing 40 randomly selected shopkeepers using the self- structured questionnaire. It was concluded that none of the shopkeepers had the knowledge of foxtail millet *laddu* and were not available in the shops.

### 4.5.1 Market potentiality, consumer acceptability and economic analysis of foxtail millet *laddu*

Developed foxtail millet *laddu* were packed in HDPE covers and kept in the 10 shops. Each shop was provided with 10 packets each packet weighing 100g with 4 *laddus* of *besan* and developed foxtail millet *laddu*. The economic analysis of *besan* and foxtail millet *laddu* and *besan laddu* was done (for 1 kg of *laddu* preparation Table 20) and the cost of 100 g packet of each was Rs. 23.65 and Rs. 22.35 respectively including the price of ingredients, HDPE packets (as packaging material), labels, labour charge, fuel, transportation and milling charges (Table 20). Therefore, with 25 per cent profit the *laddus* were sold *i.e.* for *besan laddu* (Rs. 30) and foxtail millet *laddu* (Rs. 28). These *laddus* packets were kept for one month for sale. From 100 packets of each *besan* and foxtail millet *laddu* 78 and 86 packets were purchased respectively (Table 21). Feedback was taken from the shopkeepers about the millet *laddu* using self-structured questionnaire.

**Table 16: Mineral Composition of *besan laddu* and foxtail millet *laddu***

| Minerals (mg/100g) | *Besan laddu* | Foxtail millet *Laddu* | ‘t’ Value |
|---|---|---|---|
| Iron | 2.44 ± 0.02 | 2.72 ± 0.02 | $14.84^{NS}$ |
| Calcium | 8.27 ± 0.04 | 9.34 ± 0.46 | $2.82^{NS}$ |
| Zinc | 0.46 ± 0.15 | 0.44 ± 0.03 | $0.29^{NS}$ |
| Copper | 0.05 ± 0.02 | 0.18 ± 0.02 | $7.18^{NS}$ |
| Manganese | 0.64 ± 0.03 | 0.6 ± 0.03 | $0.27^{NS}$ |

NS – Non significant
Each value is mean of three replications

**Table 17: Effect of storage on moisture content of *Besan laddu and* foxtail millet *laddu***

| Storage days | Moisture (%) | | |
|---|---|---|---|
| | *Besan laddu* | Foxtail millet *laddu* | |
| 1 | 0.44 ± 0.05[a] | 0.27 ± 0.02[a] | |
| 15 | 0.57 ± 0.03[a] | 0.49 ± 0.03[ab] | |
| 30 | 0.65 ± 0.04[a] | 0.67 ± 0.02[b] | |
| 45 | 0.71 ± 0.02[a] | 0.75 ± 0.04[b] | |
| 60 | 0.81 ± 0.79[b] | 0.85 ± 0.04[c] | |
| 75 | 0.92 ± 0.04[b] | 1.12 ± 0.05[c] | |
| 90 | 1.18 ± 0.03[b] | 1.44 ± 0.05[d] | |
| | SEM | CD | F value |
| Days (D) | 0.21 | 0.35 | 398.44** |
| Sample (S) | 0.17 | 0.44 | 17.83** |
| S*D | 0.08 | 0.16 | 22.88** |

** Significant at 1% level
Each value is mean of three replications
Values with same superscript are not significantly different

**Table 18: Effect of storage on free fatty acid content of *Besan laddu and* foxtail millet *laddu***

| Storage days | Free fatty acid (mgKOH/g) | | |
|---|---|---|---|
| | *Besan laddu* | Foxtail millet *laddu* | |
| 1 | 1.91 ± 0.03$^{a}$ | 2.88 ± 0.40$^{a}$ | |
| 15 | 2.21 ± 0.05$^{a}$ | 3.16 ± 0.14$^{ab}$ | |
| 30 | 4.80 ± 0.13$^{b}$ | 5.40 ± 1.22$^{bc}$ | |
| 45 | 5.03 ± 0.46$^{b}$ | 5.31 ± 0.34$^{bc}$ | |
| 60 | 5.61 ± 0.02$^{b}$ | 7.49 ± 0.11$^{d}$ | |
| 75 | 9.96 ± 0.43$^{c}$ | 11.14 ± 1.23$^{e}$ | |
| 90 | 10.40 ± 0.32$^{c}$ | 11.67 ± 1.63$^{e}$ | |
| | SEM | CD | F value |
| Days (D) | 1.17 | 2.40 | 152.84** |
| Sample (S) | 1.46 | 3.00 | 23.41** |
| D*S | 0.55 | 1.13 | 0.82** |

** Significant at 1% level
Each value is mean of three replications
Values with same superscript are not significantly different

**Plate 6. Stored samples at ambient conditions**

**Table 19: Effect of storage on sensory parameters of foxtail millet *laddu* and *besan laddu***

| Storage days | Appearance | | | Colour | | | Texture | | | Taste | | | Flavour | | | Overall acceptability | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BL | FL | | BL | FL | | BL | FL | | BL | FL | | BL | FL | | BL | FL | |
| 1 | $8.7^{a}$ ± 0.48 | $8.6^{a}$ ± 0.51 | | $8.6^{a}$ ± 0.51 | $8.5^{a}$ ± 0.52 | | $8.7^{a}$ ± 0.48 | $8.5^{a}$ ± 0.52 | | $8.6^{a}$ ± 0.51 | $8.6^{a}$ ± 0.69 | | $8.5^{a}$ ± 0.52 | $8.4^{a}$ ± 0.51 | | $8.7^{a}$ ± 0.48 | $8.5^{a}$ ± 0.52 | |
| 15 | $8.6^{a}$ ± 0.51 | $8.4^{a}$ ± 0.51 | | $8.5^{a}$ ± 0.52 | $8.2^{a}$ ± 1.03 | | $8.5^{a}$ ± 0.52 | $8.2^{a}$ ± 0.91 | | $8.5^{a}$ ± 0.52 | $8.2^{a}$ ± 0.91 | | $8.5^{a}$ ± 0.52 | $8.4^{a}$ ± 0.84 | | $8.6^{a}$ ± 0.51 | $8.3^{a}$ ± 0.67 | |
| 30 | $8.5^{a}$ ± 0.52 | $8.1^{a}$ ± 0.56 | | $8.5^{a}$ ± 0.52 | $8.4^{a}$ ± 0.51 | | $8.5^{a}$ ± 0.52 | $8.1^{a}$ ± 0.99 | | $8.4^{a}$ ± 0.69 | $8.0^{a}$ ± 0.81 | | $8.4^{a}$ ± 0.69 | $8.3^{a}$ ± 0.67 | | $8.6^{a}$ ± 0.51 | $8.3^{a}$ ± 0.42 | |
| 45 | $8.0^{a}$ ± 0.66 | $8.1^{a}$ ± 0.31 | | $8.2^{a}$ ± 0.78 | $8.2^{a}$ ± 0.63 | | $8.2^{a}$ ± 0.63 | $8.1^{a}$ ± 0.87 | | $8.3^{a}$ ± 0.82 | $8.0^{a}$ ± 0.47 | | $8.3^{a}$ ± 0.82 | $8.1^{a}$ ± 0.73 | | $8.4^{a}$ ± 0.69 | $8.2^{a}$ ± 0.78 | |
| 60 | $7.9^{a}$ ± 0.73 | $8.1^{a}$ ± 0.73 | | $8.0^{a}$ ± 0.81 | $8.0^{a}$ ± 0.47 | | $7.8^{a}$ ± 1.13 | $7.9^{a}$ ± 0.99 | | $7.9^{a}$ ± 0.73 | $8.0^{a}$ ± 0.81 | | $7.7^{a}$ ± 0.94 | $7.8^{a}$ ± 0.91 | | $7.9^{a}$ ± 0.87 | $8.0^{a}$ ± 0.66 | |
| 75 | $7.8^{a}$ ± 0.42 | $7.3^{a}$ ± 0.48 | | $7.9^{a}$ ± 0.31 | $7.5^{a}$ ± 0.70 | | $7.6^{b}$ ± 0.84 | $7.5^{b}$ ± 0.70 | | $7.6^{a}$ ± 0.69 | $7.5^{b}$ ± 0.84 | | $7.5^{a}$ ± 0.84 | $7.7^{a}$ ± 0.94 | | $7.4^{b}$ ± 0.69 | $7.4^{a}$ ± 0.69 | |
| 90 | $7.2^{b}$ ± 0.63 | $6.8^{b}$ ± 0.91 | | $7.3^{b}$ ± 0.67 | $6.5^{a}$ ± 0.84 | | $5.6^{c}$ ± 0.84 | $5.8^{c}$ ± 0.91 | | $5.0^{b}$ ± 1.15 | $5.7^{c}$ ± 1.05 | | $5.0^{b}$ ± 1.15 | $5.4^{b}$ ± 1.07 | | $5.8^{c}$ ± 0.63 | $5.1^{b}$ ± 0.52 | |
| | F value | SEM | CD | F value | SEM | CD | F value | SEM | CD | F value | SEM | CD | F value | SEM | CD | F value | SEM | CD |
| Days D | 18.65** | 0.70 | 1.38 | 18.67** | 0.72 | 1.44 | 28.94** | 0.96 | 1.90 | 38.57** | 0.93 | 1.84 | 39.35** | 0.97 | 1.93 | 53.42** | 0.74 | 1.48 |
| Sample S | $3.43^{NS}$ | 1.87 | 3.70 | 4.22* | 1.94 | 3.85 | $0.68^{NS}$ | 2.56 | 5.08 | $0.10^{NS}$ | 2.48 | 4.92 | $0.04^{NS}$ | 2.60 | 5.16 | $2.98^{NS}$ | 2.00 | 3.95 |
| D*S | $1.01^{NS}$ | 0.26 | 0.52 | $1.11^{NS}$ | 0.27 | 0.54 | $0.33^{NS}$ | 0.36 | 0.71 | $1.10^{NS}$ | 0.35 | 0.69 | $0.33^{NS}$ | 0.36 | 0.72 | $0.38^{NS}$ | 0.28 | 0.55 |

*significant at 0.5 %    ** significant at 0.1 %    NS – Non significant

FL – Foxtail millet *laddu*,  BL – *Besan laddu*

Values with same superscript are not significantly different

**Table 20: Economic analysis of foxtail millet *laddu* and *besan laddu* (For 1 Kg)**

| Particulars | Foxtail millet *laddu* | | | *Besan laddu* | | |
|---|---|---|---|---|---|---|
| | Quantity (g) | Rate (1 Kg) | Amount (Rs) | Quantity (g) | Rate (1 Kg) | Amount (Rs) |
| Bengal gram dhal flour | 225 | 88 | 15 | 450 | 88 | 40 |
| Foxtail millet | 225 | 66 | 20 | - | - | - |
| Ghee | 204 | 376 | 77 | 225 | 376 | 85 |
| Sugar | 339 | 46 | 16 | 384 | 46 | 18 |
| Labour charge (Rs) | 37.50 | | | 37.50 | | |
| Fuel (Rs) | 20 | | | 20 | | |
| HDPE packets (Rs) | 10 | | | 10 | | |
| Label (Rs) | 2 | | | 2 | | |
| Transportation (Rs) | 24 | | | 24 | | |
| Milling charges(Rs) | 2 | | | - | | |
| Total (Rs) | 223.50 | | | 236..50 | | |

It was revealed that none of the consumers knew about the availability of foxtail millet *laddu*. None of the shops earlier sold foxtail millet *laddu* and presently also they did not have foxtail millet in the shop. Seventy per cent of shopkeepers expressed that consumers preferred to purchase foxtail millet *laddu* and 30 per cent of consumers preferred *besan laddu*. In general, frequency of purchase of *besan laddu* was asked to shopkeepers and it was revealed that 60 per cent of consumers purchase the *besan laddu* monthly however 40 per cent purchase twice in a month. Seventy per cent of shopkeepers reported that the consumers showed interest in purchasing the foxtail millet *laddu* while 30 per cent of shopkeepers reported that consumers showed interest in purchasing the *besan laddu.* Eighty per cent of shopkeepers revealed that about '6-10' consumers purchased the foxtail millet *laddu* while 20 per cent of shopkeepers said only '1-5' consumers purchased the foxtail millet *laddu.* In every shop, '1-5' consumers enquired the price of foxtail millet *laddu* but did not purchase, as told by the shopkeepers. About 6-8 consumers enquired about foxtail millet *laddu* after the sale of foxtail millet *laddu* in shops. Sixty per cent shopkeepers expressed that low cost of foxtail millet *laddu* was also the factor for sale of the foxtail millet *laddu.* Seventy per cent of the shopkeepers expressed the sale of foxtail millet *laddu* as profitable (Plate 7).

**Table 21: Evaluation of market potentiality of foxtail millet *laddu****

| Type of *laddu* | Number of shops | Packets provided | Packets sold (%) |
|---|---|---|---|
| Foxtail millet *laddu* | 10 | 100 | 86 |
| *Besan laddu* | 10 | 100 | 78 |

*For period of one month
Each packet weighs 100g

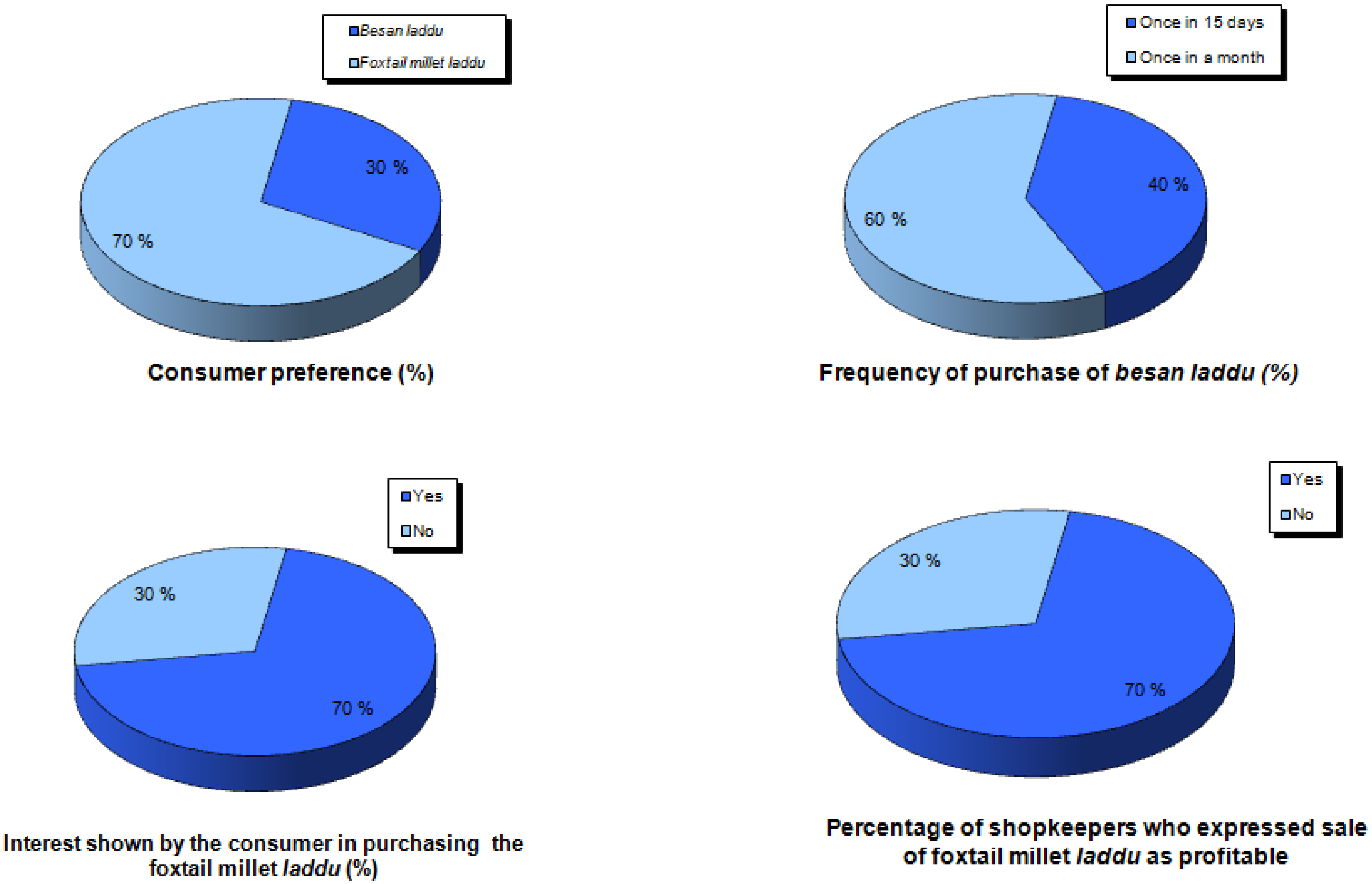


**Fig. 2. Market potentiality and consumer acceptability**

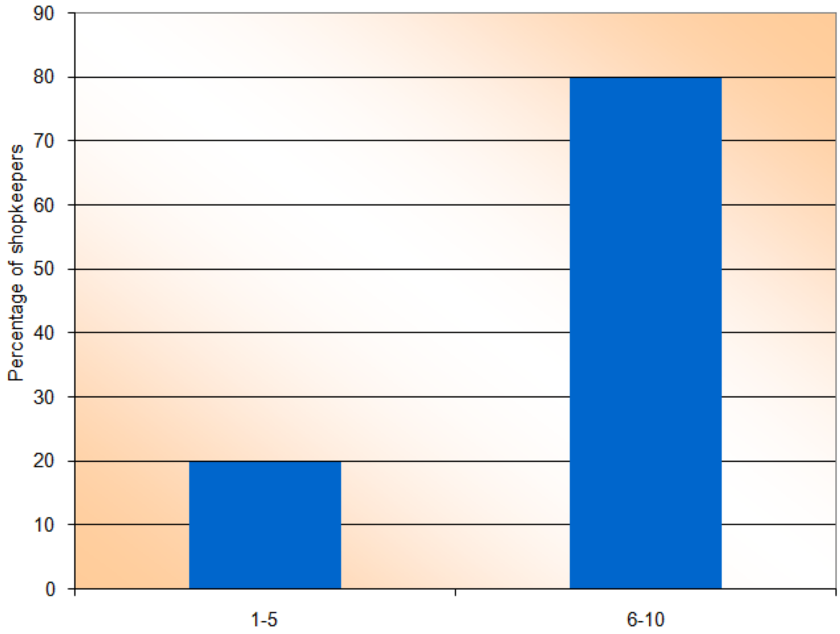


**Fig. 3. Number of consumers purchased foxtail millet *laddu***

**Plate 7. Consumers purchasing foxtail millet *laddu***

# 5. DISCUSSION

Modern food technology has enabled production of several ready to eat convenience foods ranging from snacks to infant foods based on various combinations that contribute to nutrition of consumers. Multinational companies and modern communication media are also catalysing the process. Hence today food industry is growing up as a profitable and diverse segment in India. In this context, provision of millet based products would not only encourage the modern consumers but also the farming community.

Reintroduction of foxtail millet in the regular diet and traditional dishes can be encouraged. Processing technologies can be used for development of diversified ready to eat foods enhancing the economic value. Recent studies have shown the foxtail millet flour can be replaced in preparation of variety of biscuits, cookies, muffins and bread. In the present study nutritionally superior foxtail millet flour was used in the development of *laddu*.

The results of physico-chemical properties and nutritional changes of flours, standardization of *laddu* for optimum incorporation of foxtail millet flour to bengal gram dhal flour, ghee, sugar powder and time required for roasting in the development of the foxtail millet *laddu*, evaluation for physical, descriptive qualities, organoleptic characteristics, its nutritional quality, storage stability, market potentiality in comparison to *besan laddu* are discussed here.

## 5.1 PHYSICO-CHEMICAL PROPERTIES AND NUTRITIONAL CHANGES OF FLOURS

The physico-chemical properties of the raw and roasted flours were differed significantly (Table 1). These changes could be due to the chemical composition of flours. The volume and bulk density of the flours decreased with the roasting process may be due the loss of the moisture content in the flours. The low bulk density of foxtail millet flour was due to its lower particle density and the large particle size (Kamara *et al*., 2009). In the present study, water absorption index, oil absorption index, swelling power and per cent solubility of flours increased with the roasting process may be due to the loss of the moisture content. The water absorption index was more in foxtail millet flour when compared to the bengal gram dhal flour.

Swelling power and per cent solubility of flours increased with the roasting process may be due to the loss of the moisture content, these changes may be due to starch content (amylose and amylopectin chains) (Coulibaly *et al.,* 2012). The water absorption index measures the volume occupied by the starch after swelling in excess water, which maintains the integrity of starch in aqueous dispersion. WAI was high in millet flour when compared to pulse flour (Thilagavathi *et al*., 2015). Increased WAI of roasted flours could be due to partial gelatinization of starch due to dry heat processing (Njoki *et al.,* 2014). There was increase in the oil absorption capacity, water absorption capacity and swelling power of roasted millet flour. High swelling of millet flour could be due to high content of starch and low protein and fat content. It was also reported that roasting increased WAI and OAI in pearl millet (Sade *et al*., 2009). Interactions of water and oil with protein are very important in the food systems because of their effects on the flavour and texture of foods. Intrinsic factors affecting water binding of food protein include amino acids composition, protein conformation and surface hydrophobicity/polarity (Barbut, 1999). The oil absorption index was more in bengal gram dhal flour when compared to the foxtail millet flour. The result shows that foxtail millet flour may be a lower retainer than raw winged bean (Narayana and Narasingha, 1982). The lower oil absorption capacity of foxtail millet flour might be due to low hydrophobic proteins which show superior binding of lipid (Kinsella, 1979). Abbey and Ibeh, (2006) also reported that water and oil absorption capacities of raw cowpea flour increased with heat processing. It was also reported that in the foxtail millet *laddu,* the ghee uptake was lesser compared to *besan laddu.*

In the present study, colour (L) values of flour decreased after roasting indicated that the lightness of the flour decreased and darkness increased (Table 2). Darkness browning reactions such as maillard reaction and degree of cooking and pigment degradation that take place during the starch extraction process (Altan *et al., 2008*).

The nutritional changes of the raw and roasted flours were differed significantly (Table 3). Moisture content of flours significantly decreased after the roasting process because of evaporation of moisture during heating process. Protein content of bengal gram dhal flour increased after roasting of the flour due to break down of complex protein to simpler protein increasing the protein availability. However, roasting technology resulted in the decrease in the protein content of the foxtail millet flour. The change in the protein content of roasted flour could be due to loss of amino acids (Mauron, 1982 and Sade *et al.* 2009). Moisture, fat, protein, crude fibre and ash content decreased in foxtail millet flour in the present study. It has been reported that moisture, protein, fat, ash and fibre contents decreased in foxtail and barnyard millet by the effect of milling and roasting (Choudhury *et al.,* 2011 and Lohani *et al.,* 2012 ).

## 5.2 DEVELOPMENT OF FOXTAIL MILLET *LADDU*

In present study, the foxtail millet *laddu* was developed by varying the proportion of incorporation of foxtail millet flour at different levels and varying proportion of other ingredients.

Increased addition of foxtail millet flour at 25, 50, 75 and 100 per cent resulted in decrease in the weight of the roasted flour mix because it has lower bulk density compared to foxtail millet flour. Therefore weight and volume of each *laddu* also decrease. As the level of foxtail millet flour incorporation increased there was increase in the grainy texture and decrease in the stickiness of *laddu.* This is due to the large particle size and fibre content of the foxtail millet flour. Bengal gram dhal flour had the very fine particle size and is known for its binding property hence the stickiness is more in *besan laddu.* Upto the level of 75 per cent incorporation of foxtail millet flour to the bengal gram dhal flour, the *laddus* prepared had the golden brown colour because of presence of bengal gram dhal flour.

Binding property (binding the *laddu* in round shape) for up to 25 per cent incorporation of foxtail millet flour was excellent and for 50 and 75 per cent, it was very good and good respectively. This is because of presence of bengal gram dhal flour which makes the dough sticky as its oil absorption index is more. The 50 per cent foxtail millet flour incorporated *laddu* had very good binding as well as golden brown colour. Hence, the formula was further selected for further study. However, the 100 per cent foxtail millet *laddu* had the creamish colour, it was grainy in texture (particle size) and dough handling property was poor as the oil absorption index of foxtail millet flour is less. Hence it was not acceptable.

Though there were significant changes in physical characteristics of foxtail millet *laddu*, organoleptically there was no significant variation in foxtail millet *laddu* prepared upto 50 per cent replacement. In some of the other value added products like foxtail millet based burfi, muffin, bread, vermicelli, pasta and extruded snacks upto 50 per cent incorporation of foxtail millet was carried out and were highly acceptable (Srivastava and Singh, 2003, Garwadhiremath 2011, Deshapande and Poshadri, 2011, Balloli *et al.,* 2014, Ranganna *et al.,* 2014 ). However, 50 per cent incorporated foxtail millet *laddu* scored high in all the parameters and overall acceptability. Further variations of other ingredients were carried out with the foxtail millet flour at 50 per cent.

To optimise the addition of ghee to foxtail millet based *laddu,* the ghee variation at 40, 45, 50, 55 and 60 per cent was done to standard recipe. On variation of ghee quantity, colour and consistency of roasted flour mix was altered. Similarly *laddu* prepared with varying quantity of ghee varied significantly in physical and organoleptic quality (Table 6). Increased addition of ghee increased the weight of the flour after roasting and increased the weight and volume of *laddu. Laddu* with increased addition of ghee was poor in organoleptic scores. Fifty and 60 per cent increase in ghee made the roasting process easy as the consistency was semi solid and *laddus* prepared did not retain shape. However at 45 per cent, there was slight difficulty in roasting but binding of *laddu* was good and shape of *laddu* was retained. Sensory evaluation showed highest scores for all parameters and overall acceptability. Hence, 45 per cent addition of ghee was optimised for foxtail millet *laddu*. Similar findings were reported by Garwadhiremath (2011) in the optimization of foxtail millet based muffin where 5 per cent decrease in addition of fat was made. It was very difficult to roast and bind into *laddus* at 40 per cent addition of ghee.

Sugar is a principle ingredient in preparation of sweet products and its role extends for providing energy and sweetness. Foxtail millet based *laddu* were prepared with increasing and decreasing the sugar quantity by 5 per cent variation. With increase in the addition of sugar powder, there was increase in the weight of the flour after roasting and hence the weight and volume of *laddu* prepared also increased. *Laddu* binding property was fair as the resultant mixture was powdery at 80, 85, 90 and 95. Therefore there was difficulty in making the *laddu* in round shape. *Laddu* binding property at 75 per cent of sugar powder was very good and could be made to round shape and retained the shape also. Hence it was considered as the optimum level of addition.

Roasting brings change in colour and flavour through dextrinization and Maillard reaction. With increase in the roasting time there was decrease in the weight of the flour after roasting and hence the weight and volume of *laddu* prepared also decreased. Millet mix got charred with the increase in the roasting time (50, 55 minutes). However *laddus* prepared from 40 minutes roasting had golden brown colour and were highly acceptable organoleptically and *laddu* binding property was also very good (Table 10 and 11). Therefore it was considered as the optimum level of roasting time.

Hence the developed foxtail millet *laddu* was optimised for foxtail millet flour (50%), bengal gram dhal flour (50%), ghee (45%), sugar powder (75%) and time taken for roasting was 40 minutes.

Nutritional quality of optimised foxtail millet based *laddu* was assessed for proximate composition, sugars and trace elements. It was observed that moisture (0.45), fat (21.49 g/100 g), protein (13.55 g/100 g) content of the *besan laddu* was higher when compared to foxtail millet based *laddu* (moisture 0.25 %, fat 17.52 g/100 g, protein 11.61 g/100 g) which may be due to higher protein content in bengal gram dhal flour (Table 3) and more quantity ghee in *besan laddu*. On incorporation of foxtail millet flour at 50 per cent to bengal gram dhal flour, crude fibre (2.64) and the total minerals (1.11) increased when compared to *besan laddu* (crude fibre 0.56 and total minerals 0.96). There was no significant difference in the sugar profile of foxtail millet based *laddu* and besan *laddu.* There was also increase in the iron, zinc, copper, manganese and calcium content of foxtail millet *laddu.* This may be attributed to the incorporation of foxtail millet flour which is a rich source of trace elements.

## 5.3 STORAGE STABILITY, MARKET POTENTIALITY AND CONSUMER PREFERENCE OF FOXTAIL MILLET BASED *LADDU*

Shelf life is an important determinant of marketability, consumer acceptance and possible inclusion in daily food pattern. Storage quality of food is influenced by storage environment, packaging material and subsequent handling operations. In this study developed foxtail millet *laddu* packed in HDPE was evaluated for storage stability in comparison with *besan laddu*.

During storage period at ambient condition, the moisture content raised in both control and foxtail millet *laddu*. The moisture and free fatty acid content was increased significantly during storage periods. The moisture content of *besan laddu* increased from 0.44 to 1.18 per cent and for foxtail millet *laddu* from 0.27 to 1.44 per cent. This increase may be due to environmental conditions. The FFA content of *besan laddu* increased from 1.91 to 10.40 mgKOH/g and for foxtail millet *laddu* from 2.88 to 11.67 mgKOH/g. After 90 days of storage, the increase in the FFA content might be due to the formation of secondary oxidative products resulting from the breakdown of hydroperoxide with increase in the moisture (Lean and Mohamed, 1999 and Alyas *et al.,* 2006). Coulibaly and Chen (2012) reported that breakfast food developed based on processed foxtail millet and soybean were stored upto 90 days without preservatives and fat acidity reported 3 mg of KOH/100 g. Ranganna *et al*. (2014) also reported that cold extruded products like vermicelli and pasta prepared from barnyard, foxtail, kodo, little and proso millets to be stored upto 2 months affecting the quality in 300, 400 polyethylene package. In present study, on 60 days of storage, there was no difference in sensory parameters and overall acceptability in foxtail millet *laddu* and *besan laddu*. There was decrease in the scores might be due to absorption of moisture from atmosphere and oxidation of fats. The *laddus* were acceptable till the 75 days of storage. However, the scores decreased significantly after 75 and 90 days of storage when compared to initial scores.

The market survey revealed that none of the shopkeepers reported regarding the knowledge of foxtail millet *laddu* among consumers and foxtail millet *laddus* were not available in any of the shops surveyed. It was concluded that none of the consumer had the knowledge of availability of foxtail millet *laddu* but shown interest in purchasing the foxtail millet *laddu.* From 100 packets of each *besan* and foxtail millet *laddu* 78 and 86 packets were purchased respectively. Majority of consumers preferred to purchase foxtail millet *laddu* over *besan laddu* which shows that consumer preferred to purchase foxtail millet *laddu.* It may be because of awareness of millet nutrition and lesser cost of product. Cardello *et al.,* (2007) reported that taste was consistent rate as the most important factor that influence consumption and repeat purchase. Kusumad (2011) concluded that, farmers can better utilize their marginal lands by cultivating foxtail millet on them. Value added products of foxtail millet brought more returns to the farmers than the foxtail millet grains. Hence, suggested the farmers to involve in value addition of foxtail millet and get better returns rather than selling it in raw form. In this study, majority of the shopkeepers expressed sale of *laddu* as profitable venture.

The results of the study on nutrition and storage of foxtail millet *laddu* concluded that developed *laddu* was rich in protein, fibre and trace minerals and was highly acceptable. At present there is demand for ready to eat foods and therefore it has opened challengeable avenue to start production of such foods at commercial scale to benefit innumerable population and it can provide ample opportunity of employment for the enthusiastic entrepreneurs.

# 6. SUMMARY AND CONCLUSIONS

Physico-chemical and nutritional changes of flour during the roasting were studied. Physico chemical properties include the colour of the flour, volume, bulk density, water absorption index, oil absorption index, swelling power and percent solubility. Proximate composition of flours were also studied. Development of foxtail millet based *laddu* was standardised for optimum incorporation of foxtail millet flour, addition of ghee, sugar powder and the time taken for roasting and were evaluated for physical and organoleptic characters by standard procedures and semi- trained panellists respectively. Physical and nutritional quality of *laddu* were also studied. Physical parameters include the colour, weight, volume and circumference of *laddu*. For nutritional quality the proximate composition, sugars and mineral content were studied. The storage stability of the product was assessed for moisture, free fatty acid (FFA) and organoleptic quality. Market potentiality and consumer acceptance were also studied.

Salient features of present investigation are summarised below:

- The colour values of flours. The values of 'L' of raw bengal gram dhal flour, foxtail millet flour and millet mix were 91.74, 87.36 and 90.23 respectively. The values of 'L' decreased with roasting of flours *i.e.* bengal gram dhal flour (83.93), foxtail millet flour (79.85) and millet mix (83.31) which indicates lightness decreased and darkness increased.
- The values of 'a' of raw bengal gram dhal flour, foxtail millet flour and millet mix were 1.31, 1.41, 1.20 respectively. The values of 'a' increased with roasting of flours *i.e.* bengal gram dhal flour (3.92), foxtail millet flour (3.85) and millet mix (3.51) which indicates redness of flour increased.
- The values of 'b' of raw bengal gram dhal flour, foxtail millet flour and millet mix were 18.61, 14.83, 17.80 respectively. The values of 'b' increased with roasting of flours *i.e.* bengal gram dhal flour (23.54), foxtail millet flour (18.44) and millet mix (20.54). There was significant difference in values for 'a' and 'b'.
- The volume of flours varied from 43.33 to 33.33 ml. The volume of the flours decreased after roasting process.
- The bulk density of flours ranged from 0.63 to 0.56 g/cm$^3$. The foxtail millet flour had the highest bulk density *i.e.* 0.63 g/cm$^3$ then followed by the roasted foxtail millet flour (0.62 g/cm$^3$), millet mix (0.62 g/cm$^3$), roasted millet mix (0.61 g/cm$^3$), bengal gram dhal flour (0.58 g/cm$^3$) and roasted bengal gram dhal flour (0.56 g/cm$^3$). Bulk density also decreased with the roasting process.
- Water absorption index (WAI) of roasted foxtail millet flour was highest with 2.11 g/g and in raw foxtail millet flour was 1.57 g/g. WAI of bengal gram dhal flour was 1.08 which increased with roasting to 1.68 g/g. WAI of millet mix was 1.11 which also increased with roasting to 1.62 g/g.
- Oil absorption index (OAI) of raw bengal gram dhal flour, foxtail millet flour and millet mix were 1.21, 1.02 and 1.01 g/g respectively. However, OAI increased with roasting i.e roasted bengal gram dhal flour (1.24 g/g), roasted foxtail millet flour (1.21 g/g) and roasted millet mix (1.21 g/g).
- Swelling power of bengal gram dhal flour was 3.74 g/g which increased with roasting to 5.85 g/g. Swelling power of millet mix was 5.34 g/g which increased with roasting to 5.58 g/g and swelling power of foxtail millet flour was 5.75 g/g which increased with roasting to 6.17 g/g.

- Per cent solubility of bengal gram dhal flour (0.08), foxtail millet flour (0.07) and millet mix (0.09) increased with the roasting process *i.e.* 0.10, 0.12 and 0.14 per cent respectively. There was significant difference in volume, bulk density, WAI, OAI, swelling power and percent solubility.
- Moisture content of flours ranged from 8.74 to 0.77 per cent *i.e.* bengal gram dhal flour (8.74), roasted bengal gram dhal flour (1.20), foxtail millet flour (8.53), roasted foxtail millet flour (0.81), millet mix (8.59) and roasted millet mix (0.77). There was decrease in the moisture content after roasting of flours.
- The fat content of bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix and roasted millet mix were 4.80, 4.46, 4.29, 4.13, 4.59 and 4.19 g/100g respectively. Fat content decreased with the roasting of flours.
- Protein content of flours ranged from 11.46 to 20.90 g/100 g *i.e.* bengal gram dhal flour (19.56 g/100 g), roasted bengal gram dhal flour (20.90 g/100 g), foxtail millet flour (`13.01 g/100 g), roasted foxtail millet flour (11.46 g/100 g), millet mix (14.03 g/100 g) and roasted millet mix (12.58 g/100 g). There was increase in the protein content after roasting of flours.
- Crude fibre content decreased with the roasting process in bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix and roasted millet mix *i.e.* 1.79, 0.93, 7.92, 7.13, 4.67 and 3.07 g/100 g respectively.
- There was decrease in the ash content of flours after roasting *i.e.* bengal gram dhal flour (2.54 g/100 g), roasted bengal gram dhal flour (2.35 g/100 g), foxtail millet flour (2.78 g/100 g), roasted foxtail millet flour (2.64 g/100 g), millet mix (2.60 g/100 g) and roasted millet mix (2.16 g/100 g).
- Carbohydrate content also increased with the roasting in bengal gram dhal flour, roasted bengal gram dhal flour, foxtail millet flour, roasted foxtail millet flour, millet mix and roasted millet mix *i.e.* 62.54, 70.15, 65.00, 72.28, 66.49 and 75.21 g/100 g respectively.
- The energy also increased with roasting process *i.e.* bengal gram dhal flour (371.68), roasted bengal gram dhal flour (404.38), foxtail millet flour (344.50), roasted foxtail millet flour (378.41), millet mix (357.46) and roasted millet mix (394.92). There was significant difference in moisture, fat, protein, crude fibre, ash, carbohydrate and energy.
- The *besan laddu* was prepared by 100 per cent bengal gram dhal flour (150 g), ghee 75 g (50 %), sugar powder 128 g (85 %) and the time taken for roasting was 45 minutes.
- Foxtail millet flour was incorporated at 25, 50, 75 and 100 per cent to bengal gram dhal flour.
- Increased addition of foxtail millet flour had increased the grainy texture and decreased the stickiness in *laddu.*
- *Laddu* prepared by addition of foxtail millet flour (upto 75 per cent) had attained the golden brown colour, but *laddu* prepared by 100 per cent of foxtail millet flour had the creamish white colour, was grainy and could not hold the shape for long time.
- The weight of each *laddu* decreased with incorporation of foxtail millet flour and therefore volume also.
- *Laddus* prepared from 50 per cent incorporated foxtail millet had the highest overall acceptability scores followed by 75:25, 100:0 and 25:75 level.

- Fifty per cent foxtail millet flour incorporated *laddu* also had the highest scores for appearance (8.7), colour (8.7), texture (8.9), taste (8.5) and flavour (8.6).
- There was not much change in the organoleptic scores of *laddu* prepared by 100:0 and 75:25 proportions of bengal gram dhal flour: foxtail millet flour.
- *Laddu*s prepared with 100 per cent foxtail millet flour had the lowest scores for overall acceptability (5.3), appearance (4.9), colour (5.1), texture (5.2), taste (5.5) and flavour (5.6).
- As the 50 per cent incorporated foxtail millet *laddu* had the highest overall acceptability score and all other parameters, it was considered as optimum level of incorporation.
- *Laddus* were prepared from 150 g of flour mix containing 1:1 proportion of bengal gram dhal flour and foxtail millet flour, 128 g of sugar powder, 45 minutes roasting time and with ghee variation from 90, 83, 75, 68 and 60 g of ghee (which accounts 60 % to 40 % variation).
- With increased ghee addition, there was increase in the weight of roasted flour mix which ranged from 328.66 to 349.33 g.
- Increased addition of ghee made roasting easy but the round shape of the *laddu* could not be retained.
- There was slight difficulty in the roasting in case of 45 per cent ghee addition. Roasting was very difficult in the 40 per cent incorporation of *laddu*.
- *Laddus* with 45 per cent addition of ghee had the highest overall acceptability scores (7.7) and it also had the highest scores for appearance (8.2), colour (7.7), texture (7.8), taste (7.8) and flavour (7.8).
- Addition of ghee (90 g) had the lowest scores for appearance (2.5), colour (1.9), texture (2.2), taste (1.6) and flavour (1.5).
- It was observed that addition of ghee 68 g (45 %) was optimal for development of foxtail millet based *laddu*.
- Bengal gram dhal flour and foxtail millet flour in 1:1 proportion with ghee 68g (45 %) and 45 minutes roasting time was used in preparation of *laddu* with varying quantity of sugar powder which ranged from 113 g to 143 g (*i.e.* 95 to 75 %).
- With increased addition of sugar powder there was increase in the roasted flour mix weight that ranged from 317.66 to 347.66 g. The weight (31.25 to 34.20 g) and volume (40.20 to 36.75 ml) of each *laddu* increased with increased addition of sugar powder.
- As there was increase in the addition of sugar powder, the flour mix resulted in powdery mixture which made fair handling of roasted flour mix. The sweetness increased with the addition of sugar powder and the *laddu* became lighter in colour.
- Addition of 75 per cent sugar powder, the *laddus* had the highest overall acceptability (8.2), and also had the highest scores for appearance (8.7), colour (8.8), texture (8.7), taste (8.5) and flavour (8.8).hence considered the optimum quantity.
- *Laddus* were prepared from 150 g flour mix containing 1:1 proportion of bengal gram dhal flour and foxtail millet flour, ghee 68 g (45 %), sugar powder 113 g (75 %) and with roasting time variation from 55 to 35 minutes.

- However 40 minutes roasting time was found to be acceptable for foxtail millet *laddu* as the colour turned out golden brown. Increase in the roasting time resulted in the charring of the roasted flour mix and therefore the colour resulted was dark brown.
- Foxtail millet *laddus* prepared by roasting for 40 minutes had the highest overall acceptability scores (8.1) and it also had the highest scores for appearance (8.5), colour (8.4), texture (8.0), taste (7.9) and flavour (6.5).
- The *laddu*s prepared from the roasting time 55 and 50 minutes scored lowest for all the parameters.
- The optimised foxtail millet based *laddu* was prepared by incorporating the foxtail millet flour 75 g (50 %), bengal gram dhal flour 75 g (50 %), ghee 68 g (45 %) and sugar powder 113 g (75 %). The time taken for roasting was 40 minutes and it was highly acceptable by sensory evaluation.
- For physical parameters, it was observed that there was no significant difference in 'L' values of *laddu i.e. besan laddu* (53.56) and foxtail millet *laddu* (52.99). This shows, there was increase in darkness and decrease in the lightness of *laddu*. Value of 'a' were 13.14 and 14.32 for foxtail millet *laddu* and *besan laddu* respectively. Value of 'b' for foxtail millet *laddu* and *besan laddu* were 29.91 and 32.73 respectively.
- Weight of the foxtail millet *laddu* and *besan laddu* were 30.66 g and 33.66 g respectively. Hence, volume and circumference was less in foxtail millet *laddu.*
- The crude fibre, ash and carbohydrate content was found higher in foxtail millet based *laddu*. It had the higher crude fibre content (2.64 g), ash (1.11 g) and carbohydrate (66.85 g) as compared to *besan laddu*.
- Moisture (0.45 %), protein (13.55 g/100 g), fat (21.49 g/100 g) and energy (499.61 Kcal) content of the *besan laddu* was higher as compared to foxtail millet based *laddu.*
- There was no significant difference found in sugar composition between the control and the optimised *laddu*.
- It was observed that the calcium, iron, zinc, copper and manganese content of foxtail millet *laddu* was high as compared to control *laddu*. Statistical analysis showed that there was no significant difference in the mineral values.
- The foxtail millet *laddu was* evaluated for changes in moisture content, free fatty acid and organoleptic charateristics during storage period at ambient conditions in comparison with *besan laddu* packed in high density polyethylene (HDPE) covers.
- As the storage period advanced, the moisture and free fatty acid content increased in *besan laddu* and foxtail millet *laddu*.
- There was significant decrease in the scores for sensory parameters as the storage period advanced. Hence the *laddus* were acceptable till the 75 days of storage.
- To know the market potentiality and consumer acceptance of foxtail millet *laddu* survey was done. Shopkeepers reported that consumers had no knowledge of foxtail millet *laddu* as they did not enquire about foxtail millet *laddu* and they were not available in the shops.
- Seventy per cent of shopkeepers expressed that consumers preferred to purchase foxtail millet *laddu* and 30 per cent of consumers preferred *besan laddu*.

- In general, frequency of purchase of *besan laddu* was asked to shopkeepers and it was revealed that 60 per cent of consumers purchase the *besan laddu* monthly however 40 per cent purchase twice in a month.
- Seventy per cent of shopkeepers reported that the consumers showed interest in purchasing the foxtail millet *laddu* while 30 per cent of shopkeepers reported that consumers showed interest in purchasing the *besan laddu*.
- Eighty per cent of shopkeepers revealed that about '6-10' consumers purchased the foxtail millet *laddu* while 20 per cent of shopkeepers said only '1-5' consumers purchased the foxtail millet *laddu* in their respective shops.
- About 6-8 consumers enquired about foxtail millet *laddu* after the sale of foxtail millet *laddu* in shops.
- Sixty per cent shopkeepers expressed that low cost of foxtail millet *laddu* was also the factor for sale of the foxtail millet *laddu.*
- Seventy per cent of the shopkeepers expressed the sale of foxtail millet *laddu* as profitable.

From the study it can be concluded that, the recipe of foxtail millet based *laddu* differed from *besan laddu*. Foxtail millet based *laddu* prepared were nutritious and rich in protein, fibre and trace minerals. Production of indigenous foxtail millet *laddu* as homemade processing unit can be recommended. This technology should be encouraged among the women entrepreneurs which is profitable and cost effective.

## Future line of work

- To provide foxtail millet *laddu* making technology to the SHG's to take up as income generating activity and record the economics.
- Further in-depth studies on market promotion and with different packaging materials.
- Development of *laddus* by incorporating other millets.
- Development of other snack products like *Nippattu* and *Chakli* using foxtail millet.

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# APPENDIX I

## Procedure for preparation of *besan laddu*

Ingredients used:

Bengal gram dhal flour-150 g
Ghee-75 g
Sugar powder-128 g
Roasting time: 45 minutes.
Procedure

Firstly, heat the ghee in frying pan. Add bengal gram dhal flour to it. Roast it till colour turns to golden brown and develops aroma (it takes 45 minutes). Allow it to rest to warm temperature. Add powdered sugar to the roasted flour mix. Mix well and make small balls by hands.

# APPENDIX II

Date:

Score card for organoleptic evaluation of foxtail millet *Laddu*

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.

| Parameters | A | B | C | D | E |
|---|---|---|---|---|---|
| Appearance | | | | | |
| Colour | | | | | |
| Texture | | | | | |
| Flavour | | | | | |
| Overall acceptability | | | | | |

Name :
Sign :
Comments:

# APPENDIX III

Date:

Score card for organoleptic evaluation of foxtail millet *laddu* during storage

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.

| Parameters | Sample | Appearance | Colour | Texture | Taste | Flavour | Overall acceptability |
|---|---|---|---|---|---|---|---|
| 0 days | 102 | | | | | | |
| | 203 | | | | | | |
| 15 days | 102 | | | | | | |
| | 203 | | | | | | |
| 30 days | 102 | | | | | | |
| | 203 | | | | | | |
| 45 days | 102 | | | | | | |
| | 203 | | | | | | |
| 60 days | 102 | | | | | | |
| | 203 | | | | | | |
| 75 days | 102 | | | | | | |
| | 203 | | | | | | |
| 90 days | 102 | | | | | | |
| | 203 | | | | | | |

(Code number was given to the foxtail millet *laddu* as 102 and for *besan laddu* (control) as 203)

Name :<br>
Sign :<br>
Comments:

# APPENDIX IV

## Market survey

Shopkeepers name:

Name of the shop and address:

1. Do consumers have the knowledge of foxtail millet *laddu* ?
2. Have you sold foxtail millet *laddu* earlier ?
3. In your shop, are foxtail millet *laddus* available presently ?

ಅಂಗಡಿಯ ಮಾಲಿಕರ ಹೆಸರು:

ಅಂಗಡಿಯ ಹೆಸರು, ವಿಳಾಸ:

1. ಗ್ರಾಹಕರಿಗೆ ನವಣೆ ಲಡ್ಡು ಬಗ್ಗೆ ಮಾಹಿತಿ ಇದೆಯೆ?
2. ನೀವು ನವಣೆ ಲಡ್ಡು ಮಾರಾಟ ಮಾಡಿದ್ದಿರಾ?
3. ನಿಮ್ಮ ಅಂಗಡಿಯಲ್ಲಿ ನವಣೆ ಲಡ್ಡು ಇದೆಯೆ?

# APPENDIX V

## Market potentiality and consumer acceptability

Shopkeepers name:

Name of the shop and address:

1. Do consumers know about the availability of foxtail millet *laddu* ?

   a. Yes   b. No

2. Which *laddus* are purchased more by consumers ?

   a. Foxtail millet *laddu*   b. *Besan laddu*

3. In general, what is the frequency of purchase of *besan laddu* ?

   a. Once in 15 days   b. Once in a month

4. Have consumer shown interest in purchasing the foxtail millet *laddu* ?

   a. Yes   b. No

5. How many consumers have purchased foxtail millet *laddu* ?

   a. 1-5   b. 6-10

6. How many consumers have enquired the price of foxtail millet *laddu* but did not purchase ?

   a. 1-5   b. 6-10

7. After the sale of foxtail millet *laddu*, any consumer asked about availability of foxtail millet *laddu* ?

   a. Yes   b. No

8. How many consumers purchased foxtail millet *laddu* over *besan laddu* as its price is comparatively less ?

   a. 1-5   b. 6-10

9. Any difference of opinion expressed by consumers about packaging material ?

   a. Yes   b. No

10. Do you find sale of foxtail millet *laddu* as profitable ?

    a. Yes   b. No

ಅಂಗಡಿಯ ಮಾಲಿಕರ ಹೆಸರು:

ಅಂಗಡಿಯ ಹೆಸರು, ವಿಳಾಸ:

1. ನವಣೆ ಲಡ್ಡು ಲಭ್ಯತೆ ಬಗ್ಗೆ ಗ್ರಾಹಕರಿಗೆ ಅರಿವು ಇದೆಯೇ?
   ಅ) ಹೌದು ಬ) ಇಲ್ಲ

2. ಗ್ರಾಹಕರು ಯಾವ ಲಡ್ಡು ಹೆಚ್ಚು ಖರೀದಿಸುತ್ತಾರೆ?
   ಅ) ನವಣೆ ಲಡ್ಡು ಬ) ಬೆಸನ್ ಲಡ್ಡು

3. ಗ್ರಾಹಕರು ಎಷ್ಟು ದಿನಗಳಿಗೊಮ್ಮೆ ಬೆಸನ್ ಲಡ್ಡು ಖರೀದಿಸಲು ಬಯಸುತ್ತಾರೆ?
   ಅ) 15 ದಿವಸಗಳಿಗೊಮ್ಮೆ ಬ) ತಿಂಗಳಿಗೊಮ್ಮೆ

4. ಗ್ರಾಹಕರು ನವಣೆ ಲಡ್ಡು ಖರೀದಿಗೆ ಆಸಕ್ತಿ ತೋರಿಸಿದ್ದಾರೆಯೇ?
   ಅ) ಹೌದು ಬ) ಇಲ್ಲ

5. ಎಷ್ಟು ಜನ ನವಣೆ ಲಡ್ಡು ಖರೀದಿಸಿದ್ದಾರೆ
   ಅ) 1–5 ಬ) 6–10

6. ಎಷ್ಟು ಜನ ನವಣೆ ಲಡ್ಡು ದರ ವಿಚಾರಿಸಿದ್ದಾರೆ, ಆದರೆ ಖರೀದಿಸಿಲ್ಲ?
   ಅ) 1–5 ಬ) 6–10

7. ನವಣೆ ಲಡ್ಡು ಪ್ಯಾಕೆಟ್ ಮಾರಟವಾದ ನಂತರ ಮತ್ತೆ ಗ್ರಾಹಕರು ನವಣೆ ಲಡ್ಡು ಲಭ್ಯತೆ ಬಗ್ಗೆ ವಿಚಾರಿಸಿದ್ದಾರೆಯೇ?
   ಅ) ಹೌದು ಬ) ಇಲ್ಲ

8. ಗ್ರಾಹಕರು ನವಣೆ ಲಡ್ಡು ದುಬಾರಿಯಂದು ಬೆಸನ್ ಲಡ್ಡು ಎಷ್ಟು ಜನ ಖರೀದಿಸಿದ್ದಾರೆ?
   ಅ) 1–5 ಬ) 6–10

9. ಲಡ್ಡು ಪ್ಯಾಕೆಟ್ ಬಗ್ಗೆ ಗ್ರಾಹಕರು ಬಿನ್ನಾಬಿಪ್ರಾಯ ವ್ಯಕ್ತಪಡಿಸಿದ್ದಾರೆಯೇ?
   ಅ) ಹೌದು ಬ) ಇಲ್ಲ

10. ನಿಮಗೆ ಲಡ್ಡು ಮಾರಟ ಲಾಭದಾಯಕವಾಗಿದೆಯೇ?
    ಅ) ಹೌದು ಬ) ಇಲ್ಲ

# DEVELOPMENT AND STORAGE QUALITY OF FOXTAIL MILLET (*Setaria italica*) *LADDU*


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## ABSTRACT

Foxtail millet (*Setaria italica*) is one of the most important food crops of semi-arid tropics, originated from China and now planted all over the world. It is the second most widely planted species of millet. Nutritional analysis revealed that moisture, fat, protein, crude fibre, ash and carbohydrate of raw foxtail millet flour was 8.53, 4.29, 13.01, 7.92, 2.78 and 65 per cent respectively. However, after roasting process, there was decrease in the moisture, fat, protein, crude fibre, ash and carbohydrate of foxtail millet flour *i.e.* by 0.81, 4.13, 11.46, 7.13, 2.64 and 72.28 per cent respectively. *Laddu* are ball-shaped sweets popular in the Indian Subcontinent. *Laddus* are made of flour, ghee and sugar with other ingredients that vary by recipe. They are often served at festive or religious occasions. Hence, an attempt was made to develop foxtail millet based *laddu*. Standardization trials indicated that acceptable foxtail millet *laddu* could be developed by incorporating 50 per cent foxtail millet flour, 50 per cent bengal gram dhal flour, 45 per cent ghee, 75 per cent sugar powder and 40 minutes roasting time in the standard *laddu* recipe. The developed *laddu* had good binding property and was highly acceptable by sensory evaluation. Nutritional analysis of foxtail millet *laddu* revealed that protein, fat, crude fibre, ash and carbohydrate of 11.61, 17.52, 2.64, 1.11 and 66.85 per cent respectively. The mineral composition of developed *laddu* include calcium (9.34 mg/100 g), iron (2.72 mg/100 g), zinc (0.44 mg/100 g), copper (0.18 mg/100 g) and manganese (0.60 mg/100 g). The developed foxtail millet *laddu* was acceptable and could be stored well upto 75 days. Developed foxtail millet *laddu* was accepted and preferred by the consumers. Thus, the study presented an upshot of potential as income generating activity among the women entrepreneurs which is profitable and cost effective.