# DEVELOPMENT AND EVALUATION OF FOXTAIL MILLET BASED VERMICELLI

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# INTRODUCTION

Pasta is a staple food of traditional Italian cuisine, now renowned worldwide. It takes the form of unleavened dough, mostly of durum wheat, rarely buckwheat flour, water and sometimes eggs, then it is extruded in various shapes and sizes. Pasta products come in many forms. They may be stored at frozen, chilled or ambient temperature. There is probably no other food from a single common source that is wheat which offers such a variety of shapes and sizes as macaroni, spaghetti, vermicelli, tagliatelli, noodles and lasagna which are but a few of the names given to different shapes.

Vermicelli is a type of pasta, basically made from durum wheat semolina in the form of long, slender, solid threads, resembling spaghetti but thinner. Vermicelli originated from Italy in 1669 and means "Little worms". In India, vermicelli is also called as *Seviyan* is made of refined wheat flour. The thickness of vermicelli ranges between 2.08-2.14 mm with little variation between different producers. Vermicelli is a source of carbohydrates (74–77%, dry basis) whose interest is increasing due to its nutritional properties. It also contains 11 per cent proteins. Vermicelli is a popular instant food product. It falls under the category of extruded product, liked by people from all walks of life, irrespective of age. They are easily affordable, tasty and easy to make and bare a long shelf life. It is basically a snack food item and at times it is also used as a table enricher. It is known as *Jawe* in Hindi, *Seviyan* in Urdu, *Shemai* in Bengali, *Sev* in Gujrati, *Shavige* in kannada, and *Semiya* in Telugu, Tamil and Malyalam.

Vermicelli is used in every home in India on different occasions and in various traditional dishes like vermicelli *kheer*, upma, *pulao, paysam* etc. At house hold level, vermicelli is made in the summer season because it dries up easily. Once vermicelli is dry, it is kept in the air tight containers and used for a year. Some home makers, dry roast the vermicelli which can be stored for a year. Today, mostly vermicelli is manufactured by continuous, high capacity extruders, which operate on the auger extrusion principle in which kneading and extrusion are performed in a single operation.

Pasta is considered a slowly digestible starch food, a feature governed by the particular physical characteristics of the product (Granfeldt, 1994). It is a prepared by using whole or refined wheat flour. Refining of wheat further reduces nutritional quality. Traditional vermicelli are prepared using wheat, gluten free vermicelli are prepared using rice, millets and other grains. Vermicelli from maize and other millets like foxtail millet, pearl millet, sorghum etc. are still to appear in the market. Value added vermicelli like gluten-free vermicelli, fibre enriched vermicelli, antioxidants rich vermicelli have been developed by the researchers in India and other parts of the world. Vermicelli, spaghetti and noodles have been designed with millets, green leafy vegetables, pulses and legumes. Vermicelli and noodles incorporating finger millets, soy flour, pulses, leafy vegetables, carrots and pumpkin, alge and bran have been developed to improve the nutritive value, functional quality and glycemic index.

With changing lifestyles, greater awareness about health and preference for instant food items have made vermicelli very popular and an item of mass consumption. In this era of global industrialization and advancement of technologies, the life style of the people has changed a lot. Demand for ready to eat foods like extruded foods has risen considerably. Among ready to eat foods, vermicelli form an important part of Indian dietary. It is rich in starch and energy but depleted in fiber and other nutrients. So Value addition to vermicelli can help to improve its physicochemical and sensory characteristics.

Therefore, value addition of vermicelli is of prime importance to improve nutrient content and to save its delicacy. Secondly, use of value added convenient/processed foods could be a solution to the problem of supplementary feeding in under nutrition (Gernah, 2011). Due to the nutritional advantages and along with the appeal of vermicelli amongst consumers, have made this food product a potential vehicle for neutraceuticals.

Minor millets are a group of grassy plants with small grains possessing remarkable ability to survive under severe drought. By any nutritional parameters millets are miles ahead of rice and wheat in terms of their mineral content. Each one of the millets has more fiber than rice and wheat. Some as much as fifty times that of rice. In their iron content foxtail millets are so rich that rice is nowhere in the race. In fashion, nutrient to nutrient, every single millet is extraordinarily superior to rice and wheat therefore is the solution for the malnutrition that affects a vast majority of the Indian population.Health benefits of millets are known from historic days. Millets are nutritious food and they are rich in phytochemicals, fiber and minerals.Magnesium in millet can help in reducing the affects of migraines and heart attacks, Niacin (vitamin B3) in millet can help in lowering the cholesterol levels, phosphorous in millets helps with fat metabolism, body tissue repairs and creating energy.

They can help lower risk of type 2 diabetes, fiber from whole grains has been shown to protect against breast cancer and whole grains have been shown to protect against childhood asthma.

The quantitative analysis for different bioactive phytochemical compounds shows that, all the small millets tested were found to contain phenol, tannins alkaloids, flavanoids and saponins and reported to possess anti-carcinogenic properties, immune modulation activities and regulations of cell proliferation as well as health benefits such as inhibition of the growth of cancer cells and cholesterol lowering activity.

Foxtail millet (*Setaria italica*) is the second-most widely planted species of millet. It can be cultivated in all types of soils and sustains adverse climatic conditions. It has an excellent rejuvenating capacity compared to other cereal crops. The fast growing nature of the crop suppresses the weed growth. Thus, it is a promising crop under adverse agro climatic conditions. Nutritionally too, foxtail millet is an important crop. It is made up of 10-12 per cent protein, 351 kcal energy, 2.29-2.7 per cent lysine, 0.59 mg thiamine, 4-5 per cent fat and 17.62 per cent of dietary fibre. Foxtail millet is nutritionally superior to conventional food grains and exhibits hypoglycemic effect due to presence of higher proportion of unavailable complex carbohydrate and resistant starch. In addition, it contains water-soluble gums, beta glucans, which might improve glucose metabolism and is an excellent source of dietary fibre with good amounts of soluble and insoluble fractions. The carbohydrate content is low and slowly digestible, which makes the foxtail millet a nature's gift for the modern mankind who is engaged in sedentary activities.

Thus, for the health conscious genre of the present world, minor millet especially foxtail millet is perhaps one more addition to the proliferating list of healthy foods, owing to its nutritional superiority. It is springtime for potential minor millets like foxtail millet to be woven in the fabric of daily diet. Foxtail millet has been utilized for formulation of ready to eat items, fermented foods, bakery foods and convenience mixes. Very few studies have been carried out on development of pasta and vermicelli from foxtail millet and other functional ingredients.

There is a need to increase the consumption of foxtail millet by incorporating into food products like vermicelli, which are liked by all age group people. With the modern people chasing healthy foods and ready to cook items and owing to nutritional superiority of millets, there is a need to develop millet based processed foods such as vermicelli. Therefore, the present study was taken up with the following objectives:

- To develop foxtail millet based vermicelli.
- To characterise the product in terms of sensory and nutrient profile.
- To study the storage quality of the developed vermicelli.

# REVIEW OF LITERATURE

Pasta products, traditionally manufactured from durum wheat semolina are known to be the best raw material suitable for pasta production (Feillet and Dexter 1996).With changing lifestyles, increasing awareness of consumers regarding health and nutrition has led to experimentations for modification and development of pasta products to value added health foods. The review pertaining to physicochemical properties of millets, value added foods from foxtail millet, Foxtail millet based convenience and health foods, development of value added pasta, its physicochemical and nutritional quality, acceptability of pasta and storage stability are reviewed here.

## 2.1 Physico Chemical properties of minor millets

Physico chemical characteristics of food grains are influenced by many factors such as season, soil type, agronomic practices, species and varieties. Minor millets also vary in physico chemical characteristics as indicated by various reviews in following paragraphs.

### 2.1.1 Physical characteristics

Physical appearance of grains is an important characteristic which determines consumer acceptability.

Srivastava and Batra (1998) reported that the colour of five different varieties of foxtail millet ranged between pale yellow to brownish yellow, however barnyard millet and proso millet were olive yellow and yellowish in colour. Further the thousand kernel volume of foxtail millet was reported as 1.5 to 3.5 g and 1.3 ml respectively. Grain weight and volume determines the seed density. The seed density was lowest in foxtail millet (1.42 g/ml), however highest was recorded in barnyard millet (1.18 g/ml) (Malleshi and Dsikachar 1985).

### 2.1.2 Functional properties of millets

Utilization of food grains depends on their physical and physicochemical characteristics. It reflects the potentials of millets for utilization.

Kulkarni (1990) assessed the changes in volume of millets upon cooking. It was reported that highest expansion was in little millet followed by Italian and proso millets.

Hadimani and Malleshi (1993) assessed the cooking time of five minor millets. It was observed that foxtail, proso and barnyard millets were well cooked in four minutes whereas, kodo and little millet required three minutes.

## 2.2 Chemical composition of millets

Ravindran (1991) conducted a study on millets for proximate composition, mineral composition, and phytate and oxalate contents. Grain samples of six varieties of common millet (*Panicum miliaceum*), three varieties of finger millet (*Eleusine coracana*) and four varieties of foxtail millet (*Setaria italica*) were analyzed for their proximate composition, mineral composition and phytate and oxalate contents. The average protein content of common millet, finger millet and foxtail millet were 14·4, 9·8 and 15·9%, respectively. The crude fibre content of the millets ranged from 3·2 to 4·7%. In general, the mineral contents were high compared with those of other common cereal grains. The oxalate contents (21–29 mg/100 g dry weight) of the millets were low. Considerable between- and within-millet differences were observed with regard to most nutrients analyzed. The overall results are suggestive of the underexplored potential of millets as sources of dietary nutrients.

## 2.3 Foxtail millet based convenience and health foods

Foxtail millet is versatile food suited for varied purposes. Several studies have been conducted to develop millet based foods for specific end uses and to introduce millet based new foods, which have potential market value in modern era of busy work schedules.

A weaning food based on malted foxtail millet flour (30 %), malted barnyard millet flour (30 %), roasted soybean flour (25 %) skim milk powder was developed by Thathola and Srivastava (2002). The mix contained 18.37 g protein and 398 Kcal of energy per 100 g. The protein efficiency ratio of mix was 2.25 against a casein control (2.5).

The cost of mix was reported to be Rs. 30 /Kg. The mix could be stored in plastic air tight containers at room temperature for 4 months without any changes in sensory quality.

Joshi *et al* (2003), undertook an experiment to diversify the use of foxtail millet in cake preparation. Flour blends of wheat and foxtail millet in the ratio of 10:0, 95:5, 90:10, 85:15, 80:20 and 75:25 were used. The blend of 75:25 was highly acceptable although it decreased the cake volume and specific volume from 665 to 590 ml and 2.43 to 2.15 ml/g, respectively. The substitution also reduced the volume index of cake from 14.95 to 14.18, but did not affect symmetry and uniformity indices, but increased total ash content. However, there was a gradual decrease in texture and crumb colour scores from 29.6 to 28.5 and 8.4 to 7.1 respectively.

An investigation was conducted by Kulkarni (2003) to develop ready to eat (RTE) value added snacks by incorporating and/ or substituting foxtail millet and little millet in *chakli, sev* and *khara* strips with high iron and β carotene. The stored snacks were acceptable till 41 days of storage period.

Torangatti (1995) evaluated the glycemic response of six test meals among which foxtail millet rice was one. The glycemic response for mixed meals ranged from 55 to 63 in normal and 60 to 65 in diabetic subjects, the lowest glycemic response was observed for foxtail millet rice with curds (55.01± 10.74) in healthy volunteers and pearl millet *roti* and brinjal *bhaji*.

Mixes, based on foxtail millet in combination with fenugreek seeds and legumes were formulated for different food products such as *dhokla,* upma and *laddu* (Pathak and Srivastava, 1998). Protein content of *dhokla*, upma and *laddu* was 4.46, 5.15 and 9.32 per cent respectively. Fat content was 3.75, 8.06 and 2.81 per cent, crude fiber was 2.74, 3.34 and 6.08 per cent, carbohydrate was 19.54, 21.49 and 62.63 per cent and energy 131. 182 and 325 Kcal, respectively. The millet based food products elicited a lower GI for upma (17.6), *dhokla* (35.0) and *laddu* (23.5), when tested against 25 g carbohydrate load in normal subjects.

Composite mixes suitable for diabetics were prepared using regional millets such as foxtail millet and little mill*et al*ong with wheat and black gram dhal and hypoglycaemic spices such as fenugreek seeds by Itagi *et al.* 2003. Lysine was most limiting amino acid in the mixes (0.56 in both). The efficacy of diabetic mix was investigated on type II diabetics. Lowest glycemic index was elicited for foxtail and little millet grain mixes (54.39 and 58.75, respectively), followed by millets (57.91 and 61.98, respectively) in six non diabetics with 50 g carbohydrates load.

On the whole it can be concluded that millets have outstanding storage quality however, storage environment such as temperature and relative humidity and packaging materials have a profound effect of stored food mixes.

## 2.4 Development of value added pasta

Today, mostly pasta is manufactured by continuous, high capacity extruders, which operate on the auger extrusion principle in which kneading and extrusion are performed in a single operation. Due to the nutritional advantages and along with the appeal of pasta amongst consumers, have made this food product a potential vehicle for neutraceuticals, such as vitamins or polyunsaturated fatty acids. In fact, pasta was one of the first foods for which USFDA permitted vitamin and iron enrichment in 1940’s. These products are rich in starch, fat and energy but depleted in fibre and other nutrients so value addition to pasta can help to improve its physicochemical and sensory characteristics, to enhance its antioxidant properties and to add fiber in the diet and to provide health benefits to consumer with reduced production cost and a product with a higher nutritional quality.

### 2.4.1 Value addition through millets

Use of wheat based pasta products often leads to unbalanced nutrient among the consumers. The functional effect of some of the millets is quite useful in changing many ready to eat or cooked pasta products and will provide balanced nutrients

Shukla and Srivastava (2011) evaluated finger millet incorporated noodles for nutritive value and glycemic index.

The finger millet flour (FMF) was blended in various proportions (30 to 50%) in refined wheat flour and used for the preparation of noodles. Control consisted of Refined Wheat Flour (RWF) noodles. Among all the formulations vermicelli from 30 per cent finger millet flour was found to be best as it was on par with that of control based on sensory evaluation.

Mridula *et al.* (2008) studied effect of sorghum flour on quality of noodles. Noodle samples were prepared using sorghum flour at 0, 10,20,40,50 and 60 percent level with wheat flour.

As per sensory characteristics among all the formulations noodles with 10 percent sorghum was found to be highly acceptable.

Suhendro *et al.* (2000) studied cooking characteristics and quality of noodles from food sorghum. The study revealed that sorghum flours with smaller particle sizes yielded better noodles. The microwave preheating method yielded better noodles than the hot-plate method. Stronger and firmer noodles, dry or cooked, were prepared using two-stage drying compared with the other drying methods. Fine flour that was preheated using a microwave oven and dried using the two-stage method gave the best noodles with moderate (10%) dry matter loss. Optimized processing conditions yielded sorghum noodles with good qualities when properly cooked.

Srivastava and Singh (2007) developed noodles with acceptable characteristics were developed by incorporating foxtail millet flour in ratio of 70:30(semolina-millet flour).

Devaraju *et al.* (2008) studied that fortification of finger millet with defatted soy flour and whey protein concentrate helped in improving the sensory profile as well as protein content.

Ugare (2009) conducted a study on health benefits, storage quality and value addition of barnyard millet. Acceptable value added barnyard millet incorporated noodles (20%) were developed with whole wheat flour as base material along with refined flour and fat.

Desai *et al.* (2012) developed noodles by supplementation with malted ragi flour. Combination of wheat and malted ragi flour in the ratio of 90:10 ,70:30, 60:40, 50:50 with other ingredients like vegetable oil, corn flour, wheat gluten, GMS and guargum were optimized. The results revealed that among all the formulations tried, noodles sample prepared from 70:30 flour combination had same sensory scores as that of control.

2.4.2 Value addition by fruits and vegetables

Scientists have found that the fruits and vegetables contain higher level of cellulose than cereals. Besides having good amount of dietary fibre, vegetables and fruits are also considered to be chemical power houses that produce dozens of unique, complex and biologically active organic compounds which are known to affect significantly the quality and duration of life. Hence, incorporation of such ingredients in extruded products will improve their nutraceutical properties and help to cater to the health needs of various cross-sections of the population.

Lee *et al.* (2002) developed noodles from pumpkin powder. Varying amounts of pumpkin powder levels (0, 2.5, 5.0, and 10%) were added in making instant fried noodles. Noodles with 5.0% pumpkin powder were the most favorable in appearance, taste, texture, and acceptability among the four samples.

Obadina*, et al.* (2011) produced noodles from corn grit and cassava flour. The study revealed that noodles from wheat: corn grit (2:1) is more acceptable than that from wheat: cassava flour (2:1).

Wani *et al.* (2011) developed roasted wheat noodles supplemented with cauliflower leaf powder. The result revealed that acceptable noodles in terms of physico-chemical and sensory properties could be produced by incorporating cauliflower leaf powder into roasted wheat flour up to the level of 10 per cent flour weight basis.

2.4.3 Value addition with pulses and legumes

Plant foods such pulses and legumes have consistently been considered as the major potential sources of dietary protein for feeding the growing population. The studies pertaining value addition with pulses and legumes are reviewed here.

Park and Lee (2008) developed rice noodle added with isolate soybean protein. As the levels of isolate soybean protein and rice flour increased gumminess, springiness, chewiness were increased. Sensory evaluation showed significant increase in hardness and chewiness of the cooked rice noodles. Color and overall- acceptability were also increased.

Sensory analysis of enriched spaghetti containing up to 35 per cent soy flour indicated no significant difference in flavor and texture compared with control without soy. Spaghetti with 50 per cent soy flour had slightly higher beany and bitter flavors compared with control. This study showed that high-protein and high-lysine spaghetti can be made with 35per cent soy flour without adverse effect on flavor and texture and should result in greater acceptability of soy-based foods (Shogren *et al.* 2006).

Bashir *et al.* (2012) studied the sensory characteristics of pasta fortified with chickpea flour and defatted soy flour. The fortification of durum wheat semolina was done by the combination of chickpea flour and defatted soy flour at levels (0, 0) per cent containing only semolina as control, (10, 6) per cent, (14, 10) per cent, (18, 14) per cent respectively. On the basis of cooking and sensory quality, pasta containing 14 per cent chickpea flour and 10 per cent defatted soy flour resulted in better quality and nutritious pasta.

Morga and Midha (2011) developed vermicelli using whole-wheat flour (WWF); malted wheat flour (MWF); green gram, spinach and sago (MGSS). A spice mix containing powders of tomato, coriander, chillies, turmeric, salt, raw mango powder, black pepper, cloves and asafoetida was also prepared. Results revealed that the overall acceptability scores for WWF, MWF and MGSS were 7.3 ± 6.13, 6.5 ± 0.06 and 8.1 ± 0.01 on 9-point hedonic scales. MGSS vermicelli was most acceptable by the panel members than the other counterparts.

Perez and Perez (2009) studied the effects of the addition of cassava (Manihot esculenta C.) flour, and beetroot juice on fettuccine .The sensory evaluation indicates that there was no significant difference between the fettuccines with respect to color, taste, texture and global appearance compared to the control (100% wheat semolina). The fettuccine made with the blend showed similar quality and preference to the fettuccine made with semolina. Fettuccines with a good texture, physical properties, proximate composition and eating quality, and stable shelf life can be made with semolina, cassava flour and beetroot juice.

### 2.4.5 Value addition through fibre

It is feasible to incorporate dietary fibre ingredients into pasta which may increase its nutritional value to the consumer, compared to conventional pasta. Therefore, the development of enriched pasta with a higher dietary fibre content would be a good way to increase the fibre intake and reduce the glycemic index of pasta, which would result in a product for specific nutritional purposes.

Vatanasuchart *et al.* (2009) studied resistant starch contents and the in Vitro starch digestibility of thai starchy foods. Among the rice noodles, vermicelli contained a higher RS content than the others.

Bustos *et al.* (2011) evaluated sensory and nutritional attributes of fibre-enriched pasta. Results suggest that by using insoluble fibre it is possible to enhance the nutritional quality of pasta, without affecting its sensory properties negatively.

Aravind *et al. (*2012) optimized the level of resistant starch II and III in durum wheat pasta to reduce in vitro digestibility.The addition of RS up to 20 percent substitution did not alter the sensory properties of cooked pastas. Importantly, increasing the RS content of the pasta resulted in a lower *in vitro* starch digestion relative to durum pasta as a result of the substitution of digestible starchwith resistant starch in the pasta formulations.

Padalino *et al.* (2011) developed gluten-free spaghetti based on pre-gelatinized maize flour. To develop this spaghetti pre-gelatinized maize flour was added with oat bran (20%) enriched with β-glucans (22%). To enhance the sensory attributes of spaghetti 2% of carboxymethylcellulose and chytosan were added. It was found that the pre-gelatinization of maize flour combined with the use of structuring agents, could be a useful tool to obtain oat- enriched gluten free spaghetti.

### 2.4.6 Value addition with diccocum wheat

Bhuvneshwari *et al.* (2005) developed vermicelli with semolina from eight 'diccocum' wheat varieties which were compared with one each check varieties of durum and bread wheat. Vermicelli prepared from most of the diccocum varieties were fair to good quality, less bulky and had more strands like durum wheat vermicelli.

### 2.4.7 Value addition through composite mix flour:

In order to overcome imbalance in nutrients by the consumption of pasta products, balanced nutrient can be provided by composite flour mixtures (Shanthi *et al.* 2005).

Collado *et al.* (2001) developed Bihon-Type Noodles from Heat-Moisture-Treated Sweet Potato Starch. Heat-moisture treatment was applied to native Sweet Potato Starch (HMTSPS), which was used as a substrate and composite with maize starch (MS) to produce Bihon-type starch noodles.

Preliminary quality scoring showed that acceptability scores of raw starch noodles, plain boiled, and sautéed noodles made from 100 per cent HMTSPS and 50 per cent HMTSPS:50 per cent MS were not significantly different from the commercial Bihon.

Vijayakumar *et al.* (2010) conducted a study on quality evaluation of noodles from millet flour blend incorporated composite flour. By all means, 20 percent level of millet flour blend incorporation was found to be acceptable. The incorporation of millet flour blend and soy flour improved the quality of noodle in terms of nutrient density and glycemic response.

Acceptable pasta were developed with finger millet composit flour by incorporating 50% of finger millet flour(FMF)/refined wheat flour (RFWF),40% refined wheat flour (RWF), 10% defatted soya flour ( DSF)/ whey protein concentrate (WPC), using cold water as well as hot water for dough preparation, extracted in dolly pasta machine. (Devaraju *et al.* 2006)

## 2.5 Physicochemical characteristics of pasta

Pasta varies in their physicochemical characteristics and nutrient composition depending on the ingredients used. Several studies are initiated here to determine physicochemical characteristics and nutrient profile of pasta products.

Shogren *et al.* (2006) studied composition of spaghetti fortified with soy flour spaghetti was prepared from durum wheat supplemented with soy flour .Up to 50 per cent soy flour was incorporated into spaghetti, resulting in a protein content of 33.5 per cent (compared with 15.4% for control without soy) and a lysine content of 1.75 per cent (compared with 0.41% for control).

Kulkarni and Desai (2012) developed malted ragi noodles. The results revealed that among all the formulations tried, noodles sample prepared from 70:30 flour combinations had higher values of protein, fibre and minerals (i.e. calcium, iron and phosphorus) as that of control.

Sudha *et al.* (1998) developed vermicelli from finger millet (*Elusine coracana*) and its blend with different milled wheat fractions. Blends of flour from FM with each of the different wheat fractions (WWF, wheat semolina and wheat flour) were prepared in the ratio of 100:0, 90:10, 85:15, 80:20, 75:25, 50:50, 25:75, 20:80, 15:85, 10:90 and 0:100. The study revealed that acceptable vermicelli can be developed by incorporating finger millet upto 50 per cent as per sensory evaluation.

Lee *et al.* (2002) investigated the influence of ripened pumpkin powder on the physicochemical characteristics and qualities of noodles. Adding more pumpkin powder increased the level of β-carotene in the noodles. Amylograph maximum viscosity and temperature and farinograph water absorption and stability decreased as the amount of pumpkin powder increased. Noodles made with more pumpkin powder had a more yellow color than those with less pumpkin powder. Cooked weight and volume were increased by 37 and 59%, respectively, when 5.0% pumpkin powder was added to the flour sample. Gumminess was lowest in the noodles with 5.0% pumpkin powder, while chewiness and hardness were lowest in the noodles with 10.0% pumpkin.

Park and Lee (2008) conducted a study on characteristics and development of rice noodle added with isolate soybean protein. As the levels of isolate soybean protein and rice flour increased, water binding capacity, swelling power of rice noodle increased.

The weight, water absorption and volume of the cooked noodles were decreased. The turbidity of rice noodle increased. Cooked rice noodle quality increased with by decreasing the level of rice flour level. Texture profile analysis of cooked rice noodle showed an increase of hardness. Adhesiveness, cohesiveness of cooked rice noodles decreased with by decreasing the level of isolate soybean protein and rice flour.

Bhattacharya *et al.* (1990) conducted a study on physicochemical properties related to quality of noodles. The study revealed that amylose content was the major factor affecting the pasting and textural properties of rice genotypes, although solubility and swelling behavior of the flour samples also had a significant effects, the RVA (rapid visco analyzer) pasting properties as well as the texture of the gels formed in the RVA canister correlated very highly with the cooking and textural properties of rice noodles.

Wani *et al.* (2011) studied nutritional and properties of roasted wheat noodles supplemented with cauliflower leaf powder. The alterations in chemical constituents (moisture, protein, fat, ash and fibre) of noodles were examined by adding cauliflower leaf powder to the noodle formation at the level of 0, 10, 15, 20 percent flour weight basis.

The study revealed that samples of cauliflower leaf powder added noodles, for all addition levels, contained more protein, fibre and ash as compared to control sample.

Shukla and Srivastava (2011) conducted a study on evaluation of finger millet incorporated noodles for nutritive value and glycemic index. The finger millet flour (FMF) was blended in various proportions (30 to 50%) in refined wheat flour and used for the preparation of noodles. Control consisted of RWF noodles. Nutrient composition of noodles showed that 50% finger millet incorporated noodles contained highest amount of crude fat (1.15%), total ash (1.40%), crude fiber (1.28%), carbohydrate (78.54%), physiological energy (351.36 kcal), insoluble dietary fiber (5.45%), soluble dietary fiber (3.71%), iron (5.58%) and calcium (88.39%), respectively. However, control RWF noodles contained highest amount of starch (63.02%), amylose (8.72%) and amylopectin (54.29%). The glycemic index (GI) of 30% finger millet incorporated noodles (best selected by sensory evaluation) was observed significantly lower (45.13) than control noodles (62.59).

Perez and Perez (2009) studied the effects of the addition of cassava flour, and beetroot juice on fettuccine quality. Results showed that the protein content of the fettuccine lightly decreased with an increase in the blend of cassava flour, whereas it increased with the addition of beetroot juice. Beetroot juice improves the diminution of protein content as a consequence of the substitution of wheat semolina with cassava flour.

Devaraju *et al.* (2006) studied the effect of temperature on physical properties of pasta from finger millet composite flour. Pasta with finger millet composite flour were formulated with 50% of finger millet flour(FMF)/refined wheat flour (RFWF),40% refined wheat flour (RWF), 10% defatted soya flour ( DSF)/ whey protein concentrate (WPC), using cold water as well as hot water for dough preparation. Pasta with finger millet composite flour was extracted in dolly pasta machine. Pasta prepared from FMF+ RWF+WPC had maximum length and width, the bulk density and hydration index were highest in pasta prepared from FMF+RWF+WPC. The weight of 100 pasta was maximum for control (refined wheat flour). Hydration capacity swelling capacity and swelling index were highest for FMF+RWF+WPC blend.

Bashir *et al.* (2012) studied the physico-chemical and sensory characteristics of pasta fortified with chickpea flour and defatted soy flour. It was observed as the concentration of legumes was increased the cooking time also increased. The cooking quality of the pasta was enhanced by steaming.

## 2.6 Pasta making quality

The vermicelli of acceptable quality were made using finger millet flour of medium coarse granulation in combination with milled wheat fractions where toasting of dried vermicelli for 3.0 min at $120^0$C further improved the cooking quality( Sudha *et al.* 1998).

Chillo *et al.* (2010) studied the effect of incorporating legume flour into semolina spaghetti on its cooking quality. Four types of spaghetti containing 10 per cent of either mung bean, soya bean, red lentil or chickpea flour were made and compared with a spaghetti control made only of durum wheat semolina.

Cooking quality was determined as the optimal cooking time (OCT), cooking loss (CL), dry matter (DM), swelling index, colour, hardness and adhesiveness. The spaghetti samples with legume flour were similar to one another and to the control in values of OCT, DM, swelling index, colour, CL, hardness and adhesiveness.

Zaigui *et al.* (2008) studied properties and qualities of vermicelli made from sour liquid processing and centrifugation starch. Vermicelli made from sour liquid starch had more significant mashy structure than vermicelli made from centrifugation. Amylose content of starch and TCL of vermicelli, degradation rate and TCL of vermicelli all had significance negative correlation. Amylose content had significant positive correlation with the degradation rate of vermicelli. The swelling index and TCL had no significance correlation

Devaraju *et al.* (2006) studied the effect of temperature on physical properties of pasta from finger millet composite flour. Pasta with finger millet composite flour were formulated with 50% of finger millet flour(FMF)/refined wheat flour (RFWF),40% refined wheat flour (RWF), 10 per cent defatted soya flour ( DSF)/ whey protein concentrate (WPC), using cold water as well as hot water for dough preparation. Pasta prepared from FMF+ RWF+WPC had maximum length and width, the bulk density and hydration index were highest in pasta prepared from FMF+RWF+WPC. The weight of 100 pasta was maximum for control (refined wheat flour).

Hydration capacity swelling capacity and swelling index were highest for FMF+RWF+WPC blend. Thus, there is significant difference between water, temperature and physical propertied of pasta prepared from composite flour and control.

Sudha *et al.* (2004) studied effect of extraction rate of wheat flour on the quality of vermicelli. With increase in extraction rate, the water absorption of the vermicelli dough increased from 35 per cent to 42.5 per cent. There was no significant difference in the colour of vermicelli when extraction rate was increased from 66 per cent to 80 per cent. However, a further increase made the vermicelli more brownish. The cooking quality of vermicelli made from different extraction rate flour of wheat showed reductions in cooked weight from 420 per cent to 315 per cent, and increase in solid loss during cooking from 8 per cent to 10.5 per cent, with increase in extraction rate. The solid loss during cooking was reduced by the addition of 0.25 per cent glycerol mono-stearate and 0.25% of sodium stearoyllactylate, whereas the water uptake increased. Addition of 2% gluten strengthened the strands and reduced surface stickiness. The results show the possibility of making vermicelli from either 100 per cent extraction rate flour or whole-wheat flour, which could be a product of better nutritional value.

Perez and Perez (2009) studied the effects of the addition of cassava (*Manihot esculenta* C.) flour, and beetroot juice on fettuccine quality. The cooking solids losses and the cooking time of the experimental fettuccine were similar to those of the control (100% wheat).

Foo *et al.* (2011) studied the Influence of formulations on textural, mechanical and structural breakdown properties of cooked yellow alkaline noodles. The physical attributes (pH and colour), cooking yield, textural and mechanical properties (firmness, tensile and texture profiles analyses) and structural breakdown properties (multiple extrusion cell with added artificial saliva) of five yellow alkaline noodle (YAN) formulations were studied. Samples used were noodles with (a) typical formulation (control), (b) soy protein isolate (SPI), (c) soy protein isolate plus microbial transglutaminase enzyme (SPI/MTGase), (d) green banana pulp flour (GBPu) and (e) green banana peel flour (GBPe). Compared to other noodles SPI/MTGase noodle showed significantly ($P < 0.05$) higher values in terms of textural, mechanical and breakdown properties. Incorporating SPI, banana pulp and peel flours into the noodles had imposed some differences on most of the mechanical and textural parameters from the control YAN.

Ugarčić-Hardi *et al.* (2007) studied the quality parameters of noodles made with various supplements. The influence of various supplements (extruded maize, maize, defatted soy flour and maize/soy flour blends, lecithin and wheat straw) on the pasta quality has been examined. Common wheat flour supplemented with 1 per cent lecithin powder, 20 per cent extruded maize flour, 20 per cent maize flour, 10 per cent defatted soy flour, 20 per cent defatted soy and maize flour blend (1:1), and 7.5 per cent wheat straw was used. The noodles made with extruded maize flour, maize flour, and wheat straw supplements had the highest total sensory score. Cooking losses of these samples were below 10 per cent.

Vijayakumar *et al.* (2010) conducted a study on quality evaluation of noodles from millet flour blend incorporated composite flour. The author concluded that incorporation of millet flour blend and soy flour improved the quality of noodle in terms of nutrient density, glycemic response, gruel solid loss and taste. But the cooking volume expansion and elongation index of cooked noodle was less; cooking time was more.

Devaraju *et al.* (2006) studied the effect of temperature on physical properties of pasta from finger millet composite flour. Pasta with finger millet composit flour were formulated with 50% of finger millet flour(FMF)/refined wheat flour (RFWF),40% refined wheat flour (RWF), 10% defatted soya flour ( DSF)/ whey protein concentrate (WPC), using cold water as well as hot water for dough preparation. Pasta prepared from FMF+ RWF+WPC had maximum length and width, the bulk density and hydration index were highest in pasta prepared from FMF+RWF+WPC. The weight of 100 pasta was maximum for control (refined wheat flour). Hydration capacity swelling capacity and swelling index were highest for FMF+RWF+WPC blend. Thus, there is significant difference between water, temperature and physical propertied of pasta prepared from composite flour and control.

## 2.7 Storage stability

Good storage quality of processed food is an essential attribute to extend their utilization. Various factors like quality of raw foods, pre-processing methods, composition of food, packaging material, and extent of heat application influence the storage quality. The storage quality of processed foods is evaluated by several investigators in terms of sensory characters and chemical components.

Lee *et al.* (2009) conducted a study on extending shelf-life with addition of ethanol of wet noodles. The study revealed that, the shelf-life of wet noodle with addition of ethanol at the standard were 9.17 days at no ethanol, 15.02 days at ethanol and 27.03 days at 2% ethanol. The respective percentage increases in the shelf-life observed at both 1 and 2% ethanol addition were 63.8% and 194.8% comparing with no ethanol treatment. Consequently, addition of ethanol into fresh wet noodle inhibited growth of total aerobic bacteria and extended shelf-life.

Dziki and Laskowski (2005) conducted a study on evaluation of the cooking quality of spaghetti. Ten types of commercial spaghetti samples were used for investigations. The storage of pasta after cooking also caused a decrease in these parameters (the maximum shear force decreased by about 50% in all samples, and the shear work by 72 to 97%, depending on the sample The results showed that the parameters described on the basis of the shear test of spaghetti well describe the pasta cooking quality in terms of cooking time and time of pasta storage after cooking.

Pangolin *et al.* (2001), conducted a study on storage conditions affect quality of noodles with added soy flour and sweet potato. Noodles were prepared from a formulation in which a portion of the flour was replaced with 10% defatted soy flour and sweet potato as 10 per cent flour or 15% puree. Dried noodles were packaged in plastic bags under partial vacuum or air and stored at 4.4 ℃ or 22–30 ℃ for 6 months. Colour, β-carotene and sensory characteristics were analyzed at 2-month intervals. Packaging atmosphere had minor effects on colour. Stored noodles became lighter and yellower, and β-carotene decreased, with all changes being greater at 22–30 ℃. Storage conditions influenced acceptability scores minimally. Noodles were stored successfully under air with greater quality retention with 4.4 ℃ storage.

Vidhya and Narayan, (2008) studied storage stability of value added pasta. Green gram dhal flour (G), defatted soya bean flour (S), ragi flour (R) and mint leaves powder (M) were selected for enrichment of vermicelli which was replaced with whole wheat flour (W). Total four samples of vermicelli were developed. The formulations developed were WGM: 70:20:10, WGR: 70:20:10, WSM: 80:10:10 and WSR: 80:10:10. Among all the formulations WSR and WGR were found to be the best among four varieties upon 90 days of storage.

Ugare (2009) conducted a study on health benefits, storage quality and value addition of barnyard millet. Acceptable value added barnyard millet incorporated noodles (20%) were developed with whole wheat flour as base material along with refined flour and fat. The study revealed that the noodles were acceptable and could be stored well beyond three months.

# MATERIAL AND METHODS

The present study was carried out in the Department of Food Science and Nutrition, College of Rural Home Science, University of Agricultural Sciences, Dharwad, Karnataka. The study aimed to develop and evaluate the foxtail millet based vermicelli.

The chapter on methodology has been discussed under the following headings:

3.1 Procurement of foxtail millet and other grains used for vermicelli development

3.2 Physical characteristics of foxtail millet and other ingredients used

3.3 Flour quality characteristics of foxtail millet and other ingredients

3.4 Trials for standardization of foxtail millet based vermicelli for optimization

3.5 Physical properties of vermicelli

3.6 Cooking quality

3.7 Organoleptic evaluation of developed foxtail millet based vermicelli

3.8 Nutrient profile of composite mix flour and developed vermicelli

3.9 Storage of vermicelli

3.10 Statistical Analysis

## 3.1 Procurement of foxtail millet and other grains used for vermicelli development

Local variety of decorticated foxtail millet, black gram dhal, fenugreek seeds and commercial semolina were procured from the local market of Dharwad- Hubli.

The grains were cleaned manually and stored at ambient conditions for the further investigations.

## 3.2 Physical characteristics of foxtail millet and other ingredients used

Physical characteristics generally influence the functional and organoleptic characteristics. They were studied using standard procedures.

### 3.2.1 Seed weight (Balasubramanian and Vishwanathan, 2010)

Counting of 1000 grains was done using seed counter in duplicate for each variety. Each duplicate was weighed in grams to one decimal place.

### 3.2.2 Seed volume (William *et al.,* 1983)

Thousand seeds were transferred to a 15 ml measuring cylinder to which 5 ml demineralised water was added using a pipette. Seed volume (ml/seed) was calculated as below.

$$\text{Seed volume} = \frac{\text{Total Volume - 5}}{1000}$$

### 3.2.3 Bulk density (g/ml)

Bulk density was determined using the formula

$$\text{Bulk density (g/ml)} = \frac{\text{Thousand grain weight (g)}}{\text{Thousand grain volume (ml)}}$$

## 3.3 Flour quality characteristics of foxtail millet and other ingredients

The foxtail millet flour, semolina, black gram dhal flour and fenugreek seed powder were studied for physical and functional properties.

3.3.1. Physical characteristics of flour

a) Volume: Twenty grams of flour was taken in a measuring cylinder and was tapped 100 times tightly and final volume was recorded.

b) Density: Density of flour was determined using the formula

$$\text{Flour density} = \frac{\text{Flour weight (g)}}{\text{Flour Volume}}$$

c) Colour: The colour determinations were carried out using a colorimeter (Premier color scan SS 5100A model) and results were expressed in accordance with the Hunter lab colour space. The parameters determined were L (L=0 (black) and L=100 (white), a (-a= greenness and+ a = redness), b (- b = blueness and +b yellowness) and C (+ C lightness – C= darkness)

3.3.2 Functional properties of foxtail millet flour and other ingredients

a) Water absorption of flour: Twenty grams of flour was kneaded into a normal dough with requisite amount of water and water added measured as absorption capacity and noted down (Austin and Ram, 1971)

b) Swelling power and percent solubility: Swelling power and percent solubility was determined according to the method of Schoch (1964). About 500 mg ($W_1$) of flour taken in a centrifuge tube and weighed the centrifuged tube with flour ($W_2$) and 20 ml (Ve) of distilled water was added. Then it was allowed for 30 minutes in a boiling water bath. The contents were cooled and centrifuged at 5000 X g for 10 minutes. The aliquot was transferred to a test tube and was wiped well and again the centrifuge tube was weighed with swelled material ($W_3$). Swelling power of semolina per gram was calculated by using the formula.

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

For percent solubility of semolina the dried moisture dish was weighed ($W_4$) and 10 ml of aliquot (Va) was pipette out in to the moisture dish. Then it was dried at 110˚C in an oven, cooled in a desiccators and again weighed the moisture dish ($W_5$). The percent solubility in the aliquot was calculated by

$$\% \text{ Solubility} = \frac{(W5\text{-}W4) \times Ve \times 100}{Va\ W1}$$

## 3.4 Trials for standardization of foxtail millet based vermicelli for optimization

Foxtail millet based vermicelli was developed by using semolina, foxtail millet flour, black gram dhal flour and fenugreek seed powder. The optimization for quantity of various ingredients used in the development of the product i.e., foxtail millet flour, black gram dhal flour, fenugreek powder and water along with some of the parameters like mixing time, dough development time, drying time and drying temperature for vermicelli was done.

3.4.1. Ingredients used for development of vermicelli

Foxtail millet based vermicelli was developed by replacing wheat semolina with foxtail millet flour for improving therapeutic value i.e., for increasing for fibre content. For further improvement in functional characteristics, black gram dhal flour and fenugreek seed powder were added by replacing wheat semolina.

The different proportion of foxtail millet flour, black dhal flour and fenugreek seed powder used for the trails have been given in table 1.

3.4.2. Processing of foxtail millet

The foxtail millet flour was tried in the above treatments in two forms i.e., in unprocessed flour and in processed form. The steaming of foxtail millet was carried out as given figure 1.

3.4.3 Processing of fenugreek seeds

The fenugreek was processed prior to incorporation in the vermicelli mix to decrease the bitterness as given in figure 2.

## 3.5 Physical properties of vermicelli

3.5.1 Colour:

Colour was measured as described in 3.3.1.c

3.5.2 Texture

Texture was analysed by Texturometer. Vermicelli were subjected to a compression test by using fracture wedge probe attached to an Instron Universal Testing Machine of TAXT. Plus texture analyzer with 5 kg load cell. Pre test speed of 2.50 mm/sec, test speed 3.300 mm/sec and post test speed of 10.00 mm/sec were maintained. The force required to break the vermicelli was measured to indicate texture (hardness) in terms of grams.

## 3.6 Cooking quality

3.6.1 Cooking time

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

3.6.2 Cooked weight and volume

A 10 g of vermicelli was taken and cooked in 200 ml of water. Weight of cooked vermicelli was measured by using electronic balance and volume of cooked vermicelli was measured using measuring cylinder.

3.6.3 Bulk density:

Bulk density of cooked vermicelli was determined using the formula,

$$\text{Bulk density of cooked vermicelli} = \frac{\text{Cooked weight of vermicelli (g)}}{\text{Cooked volume of vermicelli (ml)}}$$

The amount of total solid lost in cooking water (gruel) was determined by cooking 10 g vermicelli in 200 mL of water until cooked. The gruel was taken in a Petri dish and oven dried at 110˚ C until its weight became constant. Cooking loss was calculated by taking the difference in the weights and reported on dry basis.

## 3.7. Organoleptic evaluation of developed foxtail millet based vermicelli

Both raw and cooked vermicelli were evaluated for organoleptic characteristics like appearance, colour, texture, smoothness, firmness, taste, flavour and overall acceptability by scoring method using nine point hedonic scale by a panel of 10 semi trained members (Appendix I, II).

## 3.8. Nutrient profile of composite mix flour and developed vermicelli

Preparation of sample:

Vermicelli sample was powdered using pestle and mortor to a fine particle size. Both powdered vermicelli sample and composite mix flour were dried for further chemical analysis.

3.8.1. Estimation of moisture:

Moisture was determined by taking about 10 g of powdered sample in petridish and dried in an oven at 105˚ C till the weight of the petridish with its content was constant. Each time before weighing, the petridish was cooled in a dessicator. Moisture content of the sample was expressed in g/ 100 g of sample (AOAC, 1995).

**Semolina** **Foxtail millet**

**Blackgram dhal** **Fenugreek seeds**

**Plate 1. Raw ingredients used to develop foxtail millet based vermicelli**

**Table 1. Composition of different trials of vermicelli tried for optimization**

| Sample | Semolina (%) | Unprocessed foxtail millet flour (%) | Steamed foxtail millet flour (%) | Black gram dhal flour (%) | Fenugreek seed flour (%) |
|---|---|---|---|---|---|
| NSF20 | 80 | 20 | ---- | ---- | ---- |
| NSF30 | 70 | 30 | ------ | ------- | ----- |
| NSF40 | 60 | 40 | ------- | ------- | ------- |
| FS30 | 70 | --------- | 30 | ------- | ------- |
| FS40 | 60 | --- | 40 | --- | ------- |
| FS50 | 50 | ----- | 50 | ---- | -------- |
| FS60 | 40 | ----- | 60 | ---- | --------- |
| FSB10 | 40 | ----- | 50 | 10 | ----------- |
| FSB15 | 35 | ----- | 50 | 15 | --------- |
| FSB20 | 30 | ------ | 50 | 20 | -------- |
| FSB25 | 25 | --------- | 50 | 25 | -------- |
| FSBF1 | 29 | --------- | 50 | 20 | 1 |
| FSBF2 | 28 | ------ | 50 | 20 | 2 |
| FSBF3 | 27 | --- | 50 | 20 | 3 |

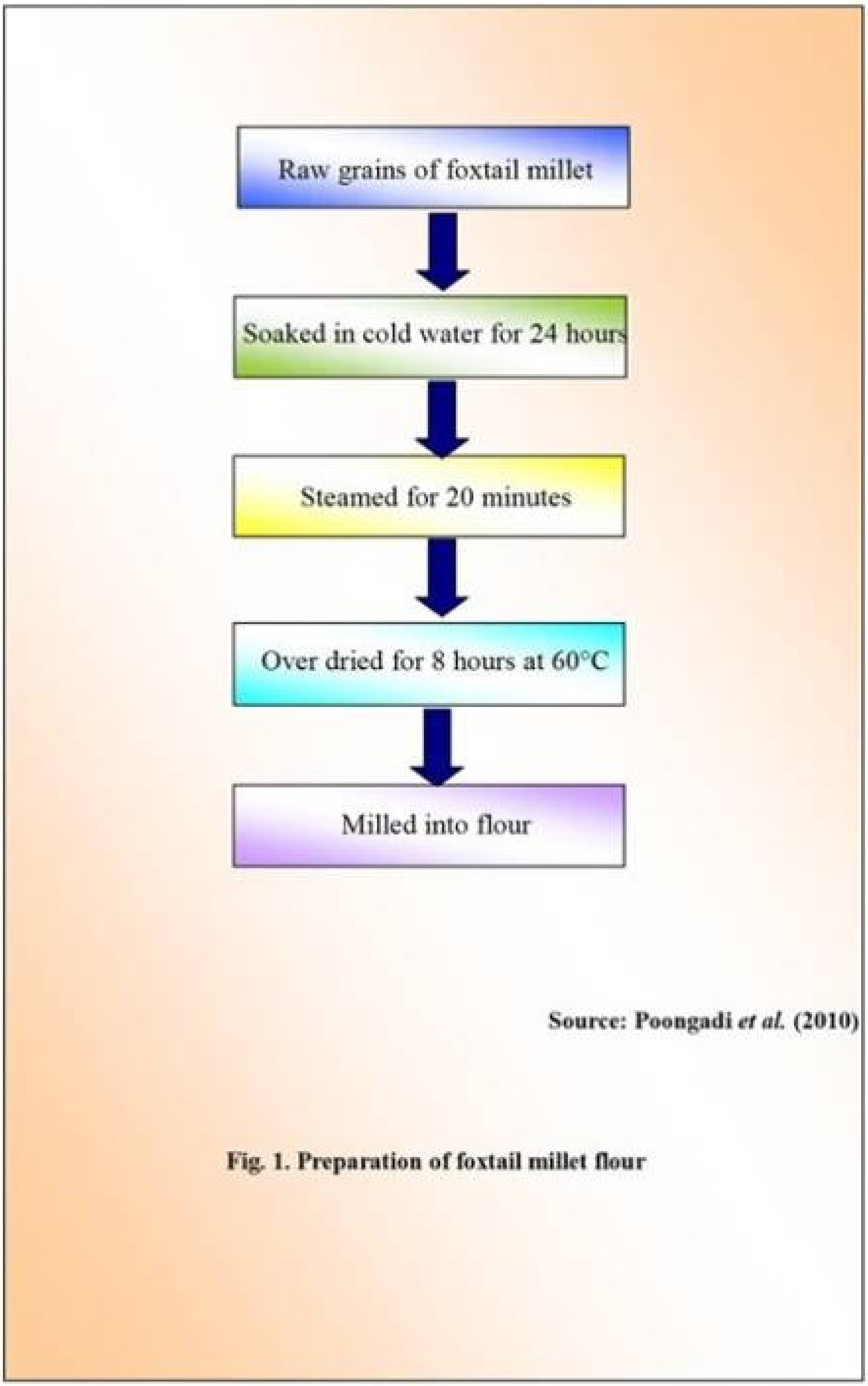


**Fig 1. Preparation of foxtail millet flour**

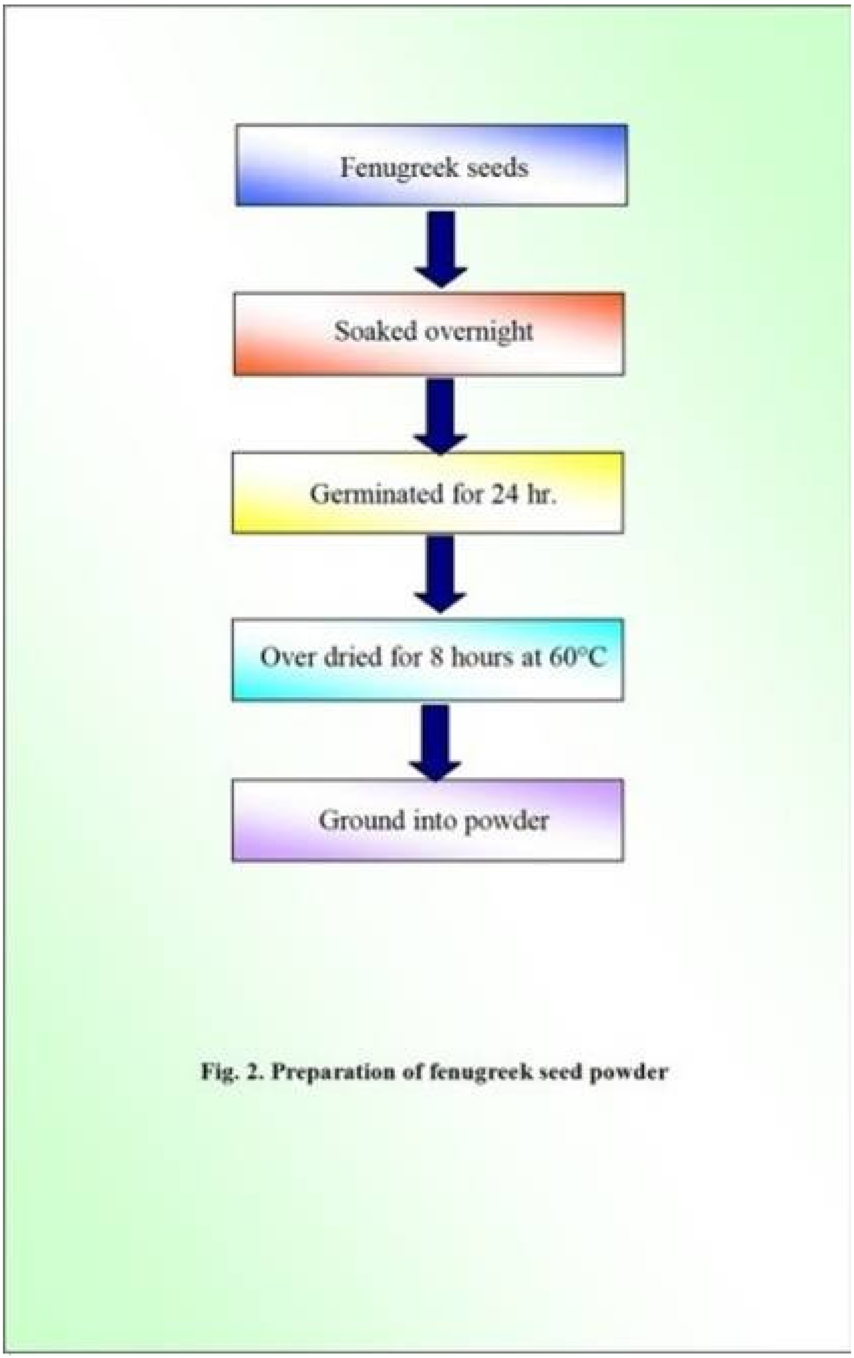


**Fig 2. Preparation of fenugreek seed powder**

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

3.8.2 Estimation of Protein (AOAC, 1980)

For the digestion of samples the Pelican digestion unit was used. The distillation was carried out in Socs plus. The protein content of the dried sample was estimated as per cent total nitrogen by the Micro-kjeldahl method (AOAC, 1980) and computed by multiplying the per cent nitrogen using conversion factor 6.25 (Appendix III).

3.8.3 Estimation of Fat (AOAC, 1980)

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

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

3.8.4 Estimation of crude fibre (AOAC, 1980)

Crude fibre of the sample was estimated by using moisture and fat free samples and expressed as gram/100 g of the sample (Appendix V).

$$\text{Crude fibre (g/100g)} = \frac{[100-(\text{moisture}+\text{fat})] \times (W_e-W_a)}{\text{Weight of sample taken(moisture and fat free)}}$$

$W_e$-pre weighed ashing dish

$W_a$-weight of the dish after ashing

3.8.5 Computation of carbohydrate (AOAC, 1980)

Carbohydrate content was calculated by differential method.

Carbohydrate(g/100g)=100–[Protein(g)+Fat(g)+Fiber(g)+Ash(g)+Moisture(g)]

3.8.6 Estimation of ash (AOAC, 1980)

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

$$\text{Ash content (g/100g)} = \frac{\text{Weight of the ash}}{\text{Weight of the sample}} \times 100$$

3.8.7 Estimation of insoluble dietary fibre (AOAC, 1995)

Defatted foods were gelatinized and proteins and starch were removed by enzymatic digestion. The residue was quantitated gravimetrically (Appendix VI).

$$\text{IDF\%} = \frac{\text{Wt of the IDF residue (g)} - \{\text{Protein (g) in IDF residue} + \text{Ash(g) in IDF residue}\}}{\text{Weight of the sample (g)}} \times 100$$

3.8.8 Estimation of soluble dietary fibre (AOAC, 1995)

The soluble fibre is estimated in the filtrate obtained after enzymatic digestion of protein and carbohydrates of defatted food. The soluble fibre was precipitated and estimated gravimetrically (Appendix VII).

$$\text{SDF \%} = \frac{\text{Wt of the SDF residue (g)} - \{\text{Protein (g) in SDF residue + Ash (g) in SDF residue}\}}{\text{Weight of the sample (g)}} \times 100$$

3.8.9 Estimation of total dietary fibre (AOAC, 1995)

The total dietary fibre was the sum of the insoluble and soluble dietary fibre. It was estimated as follows

Blank % = Wt of the blank residue (g)— {Protein(g) in the blank residue + Ash(g) in blank residue}

Total Dietary Fibre = IDF+SDF values

## 3.9 Storage of vermicelli

Developed foxtail millet based vermicelli was stored along with a control in polyethylene covers of 120 gauge for 6 months.

The samples were drawn at every month. The samples were evaluated for physical and sensory characteristics. Moisture and free fatty acids content was determined.

3.9.1 Physical characteristics of vermicelli

a) Width of vermicelli: Width of raw and cooked vermicelli was determined by using Vernier calliper.

b) Bulk density: Bulk density of raw and cooked vermicelli was calculated from weight and volume of the raw and cooked vermicelli and recorded as g/ml.

3.9.2 Cooking characteristics of vermicelli

a) Expansion ratio: A known volume of raw vermicelli was taken and cooked. The ratio of volume of the cooked sample to the volume of raw sample was taken as expansion ratio.

b) Cooking loss: 10 g sample were placed into 500 ml beaker with 200 ml of obiling distilled water. After the required cooking time, the cooked product was drained the cooking water was then collected in an aluminium vessel, placed into an oven at 105℃ and evaporated to dryness. The residue was weighed and reported as per cent of cooking loss (Gimenez *et al.*, 2013).

3.9.3 Moisture content: the procedure followed as 3.8.1.

3.9.4 Free fatty acid content: The free fatty acid was estimated by titrating the chloroform extract of sample against potassium hydroxide in the presence of phenopthalene indicator. The amount of FFA was expressed as oleic acid equivalents (Sadashivam and Manickam, 2008).

3.9.5 Sensory evaluation: Vermicelli were evaluated for organoleptic characteristics like appearance, colour, texture, smoothness, firmness, taste, flavour and overall acceptability by scoring method using nine point hedonic scale by a panel of 10 semi trained members (Appendix II).

## 3.10 Statistical Analysis

The data collected in triplicate values for all the quality parameters was statistically analyzed. The data was analyzed by using one way ANOVA to test significant difference among different trials tried for development of foxtail millet vermicelli also the chemical composition of the vermicelli. For storage studies two way ANOVA was used to test significant difference in the quality attributes of developed vermicelli. Paired t test was used to compare nutrient composition of wheat and foxtail millet noodles.

# EXPERIMENTAL RESULTS

The results of the study on “Development and evaluation of foxtail millet based vermicelli” are presented in this chapter.

## 4.1 Physical and functional characteristics of grains and flours used for vermicelli making

Physical properties of ingredients used for vermicelli is given in Table 2. Weight (23.07g) and volume (11.30 gm) of 1000 black gram dhal was higher than the fenugreek seeds (16.67 g and 11.07ml) and foxtail millet (2.39 g and 0.85 ml) respectively. Whereas, density was higher for foxtail millet (2.81 g/ml) compared to black gram dhal (2.04 g/ml) and fenugreek seed (1.51 g/ml).

Physical and functional characteristics of foxtail millet flour, black gram dhal flour, fenugreek seeds powder and semolina are presented in Table 3. When the volume of the flour per ml was considered, the values were similar with respect to semolina, foxtail millet flour and fenugreek seed powder (1.04 ml/g). However, the volume of black gram dhal flour was significantly lower (1.02ml/g) (at 5% level) compare to the other flours. The density of the different flour used for vermicelli development was found be similar (0.97g/ml).

The water absorption capacity of semolina was found to be significantly higher (0.8 ml/g) than the foxtail millet (0.50 ml/g) and black gram dhal flour (0.48 ml/g). The swelling power (per gram) of fenugreek seed powder was highest (8.91 %) followed by semolina (8.00%), foxtail millet (7.2%) and least was observed in black gram dhal flour (5.53%). These values were found to be highly significant (at 1% level). The per cent solubility was found to be highest for semolina (30.53%) followed by foxtail millet flour (22.36 %) and fenugreek seed powder (26.07%), however least was found in black gram dhal flour (21.53 %).

Colour Characteristics of flour used for vermicelli development is given in table 3. L value indicates lightness and darkness, ranged from 92.98 to 93.85 . Foxtail millet flour had lowest L value and fenugreek seed powder had the highest. The ‘a’ values representing redness, ranged from -0.27 to 0.71. The difference between sample was not significant. The ‘b’ and ‘c’ values, which indicate yellowness and brightness were found to be highest in fenugreek seed powder (9.57, 9.6) and lowest in foxtail millet flour (7.71, 7.72 respectively). There was a significant difference ($P \geq 0.05$) among the flour samples for b and c values.

## 4.2 Development of foxtail millet based vermicelli

### 4.2.1. Optimization of unprocessed foxtail millet flour for vermicelli preparation

The foxtail millet based vermicelli was developed by optimizing the different ingredients and the process. The flour formulation and the resultant vermicelli quality is presented in Table 4. Vermicelli prepared with wheat semolina was used as control to compare developed foxtail millet vermicelli. Dough properties revealed variations across the different levels of unprocessed foxtail millet incorporation. The dough of control sample (100 % wheat semolina) was creamish brown, stretchable and sticky. Strands were long, firm and sticky. Cooked vermicelli were creamish in colour with good strength, firm texture and no starchy mouth coating was observed, leached out water was clear and vermicelli were found to be highly acceptable The first level of foxtail millet incorporation (20 %) resulted in light creamish, less stretchable and less sticky dough with long, firm and less sticky strands. Cooked vermicelli were whitish in colour with good strength and firm texture without starchy mouth coating acceptable, leached out water was clear. As the level of unprocessed foxtail millet level (30 % and 40 % increases), the strands were less firm, less sticky and broke easily without any force. Thirty and forty per cent foxtail millet incorporated cooked vermicelli showed less strength and starchy mouth coating. Resulted vermicelli was unacceptable. Hence, another trial was conducted to improve the vermicelli quality.

### 4.2.2 Optimization of addition of steamed foxtail millet flour in place of foxtail millet for development of vermicelli

In the next trial, the foxtail millet was processed to obtain good quality vermicelli. Millets were steamed for 20 min, cabinet dried for 8 hrs and then milled in to fine flour. Quality characteristics of vermicelli prepared with steamed millet flour are given Table 5.

**Table 2. Physical characteristics of foxtail millet and other ingredients used for vermicelli development**

| Ingredients | Physical characteristics | | |
|---|---|---|---|
| | Weight (g) | Volume(ml) | Density (g/ml) |
| Foxtail Millet | 2.39 | 0.85 | 2.81 |
| Black gram dhal | 23.07 | 11.30 | 2.04 |
| Fenugreek Seed | 16.67 | 11.07 | 1.51 |

**Table 3. Physical and functional characteristics of flour used for vermicelli development (Mean ± SD)**

| Type of flour | Volume (ml/g) | Density (g/ml) | Water absorption capacity (ml/g) | Swelling power (%) | Percent solubility | Colour values | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | L* | a* | b* | C |
| Semolina | 1.04±0.01 | 0.97±0.002 | 0.80 ±0.01 | 8.00±0.05 | 30.53±.11 | 93.59±0.23b | 0.71±0.11a | 9.35±0.63a | 9.38±0.63a |
| Black gram dhal | 1.02±0.01 | 0.99±0.01 | 0.48±0.05 | 5.53±0.09 | 21.53±1.5 | 93.47±0.04b | 0.14±0.08ab | 8.67±0.10b | 8.69±0.10c |
| Foxtail millet | 1.04±0.01 | 0.97±0.02 | 0.50±0.01 | 7.21±0.27 | 22.36±0.49 | 92.98±0.05c | 0.44±0.07ab | 7.71±0.17c | 7.72±0.17c |
| Fenugreek seed | 1.04±0.02 | 0.97±0.01 | 0.50±0.00 | 8.91±0.13 | 26.07±0.37 | 93.85±0.09a | -0.27±0.88b | 9.57±0.24a | 9.60±0.24a |
| 'F' value | 0.85 | 2.93 | 0.739 | 7.59 | 0.046 | 24.70** | 2.64 | 17.7** | 17.51** |
| Sem ± | 0.01 | 0.01 | 0.01 | 0.92 | 2.92 | 0.07 | 0.26 | 0.20 | 0.20 |
| CD | 0.02* | 0.96 | 0.30 * | 0.``1437** | 1.5 ** | 0.24 | NS | 0.66 | 0.66 |

*Significant at 5 % level, ** Significant at 1% level, NS= Non significant

Values with the same letter are not significantly different

**Table 4. Optimization of unprocessed foxtail millet flour in the development of vermicelli**

| WS : UFMF | Dough properties | Strand formation | Cooked vermicelli quality |
|---|---|---|---|
| 100:0 | Creamish brown, stretchable and sticky | Long, firm and sticky | Creamish, good strength, firm texture, No starchy mouth coating, clear leached out water, highly acceptable. |
| 80:20 | Light creamish, less stretchable and less sticky | Long, firm and less sticky | Whitish, good strength, firm texture, starchy mouth coating absent, acceptable, leached out water clear |
| 70:30 | Light creamish, less stretchable and less sticky | Breakable, less firm and less sticky | Whitish, less strength, less firm texture, starchy mouth coating present, little sticky, short and broken strands, solid losses in leached out water, not acceptable |
| 60:40 | Off white, non stretchable and less sticky | Easily breakable, less firm and non sticky | creamish, poor strength, poor texture, sticky and easily breakable strands, starchy mouth coating present, too much solid loss in leached out water, not acceptable |

WS- Wheat Semolina, UFMF -Unprocessed Foxtail Millet Flour

**Table 5. Optimization of steamed foxtail millet flour in the development of vermicelli**

| WS: SFMF | Dough properties | Strand formation | Cooked vermicelli quality |
|---|---|---|---|
| 100:0 | Creamish brown, stretchable and sticky | Long, firm and sticky | Creamish, good strength, firm texture, No starchy mouth coating, clear leached out water, highly acceptable. |
| 70: 30 | Light creamish, stretchable and sticky | Long, firm and sticky | Off-white in colour, very good strength, no stickiness, no starchy mouth coating, firm long and separate strands, acceptable |
| 60:40 | Light creamish, stretchable and sticky | Long, firm and sticky | Creamy- white in colour, good strength, no stickiness, no starchy mouth coating, firm long and separate strands, acceptable |
| 50:50 | Dark creamish, less stretchable and less sticky | Breakable, firm and less sticky | Cream colour, little less strength, no stickiness, starchy mouth coating absent, firm long and separate strands, acceptable |
| 40:60 | Off white, non stretchable and less sticky | Easily breakable, less firm and non sticky | Cream colour, poor strength, slightly sticky, slightly starchy mouth coating, weak and separate strands, not acceptable |

WS- Wheat Semolina SFMF –Steamed Foxtail Millet Flour

**Table 6. Optimization of black gram dhal flour in the development of vermicelli**

| WS: SFMF: BF | Dough properties | Strand formation | Cooked vermicelli quality |
|---|---|---|---|
| 40:50:10 | Creamish white, less stretchable and less sticky | Breakable, firm and less sticky | Cream colour, good strength, no sticky, starchy mouth coating absent, firm smooth and separate strands, acceptable |
| 35:50:15 | Creamish white, less stretchable and less sticky | Breakable, firm and less sticky | Cream colour, very good strength, less sticky, no starchy mouth coating, firm smooth and separate strands, acceptable |
| 30:50:20 | White, stretchable and sticky | Long, firm and sticky | Creamish-white colour, very good strength, not sticky, starchy mouth coating was absent, very firm ,smooth and separate strands, highly acceptable, no after taste |
| 25:50:25 | White, stretchable and sticky | Long, firm and sticky | Cream colour, good strength, stickiness-absent, starchy mouth coating- absent, firm smooth and separate strands, after taste of black gram dhal was present, not acceptable |

WS- Wheat Semolina; SFMF –Steamed Foxtail Millet Flour; BF- Black gram dhal flour

In the previous trial, 20 per cent foxtail millet flour addition gave good quality vermicelli strands, beyond 20 per cent, the quality were not acceptable. Hence to increase the foxtail millet incorporation level, steamed foxtail millet flour was used at 30 to 60 per cent level. Thirty per cent incorporated millet yielded long firm and sticky strands. Cooked vermicelli were acceptable with good strength, non sticky, firm, long and separate strands. Starchy mouth coating was absent. Hence, with hope, the proportion of steamed foxtail millet was increased to 50 per cent. Although the dough was dark creamish in colour, the cooked vermicelli were creamish in colour with non sticky, firm, long and separate strands. It had starchy mouth coat and was acceptable. Because of acceptable quality, the steamed foxtail millet incorporation level was increased to 60 per cent. The dough was off white, non stretchable and less sticky gave easily breakable, less firm and non sticky strands. The cooked vermicelli was creamish in colour with poor strength and sticky and starchy mouth feel so not acceptable. Hence, previous trial with 50 per cent steamed foxtail millet was chosen for addition of functional ingredient black gram dhal to improve the functional quality and therapeutic value of foxtail millet vermicelli.

4.2.3 Optimization of black gram dhal flour for preparation of vermicelli

Optimization of black gram dhal flour for the development of vermicelli is given in Table 6. Black gram dhal was used at 10, 15 20 and 25 per cent level to improve the functional property of developed foxtail millet vermicelli. Addition of 10 per cent black gram dhal flour in vermicelli preparation resulted in creamish white, less stretchable and less sticky dough, strands were less sticky and broken easily. Cooked vermicelli was creamish in colour with good strength with no starchy mouth feel. Hence, the per cent incorporation of black gram dhal was increased to 15 per cent to know the quality. The resultant vermicelli strands were firm and less sticky. Cooked vermicelli were cream in colour, firm, smooth and separate strands. Further to improve the quality, the proportion of black gram dhal flour was increased to 20 and 25 per cent. The resultant vermicelli strands were long, firm and sticky good cooking quality parameters. Cooked strands were smooth and separate, without any starchy moth feel and no after taste for 20 per cent incorporation but slight after taste and flavour of black gram dhal was sensed for 25 per cent incorporation level. Hence the foxtail millet vermicelli with 20 per cent black gram dhal was chosen for further value addition with therapeutic ingredients like fenugreek seed powder.

4.2.4 Optimization of fenugreek seed powder in development of vermicelli

Table 7 depicts the characteristics of fenugreek seed powder incorporated foxtail millet vermicelli. Fenugreek seed powder was incorporated at 1, 2 and 3 per cent level by replacing wheat semolina in vermicelli preparation. Addition of 1 per cent fenugreek seed powder resulted in long, firm and sticky strands and cooked vermicelli exhibited very good strength and stickiness was absent, starchy mouth coating- absent, very firm, smooth and separate strands. Although the quality of strands improved with increased level of incorporation (at 1 and 2 %), but the taste of cooked vermicelli was not acceptable. Hence, 1 per cent fenugreek seed powder incorporate d vermicelli was chosen for further study.

4.2.5 Optimization of vermicelli preparation for different processing conditions

For the development of vermicelli, optimization was done for water addition required for the kneading of the dough. The water was added at different levels (45 ml, 65 ml and 75 ml) for kneading 100 gm of flour (Table 8). The minimum amount of water required for preparation of dough was 45 ml, but the prepared dough was found to be very hard and very difficult for extrusion of vermicelli. Water level was increased up to 65 ml, Medium hard dough was formed which resulted in good extrusion quality. The vermicelli stands were separate and firm in texture. The treatment with 75 ml of water resulted in soft dough which was very easy to extrude but the formed vermicelli stands were sticky. Hence, 65 ml of water addition was accepted and was used in further experiments.

Optimization for kneading time of 100 g of flour was done by kneading the dough for different time intervals *viz.,* 3 min, 4 min and 5 min. When dough was kneaded for 3 minutes, dough could not be formed properly and when kneading time was increased to 4 minutes rough dough was formed which was not suitable for extrusion of vermicelli. However, kneading of dough for 5 minutes resulted in smooth and uniform dough which was suitable for vermicelli extrusion; hence it was accepted for further experiments. For gluten development dough has to be kept for certain time before extrusion of vermicelli.

**Table 7. Optimization of fenugreek seed powder in the development of vermicelli**

| WS: SFMF: BF: FSP | Dough properties | Strand formation | Cooked vermicelli quality |
|---|---|---|---|
| 29:50:20:1 | White, stretchable and sticky | Long, firm and sticky | Creamish-white colour, very good strength, stickiness-absent, starchy mouth coating- absent, very firm ,smooth and separate strands, acceptable |
| 28:50:20:2 | White, stretchable and sticky | Long, firm and sticky | Creamish-white colour, very good strength, stickiness-absent, starchy mouth coating- absent, very firm ,smooth and separate strands, , flavour of fenugreek was present, not acceptable |
| 27:50:20: 3 | White, stretchable and sticky | Long, firm and sticky | Creamish-white colour, very good strength, stickiness-absent, starchy mouth coating- absent, very firm ,smooth and separate strands, strong flavour of fenugreek, not acceptable |

SFMF –Steamed Foxtail Millet Flour; BF- Black gram dhal flour; WS- Wheat Semolina; FSP- Fenugreek Seed Powder

To optimize the keeping time, dough was kept for different time intervals *viz.* 15, 30, and 60 minutes respectively, at room temperature when dough was kept for 15 minutes no changes were observed (Table 8.), as the time was too short for gluten development. When keeping time was increase up to 30 minutes dough became slightly smooth but it was not completely developed. Whereas, when dough was kept for 60 minutes it became soft and smooth resulting in complete dough development. Hence this was accepted for further experiments.

For the optimization of drying time (Table 8) vermicelli was dried at different time intervals viz. 1 hour, 2 hour and 4 hours by keeping the temperature constant at $60^0$C.When vermicelli was kept for 1 hr it did not dry completely. When drying time was increase up to 2 hrs, it was not dried properly. Whereas, the vermicelli kept for 4 hr at $60^0$C resulted in complete dried strands.

4.2.6 Texture analysis of vermicelli

Texture analysis of vermicelli prepared with different combinations of flour was evaluated for its breaking strength and extensibility is presented in Table 9. The control sample (100% semolina) required highest maximum force (49.17 g) for breaking. Unprocessed foxtail millet flour was added at different levels required different force to break strands. It varied from 10.87 g (20 % level) to 24.90 g (30 % level).

However, when steamed foxtail millet flour was incorporated in semolina at different levels (30, 40, 50 and 60%) the breaking strength of prepared vermicelli increased as compared to unprocessed foxtail millet vermicelli. As the level of steamed foxtail millet flour was increased from 30-60 per cent the max force required for breaking decreased from 40.51 g to 30.20 g. The max force required to break vermicelli decreased from 36.99 to 33.7, with increased incorporation of black gram dhal (from 10 to 25 %).

With addition of fenugreek seed powder at different level (1, 2, 3%) into developed composite mix flour, no significant difference was observed for tensile force and maximum force resistance to extension (35.33).

The similar trend was observed when texture was analysed in terms of extensibility. The wheat vermicelli had the highest distance (23.91mm). With increased incorporation of unprocessed foxtail millet flour, extensibility decreased from 10.25 mm – 6.78 mm. Similar trend was observed in steamed foxtail millet vermicelli also (from 13.23 to 7.17 mm). Extensibility did not change significantly with addition of black gram dhal at 10 to 25 per cent and fenugreek seed powder at 1 to 3 per cent level.

4.2.7 Cooking quality of different trials for vermicelli development

The Table 10 shows the cooking behaviour of different vermicelli prepared during the optimization. The cooking quality of all the trails varied significantly. Incorporation of black gram dhal into foxtail millet based vermicelli showed a significant decrease in the cooking time as compared to vermicelli from steamed foxtail millet flour. The maximum time taken for cooking was observed for 20 per cent unprocessed foxtail millet incorporated vermicelli and the lowest was observed for 15 per cent black gram dhal incorporated vermicelli.

With regard to cooked weight, 20 per cent unprocessed foxtail millet incorporated vermicelli showed the highest (53.2 g /10 g). Whereas, addition of fenugreek powder showed significant decrease in cooked weight (ranged from 35.33 to 38.53 g/10 g) compared to wheat semolina (51.55 g).

Cooked volume (table 10) of developed vermicelli ranged from 31.00 ml (20 % unprocessed steamed foxtail millet vermicelli) to 37.0 ml (20 per cent black gram dhal flour vermicelli), which is significantly lower than the wheat semolina vermicelli (47.33 ml).

Significantly lower cooking loss was observed for wheat semolina vermicelli (7.20 g/100 g). Whereas, significantly higher cooking loss was observed for vermicelli prepared with 40 per cent incorporation of unprocessed foxtail millet flour (34.37 g/100 g).

Bulk density of foxtail millet vermicelli (Table 10) prepared with addition of fenugreek seed powder (at 1, 2 and 3 % level) 1.07 g/ml was on par with wheat semolina vermicelli (1.09 g/ml). Significantly higher bulk density was noted in 30 per cent unprocessed foxtail millet incorporated vermicelli (1.58 g/ml).

**Table 8. Optimization of vermicelli preparation for different processing conditions**

| Different processing conditions | Variations in water added (ml) | | | | Variations in kneading time (min) | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | Control vermicelli (Semolina) | Foxtail millet vermicelli | | | Control vermicelli (Semolina) | Foxtail millet vermicelli | | |
| | 80 | 45 | 65 | 75 | **7** | 3 | 4 | 5 |
| Descriptive characteristics | Smooth and soft, stretchable, easy to extrude, smooth, separate and firm strands | Crumbly dough, difficult to extrude, un uniform broken strands after extrusion | Optimum quality dough, can easily extrude, separate and firm strands. | Soft dough, difficult to extrude, sticks to vermicelli moulds, sticky vermicelli strands | Uniform consistency dough, easy to extrude, uniform, firm and strong strands | Dough could not formed, hard dough, difficult to extrude, no uniform and long strands | Hard dough, difficult to extrude, broken strands | Smooth and optimum consistency dough, easily extrudable, smooth, uniform and non sticky strands |

| Different processing conditions | Variations in keeping time (min) | | | | Variations in drying time (Hr) | | | |
|---|---|---|---|---|---|---|---|---|
| Sample | Control vermicelli (Semolina) | Foxtail millet vermicelli | | | Control vermicelli (Semolina) | Foxtail millet vermicelli | | |
| | 60 | 15 | 30 | 60 | 1 | 1 | 2 | 4 |
| Descriptive characteristics | smooth and soft dough, ,stretchable and sticky, Easily extrudable but sticky | No effect on dough development (gluten development) | Dough became slightly smooth | Smooth and soft dough | Completely dried, firm and strong strands | Not dried, weak and breakable strands | Did not dried properly | Dried completely |

**Table 9. Texture analysis of vermicelli trials (mean± S.D)**

| WS: UFMF: SFMF:BF:FSP | Raw vermicelli | Cooked vermicelli | |
|---|---|---|---|
| | Tensile force (g) | Max force 'resistance to extension (g) | Distance at Max force 'Extensibility' (mm) |
| 100:0:0:0:0 | 0.24±0.01 a | 49.17±1.401 a | 23.91±0.53 a |
| 80:20:00:0:0 | 0.21±0.003a | 39.85±0.54 b | 10.87±0.72 |
| 70:30:0:0:0 | 0.20±0.003 b | 24.90±0.36 g | 9.45±0.05 g |
| 60:40:0:0:0 | 0.17±0.01 c | 20.18±0.43 h | 6.78±0.11 h |
| 70:0:30:0:0 | 0.17±0.01 c | 40.51±0.64 b | 13.23±0.26 c |
| 60:0:40:0:0 | 0.14±0.01 de | 37.43±0.61 c | 11.69±0.20 e |
| 50:0:50:0:0 | 0.10±0.01 e | 35.27±0.05 d | 10.43±0.16f |
| 40:0:60:0:0 | 0.098±0.01 ef | 30.20±0.95 f | 7.17±0.31 h |
| 50:0:40:10:0 | 0.054±0.03 g | 36.99±0.66 c | 11.53±0.05 e |
| 35:0:50:15:0 | 0.062±0.02 i | 34.95±0.63 d | 12.60±0.10 d |
| 30:0:50:20:0 | 0.076±0.11 h | 34.63±0.57 de | 13.35±0.41 c |
| 25:0:50:25:0 | 0.076±0.03 gh | 33.7±0.37 e | 13.33±0.15 c |
| 29:0:50:20:1 | 0.086±0.06 fg | 34.92±0.75 d | 13.34±0.32c |
| 28:0:50:20:2 | 0.086±0.015fg | 35.33±0.52 d | 13.19±0.41 c |
| 27:0:50:20:3 | 0.088±0.02 f | 34.84±6.27d | 12.99±0.08 cd |
| F value | 246.08 | 248.19 | 0.33 |
| CD | 0.02 | 1.51** | NS |
| CV | 7.91 | 1.95 | 90.24 |
| S. Em | 0.08** | 0.39 | 4.33 |

*Significant at 5 % level, ** significant at 1 % level, Values with the same letter are not significant

WS- Wheat Semolina ; UFMF -Unprocessed Foxtail Millet Flour; SFMF –Steamed Foxtail Millet Flour; BF- Black gram dhal flour; WS- Wheat Semolina; FSP- Fenugreek Seed Powder

**Table 10. Cooking quality of different trials of vermicelli (mean**± S.D)

| WS: UFMF: SFMF:BF:FSP | Cooking time (min) | Cooked volume (ml) | Cooked weight (g) | Cooking loss (g/100g) | bulk density (g/ml) |
|---|---|---|---|---|---|
| 100:0:0:0:0 | 6.90±0.36 $^{a}$ | 47.33±2.08$^{a}$ | 51.55±0.51 $^{b}$ | 7.20±0.10 $^{i}$ | 1.09±0.04 $^{gf}$ |
| 80:20:00:0:0 | 8.50±0.10 $^{gfed}$ | 34.00±1.00$^{gfed}$ | 53.2±0.73 $^{b}$ | 19.05±0.16 $^{d}$ | 1.56±0.055 $^{b}$ |
| 70:30:0:0:0 | 7.20±0.20 $^{h}$ | 31.00±1.00$^{h}$ | 48.96±1.70 $^{c}$ | 23.03±0. 03 $^{b}$ | 1.58±0.11 $^{b}$ |
| 60:40:0:0:0 | 8.37±0.42$^{i}$ | 28.00±1.00$^{i}$ | 47.00±1.00 $^{c}$ | 34.37±1.10 $^{a}$ | 1.68±0.024 $^{a}$ |
| 70:0:30:0:0 | 8.20±0.20 $^{dc}$ | 36.00±1.00$^{dc}$ | 41.00±1.00 $^{e}$ | 17.24±0.21 $^{e}$ | 1.14±0.00 $^{gfed}$ |
| 60:0:40:0:0 | 7.17±0.153 $^{gh}$ | 31.67±0.58$^{gh}$ | 38.00±1.00 $^{f}$ | 18.34±0.51 $^{d}$ | 1.20±0.02 $^{d}$ |
| 50:0:50:0:0 | 6.17±0.15 $^{edc}$ | 35.33±0.58$^{edc}$ | 38.67±0.58 $^{f}$ | 18.87±0.45 $^{d}$ | 1.09±0.02 $^{gfe}$ |
| 40:0:60:0:0 | 5.25±0.25 $^{ghf}$ | 32.53±0.50$^{ghf}$ | 36.40±0.53 $^{gf}$ | 21.97±1.19 $^{c}$ | 1.12±0.01 $^{gfed}$ |
| 50:0:40:10:0 | 4.53±0.058 $^{dc}$ | 36.10±0.82 $^{dc}$ | 41.00±0.87 $^{e}$ | 16.89±0.34 $^{e}$ | 1.14±0.05 $^{gfed}$ |
| 35:0:50:15:0 | 4.34±0.14$^{c}$ | 36.67±0.58 $^{c}$ | 42.40±0.34 $^{ed}$ | 10.20±0.10 $^{h}$ | 1.16±0.01 $^{fed}$ |
| 30:0:50:20:0 | 4.73±0.25$^{c}$ | 37.00±1.00 $^{c}$ | 43.33±1.53 $^{d}$ | 12.40±0.56 $^{g}$ | 1.17±0.07 $^{fed}$ |
| 25:0:50:25:0 | 5.07±0.06$^{h}$ | 30.94±0.83 $^{h}$ | 36.33±0.58 $^{gf}$ | 15.60±0.36 $^{f}$ | 1.17±0.03 $^{ed}$ |
| 29:0:50:20:1 | 5.03±0.03$^{hgfe}$ | 33.00±3.61 $^{hgfe}$ | 35.33±3.05 $^{g}$ | 10.27±0.04 $^{h}$ | 1.07±0.027 $^{g}$ |
| 28:0:50:20:2 | 5.10±0.10f$^{edc}$ | 34.67±1.53$^{fedc}$ | 36.73±2.05 $^{gf}$ | 10.85±0.67 $^{h}$ | 1.06±0.05 $^{g}$ |
| 27:0:50:20:3 | 5.13±0.15 $^{dc}$ | 36.00±1.00 $^{dc}$ | 38.53±1.56 $^{f}$ | 10.69±0.51 $^{h}$ | 1.07±0.02 $^{g}$ |
| F value | 151.23** | 29.777** | 79.71** | 485.6** | 65.4** |
| CD | 4.71 | 29.80 | 27.29 | 10.71 | 0.92 |

*Significant at 5 % level, ** significant at 1 % level, Values with the same letter are not significantly different

WS- Wheat Semolina ; UFMF -Unprocessed Foxtail Millet Flour; SFMF –Steamed Foxtail Millet Flour; BF- Black gram dhal flour; WS- Wheat Semolina; FSP- Fenugreek Seed Powder

4.2.8 Sensory analysis of vermicelli:

4.2.8.1 Sensory analysis for optimized combinations of raw vermicelli

Sensory evaluation of vermicelli prepared from different proportions of flours was done for different parameters *viz.,* appearance, colour texture firmness and overall acceptability with the help of semi-trained panel.

When each sensory parameter was considered individually, the sensory scores for 50:29:20:1 was on par with wheat semolina. The firmness of 20 per cent black gram dhal flour incorporated vermicelli was significantly higher than the wheat semolina vermicelli (Table 11)

4.2.8.2 Sensory evaluation of cooked vermicelli:

The Sensory score for appearance, colour, texture, smoothness, firmness, flavour, taste and overall acceptability were highest for wheat semolina vermicelli.

With respect to overall acceptability the wheat semolina vermicelli scored highest (8.4). 20 per cent black gram dhal vermicelli and 1 per cent fenugreek seed powder incorporated vermicelli stood next to semolina vermicelli (7.8 and 7.6) which was significantly not different from each other. Hence, 1 per cent fenugreek seed powder incorporated vermicelli was chosen for further study.

## 4.3. Characterisation of developed vermicelli

Table 13 shows the physical characteristics of wheat and foxtail millet vermicelli the wheat and foxtail millet vermicelli was white in colour where as foxtail millet vermicelli was dark cream in colour. The L value which depicts lightness was significantly higher in case of foxtail millet vermicelli (92.98). A values which depects redness was higher in wheat vermicelli (0.39) than foxtail millet vermicelli (0.35) where as b and c values were higher in foxtail millet vermicelli (7.53, 7.53) than wheat vermicelli (6.85, 6.86).

4.3.1 Physical characteristics of developed foxtail millet vermicelli

The diameter of raw strands of vermicelli was significantly higher in wheat vermicelli (0.85) than foxtail millet vermicelli (0.74). Volume of raw wheat vermicelli was (1.06) was significantly higher than the raw foxtail millet vermicelli (1.13). Raw bulk density of foxtail millet vermicelli was significantly higher in foxtail millet vermicelli (1.13 ml) than wheat vermicelli (0.24) than foxtail millet vermicelli (1.13 grams)

4.3.2 Physical and functional properties of vermicelli

The swelling power and per cent solubility of wheat vermicelli (12.28, 33.67 respectively) significantly higher than the foxtail millet vermicelli (8.2, 36.48 respectively)

Time taken for cooking was significantly higher in case of wheat vermicelli (6.9) than foxtail millet vermicelli (5.03 min) With regard to cooked weight, volume, Expansion ratio, wheat vermicelli was significantly higher (59.11, 55.1 and 1.45) than foxtail vermicelli. Whereas expansion ratio of wheat vermicelli.

4.3.3 Sensory quality of developed cooked foxtail millet vermicelli

The Sensory quality of developed cooked foxtail millet vermicelli is presented in table 15. The mean sensory scores of the developed foxtail millet *viz.,* appearance, colour, texture, smoothness, firmness, flavour and taste were significantly higher (1% level) in the wheat semolina vermicelli compared foxtail millet vermicelli.

4.3.4 Chemical composition of vermicelli

The chemical composition of foxtail millet based vermicelli has been presented in Table (16). The chemical composition of composite mix flour showed the higher values when compared to the developed vermicelli with respect to moisture (9.36% Vs 6.71), fat (0.47 Vs 0.21) and crude fiber (0.45 Vs 0.31). However, the means for moisture content were significantly different (at 1% level)

On the other hand foxtail millet vermicelli showed higher values compared to composite mix flour in terms of protein (13.3 Vs. 14.3 %), ash (1.18 Vs. 1.4%) and total dietary fiber ( 21.8 Vs 22.16 %), whereas only ash and carbohydrate content were found to be significantly different (at 5% levels).

**Table 11. Sensory analysis optimised raw vermicelli (mean± S.D)**

| WS: UFMF: SFMF:BF:FSP | Appearance | Colour | Texture | Firmness | Overall |
|---|---|---|---|---|---|
| 100:0:0:0:0 | 8.1±0.99a | 8.1±1.197a | 8.1±0.99a | 8.1±0.99a | 8.2±0.79a |
| 50:0:50:0:0 | 6.6±0.7b | 6.9±0.74c | 6.6±0.84b | 6.5±0.71c | 6.5±0.53b |
| 30:0:50:20:0 | 6.6±1.51b | 6.6±1.075c | 6.8±1.23b | 7.0±1.33b | 6.6±1.58b |
| 29:0:50:20:1 | 7.9±1.1a | 7.7±0.67a | 7.9±0.88a | 7.9±0.88a | 7.8±0.79a |
| 'F' value | 2.73 | 5.38 | 5.3 | 5.64 | 7.27 |
| Sem ± | 0.37 | 0.31 | 0.31 | 0.32 | 0.32 |
| CD | NS | 1.15** | 1.21** | 1.22** | 1.22** |
| CV | 16.28 | 12.93 | 13.46 | 13.62 | 13.76 |

*Significant at 5 % level, ** significant at 1 % level, Values with the same letter are not significantly different

WS- Wheat Semolina ; UFMF -Unprocessed Foxtail Millet Flour; SFMF –Steamed Foxtail Millet Flour; BF- Black gram dhal flour; WS- Wheat Semolina; FSP- Fenugreek Seed Powder

**Table 12. Sensory evaluation of optimised cooked vermicelli #**

| WS: UFMF: SFMF:BF:FSP | Appearance | Colour | Texture | Smoothness | Firmness | Flavour | Taste | Overall acceptability |
|---|---|---|---|---|---|---|---|---|
| 100:0:0:0:0 | 8.30±0.82a | 8.30±0.67a | 8.00±0.82c | 8.20±0.79a | 8.00±0.82a | 7.90±0.74a | 8.10±0.74a | 8.40±0.70a |
| 50:0:50:0:0 | 7.00±0.82b | 7.10±0.74b | 6.60±1.17b | 6.90±0.74b | 6.70±1.25a | 7.00±0.67ab | 6.50±1.18b | 7.10±0.74c |
| 30:0:50:20:0 | 7.00±0.82b | 7.00±0.82b | 6.80±0.63b | 6.90±0.57b | 7.20±0.42b | 7.40±0.84ab | 7.00±0.47b | 7.80±0.42b |
| 29:0:50:20:1 | 6.90±0.57b | 7.00±0.67b | 6.90±0.74b | 6.80±0.79b | 7.20±0.63b | 7.30±0.67a | 6.90±1.10b | 7.60±0.52bc |
| F value | 7.66** | 4.03** | 5.30** | 8.46** | 4.12* | 1.4NS | 5.57** | 7.83* |
| S Em | 0.95 | 0.92 | 1.06 | 0.91 | 0.99 | 0.92 | 1.10 | 0.75 |
| CD | 4.30 | 4.12 | 4.78 | 4.10 | 4.44 | NS | 4.96 | 3.38 |

*Significant at 5 % level, ** significant at 1 % level, **# -** evaluated by using 9 pint hedonic scale by panel of semi trained judges**.**

Values with the same letter are not significantly different

WS- Wheat Semolina ; UFMF -Unprocessed Foxtail Millet Flour; SFMF –Steamed Foxtail Millet Flour; BF- Black gram dhal flour; WS- Wheat Semolina; FSP- Fenugreek Seed Powder

**Table 13. Physical characteristics of developed foxtail millet vermicelli**

| **Physical Parameters** | **Vermicelli** | | **'t' value** |
|---|---|---|---|
| | **Foxtail millet** | **Wheat semolina** | |
| Colour (visual appearance ) | Dark cream | White | |
| L | 92.76 ± 0.02 | 92.98 ± 0.01 | 24.58** |
| a* | 0.39 ± 0.01 | 0.35 ± 0.01 | 5.5 * |
| b* | 6.85 ± 0.01 | 7.53 ± 0.01 | 117** |
| C | 6.86 ± 0.01 | 7.53 ± 0.01 | 116** |
| Diameter (cm) | 0.74 ± 0.01 | 0.85 ± 0.01 | 34.00** |
| Volume (ml) | 9.6 ± 0.1 | 8.77 ± 0.02 | 16.97** |
| Bulk density(g/ml) | 1.13 ± 0.02 | 1.06 ± 0.01 | 4.5* |
| Tension force (g) | 0.09 ± 0.01 | 0.24 ± 0.02 | 5.6** |

L=lightness, -b=yellowness, +b=greenness

*Significant at 5 % level, ** significant at 1 % level

**# -** evaluated by using 9 pint hedonic scale by panel of semi trained judges**.**

Values with the same letter are not significantly different

**Table 14. Functional properties of developed foxtail millet vermicelli**

| Parameters | Vermicelli | | 't' value |
|---|---|---|---|
| | Foxtail millet | Wheat semolina | |
| Weight (g/10) | 46.07 ± 0.11 | 59.11 ± 0.01 | 23.21** |
| Volume (ml/10g) | 41.17 ± 0.15 | 55.1 ± 0. 1 | 41.8** |
| Density (g/ml) | 1.12 ± 0.01 | 1.07 ± 0.01 | 6.04* |
| Cooking time (min) | 5.03 ± 0.01 | 6.9 ± 0.01 | 61.1** |
| Swelling power | 8.2 ± 0.23 | 12.28 ± 0.36 | 12.3** |
| Percent solubility | 30.67 ± 5.2 | 36.48 ± 0.01 | NS |
| Cooking loss (g/100g) | 12.31 ± 0.01 | 8.83 ± 0.01 | 39.4** |
| Expansion ratio | 1.33 ± 0.01 | 1.45 ± 0.02 | 20.78** |

*Significant at 5 % level, ** significant at 1 % level

**Table 15. Sensory quality of developed cooked foxtail millet vermicelli**

| Sensory Characteristics | Wheat vermicelli | Foxtail Millet | 't' value |
|---|---|---|---|
| Colour | 8.30±0.67 | 7.2±0.67 | 24.26** |
| Flavour | 7.90±0.74 | 7.3±0.67 | 18.3 ** |
| Appearance | 8.32±0.82 | 6.98±0.57 | 44.6** |
| Texture | 8.25±0.82 | 7.23±0.74 | 23.06** |
| Smoothness | 8.24±0.79 | 6.9±0.79 | 22.03** |
| Firmness | 8.00±0.82 | 7.15±0.63 | 11.13** |
| Taste | 8.12±0.74 | 6.91±1.10 | 22.01** |
| Overall acceptability | 8.41±0.70 | 7.67±0.52 | 23.9** |

* Significant at 1% level, ** Significant at 5% level

**Table 16. Nutritive value of composite flour and foxtail millet vermicelli**

| Nutrient (%) | Composite mix flour | Vermicelli | | 't' value between mix and foxtail millet vermicelli | 't' value between foxtail millet vermicelli and wheat vermicelli |
|---|---|---|---|---|---|
| | | Foxtail millet | Wheat Semolina # | | |
| Moisture | 9.36±0.17 | 6.73±0.18 | 11.7 | 23.99** | 0.00** |
| Fat | 0.27±0.02 | 0.21±0.02 | 0.40 | NS | 0.002** |
| Crude fibre | 0.45±0.07 | 0.32±0.02 | 0.20 | NS | 0.007** |
| Protein | 13.33±0.37 | 14.32±0.29 | 8.70 | NS | 32.85** |
| Ash | 1.18±0.082 | 1.42±0.08 | 0.70 | 5.6* | 15.9** |
| Carbohydrate | 75.41±0.40 | 77.0±0.09 | 78.24 | 6.5* | 6.80* |
| SDF | 4.9±0.09 | 4.79±0.2 | --- | NS | |
| TDF | 16.93±0.07 | 17.4±1.11 | --- | NS | |
| IDF | 21.83±0.07 | 22.17±1.31 | --- | NS | |

*Significant at 5 % level, ** significant at 1 % level

# computed values: Gopalan *et.al.* 2008.

## 4.4 Storage quality of developed foxtail millet vermicelli

### 4.4.1 Effect of storage on physical characteristics of vermicelli

The physical parameters *viz*. width of raw and cooked vermicelli, raw and cooked bulk density were assessed for wheat and foxtail millet vermicelli at monthly intervals for a period of six months of storage.

Diameter of wheat vermicelli (0.85 mm) was significantly higher than the foxtail millet vermicelli (0.73mm) at zero days of storage (Table 17). On the other hand the diameter did not vary with storage of six month in wheat and foxtail vermicelli. The cooked diameter of wheat semolina vermicelli was higher than the foxtail millet vermicelli at zero days of storage, which did not differ significantly at the end of the storage period. The raw bulk density of foxtail millet vermicelli (1.19 g/ml) was significantly lower than the wheat vermicelli (1.05 g/ml) at zero days of storage. In, wheat semolina and foxtail millet vermicelli, the bulk density significantly decreased (0.98, 1.17 respectively) at the end of the storage period.

Cooked bulk density was found to be similar in wheat and foxtail vermicelli (1.10 g/ml) at initial stage of storage. But it did not differ significantly at the end of the storage period.

### 4.4.2 Effect of storage on cooking quality of vermicelli

The cooking loss of foxtail millet vermicelli (12.3%) was significantly higher than the control vermicelli (8.84%) at initial stage of storage (Table 18, Fig 3,4). At the end of the storage period, cooking loss was found to significantly reduced in both wheat and foxtail millet vermicelli (86.72 g/100g, 10.85 g/100g respectively). The initial expansion ratio of wheat and foxtail millet vermicelli (1.46, 1.33) increased up to 1.53, 1.36 respectively at the end of the storage period. The expansion ratio of wheat vermicelli was significantly higher than the foxtail vermicelli.

### 4.4.3 Effect of storage on organoleptic characteristics of vermicelli

Storage quality and acceptability of foods depends upon several factors such as available moisture and fat content. Packaging material, storage environment and handling operations do have a profound impact on shelf life of foods and thus affects the sensory attributes.

The results of impact of storage on the sensory attributes of foxtail millet based vermicelli in comparison with wheat vermicelli are depicted in Table 19. It was observed that storage has less effect on all sensory parameters of the vermicelli. The wheat vermicelli had higher sensory score for all parameters at zero days of storage. At the end of the storage period non significant changes were observed for all the parameters. The mean scores for different sensory parameters viz. Appearance, colour, flavour, texture and overall acceptability showed an improvement from initial storage to the end of 6 months storage for both wheat and developed vermicelli. With regard to appearance, colour and texture the wheat vermicelli was more acceptable than the foxtail millet vermicelli however, they were similar in case of taste and overall acceptability at zero days of storage. Whereas there was significant improvement in the mean scores of appearance, flavour and texture of both wheat and foxtail millet vermicelli at the end of the storage period.

### 4.4.4 Effect of storage on moisture and free fatty acid content of developed vermicelli

Table 20 (Fig5), shows the effect of storage on FFA content and moisture content of vermicelli. The initial free fatty acid content of foxtail millet vermicelli was 0.69 percent which was significantly higher than the wheat vermicelli (0.21 %)The mean FFA content during six month of storage increased significantly in both wheat vermicelli (0.21 – 0.003) and foxtail millet vermicelli (0.69 -1.50%) . The moisture content of foxtail vermicelli (5.74%) was found to be significantly lower than the control (6.83) at zero days of storage, which increased gradually with progression of storage period. At the end of the storage period the moisture content of wheat vermicelli and foxtail vermicelli increased up to 10.19 per cent and 9.61 per cent respectively (Fig 6).

**Table 17. Effect of storage on physical characteristics of vermicelli (mean ±SD)**

| Storage (months) | Width (raw) | | Diameter (cooked) | | Bulk density (raw) | | Bulk density (cooked) | |
|---|---|---|---|---|---|---|---|---|
| | Wheat vermicelli | Foxtail Millet vermicelli | Wheat vermicelli | Foxtail Millet vermicelli | Wheat vermicelli | Foxtail Millet vermicelli | Wheat vermicelli | Foxtail Millet vermicelli |
| 0 | 0.85±0.01 | 0.73±0.017 | 1.24±0.14 | 1.05±0.04 | 1.19±0.03 | 1.11±0.02 | 1.10±0.04 | 1.10±0.03 |
| 1 | 0.85±0.02 | 0.74±0.021 | 1.27±0.15 | 1.03±0.02 | 1.27±0.04 | 1.10±0.04 | 1.13±0.01 | 1.08±0.01 |
| 2 | 0.85±0.02 | 0.73±0.010 | 1.28±0.13 | 1.04±0.02 | 1.17±.01 | 1.04±0.05 | 1.13±0.02 | 1.06±0.01 |
| 3 | 0.85±0.02 | 0.73±0.015 | 1.29±0.12 | 1.04±0.03 | 1.26±0.03 | 1.03±0.01 | 1.14±0.01 | 1.09±0.03 |
| 4 | 0.85±0.02 | 0.74±0.015 | 1.31±0.15 | 1.00±0.09 | 1.25±0.01 | 1.02±0.01 | 1.11±0.01 | 1.13±0.01 |
| 5 | 0.85±0.01 | 0.74±0.021 | 1.33±0.15 | 0.98±0.07 | 1.24±0.02 | 1.00±0.00 | 1.13±0.02 | 1.09±0.02 |
| 6 | 0.85±0.02 | 0.73±0.017 | 1.37±0.06 | 0.98±0.07 | 1.17±0.01 | 1.02±0.01 | 1.13±0.03 | 1.07±0.01 |

| | Width (raw) | | | Diameter (cooked) | | | Bulk density (raw) | | | Bulk density (cooked) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ‘F’ value | SEM± | CD | ‘F’ value | SEM± | CD | ‘F’ value | SEM± | CD | ‘F’ value | SEM± | CD |
| Month (M) | 0.150 | 0.007 | NS | 0.057 | 0.041 | NS | 7.99 | 0.1 | 0.28** | 1.290 | 0.009 | NS |
| Sample (S) | 504.3 | 0.004 | 0.07** | 81.97 | 0.022 | 0.06** | 518.34 | 0.006 | 0.02** | 30.778 | 0.004 | 0.072** |
| Interaction (W*S) | 0.183 | 0.01 | NS | 0.663 | 0.058 | NS | 8.511 | 0.015 | 0.04** | 4.985 | 0.01 | 0.048* |

*Significant at 5 % level, ** significant at 1 % level

**Table 18. Effect of storage on cooking quality of vermicelli**

| Storage (months) | Cooking loss (mg/100g) | | | Expansion ratio | | |
|---|---|---|---|---|---|---|
| | Foxtail vermicelli | Wheat semolina vermicelli | | Foxtail vermicelli | Wheat semolina vermicelli | |
| 0 | 12.30±2.46 | 8.84±0.23 | | 1.33±0.07 | 1.46±0.15 | |
| 1 | 11.83±0.96 | 7.97±0.06 | | 1.39±0.03 | 1.48±0.17 | |
| 2 | 12.20±0.61 | 7.15±0.23 | | 1.41±0.01 | 1.50±0.12 | |
| 3 | 13.07±0.21 | 6.90±0.13 | | 1.33±0.10 | 1.52±0.11 | |
| 4 | 12.8±0.27 | 7.03±0.21 | | 1.34±0.06 | 1.54±0.14 | |
| 5 | 10.93±0.41 | 6.98±0.07 | | 1.34±0.10 | 1.54±0.19 | |
| 6 | 10.85±0.553 | 6.72±0.197 | | 1.36±0.09 | 1.53±0.24 | |
| | 'F' value | SEM± | CD | 'F' value | SEM± | CD |
| Month (M) | 3.99 | 0.31 | 0.86 ** | 0.18 | 0.05 | NS |
| Sample (S) | 387.24 | 0.166 | 0.46** | 10.37 | 0.03 | 0.50* |
| Interaction (W*S) | 2.81 | 0.44 | 1.22* | 0.70 | 0.07 | NS |

*Significant at 5 % level, ** significant at 1 % level

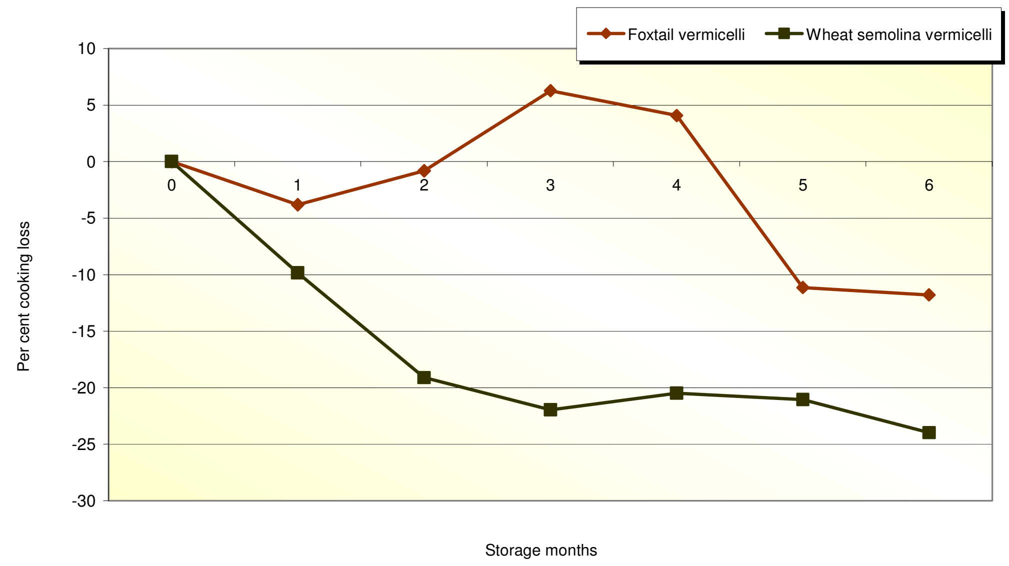


**Fig. 3. Per cent reduction in cooking loss content on storage**

**Fig. 3. Per cent reduction in cooking loss content on storage**

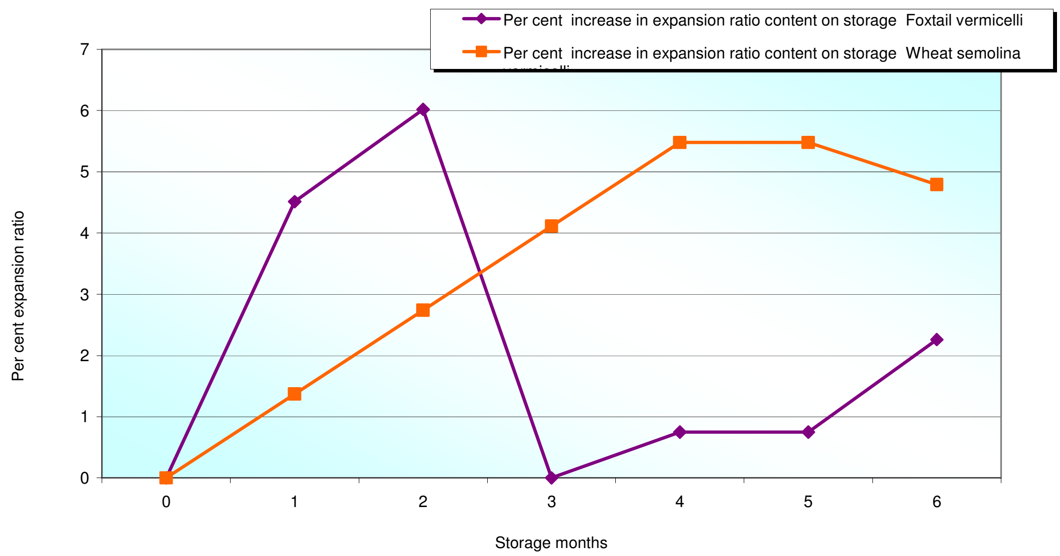


**Fig. 4. Per cent increase in expansion ratio content on storage**

**Fig. 4. Per cent increase in expansion ratio content on storage**

**Table 19. Effect of storage on sensory quality of foxtail millet vermicelli (mean ±SD)**

| Storage (months) | Appearance | | Colour | | Flavour | | Texture | | Taste | | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Wheat vermicelli** | **Foxtail vermicelli** | **Wheat vermicelli** | **Foxtail vermicelli** | **Wheat vermicelli** | **Foxtail vermicelli** | **Wheat vermicelli** | **Foxtail vermicelli** | **Wheat vermicelli** | **Foxtail vermicelli** | **Wheat vermicelli** | **Foxtail vermicelli** |
| 0 | 8.33±0.58 | 6.90±0.58 | 8.33±0.58 | 7.00±0.58 | 7.90±0.00 | 7.33±0.58 | 8.00±0.12 | 6.9±1.00 | 8.1±0.12 | 6.9±0.29 | 8.40±0.06 | 7.67±0.58 |
| 1 | 6.90±0.40 | 9.00±0.00 | 8.33±0.58 | 7.00±0.00 | 6.90±0.40 | 8.33±0.58 | 6.93±0.51 | 8.67±0.58 | 7.60±0.53 | 9.00±0.00 | 7.33±0.58 | 8.67±0.58 |
| 2 | 8.67±0.58 | 8.17±0.29 | 8.00±1.00 | 7.67±0.58 | 8.00±0.00 | 7.67±0.58 | 8.00±1.00 | 8.00±1.00 | 9.00±0.00 | 8.00±0.00 | 7.67±0.58 | 7.67±0.58 |
| 3 | 7.00±1.00 | 9.00±0.00 | 8.00±1.00 | 7.33±0.58 | 7.67±0.58 | 8.67±0.58 | 7.00±1.00 | 8.00±1.00 | 7.67±0.58 | 9.00±0.00 | 7.33±0.58 | 8.00±1.00 |
| 4 | 8.67±0.58 | 8.50±0.50 | 9.00±0.00 | 7.50±0.25 | 8.33±0.58 | 7.83±0.76 | 8.33±1.15 | 7.50±0.50 | 9.00±0.00 | 8.00±0.00 | 8.00±1.00 | 8.00±1.00 |
| 5 | 7.00±1.00 | 8.67±0.58 | 8.67±0.58 | 7.83±0.29 | 7.33±0.58 | 8.67±0.58 | 7.00±1.00 | 8.83±0.29 | 8.00±0.00 | 9.00±0.00 | 7.67±0.58 | 8.83±0.2 |
| 6 | 9.00±0.00 | 8.17±0.29 | 9.00±0.00 | 8.00±0.00 | 8.00±0.00 | 7.67±0.29 | 8.00±1.00 | 8.17±0.29 | 9.00±0.00 | 8.00±0.00 | 8.33±1.15 | 8.17±0.29 |

| | Appearance | | | Colour | | | Flavour | | | Texture | | | Taste | | | Overall | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 'F' value | SEM± | CD | 'F' value | SEM± | CD | 'F' value | SEM± | CD | 'F' value | SEM± | CD | 'F' value | SEM± | CD | 'F' value | SEM± | CD |
| Month (M) | 2.1 | 0.12 | NS | 2.20 | 0.62 | NS | 1.03 | 0.204 | NS | .346 | .334 | NS | 1.22 | 0.092 | 0.26 | 0.754 | 0.285 | NS |
| Sample (S) | 14.96 | 0.225 | 0.33** | 32.16 | 0.33 | 0.12* | 3.21 | 0.109 | NS | 4.710 | 0.178 | 0.49* | 0.92 | .049 | 0.14 | 3.28 | 0.152 | NS |
| Interaction (W*S) | 7.63 | 0.318 | 0.88* | 0.78 | 0.87 | NS | 5.23 | 0.288 | 0.80** | 2.241 | 0.472 | NS | 38.34 | 0.13 | 0.36 | 1.34 | 0.403 | NS |

*Significant at 5 % level, ** significant at 1 % level,

**Table 20. Effect of storage on moisture and free fatty acid (FFA) content of vermicelli**

| Storage (months) | Effect of storage on moisture and FFA content vermicelli | | | | | |
|---|---|---|---|---|---|---|
| | Moisture | | | FFA | | |
| | Foxtail vermicelli | | Wheat semolina vermicelli | Foxtail vermicelli | | Wheat semolina vermicelli |
| 0 | 6.83±0.03 | | 5.74±0.03 | 0.69±0.01 | | 0.21±0.00 |
| 1 | 7.15±0.05 | | 6.21±0.12 | 0.81±0.01 | | 0.28±0.01 |
| 2 | 7.80±0.05 | | 6.49±0.05 | 0.83±0.00 | | 0.32±0.01 |
| 3 | 8.2±0.04 | | 6.86±0.06 | 0.85±0.01 | | 0.42±0.02 |
| 4 | 8.91±0.13 | | 7.30±0.08 | 1.01±0.04 | | 0.47±0.01 |
| 5 | 9.57±0.10 | | 8.27±0.06 | 1.34±0.02 | | 0.53±0.01 |
| 6 | 10.19±0.20 | | 9.61±0.06 | 1.50±0.024 | | 0.57±0.01 |
| | SEM± | CD | 'F' value | SEM± | CD | 'F' value |
| Month (M) | 0.036 | 0.10** | 1.29 | 0.007 | 0.185** | 1.071 |
| Sample (S) | 0.019 | 0.05 ** | 1.89 | 0.003 | 0.28** | 1.512 |
| Interaction (W*S) | 0.050 | 0.14** | 22.11 | 0.009 | 0.22** | 202.40 |

*Significant at 5 % level, ** significant at 1 % level

# DISCUSSION

The present investigation entitled "Development and evaluation of foxtail millet based vermicelli" was carried out with an objective to develop the foxtail millet based vermicelli and to evaluate its storage stability. The results are discussed here.

## 5.1. Development of value added foxtail millet vermicelli

Vermicelli is extruded convenience food. It is manufactured using durum wheat semolina or refined wheat flour. It is extruded into strands after mixing with water, dried and stored; it has a long shelf life. It is eaten in festivals as *kheer* or a dessert and is a common snack item at homes. It is possible to use non durum wheat and other ingredients viz., millets, pulses, soybean and other functional ingredients to increase its nutritional value to the consumer compared to the conventional vermicelli.

The development of enriched vermicelli with higher nutrients and dietary fiber content would be a good way to increase the fiber intake of vermicelli.

Foxtail millet is a hardy crop, cultivated in rain fed areas. It has a capacity to survive in very harsh conditions. The grains are small in size, and do not require fertilizer application.

Nutritionally, foxtail millet is rich in phenols, fiber and mineral. However the use of foxtail millet and other small millets has been declining over the years. So in the present study an attempt was made to develop foxtail millet based composite mix flour and vermicelli.

Vermicelli is commercially available under a number of brand names and easy to cook with best time and effort. Since commercially available vermicelli is made of refined flour or semolina, it gives calorific value and protein content. Foxtail millet used in the present study would be useful in increasing the dietary fiber content. Adult consumers are giving more importance to the fiber content in food products for health and prevention of degenerative diseases. The foxtail millet is used in preparation of low glycemic products. It is rich in non starch polysaccharides and dietary fiber. Hence, the foxtail millet flour was used as a functional ingredient and incorporated in to the composite mix flour by replacing the semolina. Foxtail millet flour beyond 20 per cent level resulted in vermicelli strands that were easily breakable and short in length. On drying it was easily breakable, on cooking vermicelli disintegrated in to pieces and cooking loss was high. Vermicelli was mashy in texture. Cooked weight and volume was lower than that of the control. Further processing of foxtail millet was done by steaming (Fig.1) for improving the vermicelli quality as suggested in the literature (Poongudi *et al*, 2008). Use of processed foxtail millet flour in vermicelli showed an improvement in the vermicelli strands in terms of length, non starchy mouth coating and reduction in cooking time and cooking loss (Table 5). It also had acceptable sensory characteristics. This may be due to steaming, which leads to gelatinization of starch, after drying it leads to retrogradation of starch, which is not easily soluble in water (Bustos *et al,* 2011). Further addition of black gram dhal flour (20 %) improved the dough characteristics, cooking quality in terms of cooking time and cooking loss and bulk density. Decrease in cooking loss in black gram dhal incorporated vermicelli may be attributed to the structural changes in the protein network by foxtail millet and black gram dhal (Madhumitha *et al.*,2011) . Addition of black gram dhal improved the cooking quality, this may be due to presence of higher protein and sticky and gummy characteristics of dhal flour.

Fenugreek is one of the functional ingredients known for its high soluble fibre content, hypoglycemic and hypocholestrolemic effect. In the present study, its addition at 1 per cent level decreased the cooking loss (Table 10) and retained all the quality characteristics of vermicelli with sensory score of 7.6 which stood next to the control vermicelli in acceptability. The ratio of 50:29:20:1 for ingredients viz., foxtail millet, wheat semolina, black gram dhal, fenugreek seed powder, respectively were accepted for composite mix flour for the development of vermicelli. The process chart for the standardized vermicelli is presented in Fig 3. The density of the grains was highest in foxtail millet followed by black gram dhal and least in fenugreek seeds, however the density of semolina was higher than the other flours used in composite mix flour. The variation in density of flours affects the cooking quality of the developed vermicelli. The water addition for the preparation of vermicelli from composite mix flour required lower amount of water and less time for kneading as compared to the control (65 and 80 ml respectively, 5 and 7 minutes, Table 8). This is due to higher gluten in the control which absorbs more water and requires more time for kneading since, it is elastic in property.

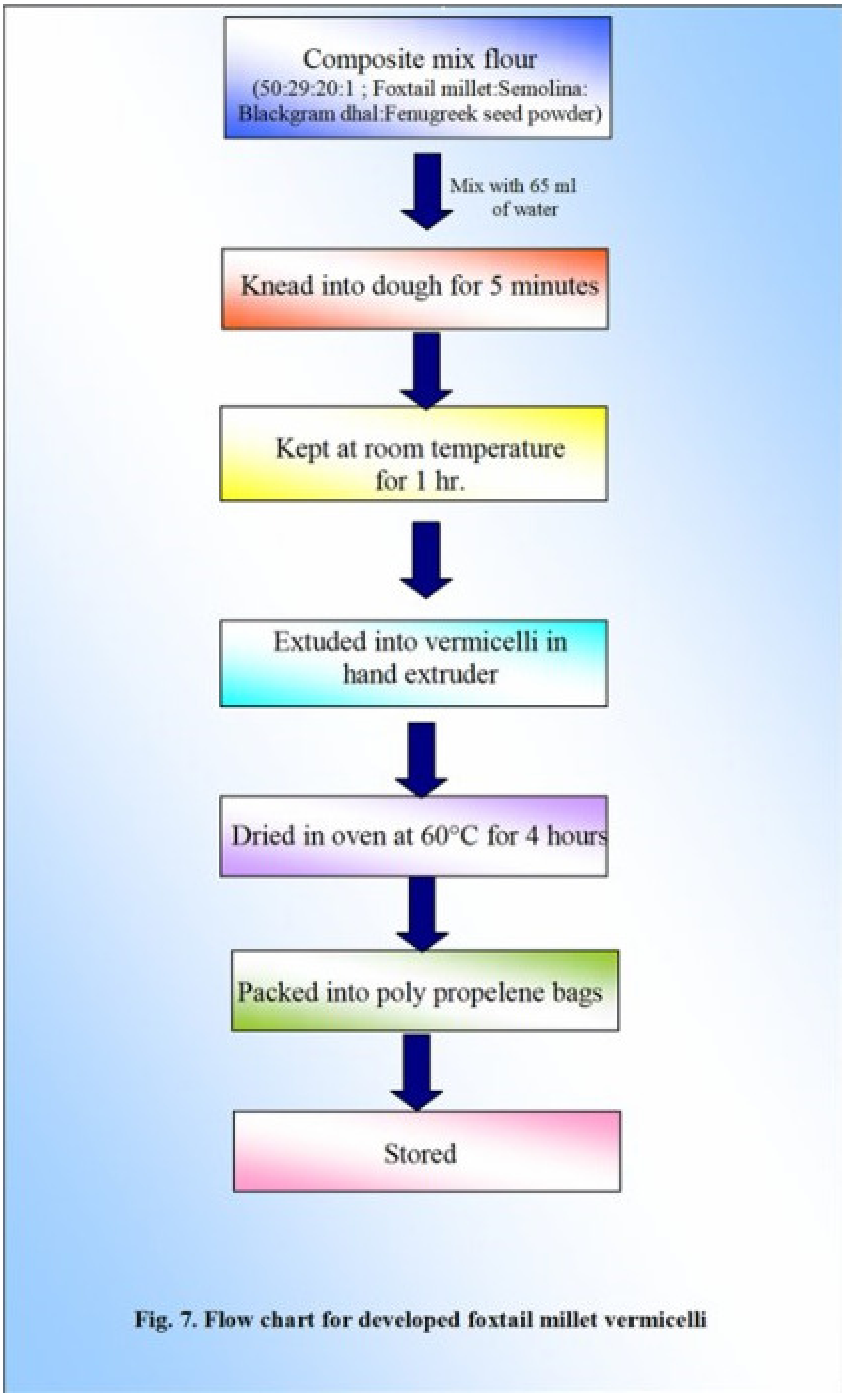


**Fig 7. Flow chart for developed foxtail millet vermicelli**

**Plate 2. Developed foxtail vermicelli**

**Plate 3. Control wheat vermicelli**

The breaking strength and extensibility (Table 9) was highest in case of wheat vermicelli, when different functional ingredients were added at different levels the strength of the strands and extensibility reduced significantly, it was because of lack of gluten in composite mix flour. Gluten has elasticity and strength which shows the higher breaking strength. With decrease in the wheat flour in composite mix flour the breaking strength decreased. Similarly, Mridula *et al*.,(2008) have noted a gradual decrease in peak breaking force, breaking energy with increase in the level of sorghum flour into the noodles. Reungmanpaitoon *et al*., (2008) found that tensile force and breaking distance of noodles decreased as rice flour content increased.

## 5.2 Characterization of vermicelli

The conventional vermicelli is low in fibre, high in carbohydrate and energy. The pasta and vermicelli can be value added to improve the nutritive value in terms of protein, antioxidants, vitamins and minerals. The dietary fibre and glycemic index can also be improved.

In the present study it was found that the developed foxtail millet vermicelli was lower in fat, higher in protein, crude fibre and ash content in comparison with the wheat vermicelli (Table 16). This was due to the addition of foxtail millet high in fibre and black gram dhal contributing to protein and ash. It is very interesting to note that total dietary fibre in our study was very high (22.17 %). This dietary fibre has useful role in maintaining health through their influence on gastrointestinal tract. Similar studies on value addition of pasta have been carried out and improvement in the nutrients were noted. Osori-Diaz *et al* (2008) have developed pasta with added chickpea flour that exhibited increase in protein, ash, lipid and resistant starch content. Vjayajaysena *et al*, (2008) found that addition of lupin upto 40 per cent significantly increased the protein content by 42 per cent and dietary fibre by 200 per cent. Shrogen *et al.,* (2006) found that durum wheat supplemented with soy flour improved the protein content. Desai *et al.,* (2012) noted that the noodles with 70:30 of wheat flour and malted ragi flour had higher value for protein, fiber and minerals.

Physical and functional parameters analysed for the developed foxtail millet vermicelli showed creamish white colour (Table13, 14). The colour value also showed that foxtail millet vermicelli was lighter, yellower and redder than the control. All the functional and cooking quality parameters were lower in the developed millet vermicelli. The bulk density of vermicelli from millet blend was significantly higher and expansion ratio was lower as compared to the control vermicelli. Camire and King (1991) reported that sample with lower bulk density had larger expansion ratio which stands true in our study. The decrease in expansion ratio was because of increase in protein form black gram dhal added into the vermicelli. Similar observation were made by Balasubramanian and Singh (2007) who reported that the decrease in expansion of extrudates with increase in level of different legumes such as chickpea, green gram and black gram. Singh *et al*. (2006) reported that lower expansion ratio (2.7-3.9) in soy-kodo blends than the wheat pasta. Diameter of raw and cooked developed foxtail millet vermicelli was lower than that of wheat vermicelli. This may be due to the different particle size and constituents of wheat semolina and the composite mix flour.

Tension force, cooked weight, cooked volume, swelling power and percent solubility were significantly higher in wheat vermicelli than foxtail millet vermicelli (Table 13, 14). It is because of different types of ingredients used in preparation of developed foxtail millet vermicelli which does not contain gluten. Proportionately the cooking time of foxtail millet vermicelli was lower than control because wheat flour/semolina has higher gelatinization temperature where as foxtail millet and black gram dhal flour has lower gelatinization temperature which requires longer time to cook. Similar results were reported by Torres *et al* (2006) and Arvind *et al.,*(2012) where they found that cooking time of developed pigeon pea flour added pasta and resistant starch pasta were significantly lower than the wheat pasta. The cooking loss is commonly used as an indicator of cooked pasta quality. Low amounts of cooking loss indicate high pasta cooking quality (Del Nobile, 2005). Dick and Youngs (1988) considered that cooking loss of 7-10 per cent to be acceptable for dried pasta. In this study cooking loss of foxtail millet vermicelli was higher than the wheat vermicelli. It was because of lack of gluten in the developed foxtail millet vermicelli. Sudha *et al*., (1998) reported similar findings in case of vermicelli prepared from finger millet incorporated into semolina. Rahim (1998) reported that vermicelli dough prepared from medium course particles displayed low water absorption (16 %). Poongodi *et al*., (2010) showed that the millet blend noodles had lower swelling power, water absorption capacity, and expansion ratio and bulk density than the branded noodles. Similar results were obtained in our study.

The incorporation of millet flour and black gram dhal flour improved the quality in terms of nutrient density (Table 16). The physical and functional properties affect the organoleptic characteristics of vermicelli.

Vermicelli prepared from semolina wheat flour had high elasticity, good chewiness, springiness and mouth feel , higher water absorption capacity, less bulkiness and had an attractive whitish colour. In our study, the developed foxtail millet vermicelli had the overall acceptability scores lower than the wheat vermicelli (Table 15). It was because foxtail millet vermicelli had lower physico-functional characteristics compared to wheat vermicelli. However, developed foxtail millet based vermicelli has scored the organoleptic scores of 7.6/9 which was acceptable (Table 15).

## 5.3 Storage stability of the developed product

India is one of the largest producer and consumer of vermicelli. It is manufactured in organized and unorganized sectors. The dried pasta products and vermicelli have a long shelf life of one year at ambient temperature due to less moisture and fat content. A number of value added vermicelli have been, developed in India. The shelf life of value added pasta varies with the type of ingredients used, packaging material used, processing conditions, environmental temperature and moisture content.

In the present study, the foxtail millet based vermicelli was stored in polyprylene bags for 6 months at ambient temperature. There was no significant change in the organoleptic characteristics at the end of the storage period. Similar studies have been reported by Gaurkirat Kam *et al.,* (2012), who found that storage of bran enriched pasta for 4 months did not affect its overall acceptability. Payumo *et al* (1969) studied the organoleptic quality of coco noodles prepared from wheat, coco and mung bean flour in the ratio of 50:30:10 and found the noodles were acceptable over storage period of 6 months. Ugare (2008) found that the barnyard millet noodles were acceptable at the end of 2 months of storage. On the other hand Sood and Kaur (2011) reported the decrease in overall acceptability score of wheat noodles at the end of 90 days of storage. This difference in storage stability of pasta many be due to the different ingredients used and moisture uptake of the product during the storage. There was a gradual increase in free fatty acid and moisture content in control and developed vermicelli. However, these chemical changes did not bring about any change in the physical characteristics of the stored vermicelli (Table 17). The free fatty acid value for the developed vermicelli was higher compared to control over a period of 6 months of storage. Similar trend was seen for moisture content but the developed product had lower moisture level than the control. Similar results have been reported by Gaurkirat *et al.,* (2012) Towseef *et al.*, (2011), Sood and Kaur (2001),Vidya and naryan (2008), who have noted increase in moisture and free fatty acids during the storage of pasta.

Apart from chemical changes, in stored vermicelli, physical and functional changes have also occurred during the storage in several studies. In our study, there was an improvement in the cooking quality in terms of reduction in cooking loss. This may be due to the change in the amylose to amyl pectin ratio. With increase in the duration of storage, straight chain amylose get converted to amylopectin which is resistant to leaching upon cooking. Similar studies have been reported by Pinarch *et al.,* (2004), who found that progress in storage of pasta did not increased the leaching of solids in cooking water. So in the present study, developed millet based pasta can be stored for more than six months without affecting its physical, treatment and sensory profile.

## Future line of work:

- Nutritional studies to find out the glycemic index and Intervention studies on health benefits of foxtail millet vermicelli
- To test consumer acceptability, market testing, economic viability and entrepreneurship development of the product.

# SUMMARY AND CONCLUSIONS

An investigation was undertaken in the Department of Food Science and Nutrition, University of Agricultural Sciences, Dharwad, Karnataka in the year 2012-2013, to develop foxtail millet based vermicelli to characterize the developed vermicelli in terms of sensory and nutritional profile and to evaluate storage quality of developed vermicelli.

For development of foxtail millet based vermicelli, the foxtail millet and other functional ingredients were purchased from local market. Physical characteristics of seed and flour *viz.,* 1000 seed volume, weight and bulk density, flour volume and density were assessed using structured procedure. The colour determinations of flour and vermicelli were done by using colorimeter for L, a, b and c values. Functional properties of foxtail millet and other flours viz., water absorption of flour, swelling power and per cent solubility were studied. The physico chemical characteristics of vermicelli like texture was determined using texturometer, cooking time, cooking weight, volume cooking loss was done. Organoleptic characters of vermicelli were done using 9 point hedonic scale by panel of 10 semi trained members. Moisture, protein fat, crude fiber and ash, insoluble and soluble dietary fiber were analysed by AOAC methods. The developed vermicelli were studied for storage stability for a period of 6 months. The samples were evaluated for physical, sensory characteristics, moisture and free fatty acids before and after the 6 months of storage period. Statistical analysis was carried out for all quality parameters using paired t test, one way Anova and two ways Anova.

The salient findings of the study are summarized below:

- The volume of foxtail millet flour semolina, fenugreek seed powder were similar (1.04 ml/g) where as black gram dhal flour had significantly lower volume (10.2 ml/g). The density of different flour did not differ significantly (0.97 g/ml)
- The foxtail millet flour was lighter in colour compared to semolina where as black gram dhal flour was bright white and fenugreek seed powder were and creamish brown in colour.
- The swelling power (per gram) of fenugreek seed powder was highest (8.91) followed by semolina (8.00), foxtail millet (7.2) and least was observed in black gram dhal flour (5.53). These values were found to be highly significant (at 1% level). The per cent solubility of semolina was found to be highest (30.53%) followed by foxtail millet flour (22.36 %) and fenugreek seed powder (26.07%) however least was found in black gram dhal flour (21.53 %).
- As the level of unprocessed foxtail millet level increased (30 % and 40 % increases), the strands were less firm, less sticky and broke easily without any force. Thirty and forty per cent foxtail millet incorporated cooked vermicelli showed less strength and starchy mouth coating.
- Vermicelli prepared with steamed foxtail millet (50 %) were creamish in colour with non sticky, firm, long and separate strands. To enhance the functional and therapeutic quality of developed foxtail millet vermicelli, functional ingredients like black gram dhal flour was tried at 10 to 25 per cent level. Twenty per cent foxtail millet incorporated millets showed acceptable result with long, firm, smooth, separate and non sticky strands. Further value addition with 1 per cent fenugreek seed powder resulted in highly acceptable vermicelli. Finally, foxtail millet flour semolina, black gram dhal flour, fenugreek seed powder in the proportion of 50:29:20:1, was arrived to obtain good quality vermicelli.
- Different processing conditions like water addition (65 ml), mixing time (5 minutes), and dough development time (60 minutes) and drying time (4 hours minutes at 60ºC) were also optimized for developed foxtail millet vermicelli.
- The cooking time of developed foxtail millet based vermicelli was significantly lower (at 1% level) than the wheat semolina vermicelli (5, 03 vs 6.90 Min).
- The cooking loss of developed foxtail millet based vermicelli was higher (10.27 g/100g) than the control vermicelli (7.20g/100g).
- Bulk density of foxtail millet based vermicelli (1.07 g/ml) was on par with wheat semolina vermicelli.
- The mean tensile force required to break raw vermicelli strands were significantly lower in developed foxtail millet than the wheat vermicelli (0.088g vs 0.24g)

- The mean maximum force required to break cooked vermicelli strands and extensibility were significantly higher in control vermicelli (49.17g 12.99 mm) than the foxtail millet based vermicelli (34.84g, 23.91 mm)
- The sensory scores for developed raw vermicelli for colour appearance texture firmness and overall acceptability were on par with control wheat semolina vermicelli.
- The sensory evaluation of cooked vermicelli showed that vermicelli prepared from 50 percent foxtail millet flour 30 per cent wheat semolina and 20 per cent black gram dhal flour had scored next to the control in sensory parameters whereas developed foxtail millet based vermicelli (50% foxtail millet flour, 20% black gram dhal, 29% semolina and 1% fenugreek seed powder) was on par with the vermicelli from 50 percent foxtail millet flour, 20 per cent black gram dhal flour and 30 per cent semolina.
- The sensory evaluation showed that the overall acceptability of foxtail millet based vermicelli did not change significantly over 6 months of storage period.
- The wheat semolina vermicelli and foxtail millet based vermicelli were significantly different from each other before storage in terms of appearance, colour texture with 6 months of storage.
- The moisture content of composite mix flour (9.36%) was significantly higher than foxtail millet vermicelli (6.73%)
- The ash and carbohydrate content of foxtail millet vermicelli (1.42%, 77%) was significantly higher than the composite mix flour (11.8, 75.41% respectively).
- The foxtail millet based vermicelli was significantly higher in free fatty acid content whereas, lower in moisture content than control vermicelli over 6 months of the storage period.
- With the advancement of storage period, mean free fatty acid content of control increased from 0.21 – 0.57 mg KOH/100 gm fat and from 0.67-1.50 mg KOH/100gm in foxtail millet vermicelli at the end of 6 months storage.
- The moisture content in control and wheat vermicelli increased from its initial values of 6.83 to 8.38 per cent and 5.74 to 7.41 per cent, respectively.
- The physical characteristics of developed foxtail millet based vermicelli *viz*, diameter of raw and cooked vermicelli and cooked bulk density did not differ significantly whereas, raw bulk density differed significantly at the end of storage period. Cooking loss decreased significantly in both control and foxtail millet based vermicelli (8.84 – 6.74, 12.30 – 10.85 g/100g, respectively) at the end of storage period.

From the above study it can be concluded that fiber rich foxtail millet based ready to cook vermicelli can be developed using foxtail millet, semolina and other functional ingredients *viz*. black gram dhal and fenugreek seeds in the ratio of 50: 29: 20: 1. The developed foxtail millet based vermicelli had a storage stability of six months.

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# APPENDIX I

SCORE CARD FOR UNCOOKED VERMICELLI
EVALUATION BY 9 POINT HEDONIC SCALE

Rating- 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

| Sample | Colour | Appearance | Texture | Firmness | Overall acceptability |
|---|---|---|---|---|---|
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Comment: Name of the Judge:

Date:

# APPENDIX II

SCORE CARD FOR COOKED VERMICELLI
EVALUATION BY 9 POINT HEDONIC SCALE

Rating: 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

| Sample | Colour | Flavour | Appearance | Texture | Smoothness | Firmness | Taste | Overall acceptability |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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Comment: Name of the Judge:

Date:

# APPENDIX III

## Estimation of protein

Principle

Organic nitrogen digested with sulphuric acid in the presence of catalyst is converted to ammonium sulphate. Ammonium liberated by making the solution alkaline is distilled into a known volume of standard acid, which is then back titrated. Protein per cent was calculated by multiplying the nitrogen presented the factor 6.25.

Reagents

1. 2% boric acid solution: 20g of boric acid was dissolved in some distilled water. The solution was then transferred to a 1000 ml volumetric flask and made up to the mark.
2. 40% NaOH (W/V).
3. 0.1 N HCl: 8.33 ml of fuming HCl was dissolved in 1000ml distilled water.
4. Mixed indicator: Was made by mixing methyl red (0.2%) and Bromocresol green (0.2%) in a 1:2 ratio (v/v) respectively.
5. Digestion mixture: Anhydrous sodium sulphate and copper sulphate
6. Concentrated sulphuric acid ($H_2SO_4$).

Procedure

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

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

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

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

Where:

$V_a$ = Titre value of sample

$V_b$ = Titre value of blank

$V_1$ = Volume to which digested sample was made up (100 ml)

$V_2$ = Volume to aliquot used in distillation

W = Weight of samples taken for digestion

# APPENDIX IV

Estimation of fat

Principle

The extraction of fat from substances is often tedious and requires thorough contact and heating with the solvent. This is done in the soxhlet apparatus in which fresh solvent continuously comes into contact with the material to be extracted over a relatively long period of time.

Procedure

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

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

# APPENDIX V

Estimation of crude fibre

Principle

During the acid and subsequent alkali treatment, oxidative hydrolytic degradation of the native cellulose and considerable degradation of lignin occurs. The residue obtained after final filtration is weighed, incinerated, cooled and weighed again. The loss in weight is the crude fiber content.

Reagents

0.255 ± 0.005 N standard $H_2SO_4$

0.313 ± 0.005 N standard NaOH

Method

Weighed amount of (2.5-5g) of moisture and fat free sample was transferred to a fibre bag which was pre heated and weighed. These bags were inserted into tubes and placed in a beaker provided in the instrument. The sample was boiled with 300ml 0.255 ± 0.005N $H_2SO_4$ for 30 minutes. Then the residue was washed with boiling water until acid free. Then residue was boiled with 300ml of 0.313 ± 0.005 N NaOH for 30 minutes. Again the residue was washed with boiling water followed by alcohol wash. The residue was transferred to pre weighed crucibles(W1) and it was dried to 2 hours at 130± 2 °C, cooled in a desiccators then weighed (W2). The dried desiccators containing samples were then ignited for 30 minutes at 600 ± 15°C. Finally the sample was cooled and weighed again.

$$\text{Crude fibre (g/100g sample)} = \frac{[100-(\text{moisture*}+\text{fat})] \times (W_e-W_a)}{\text{Weight of sample taken (moisture and fat free)}}$$

$W_e$ preweighed ashing dish $W_a$ weight of the dish after ashing

# APPENDIX VI

Estimation of Insoluble dietary fibre (AOAC 1995)

Principle: Defatted foods are gelatinized and proteins and starch are removed by enzymatic digestion. The residue is quantitated gravimetrically.

Reagents:

- 95% Ethanol
- 78% Ethanol
- 0.08M Phosphate Buffer, pH 6.0
- 0.275 N NaOH
- 0.325 N HCl
- α- Amylase heat stable solution
- Protease solution: suspended 50 g protease in 1 ml phosphate Buffer pH 6.0
- Amyloglucosidase solution

Sample Preparation: Homogenise sample and dry overnight in hot air oven at 105ºC, cool in desiccator, and dry mill portion of sample to to 0.3 to 0.5mm mesh. If sample cannot be heated, freeze-dry before milling. If high fat content (75%) prevents paper milling defat with petroleum ether before milling.

Determination: Run the blank through entire procedure along with samples to measure any contribution from reagents residue.

Weigh duplicate 1g of sample, accurate to 0.1 mg, in to 500ml beakers. Sample weight should not differ 20 mg. Add 50 ml of Phosphate buffer and adjust the pH to 6.0, if necessary. Add 0.1 ml heat stable α–amylase solution. Cover the beakers with aluminium foil and place in boiling water bath. Ensure that the contents of the beaker reach 100ºC and incubate for 15 min at this temperature and adjust pH to 7.5 with NaOH solution.

Add 0.1 ml of protease solution to each beaker. Cover beaker with aluminium foil and incubate for 30 min in 60º C with continuous agitation. Cool and adjust pH to 4.0 4.6. Add 0.3 ml amyloglucosidase, and incubate for 30ºC with continuous agitation.

Weigh crucible with a fritted disc containing 1 g celite to constant weight. The celite in the crucible is made into bed by using a stream of 78% ethanol and applying suction. Maintain suction and quantitatively transfer precipitate from enzyme digest to crucible, using filtration module.

Wash residues successively with 3 times 20 ml portions of 78%, two 10 ml portions of 95% ethanol and two 10 ml portions of acetone. Dry crucible containing residue overnight at 100ºC in hot air oven. Cool in desiccator and weigh to nearest 0.1mg. Subtract crucible and celite weight from the above to obtain the insoluble dietary fibre residue (IDF residue).

Analyse residue from one sample of set of duplicates for protein by Kjeldahl method using N ×6.25 as conversion factor and subtract from the IDF residue value.

Incinerate second residue sample of duplicate for 5 h at 525º C. cool in desiccator and weigh to nearest 0.1 mg and subtract from the IDF residue value.

Insoluble dietary fibre= IDF residue –(protein + ash)

# APPENDIX VII

Estimation of Soluble dietary fibre (AOAC 1995)

Principle: The soluble fibre is estimated in the filtrate obtained after enzymatic digestion of protein and carbohydrates of defatted food. The soluble fibre is precipitated and estimated gravimetrically.

Reagents:

- 95% Ethanol
- 78% Ethanol
- 0.08M Phosphate Buffer, pH 6.0
- 0.275 N NaOH
- 0.325 N HCl
- α- Amylase heat stable solution
- Protease solution: suspended 50 g protease in 1 ml phosphate Buffer pH 6.0
- Amyloglucosidase solution

Sample preparation: Homogenise sample and dry overnight in hot air oven at 105ºC, cool in desiccator, and dry mill portion of sample to 0.3 to 0.5mm mesh. If sample cannot be heated, freeze-dry before milling. If high fat content (75%) prevents paper milling defat with petroleum ether before milling.

Determination: Follow the steps of digestion with α-amylase, protease and amyloglucosidase and quantitative transfer the digest and collect the filtrate. Add 4 volumes of pre-heated (60ºC) 95% ethanol. Allow the precipitation to complete for 60 min. filter through an accurately weighed crucible with celite. Follow the procedure given under insoluble fibre to obtain soluble dietary fibre(SDF) residue. Duplicate samples run similarly are analysed for protein and ash.

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

# DEVELOPMENT AND EVALUATION OF FOXTAIL MILLET (*Setaria Italica*) BASED VERMICELLI

**PRAGYA PANDEY** **2013** **Dr. USHA MALAGI**
**Major Advisor**

## ABSTRACT

Foxtail millet (*Setaria italica*) is the second-most widely planted species of millet. It is nutritionally superior to conventional food grains and exhibits hypoglycaemic effect due to presence of higher proportion of unavailable complex carbohydrate and resistant starch. Vermicelli is a popular instant food product which is tasty and easy to make, liked by people of all walks of life, irrespective of age and changing lifestyles. Hence, an attempt was made to develop foxtail millet based value added vermicelli. Standardization trials indicated that acceptable foxtail millet vermicelli could be developed by incorporating 50 per cent processed foxtail millet flour, 20 percent black gram dhal flour and 1 percent fenugreek seed powder in the standard vermicelli recipe. 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/100g, respectively) at the end of storage period. Nutrient analysis revealed that, the moisture, 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. Thus, the study presented an upshot of potentials of foxtail millet as a natural designer health food for the future.