# STANDARDISATION AND QUALITY EVALUATION OF MILLET BASED DESIGNER VERMICELLI


By

S. CHANDRAPRABHA
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THESIS

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## DECLARATION

I, hereby declare that the thesis entitled "**Standardisation and quality evaluation of millet based designer vermicelli**" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed during the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other University or Society.

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Date: 28.10.17

# CERTIFICATE

Certified that the thesis entitled **"Standardisation and quality evaluation of millet based designer vermicelli"** is a bonafide record of research work done independently by **Ms. S. Chandraprabha** under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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# INTRODUCTION

# 1. INTRODUCTION

*"A healthy diet is beneficial not only for reducing the risk of chronic diseases, but also for improving mood and quality of life"*

*-Dr. Hu*

Millets are the underutilized cereal grains that can grow in adverse agro climatic conditions. They are famine reserves which play a major role in the food and nutritional security of millions of people to reduce malnutrition in poor sections of Indian community (Ushakumari *et al.,* 2004). Millets are the sixth cereal crop in terms of world agriculture production. India ranks first in millet production of 11 lakh million tonnes (FAO, 2013). Millet cultivation cover a total area of 23 million hectare.

Millets are small seeded cereals known to human race and possibly the first cereal grain to be used for domestic consumption. Millets are known as nutri cereals as they are rich in B vitamins, calcium, iron, potassium, magnesium, zinc, dietary fibre, phytochemicals and acts as therapeutic food by controlling blood pressure, diabetes and heart disease. Millets are gluten free food recommended for celiac patients.

In present study, barnyard millet (*Echinochloa frumentacea*) was used, as they are considered to be an important minor millet which consist of fair amount of highly digestible protein coupled with low amount of slowly absorbed carbohydrate. They are also a good source of micronutrients and nutraceutical components (Veena, 2003). Barnyard millet characterised by high nutritive and therapeutic qualities can be utilised to develop convenient products which can gain a greater interest among consumers. Barnyard millet consumption has a positive effect to treat several health complications diabetes, obesity, cardiovascular diseases, hypertension and celiac disease. Barnyard millet can be considered as a functional food which has a beneficial effect towards human health (Chandraseker, 2003).

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Functional foods are consumed not only to serve nutrition, beyond that they will provide positive health benefits like health promotion and disease prevention. Consumer's interest towards functional food has increased (Hasler, 1998) and now a day's people are more interested in foods fortified with functional ingredients.

In the present study, four functional ingredients (fenugreek seeds, garden cress seeds, *Brahmi* and *Ekanayakam*) with several bioactive principles were utilised to prepare value added products.

Fenugreek seeds (*Trigonella foenum - graecum*), used in traditional food preparations have several functional properties. Fenugreek seeds rich in carbohydrates and mucilaginous fibres (galactomannans) which has antidiabetic, anticarcinogenic, antioxidant, antibacterial, hypocholesterolemic and hypoglycaemic properties (Meghwal and Goswami, 2012).

Garden cress seed (*Lepidium sativum*) is a food supplement which contains several nutraceutical components with high iron content. The seeds have fair amount of protein, fat, dietary fibre and calcium (Sood and Sharada, 2002). Consumption of garden cress seed helps to prevent hypertension, renal diseases, cancer and which can also act as memory enhancer and laxative for gastrointestinal diseases.

*Brahmi* (*Bacopa monnieri*) is a therapeutic herb native to India, commonly used in ayurvedic medicine as a memory enhancer, aphrodisiac and general tonic (Gubbannavar *et al.*, 2013). *Ekanayakam* (*Salacia reticulata*) is a medicinal herb, now a days used effectively as food supplements to treat diabetes and obesity. *Salacia reticulata* extract was consumed to reduce fasting blood glucose and glycated haemoglobin level in diabetic patients (Jayawardena *et al.*, 2005).

Vermicelli can be prepared by adding a variety of functional ingredients and such a food product can be used as potential vehicle to carry nutraceutical properties (Naik, 2004). Development of functional product with nutritional and

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sensory properties may be beneficial to improve human health. Hence, the present study entitled "Standardisation and quality evaluation of millet based designer vermicelli" was undertaken with the following objectives

1. To standardise millet based designer vermicelli using barnyard millet, whole wheat flour and functional ingredients
2. To evaluate its acceptability, nutritional, health and shelf life qualities
3. To develop an acceptable instant *uppuma* mix with the standardised vermicelli.

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# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

"Our health lies in the hand through the food we consume": this slogan clearly states that consumption of nutrient rich foods enhance our well being. Millets are defined as the crop of food security, health and nutritional security and their consumption can reduce malnutrition and major micronutrient deficiencies in the poor sections of the Indian community

In this chapter, literature pertaining to the studies on the millets production, nutritional significance and value added products of barnyard millet have been reviewed under the following topics:

2.1.Millets

2.2.Barnyard millet

2.3.Nutritional significance and health benefits of barnyard millet

2.4.Value added products from barnyard millet

2.5. Functional ingredients

## 2.1 Millets

Millets, in general, are a group of several varieties of small seeded cereals; belong to the *Poaceacea* family (Hulse *et al.,* 1980). The term millet is employed for several related genera, some used to produce grain, or forage or both. Millets are cereal species growing in an equally broad range of environment.

Millets are the world's earliest food plants used by humans. It has been used as food and feed. Crawford (2006) said that millets were first cultivated in China from 5,500 BC. Millets are designated as the nutritious millets because of this superiority in nutritional properties over the major cereals (Ragaee *et al.,* 2006).

Millets have great importance in local areas, and in ancient times, millets were the staple food in arid and semi-arid tropics of the world, which are distributed in most of the Asian and African countries and certain parts of Europe. Millets are also considered as reserve crops in marginal areas (Michaelraj and Shanmugam, 2013).

Mustapha and Arshad (2014) reported that millets require less water and rainfall adapted to a wide range of ecological conditions. Millets are short duration crop and less prone to pest and diseases.

Millets were classified into two types as major and minor millets depending up on their grain size (Riley *et al.,* 1993). Major millets comprises of sorghum and pearl millet. Minor millets consist of finger millet, kodo millet, proso millet, foxtail millet, little millet and barnyard millet.

The most widely cultivated millets are finger millet (*Eleusine coracona*), foxtail millet (*Setaria itallica*), pearl millet (*Pennisetum typhoideum*), proso millet (*Panicum miliaceum*) and barnyard millet (*Echinochooa frumentacea*). Millets are considered the least important of cereals, with an annual production less than 2.21% of the world's grain (Hulse *et al.*, 1980; FAO, 2013).

Millets rank as the sixth position in cereal, which feeds one third of the total world population. India ranks first in millet production of 11 lakh million tonnes, whereas Senegal and Chad has a lowest millet production of 65 thousand million tonnes (Ahmed *et al.,* 2013). India is the leading millet producer and shares an account of 35.6% (FAO, 2014).

In India, millets are consumed more in states of Gujarat, Karnataka and Maharastra (NNMB, 2006). Radhika *et al.* (2011) reported that cereals grain provides 70-80 per cent of total calories in Indian diet. Among that only 2 per cent calories were provided from millets.

Millets are nutritionally comparable and even superior to major cereals in terms of energy value, proteins, fat and minerals. They are also good sources of

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phytochemicals (phenolic acids, lignans and phytoestrogens), phenolic acids (p – coumaric acid and vanillic acids), that are present in the bran layer of the grains (Qureshi *et al.,* 2000). Haldimani *et al.* (2001) has reported that millets are rich source of nutrients and contain 60–70% dietary carbohydrates, 6–19% protein, 1.5–5% fat, 12–20% dietary fibre, 2–4% minerals. Millet are also rich in linoleic, oleic and palmitic acids (Bagdi *et al.,* 2011).

Millets are considered to be the crops of food security, as it helps to reduce malnutrition among a large proportion of the poor communities (Ushakumari *et al.*, 2004).

Millets are rich in leucine content of 750-1040 mg (NIN, 2007). Gounga and Le (2013) reported that millets are rich in essential amino acids especially methionine and cysteine.

Millets are wonder grain with magical health benefits to reduce the risk of many life style diseases (Nambiar and Patwardhan, 2014).

Millets are rich source of magnesium and potassium which reduce the risk of atherosclerosis by lowering the blood pressure. Lignans present in millets have an ability to react with microflora present in digestive system which protect against the risk of cancer and cardiovascular risk. Millets have slowly digestible starch as they help to prevent diabetes due to their hypoglycemic properties (Itagi, 2003).

Anderson *et al.* (2003) reported that millets are recommended for diabetic patients as they are rich in β glucan which helps to improve glucose metabolism. Millets can be effectively used as a protein supplement to nourish the body due to the presence of essential amino acids like lysine, cysteine and methionine. Millets a rich source of dietary fibre and niacin are responsible to reduce Low Density Lipoprotein (LDL) and improve High Density Lipoprotein (HDL). Consumption of millets helps to prevent constipation, reduce cholesterol level and delays digestion by slow release of glucose into blood stream.

The consumption of millets helps to manage diabetes by inhibiting alpha-glucosidase (Chethan *et al.*, 2008). Thompson (2009) reported that consumption of gluten free grains like millets helps to reduce the gastrointestinal disorders.

Millets are rich in phenolic acids, tannins and phytate. Graf and Eaton (1990) carried out a study on the effect of millet consumption and proved that presence of these compounds helps to reduce the colon cancer and breast cancer in animals. Menon (2004) reported that consumption of millets reduces the risk of cardiovascular diseases, duodenal ulcer and diabetes.

Phytochemicals are non nutritive bioactive plant substance having a beneficial effect on human health. The common phytochemicals present in millets are polyphenols, flavonoids, lignans, phytates, tocopherol, sterols, β-glucan and carotenoids (Liu, 2007). According Chethan and Malleshi (2007), major polyphenols present in millets are gallic acid and ferulic acid. Seventy per cent phenolics present in seed coat of millets helps to inhibit *Helicobacter pylori* implicated in the pathogenesis of peptic ulcer. The phytochemicals present in millets act as antioxidant, improve body immune system, reduce cancer, cardiovascular diseases, obesity and diabetes.

Although millets are nutritionally superior, the non-availability of refined and processed millets in ready-to-use form has limited their wider use and acceptability. Millets are, therefore confined to traditional consumers and also to the people of lower economic strata (Desikachar, 1977). Millets have considerable potential for use as an ingredient in foods and beverages. As they are gluten-free they are suitable for celiacs. The major categories of traditional foods where millets can be effectively used are fermented and unfermented flat breads, fermented and unfermented thin and thick porridges, steamed and boiled products, snack foods, alcoholic and non alcoholic beverages. Cakes, cookies, pasta, vermicelli, noodles and snack foods have been successfully produced from millets (Schober *et al.,* 2005).

## 2. 2. Barnyard millet

Barnyard millet (*Echinochloa frumentacea*) is one of the hardiest millets which can withstand extreme weather conditions. They are short duration crops and grow within six weeks. Barnyard millet is commonly known as Japanese barnyard millet, *sanwan, sawa, shama, samu, shamula, sanwa*, *kuthiravaali* and *kavadapullu* (Lohani and Pandey, 2008).

Barnyard millet is a widely cultivated cereal grain in India, China, Pakistan, Africa, Nepal, and in other countries it is least cultivated.

Channappagoudar *et al.* (2008) reported that in Japan, barnyard millet grown in one hectare obtained a high yield of 10 tonnes whereas in India, yield is only about 1.5 to 2 tonnes. In India, barnyard millet were cultivated in 1.95lakh hectares with a production of 1.67 million tonnes with the productivity of 8.57quintol /hectares (Yadav, 2011).

Barnyard millet is mainly grown in kharif season and widely distributed in the hilly ranges of Uttarakhad and Tamil Nadu. They are extensively grown above 2300m altitude (Kumar *et al.,* 2007 and Joshi, 2013). To some extent they are grown in Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Karnataka, Maharashtra and Bihar (AICRP, 2016).

Abe *et al.* (2011) reported barnyard millet can be effectively grown in soils affected by arsenic and cadmium. Barnyard millet is a nutritious grain, and an alternative crop suitable to grow in adverse agro climate conditions. Hence, barnyard millet plays a role in food and nutritional security (Padulosi *et al.*, 2015).

## 2.3. Nutritional significance and health benefits of barnyard millet

Barnyard millet is highly nutritious compared to other cereals due to the fair amounts of protein (12%) that is highly digestible (81.13%) coupled with low carbohydrate content (58.56%) of slow digestibility (25.88%) (Veena, 2003).



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Barnyard millet contains a good source of digestible protein and dietary fibre (Subramanium and Vishwakhan, 2009).

The dehusked barnyard millet contains 2.41% nitrogen, 4.74% fat, 73.21% starch, 1.22% sugar, 1.28% ash and 4496 kcal/kg energy on dry weight basis (Geervani and Eggum, 1989)

The moisture content of barnyard millet grains was 12 per cent on dry weight basis (Singh *et al.*, 2009). Lohani *et al.* (2011) proved that milling of barnyard millet at 10% moisture exhibits high head yield of 52.97 per cent. As the moisture content of grain increases protein, fat, fibre and ash content decreases.

Mandelbaum *et al.* (1995) found that barnyard millet is rich in amylose (30.47%). Among all the minor millets the size of barnyard millet starch granules ranged from 1.2-10.0 μm with spherical or polygonal shape (Kumari and Thayumanavan, 1998).

The crude fibre and dietary fibre content present in nine different varieties of barnyard millet is between 5.35 to 7.90 per cent and 9 to 15 per cent. It was also recorded that it contains 6.0 to 6.5 per cent of soluble fibre (Hadimani and Malleshi, 1993).

Kasaoka *et al.* (1999) conducted a study on millet protein concentrate which evidently showed that amino acid score of Japanese white and black barnyard millet is 23 and 25. The Japanese barnyard millet has protein digestibility ranging from 61to 71 per cent.

Barnyard millet has a percentage of moisture (8.89% ± 0.07), crude fibre (12.08% ± 0.69), crude protein (10.39% ± 0.25) and ash (2.71% ± 0.17). They also exhibit low glucose absorption of 10 mM/lit in insoluble dietary fibre (Bisoi *et al.*, 2012). Saleh *et al.* (2013) reported that barnyard millet was the richest source of crude fibre (13.6%) and iron (18.6 mg $100g^{-1}$).

Vijayakumar *et al.* (2015) compared whole and dehulled barnyard millet and found that whole grain contain high amount of fat (4 g $100g^{-1}$), fibre (9.3g $100g^{-1}$) and ash (5.6g $100g^{-1}$) whereas dehulled grain was high in moisture (11.05%), total carbohydrates (67.95g $100g^{-1}$) and protein (12.1g $100g^{-1}$).

Veena *et al.* (2005) carried out a study on different varieties of barnyard millet and concluded that total mineral content varies from 1.5 to 4.0 per cent. Panwar *et al.* (2016) while comparing the nutritional properties of barnyard millet and finger millet found out that fibre, crude fibre, total dietary fibre, tryptophan content, total carotenoids, α tocopherol were high in barnyard millet compared to finger millet.

Kumari and Thayumanavan (1997) conducted a study on the resistant starch present in millets. They concluded that consumption of barnyard millet increased faecal weight, reduced blood glucose and lipid level compared to other millets.

Arora and Srivastav (2002) proved that presence of all essential amino acids in barnyard millet was well suited for acidity and celiac disease. Ugare (2008) found out that barnyard millet is a nature's gift to recover from diabetes as it has a low carbohydrate of slow digestibility. They reported that barnyard millet contains total phenols (51.00 mg $100g^{-1}$), phytic acid (96.00 mg $100g^{-1}$) and tannins (62.50 mg $100g^{-1}$). They also concluded that barnyard millet has nutraceutical properties.

Hedge *et al.* (2005) carried out a study on the antioxidant activity in millet. They showed that barnyard millet exhibited a high level of antioxidants and selenium and can be used as an anticancer nutraceutical food.

Barnyard millet have a high phenolic content which contributes antioxidant property (Rao and Prabhavathi, 1982). Kim *et al.* (2011) reported that selected 13 barnyard varieties had a high antioxidant activity and nutrients. Therefore barnyard millet is identified as a functional crop to heal various life style diseases.

Sharma *et al.* (2015) revealed that total phenolics content in raw and germinated barnyard millet was 29.01 and 77.68 per cent respectively. The phenol compound present in barnyard were hexadecanoic acid methyl ester (1.69%), ascorbic acid 2,6 dihexadecanoate (7.36%), methyl 10 trans 12 cisoctadecadienoate (15.91%), c-Sitosterol (1.56%) and 9,12 Octadecadienoic acid(Z,Z) (70.97%) which has functional properties to cure life style diseases.

Chaturvedi *et al.* (2015) conducted a study on different processing methods in barnyard flour extract and proved that germination exhibit high phenol content (21.3 ± 0.1%), flavonoids (43.5 ± 0.6%) and antioxidant activity of 7 μg/ml. Nazni and Devi (2016) conducted a study on characteristics changes in barnyard millet on processing, showing that germination improve availability of minerals with a decrease in antinutritional factors compared to that of raw. The germinated barnyard millet helps to improve the nutritional status of the people.

Sharma *et al.* (2016) conducted a study on raw and germinated barnyard millet by isolating functional compounds like β-glucan and γ-amino butyric acid (GABA). The functional compounds present in barnyard millet act as antioxidants and reduce blood lipid level.

Ugare *et al.* (2014) conducted a study on the nutrient composition, glycemic index and health benefits of barnyard millet. The result showed that barnyard contains 10.5% protein, 3.6% fat, 68.8% carbohydrate, 398 kcal/100 g energy and 12.6% dietary fibre. The dehulled grain and dehulled heat treated grains were fed to nine diabetic and six non-diabetic volunteers and exhibited low glycemic index of 50 and 41.7 respectively. Hence, barnyard millet was recommended for type II diabetes patients.

## 2.3. Value added products from barnyard millet

Millets are underutilised cereals with good nutritional profile which can be efficiently utilised for product development. The barnyard millet based valued added products like traditional products, bakery products, extruded products, flaked products, popped products, instant food mixes and fortified products were developed and standardised (Asha *et al.*, 2005; Anju and Sarita, 2010).

Kamaraddi and Shanthakumar (2003) prepared multigrain flour by incorporating barnyard millet and proso millet to commercial wheat flour. It was found that substitution of wheat flour with 20 per cent barnyard millet and 15 per cent proso millet was highly acceptable. When the level of millet incorporation increases, it significantly increase the ash content and decrease gluten.

Veena *et al.* (2004) standardised traditional foods like *idli*, *dosa*, *roti* and *chakli* by incorporating barnyard millet. *Idli* and *roti* were highly acceptable with 75 per cent barnyard millet whereas *dosa* and *chakli* prepared with 50 per cent barnyard millet had a good sensory score. All the products have high amount of protein, fat, dietary fibre, calcium and iron as the millet incorporation level increases. It showed higher nutritional and sensory profile for the product with barnyard millet.

Vijayakumar and Mohankumar (2011) prepared *dosa* from composite millet (barnyard and kodo millet) flour along with defatted soya flour and whole wheat flour. The *dosa* prepared with 30 per cent composite millet flour was most acceptable. As the level of millet flour incorporation increase there was a significant decrease in total minerals, glycemic index and glycemic load.

An investigation was undertaken by Vanithasri and Kanchana (2013) to develop barnyard millet *idlis*. Standardisation trials indicated that incorporation of barnyard millet at 30, 40 and 50 per cent in the standard recipe yielded an acceptable score. The organoleptic qualities of *idlis* were analysed by a panel of judges using 9 point hedonic scale and was found to be superior in organoleptic and nutritional qualities.

The foxtail and barnyard millet based traditional products like *laddu*, *halwa* and *biryani* were prepared and compared with rice based products. The millet product had good sensory and nutritional properties due to high protein, fat, fibre and minerals than rice products (Verma *et al.*, 2015).

Anju and Sarita (2010) prepared a low glycemic biscuit with a combination of 45 percent millet flour and 55 per cent whole wheat flour. It evidently proved that foxtail millet and barnyard biscuits have a glycemic index of 50.8 and 68 respectively.

Surekha *et al.* (2013a) findings indicated that plain cookies prepared with 100 per cent barnyard millet flour; pulse cookies with barnyard millet flour, soy bean flour and green gram dhal flour (30:10:10) and vegetable cookies with barnyard along with dehydrated carrot gratings (40:10) were best accepted. The developed cookies had a shelf life of 45-60 days.

Biscuits standardised with a proportion of sago (100g), peanut (50g), barnyard millet (20g) and boiled potato mash (30g) were acceptable with reference to appearance, colour, hardness, crispness and flavour and obtained a consumer index of 8.3 (Patil *et al.*, 2014).

Thathola and Srivastava (2002) formulated a weaning food for the infant of Kumaon hills. The results showed that weaning food prepared with 30 per cent of malted foxtail and malted barnyard millet flour, 25 per cent roasted soybean flour and 15 per cent skimmed milk powder had a protein content of 18.37 g and energy of 398 kcal per 100 g respectively.

Poongodi *et al.* (2003) formulated various products like *chapathi*, *dosa*, noodles and rusk by incorporating barnyard and kodo millet flour. The results of sensory evaluation showed that millet flour incorporated at a level of 30 per cent in rusk, *chapathi* and *dosa* and 20 per cent in noodles were highly acceptable.

Barnyard millet based health mix was prepared with barnyard millet, black gram dhal and dehydrated carrot (77: 4.6: 9.2). The developed products were given to seven healthy individuals and the subjects showed 2 per cent reduction in body weight, 7 per cent in blood sugar, 10 per cent in triglycerides, 8 per cent in cholesterol, 9 per cent in LDL and VLDL cholesterol. They significantly improved HDL cholesterol of 5 percent (Surekha *et al.*, 2013b).

Breads were standardised with two formulations one consisted of barnyard millet and wheat composite flour (BWCF), while the other combination was barnyard millet, finger-millet, proso millet and wheat composite flour (BFPWCF) and were compared with wheat flour. The results of sensory evaluation proved BFPWCF bread were highly acceptable followed by wheat bread and BWCF bread (Singh *et al.,* 2012).

Surekha and Naik (2014) investigated on barnyard millet *khakara* and the results showed that 40 per cent barnyard millet *khakara* was highly acceptable with a consumer acceptability of 60. The microbial study concluded barnyard *khakara* were safe up to 60 days of storage.

Goswami *et al.* (2015) mentioned that barnyard millet muffins prepared with 100 per cent millet flour were acceptable with high fibre and minerals, with a shelf life of 15 days.

Barnyard millet were used to prepare puffed RTE product by incorporating it with potato mash and tapioca powder (60:37:3) and was most acceptable. The developed product had moisture of 0.106 kg $kg^{-1}$ (dry matter), expansion ratio of 2.06, colour of 72.19 L-value, crispness of 11.65 peaks and hardness of 480.66 g (Jaybhaye and Srivastav, 2015).

Mishra *et al.* (2013b) standardised dehydrated chicken meat rings with 10 per cent barnyard millet flour by substituting lean meat. The barnyard millet based dehydrated chicken meat rings had a mean score of 6.46 for overall acceptability. The developed product had an improved lipid profile level, with 108.8mg of total lipids, 2.96mg $g^{-1}$ of cholesterol and 16.38mg $g^{-1}$ of phospholipids. The dehydrated chicken meat rings was found to have an iron content of 666.48ppm, copper of 7.56ppm, zinc of 27.53ppm, manganese of 16.45ppm and cobalt of 42.23ppm.

Dhumal *et al.* (2014) prepared a steam cold extruded product by using microwave puffing, oven toasting of potato and barnyard millet. The result showed that products prepared with 55 per cent barnyard millet and 45 per cent potato mash was highly acceptable as compared to commercially RTE snack foods. There is not much variation in fat and ash content of the product on processing where as protein content decreased on oven toasting.

Gopinath and Raj (2014) prepared cookies with barnyard millet and mushroom powder. The result significantly showed that colour and crispiness were increased with 6 percent mushroom flour in barnyard millet flour. They also exhibited good baking qualities and high protein content (10.04 + 0.502).

Takhellambam *et al.* (2016) formulated barnyard millet based, ready to cook flakes. The developed barnyard millet flakes had a desirable mean score of 7.00 (appearance, colour and taste), 6.62 (aroma), 6.75 (texture) and 6.62 (overall acceptability).

**2.5. Functional ingredients**

The nutraceuticals present in food, exert specific health benefits, including the prevention, and management of disease condition, which enables their categorisation as functional foods (Thomas and Earl, 1994). Diplock *et al.* (1999) stated that functional foods are considered to be a substitute of medicine to which provide enumerable remedies for human health problems.

The term functional foods were originated from Japan (Hasler, 1998). The functional foods are defined as foods or ingredients that provide an additional physiological benefit beyond their basic nutrition (IFIC, 2006). The functional foods are foods prepared with functional ingredients in addition to common ingredients to maintain good nutritional status. Functional foods are essential to our diet to reduce nutritional deficiencies (Misra, 2013).

In the present study, barnyard millet was used as a main ingredient for the formulation of vermicelli. Malleshi (1986) reported that barnyard-millet is three times richer than wheat in terms of mineral content. They also stated that barnyard millet is seven times richer in fat and two times richer in calcium content. Barnyard millet can be considered as an functional food which aids beneficial effect on human health (Chandraseker, 2003). Barnyard millet is a low glycemic food, as they release glucose slowly. The barnyard millet consumption can reduce health complication like obesity, diabetes, cardiovascular diseases, hypertension and diabetes (Mishra and Saha, 2010).

Hilliam (2000) stated that market demand of functional food products increased in 21st century. The consumption of functional food in our diet improves immune system, prevent from lifestyle diseases and maintain good physical and mental health (Chaturvedi, 2001). Varshey (2002) reported that functional ingredients are known as dietary ingredients which exert beneficial effects in human body. The functional ingredients like fenugreek seed, garden cress seed, *Brahmi* and *Ekanayakam* were used in the present study.

### 2.5.1. Fenugreek (*Trigonella foenum - graecum*)

Fenugreek, medicinal herb which belongs to the family *leguminosea* are widely used spices in foods. Fenugreek seeds have medicinal properties like lowering the blood glucose level and cholesterol level. They also act as lactation aids, antibacterial agents, gastric stimulants, antianorexial and antidiabetic agents, galactogogues, hepatoprotectives and anticancer agents (Kumar *et al.*, 2013).

Fenugreek seeds contain 26.51g $100g^{-1}$ protein, 6.83g $100g^{-1}$ fat, 6.79g $100g^{-1}$ fibre, 56.30g $100g^{-1}$ total carbohydrate and 391.04 Kcal $100g^{-1}$ on dry weight basis (Yadav, 2014).

Fenugreek seeds are rich in 4-hydroxyisoleucine which improves the insulin secretion in $\beta$ cells of islets of langerhans (Gupta *et al.,* 1986). Raghuram *et al.* (1994) reported that fenugreek seeds contain 17-50 per cent of galactomannans which delay the absorption of glucose. Fenugreek seeds are rich in flavoniods (>100 mg/100 g) and they also contain antioxidant, antimicrobial and anti-inflammatory properties which act as a protective mechanism against pathogens invaded in human health (Naidu *et al.*, 2011).

Shang *et al.* (1998) conducted an investigation on polyphenolic compounds mainly flavoniods present in fenugreek and isolated five types of components present in them namely; vitexin, tricin, naringenin, quercetin, and tricin-7- *O*-beta-D-glucopyranoside.

Adeeb *et al.* (2002) conducted a study on the administration of ethanol extract of fenugreek seeds to healthy and diabetic rabbits at a rate of 200mg/kg body weight. The result revealed that fenugreek seeds rich in trigonelline, an alkaloid and their presence reduce the blood glucose and lipid level in rabbits, which effectively aids as a treatment to reduce diabetics.

Kaviarasan *et al.* (2004) carried out a investigation to prevent oxidative damage in the erythrocyte. The polyphenol extract were isolated from 100g of fenugreek seed and given to both diabetic and control. They reported that polyphenol extract of fenugreek seeds reduced oxidative stress in rats.

Acharya *et al.* (2008) stated that fenugreek seed is used in pharmaceutical industries due to presence of spirostanols. The spirotanols are steroidal compounds used in pharmaceutical industries to treat hormonal imbalance and reduces blood cholesterol. Bukhari *et al.* (2008) identified some chemical compounds like saponins, coumarine, sapogenins and trigonelline from fenugreek and these compounds help to reduce cholesterol and blood sugar level.

Ghattas *et al.* (2008) conducted a study on the effect of daily consumption of whole grains. They revealed that administering 100gm of germinated fenugreek seeds and 15gm of fenugreek seed powder to 12 diabetic patients for a period of one week reduced blood glucose level and serum lipid level. Hence, fenugreek seeds were effective in treating health complications like diabetes, obesity and cardiovascular disease. Baquer *et al.* (2011) stated that 25 to 100g of fenugreek seeds has been recommended to diabetic patients and the result proved that consumption of fenugreek seeds exhibited hypoglycaemic and hypocholesterolemic properties.

Kawabata *et al.* (2011) conducted a study on fenugreek seeds and found that presence of steroidal saponins, helps to reduce inflammation and tumour formation. Hamadi (2012) carried out an investigation on effects of trigonelline and ethanol extract obtained from fenugreek seeds on rabbits, and proved that they reduce plasma malondialdehyde (PMD) and increase the plasma glutathione (GSH) markers. Hence, fenugreek seeds were effective against oxidative stress and can be used to treat diabetes.

Mandegary *et al.* (2012) conducted a study on fenugreek seeds and they concluded that fenugreek seeds help to reduce inflammation and pain due to the presence of alkaloids and flavanoids.

Khole *et al.* (2014) isolated bioactive components like apigenin, kaempferol and caffeic acid derivates from fenugreek seed. Gupta and Verma (2015) carried out a study on consumption of fenugreek seed powder and found that it reduce triglycerides, low density lipoprotein level and significantly increase high density lipoprotein and can be used to treat diabetes mellitus. He *et al.*, (2015) reported that bioactive compounds of fenugreek seed are polyphenolic compounds such as rhaponitinic and isovitexin.

Sreeja *et al.* (2009) carried out a study on *in vitro* estrogenic effect of fenugreek seeds. The fenugreek extract consist of phenolic compounds and their estrogenic effect showed that chloroform extract of fenugreek seeds helps to reduce breast cancer. The *in vitro* studies also proved that dietary supplementation of fenugreek seed are effectively used an alternate treatment for hormone replacement therapy in post menopausal women.

Nayak *et al.* (2015) isolated a 17.36 per cent mucilage fibre from fenugreek seeds. Fenugreek seed mucilage was off white creamy colour, which acts as a binding and gelling agent.

Wani and Kumar (2015a) suggested that fenugreek seeds having nutraceutical properties (antidiabetic, anti-inflammatory, anticarcinogen and antioxidant activity) can be utilized to prepare value added products (extruded and bakery products).

Miglani *et al.* (2015) formulated extruded products by incorporating 5 per cent of fenugreek seeds and flax seeds. The noodles formulated with a combination of (48%) whole wheat flour, (16%) barley flour, (26%) cowpea flour and (5%) of fenugreek and flax seeds obtained a highest means score of 8.30. whereas the extruded snacks prepared with a proportion of wheat flour, barley flour, fenugreek seeds and flax seeds in a ratio of 66:24:5:5 had a acceptable mean score of 8.35.

Solanke *et al.* (2016) standardised extruded products with a formulation of fenugreek seeds (1 to 5 per cent) and oats flour (3 to 15 per cent) in rice flour, corn flour and chickpea flour. The extruded product formulated with an increased level of fenugreek seed powder and oats flour significantly increased its expansion and decreased water absorption capacity.

### 2.5.2. Garden cress seed (*Lepidium sativum*)

Garden cress seed are medicinal plants which belong to the family *Brassicaceae,* widely seen in India, North America and Europe. In India, they are mainly cultivated in the regions of Gujarat, Maharashtra, Rajasthan, Uttar Pradesh and Andhra Pradesh. Garden cress seeds have positive health benefits to treat diabetes, anaemia, fractures, increase milk secretion and act as tonics against cold, diarrhoea (Chopra and Nayar, 1956).

Garden cress seeds are underutilised seeds comprised of nutrients which can be utilized to eradicate malnutrition, anaemia and micro nutrients deficiencies (Hernandez and Leon, 1994). Gokavi *et al.* (2004) reported that garden cress seeds consist of 33-54 per cent carbohydrate, 22-25 per cent protein, 14-27 per cent of lipids and 8 per cent crude fibre. They are rich in iron with a content of 100mg/100g.

Garden cress seeds are rich in essential fatty acids such as arachidonic acid (3.2%), linoleic acid (11.8%) and linolenic acid (34%). Garden cress seed contain 46.9 per cent of polyunsaturated fatty acids and 37.6 per cent of monounsaturated fatty acids (Diwakar *et al.*, 2010). Kasabe *et al.* (2012) reported that antioxidant activity of garden cress seed was found to be 176.18 μg/ml which helps to reduce oxidative stress.

Maier *et al.* (1998) reported that garden cress contains seven compounds namely imidazole alkaloid lepidine (B, C, D, E and F) and semilepidinoside (A and B). They reported that compounds isolated from garden cress seed exhibit hypoglycemic effect. Pande *et al.* (1999) isolated various phytochemicals like glucosinolates, glucotropaeolin, gluconasturtin, gluconain, sestenterenol, terpenoids and terpenylester. These phytochemicals are effective in preventing chronic diseases.

Lee *et al.* (2004) carried out an investigation and found that garden cress seeds contain natural antioxidants like α-tocopherol, β-sitosterol and caroteniods. They also possess other bioactive constituents like imidazole alkaloids, lepidine, monomeric alkaloids, sinapic acid and sinapin. They reported that these antioxidants possess radical scavenging activity and alkaloids like imidazole act against bacteria, fungi and reduce inflammation.

Chatoui *et al.* (2016) carried out phytochemical screening on garden cress seeds. They found that flavonoids, saponoside, tannins, alkaloid, sterol and polyterpene compounds are present in garden cress seeds.

Datta *et al.* (2011) carried out an investigation on the toxic effects of garden cress seeds. The garden cress seeds were administered a dose of 0.5-5.0g/kg body weight to wistar rats, for a period of 14 weeks. The results showed that garden cress seeds are well tolerated upto 10 per cent in our diet.

Jain *et al.* (2016) conducted a study on the effect of processing (boiling, soaking, roasting) on garden cress seeds. They found that maximum nutrient retention was observed during roasting and boiling. There was a maximum reduction in antinutritional factors on boiling.

Agarwal and Sharma (2013) reported that incorporation of 1 per cent garden cress seeds to food products like *dahiwala* bread was acceptable by all age group individuals. The products developed by incorporating garden cress seed helps to nourish and heal certain conditions like anaemia, fractures and diabetes mellitus and other chronic degenerative disease. Dashora and Choudhary (2016) reported that garden cress seeds are rich source of iron; they can be used in our dietary habits as food supplements to prevent anaemia.

### 2.5.3. *Brahmi* (*Bacopa monnieri*)

*Brahmi* (*Bacopa monnieri*), an ayurvedic herb, belongs to the family *Scrophulariaceae. Brahmi* was effectively used to cure gastrointestinal disorders, convulsions, improve brain function (memory and intellect), skin allergy, pyrexia and relieve pain (Aguiar and Borowski, 2013).

Deepak (2003) reported that *Brahmi* contains two saponins namely bacoside A and bascoside B. Bacoside is an active compound chemically represented as 3- (α- L- arabinopyranosyl)-O- β- D-glucopyranosides- 10, 20-dihydroxy- 16- keto- dammar- 24- ene. Srivastava *et al.* (2010) reported that plant extract of *Brahmi* contains bioactive constituents like bacopaside I and bacoside A. These bacosides play a major role in the development of cognitive functions

Ravikumar *et al.* (2005) isolated betulinic acid from *Brahmi* extract which exhibits antifungal activity against *Alternaria alternata* and *Fusarium fusiformis*.

Christopher *et al.* (2017) collected sixty plants of *Bacopa monniera* from different areas of Kerala. Their findings showed that *Brahmi* contains bacoside A (1.44 to 5.40%) and bacopaside (0.29 to 1.36%).

Yamada *et al.* (2011) conducted a study on changes in immune system, after the consumption of *Brahmi*. *Brahmi* was fed at 1 per cent in diet, to Sprague Dawley rat, for a period of 4 weeks. The results of the study proved that consumption of *Brahmi* significantly increased IgA, IgG and IgM in spleen lymphocytes, which enhance the immune system.

Padmanabhan and Jangle (2012) conducted a study on antioxidant and reducing power of four selected herbs (*Aloe vera, Bacopa monniera, Moringa oleifera* and rhizome of *Zingiber officinale*). Their findings showed that DDPH radical scavenging activity of *Brahmi* had inhibition rate of $37.98 \pm 0.77$ per cent and *in vitro* reducing power had an absorbance of $0.058 \pm 0.012$.

Rai *et al.* (2003) conducted a study on rats to treat acute and chronic stress, with *Brahmi* extract. Administering *Brahmi* extract of 40mg in acute stress and 80mg during chronic stress in rats significantly induced changes in ulcer index, creatine kinase and aspartate aminotransferase. They proved that *Brahmi* extract have adaptogenic effect to relieve stress.

A study carried out by Vollala *et al.* (2010) on administering an oral dose (20 to 80 mg/kg) of *Brahmi* extract to wistar rats for a period of 2 to 6 weeks, concluded that *Brahmi* extract improves memory power.

Giramkar *et al.* (2013) administered a formulation of *Brahmi* (0.9ml/kg body weight) to wistar rats. They concluded that *Brahmi,* an anticonvulsant, was effective to treat epilepsy. Suresh *et al.* (2013) subjected *Brahmi* (3.6mg/100g body weight) to rats. In *Brahmi* administered rats, there was a decrease in glucose 6 phosphate dehydrogenase and sorbitol dehydrogenase, with increased antioxidant potential, to treat oxidative stress.

Emran *et al.* (2015) reported that presence of phytochemicals in *Brahmi* extract were effective antimicrobial agents, to treat various pathogenetic complications of *Staphylococcus aureus*.

Shinomol *et al*. (2013) stated that *Brahmi* supplementation protected brain cells exposed to acrylamide from oxidative stress and neurotoxic effects.

Raj *et al*. (2013) formulated a herbal preparation, *Swarnamruta Prashan* with various medical plants (*Brahmi, Vacha, Jatamamsi, Ashwagandha, Shankhapuspi, Yasthimadhu, Pippali* and *Maricha*). When administered a dose of 4 drops to children, showed to enhance their mental ability, improve digestion, stamina and prevention from various infections.

Deo *et al.* (2014) carried out a study to examine toxicity of *Brahmi ghrita. Brahmi ghrita* were formulated with *Brahmi* to improve cognitive effect. Albino rats were subjected to an acute dose (1 to 5gm/kg) and sub chronic dose (400 and 800 mg/kg). There were no biochemical and haematological changes during the consumption of acute and sub chronic dose of *Brahmi* and was found to be safe for consumption.

### 2.5.4. *Ekanayakam (Salacia reticulata)*

*Ekanayakam* (*Salacia reticulata*) is a medicinal plant native to Sri lanka. They belong to a family of *Celastaceae* (Loesener *et al.,* 1942). Traditionally people of India, Sri lanka and Thailand utilized the roots and stems of *Ekanayakam* to cure diabetes and reduce weight.

Karunanayake *et al.* (1984) carried out a study on oral administration of 1ml of *Salacia reticulata* extract to male rats. They concluded that *Salacia reticulata* extract significantly reduce blood glucose in diabetic patients.

Yoshikawa *et al.* (1997) conducted a study on *Salacia reticulata* and isolated α glucosidase inhibitors (salacinol and kotalanol) which are considered effective compounds to treat diabetes. The bioactive compounds like salacinol and kotalanol present in *Salacia reticulata* combine with α glucosidase in small intestines. Their interaction prevents the breakdown of oligosaccharides into monosaccharides to maintain normal blood glucose level (Matsuda *et al.,* 1999).

Yoshikawa *et al.* (2002) conducted a study to reduce weight, on administering hot water soluble *Salacia reticulata* extract in rats. The result of the study showed that presence of mangiferin, catechins and condensed tannins enhanced lipolysis and inhibited porcine pancreatic lipoprotein lipase and glycerophosphate dehydrogenase. Hence, the study concluded that root extract of *Salacia reticulata* can treat obesity.

Kishino *et al.* (2006) carried out an investigation on the effect of *Salacia reticulata* extract to treat health complications like obesity. The result proved that feeding *Salacia reticulata* extract and cyclodextrin to rats significantly decreased plasma triglyceride level.

Kajimoto *et al.* (2000) observed that a diet containing aqueous extract from the stem of *Salacia reticulata* (240 mg/day for 6 weeks) can decrease fasting blood glucose and HbAIC levels in type II diabetes patients. A significant reduction in the HbAIC has been reported in the patients receiving a preparation of *Salacia reticulata* tea for 3 months (Jayawardena *et al.*, 2005).

Li *et al.* (2008) suggested that *Salacia reticulata* extracts are safe to consume and they evidently proved that *Salacia reticulata* extracts control blood glucose and lipid profile. Stohs and Ray (2015) isolated active compounds like chrysophanol, physcion, emodin and lunatin from *Salacia reticulata*. These isolated compounds are derivatives of anthraquinone, which are anticancer agents.

Deepak *et al.* (2015) stated that *Salacia reticulata* is a safe ingredient which can be utilised in formulating functional food to treat various health complications.

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

The present study was formulated to standardise millet based designer vermicelli using barnyard millet, whole wheat flour and functional ingredients and to evaluate its acceptability, nutritional, health and shelf life qualities. The study also aimed to develop an acceptable instant *uppuma* mix with the standardised vermicelli. The investigation was carried out in the Department of Community Science, College of Horticulture, Kerala Agricultural University during the year 2015-2017. The methods followed and materials used are given under following headings.

3.1. Collection of raw materials

3.2. Preparation of flour from barnyard millet and functional ingredients

3.3. Standardisation of barnyard millet vermicelli with functional ingredients

3.4. Acceptability of barnyard millet vermicelli

3.4.1. Selection of judges for acceptability studies

3.4.2. Preparation of score cards

3.4.3. Sensory evaluation

3.4.4. Selection of the most acceptable treatment among each functional ingredient

3.5. Quality evaluation of selected barnyard millet based vermicelli

3.5.1. Nutritional qualities

3.5.2. Health studies

3.5.3. Organoleptic evaluation

3.5.4. Enumeration of total microflora

3.5.5. Insect infestation in vermicelli

3.6. Standardisation of instant *uppuma* mix

3.6.1. Preparation of spice mix

3.6.2. Preparation of *uppuma*

3.6.3. Sensory evaluation of instant *uppuma* mix

3.7. Cost of production of the selected vermicelli

3.8. Statistical analysis of the data

### 3.1. Collection of raw materials

Barnyard millet (*Echinochloa frumentacea*) was collected from the pollachi market of Tamilnadu. Whole wheat flour, refined wheat flour, fenugreek (*Trigonella foenum - graecum)* seeds, garden cress (*Lepidium sativum L)* seeds were purchased from local market. *Ekanayakam* (*Salacia reticulata)* root barks were collected from local dealers of medicinal plants and *Brahmi* (*Bacopa monnieri*) leaves were collected from the Department of Medicinal and Aromatic Plants, College of Horticulture, KAU.

### 3.2. Preparation of flour from barnyard millet and functional ingredients

Barnyard millet was cleaned, washed, soaked in water at varying time intervals (4, 6, 8, 10, 12, 14, 16 and 18 hrs) with intermittent change in water every 4 hrs. The excess water was drained and allowed to germinate under a wet cloth for 24 hrs. The seeds were dried in hot air oven at $65^{\circ}C$. The germinated seeds were devegetated, powdered and sieved through 40 mesh size. For the standardisation of germination the treatments $T_0$ to $T_8$ were prepared with different soaking time as presented in Table 1. The organoleptic evaluation of barnyard millet flour was carried out to find the best treatment.

Fenugreek seeds were germinated and powdered as per the procedure of Pandey and Aswathi (2014). The seeds were then cleaned, washed and soaked in water (12hrs) with change in water for every 6hrs. The seeds were then allowed to germinate for 24 hrs, powdered and sieved through a 40 mesh size to get an uniform flour.

Garden cress seed and *Ekanayakam* root bark were dried, powdered and sieved through a 40 mesh size to get an uniform fine powder. *Brahmi* leaves were dried to a moisture content less than 10%, powdered and sieved through a 40 mesh size to get an uniform powder.

**Table 1: Treatments for the preparation of germinated barnyard millet flour**

| Treatments | Combinations |
|---|---|
| $T_0$ | Ungerminated BMF (Control) |
| $T_1$ | 4hrs soaking +24hrs germinated BMF |
| $T_2$ | 6hrs soaking +24hrs germinated BMF |
| $T_3$ | 8hrs soaking +24hrs germinated BMF |
| $T_4$ | 10hrs soaking +24hrs germinated BMF |
| $T_5$ | 12hrs soaking +24hrs germinated BMF |
| $T_6$ | 14hrs soaking +24hrs germinated BMF |
| $T_7$ | 16hrs soaking +24hrs germinated BMF |
| $T_8$ | 18hrs soaking +24hrs germinated BMF |

(Barnyard Millet Flour – BMF)

### 3.3. Standardisation of barnyard millet vermicelli with functional ingredients

Generally vermicelli is prepared with refined wheat flour. Millet based vermicelli was prepared by adapting the standard procedure of Ranganna *et al.* (2014). The treatment $T_0$ prepared served as control. Treatments $T_1$ to $T_{10}$ were prepared and the proportion of ingredients used is given in Table 2.

**Table 2. Treatments for the preparation of fenugreek incorporated barnyard vermicelli**

| Treatments | Combinations |
|---|---|
| $T_0$ | Control (100% Refined wheat flour) |
| $T_1$ | 80% BM + 15% WWF + 5% F |
| $T_2$ | 80% BM + 18% WWF+ 2% F |
| $T_3$ | 70% BM + 25% WWF + 5% F |
| $T_4$ | 70% BM + 28% WWF + 2% F |
| $T_5$ | 60% BM + 35% WWF + 5% F |
| $T_6$ | 60% BM + 38% WWF + 2% F |
| $T_7$ | 50% BM + 45% WWF + 5% F |
| $T_8$ | 50% BM + 48% WWF + 2% F |
| $T_9$ | 40% BM + 55% WWF + 5% F |
| $T_{10}$ | 40% BM + 58% WWF + 2% F |

(BM - Barnyard millet flour, WWF – Whole Wheat Flour, F – Germinated Fenugreek seed flour)

The above experiment was repeated using barnyard millet and whole wheat flour replacing the functional ingredients fenugreek with garden cress seeds and *Ekanayakam* root barks.

The functional ingredient *brahmi* was added at 1 per cent and 0.5 per cent levels along with barnyard millet flour and whole wheat flour as detailed in Table 3.

**Table 3. Treatments for the preparation of *Brahmi* incorporated barnyard vermicelli**

| Treatments | Combinations |
|---|---|
| $T_0$ | Control (100% Refined wheat flour) |
| $T_1$ | 80% BM + 19% WWF + 1% B |
| $T_2$ | 80% BM + 19.5% WWF+ 0.5% B |
| $T_3$ | 70% BM + 29% WWF + 1% B |

Table 3 Continued

| | |
|---|---|
| $T_4$ | 70% BM + 29.5% WWF + 0.5% B |
| $T_5$ | 60% BM + 39% WWF + 1% B |
| $T_6$ | 60% BM + 39.5% WWF + 0.5% B |
| $T_7$ | 50% BM + 49% WWF + 1% B |
| $T_8$ | 50% BM + 49.5% WWF + 0.5% B |
| $T_9$ | 40% BM + 59% WWF + 1% B |
| $T_{10}$ | 40% BM + 59.5% WWF + 0.5% B |

(BM - Barnyard millet flour, WWF – Whole Wheat Flour, B – *Brahmi* leaves)

### 3.4. Acceptability of barnyard millet vermicelli

The acceptability for barnyard millet vermicelli were done to find the consumers preference. All the prepared vermicelli were evaluated to find the best combination by preparing *uppuma.*

#### 3.4.1. Selection of judges

A panel of fifteen judges between age group of 18 and 35 years were selected by conducting a series of organoleptic trials using a simple triangle test at laboratory level as suggested by Jellinek (1985).

#### 3.4.2. Preparation of score cards

The organoleptic score cards with six sensory attributes like appearance, colour, flavour, texture, taste and overall acceptability were prepared based on the nine point hedonic scale and is given in Appendix I.

#### 3.4.3. Sensory evaluation

Sensory evaluation of the prepared barnyard millet vermicelli and *uppuma* were carried out by a panel of 15 judges. The quality parameters namely appearance, colour, flavour, texture, taste and overall acceptability were assessed.

#### 3.4.4. Selection of the most acceptable treatment among each functional ingredient

The best treatment most suitable for vermicelli and *uppuma* with fenugreek seeds, garden cress seeds, *Brahmi leaves* and *Ekanayakam* root barks were selected through sensory parameters by applying Kendall's coefficient of concordance. Thus 4 treatments with control were studied in detail.

### 3.5. Quality evaluation of selected barnyard millet based vermicelli

The selected barnyard millet based vermicelli were packed in polyethylene pouches (250 gauge) and kept in ambient condition for a period of four months. The quality evaluation was done initially and during the second and fourth month of the storage period for the selected vermicelli.

#### 3.5.1. Nutritional qualities

The nutritional qualities of barnyard millet based vermicelli were evaluated initially and during the second and fourth month of the storage period using standard procedures. The analysis was carried out in triplicate samples.

##### 3.5.1.1. Moisture

Moisture content of selected vermicelli was estimated by the method of A.O.A.C (1980). To determine moisture content of the sample a known weight of the sample was dried in a hot air oven at $60^0$C to $70^0$C, cooled in a desicator and weighed. The process of heating and cooling was repeated till constant weight was achieved. The moisture content of the sample was calculated from the loss in weight during drying.

##### 3.5.1.2. TSS

Total soluble solids of the vermicelli were assessed by the Erma hand refractometer which will be expressed as degree brix (°brix) as per Ranganna (1997).

##### 3.5.1.3. Total carbohydrate

The total carbohydrate content of products was estimated by the method suggested by Sadasivam and Manickam (1997). A dried sample of 100mg sample was hydrolysed with 5ml of 2.5N HCl for 3 hours by boiling in a water bath and cooled to room temperature. The residue was neutralized with sodium carbonate until effervescence ceases. The volume was made up to 100ml and centrifuged. An aliquot 0.2ml from the supernatant was pipetted out and made up to 1ml and then 4ml of anthrone reagent was added. Heated for 8 minutes in a boiling water bath, cooled rapidly and the intensity of green to dark colour was read at 630nm (OD). A standard graph was prepared using standard glucose by applying the serial dilutions. From the standard graph, the amount of total carbohydrate present in the sample was estimated and expressed in gram per 100g of sample.

**3.5.1.4. Protein**

The protein content of vermicelli was estimated using Lowry's method given by Sadasivam and Manickam (1997). A sample of 500mg was extracted using 5 to 10 ml of buffer (Tris buffer GR – tris hydroxymethyl amino methane) and centrifuged. An aliquot 0.1 ml from the supernatant was taken in a test tube, 5 ml alkaline copper solution was mixed well and allowed to stand for 10 minutes. Folin-Ciocalteau reagent of 0.5 ml was added and incubated at room temperature in the dark for 30 minutes and the developed blue colour was read at 660nm (OD). A standard graph was prepared using alkaline copper solution and Folin-Ciocalteau reagent by applying serial dilutions. From the standard graph, the amount of total protein present in sample was estimated and expressed in gram per 100g of sample.

**3.5.1.5. Total fat**

The fat content of the vermicelli was estimated using the method given by Sadasivam and Manickam (1997). Five gram of sample was taken in a thimble and plugged with cotton. The material was extracted with petroleum ether for six hours without interruption by gentle heating in a soxhlet apparatus. Extraction flask was then cooled and ether was removed by heating and the weight was taken. The fat content was expressed in gram per 100g of the sample.

**3.5.1.6. Energy**

The energy content of vermicelli was computed according to Gopalan *et al.* (1989) and expressed as kilocalories or kcal. The energy present in sample was calculated as per the formula given below.

Energy = (4 x Protein) + (4 x Total carbohydrates) + (9 x Fat)

**3.5.1.7. Fibre**

The crude fibre content was estimated using the method given by Sadasivam and Manickam (1997). Powdered vermicelli sample of two grams was boiled with 200 ml of 1.25 per cent sulphuric acid for 30 minutes. It was then filtered using muslin cloth and washed with boiling water. The residue was again boiled with 200 ml of 1.25 per cent of sodium hydroxide for 30 minutes. Repeat the filtration through muslin cloth and residue was washed with 25 ml of boiling 1.25 per cent of sulphuric acid, three 50 ml portion of water and 25 ml of alcohol. The obtained residue was taken in an ashing dish ($W_1$) and dried at $130^0C$ for 2 hours. Cool the dish in a desiccator which was reweighed and noted as $W_2$. The residue was again ignited in muffle furnace at $600^0C$ for 30 minutes, cooled in a desiccator and reweighed ($W_3$).

### 3.5.1.8. Starch

Starch present in the vermicelli was estimated colorimetrically at 630nm as per the standard protocol of Sadavisam and Manikam (1997).

The vermicelli samples of 0.5g were weighed. The samples were treated with 80% ethanol to remove the sugars. The residue was washed again and again to remove the sugars completely. The obtained residues were dried and then added 5ml of water and 6.5ml of 52% perchloric acid and extracted in cold water for 20 minutes. Centrifuge the sample for the collection of supernatant. The sample was then reextracted with fresh percholoric acid. From the sample, supernatant were collected and made up to 100ml. Pipetted out 0.2ml supernatant of and made upto 1ml with water. Then add 4ml of the anthrone reagent to it, which is heated for 8 minutes, cooled and read at 630nm.

### 3.5.1.9. Reducing sugar

Twenty five gram of vermicelli was ground with 100ml of distilled water and transferred to a conical flask. It was neutralised with 1N sodium hydroxide in the presence of phenolphthalein. For the clarification of the neutralised mixture, 2ml of lead acetate was added followed by addition of 2ml of potassium oxalate to neutralise the excess amount of lead acetate. It was then allowed to stand for 10 minutes for the settlement of precipitate. Filtered the solution through Whatman's No.1 filter paper which was made upto 250ml. Aliquot of the solution was titrated against a boiling mixture of fehlings solution A and B using methylene blue as indicator until the appears of brick red colour indicator (Ranganna, 1997). The reducing sugars present in vermicelli were computed using the formula as follows.

$$\text{Reducing sugar (\%)} = \frac{\text{Fehling's factor x dilution x 100}}{\text{Titre value x weight of the sample}}$$

### 3.5.1.10. Total sugar

From the clarified solution used for the estimation of reducing sugar, 50 ml was taken and boiled gently after adding 5g citric acid and 50ml of water. This solution was neutralized with sodium hydroxide (1N) with few drops of phenolphthalein indicator until colourless solution. An aliquot of this solution was titrated against standard Fehling's solution A and B by adding methylene blue indicator (Ranganna, 1997). The total sugars present in vermicelli were computed using the formula as follows.

$$\text{Total sugars (\%)} = \frac{\text{Fehling's factor x 250 x dilution x 100}}{\text{Titre value x 50 x weight of the sample}}$$

### 3.5.1.11. Calcium

Calcium content present in vermicelli was estimated using method suggested by Perkin – Elmer (1982). One gram of the vermicelli was pre-digested using 10 ml of 9:4 ratio of nitric and percholoric acid. The prepared diacid extract of the vermicelli sample was used for estimation of calcium in Atomic Absorption Spectrophotometer. The amount of calcium content present in sample was expressed as mg per 100g.

### 3.5.1.12. Iron

Iron content present in selected vermicelli was estimated using method suggested by Perkin – Elmer (1982). One gram of the vermicelli was pre-digested using 10 ml of 9:4 ratio of nitric and percholoric acid. The prepared diacid extract of the vermicelli sample was used for estimation of iron in Atomic Absorption Spectrophotometer. Iron content present in the sample was expressed as mg per 100g.

### 3.5.1.13. Magnesium

Magnesium present in the vermicelli was estimated using the method suggested by Perkin – Elmer (1982). One gram of the vermicelli was pre-digested using 10 ml of 9:4 ratio of nitric and percholoric acid. The diacid extract of the vermicelli sample was used for estimation of magnesium in Atomic Absorption Spectrophotometer. The amount of minerals present in the sample was expressed as mg per 100g.

### 3.5.1.14. Zinc

The amount of zinc present in the vermicelli was estimated using the method suggested by Perkin – Elmer (1982). One gram of the vermicelli was pre-digested using 10 ml of 9:4 ratio of nitric and percholoric acid. The diacid extract of the vermicelli sample was used for estimation of zinc in Atomic Absorption Spectrophotometer. The amount of zinc present in the vermicelli was expressed as mg per 100g.

### 3.5.1.15. Sodium and Potassium

Sodium and potassium present in vermicelli was estimated using method suggested by Jackson (1973) with the help of Flame Photometer. One gram of the vermicelli was digested using diacid solution. The pre-digested sample was used to measure sodium and potassium content in flame photometer and it was expressed as mg per 100g of the sample.

### 3.5.2. Health studies

### 3.5.2.1. *In vitro* starch digestibility (IVSD)

*In vitro* starch digestibility was estimated as per the standard procedure suggested by Satterlee *et al.* (1979). The vermicelli sample of one gram was gelatinised in 100 ml of boiling water for one hour. To one ml of the gelatinized solution one ml of the enzyme solution (mixture of one ml of water to one ml of the saliva) was added. Incubate the mixture for 1 to 2 hours at 37°C. Then by adding sodium hydroxide reaction was hampered which was later used for estimation of glucose as suggested by Somoygi (1952).



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**3.5.2.2.** ***In vitro* protein digestibility (IVPD)**

*In vitro* protein digestibility was assessed by following the procedure as Sadavisam and Manikam (1997). To the powdered vermicelli sample add 10ml of the distilled water where the sample will be adjusted to obtain 6.25mg of protein/litre. The sample was maintained at a temperature of 37°C with a pH of 8. To the prepared protein suspension added about 1ml of the three enzyme solution (combination of 1.65mg porcine pancreatic trypsin type IX, 3.1mg bovine pancreatic chymotrypsin type II, 1.3mg porcine intestinal peptidase grade III). An aliquot of multienzyme solution were added to one ml of the bacterial protease solution. The sample was recorded for the pH drop within ten minutes using pH meter. *In vitro* protein digestibility was calculated using the formula as suggested as follows.

$$IVPD = 210.46 - 18.10X,$$

i.e. X denoted as pH after 10 minutes of incubation

**3.5.2.3.** ***In vitro* availability of minerals**

*In vitro* availability of iron, calcium, phosphorus, potassium, magnesium and zinc were assessed using the formula of Duhan *et al.* (2001). For the *in vitro* availability, HCl extractability of minerals was estimated. The selected vermicelli samples were extracted with 0.03N HCl in a shaker for a period of three hours at 37°C. The sample was filtered with a help of Whatman no 40 filter paper to obtain a clear extract. The extracted clear extract was dried at 100°C in a oven followed by wet acid digestion. Then in the digested sample the amount of HCl extractable iron, calcium, phosphorus, magnesium and zinc were estimated as per prescribed procedures above for the estimation of minerals. The formula suggested to compute the HCl extractability were as follows.

$$\text{Mineral extractability (\%)} = \frac{\text{Mineral extractability in 0.03N HCl}}{\text{Total mineral}} \times 100$$



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#### 3.5.2.4. Total antioxidant activity

Antioxidant capacity of the vermicelli extract was measured using 1'1-diphenyl-1-picryl hydrazine (DPPH) spectrometric assay as suggested by Blois (1958). To various concentration of the sample, methanolic solution containing DPPH radicals (0.1mM) was added and shaken vigorously. The reaction mixture was incubated for 30 minutes in dark. The absorbance was measured at 517 nm in spectrophotometer. The percentage of antioxidant activity was computed by the formula as follows

$$\% \text{ Inhibition of free radical} = \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Control}} \times 100$$

The sample concentration providing 50 per cent inhibition (Inhibitory concentration - IC50) was calculated from the graph of RSA (radical scavenging activity) percentage against sample concentration. Gallic acid was used as the standard.

#### 3.5.2.5. Glycemic index

The prepared product was given to five healthy individuals for assessing the glycemic response of product and glycemic index were computed with a formula as referred by Srilakshmi (2011). This test is conducted with the help of glucometer. To find out the healthy subjects, glucose tolerance test was conducted initially. The respondents were asked to stop all medication at least 3 days before the test and to maintain 8 hours of fasting before the test. The fasting blood glucose was taken and recorded. For each subject the postprandial glucose level was assessed by feeding barnyard millet based *uppuma* in comparison with control. An equivalent quantity of test food was taken in comparison with glucose of 75g. The blood glucose levels were recorded at specific time intervals of 30 minutes upto 2 hours after the food load. From the recorded observation glycemic index of the *uppuma* were computed with formula as follows.

$$\text{Glycemic index} = \frac{\text{Incremental area under the 2 hours plasma glucose curve after eating 75g of CHO from test food}}{\text{Incremental area under the 2 hours plasma glucose curve after eating 75g of CHO from glucose}}$$

### 3.5.3. Organoleptic evaluation

Organoleptic evaluation was carried out for the selected products as described in 3.4.3. The organolpetic score card is given in Annexure II. The vermicelli and *uppuma* were prepared from the selected 5 vermicelli along with control initially and during the second and fourth month of storage. For the prepared vermicelli and *uppuma*, organoleptic evaluation were carried out by the panel of judges.

### 3.5.4. Enumeration of total microflora

The microbial population present in the vermicelli sample were estimated using serial dilution plate count method as suggested by Agarwal and Hasija (1986). The microbial analysis was carried out in vermicelli initially and during the second and fourth month of storage.

#### 3.5.4.1. Preparation of samples and media for microbial enumeration

The sample was prepared by mixing 90ml of distilled water with 10g of vermicelli and shaken well using a shaker to obtain suspension. The serial dilutions were carried out in the prepared water blank. To 9ml of water blank transfer one ml of the prepared suspension with a dilution of $10^{-2}$. This is then diluted to $10^{-3}$ followed by $10^{-4}$, $10^{-5}$ and $10^{-6}$ using serial dilution techniques. Bacteria, fungi and yeast count were assessed using Nutrient Agar (NA), Potato Dextrose Agar (PDA) and Sabouraud's Dextrose Agar (SDA) media respectively and results were given as cfu/g.

#### 3.5.4.2. Enumeration of bacterial colony

Total number of bacterial colony was enumerated in $10^{-5}$ dilution in nutrient agar medium. In a sterile petriplate, pour one ml of $10^{-5}$ dilution using a micropipette. To petriplate pour about 20ml of the nutrient agar medium which is



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uniformly spread in petriplate by rotating in clockwise and anticlockwise directions. For bacterial colony the enumerated petriplates were incubated for 48hrs at room temperature. The total number of bacterial colonies were counted and expressed as cfu/g.

**3.5.4.3. Enumeration of fungal colony**

Total number of fungal colony was enumerated in $10^{-3}$ dilution in Martin Rose agar medium. In a sterile petriplate, pour one ml of $10^{-3}$ dilution using a micropipette. To petriplate pour about 20ml of the Potato Dextrose Agar medium is uniformly spread. For fungal colony enumeration the petriplates were incubated for 4 to 5 days at room temperature. The total number of fungal colonies were counted and expressed as cfu/g.

**3.5.4.4. Enumeration of yeast colony**

Total number of yeast colony was enumerated in $10^{-3}$ dilution in Sabouraud's Dextrose Agar medium. In a sterile petriplate, pour one ml of $10^{-3}$ dilution using a micropipette. To petriplate pour about 20ml of the Sabouraud's Dextrose Agar medium which is uniformly spread in the petriplate by rotating. For enumeration of yeast population, the petriplates were incubated for 4 to 5 days in room temperature. The total number of yeast colonies were counted and expressed as cfu/g.

**3.5.5. Insect infestation of vermicelli during storage**

Insect infestation of vermicelli were observed and recorded initially and during the second and fourth month of storage. Insect infestations were assessed by visual examination.

**3.6. Standardisation of instant *uppuma* mix**

From the four selected barnyard millet based vermicelli, instant *uppuma* was standardized with 100g vermicelli with varying volume of water (200 ml, 250 ml, 300 ml, 350 ml and 400 ml) and the cooking time were noted.

**3.6.1. Preparation of spice mix**

A spice mix was prepared with 50g of onion, 50g of garlic and 20g of ginger. These ingredients were peeled, sliced and subjected to blanching with 0.2% potassium metabisulphite in boiling water for 1 minute and then grinded to obtain a paste. It was then dried, powdered and sieved in uniform size mesh to yield a fine spice mix (Lakshmy, 2011).

### 3.6.2. Preparation of instant *uppuma*

From the selected vermicelli, *uppuma* was prepared with different volume of water (200, 250, 300, 350 and 400 ml) by adding the spice mix (5g), toasted mustard (5g) and toasted curry leaves (2g) as detailed. The time of cooking was recorded during the preparation of *uppuma.*

### 3.6.3. Sensory evaluation of instant *uppuma* mix

Sensory evaluation for the prepared *uppuma* from the instant mix was assessed for the different attributes like appearance, colour, flavour, texture, taste and overall acceptability.

## 3.7. Cost of production of the selected vermicelli

The cost of production of 100g selected vermicelli and instant *uppuma* mix were computed using the market price of raw materials incurred for the product preparation along with labour charge, fuel charge, electricity charge and packaging cost.

## 3.8. Statistical analysis of the data

The data were recorded and analysed as completely randomised design (CRD). Based on organoleptic evaluation, the best treatment was identified using Kendall's Coefficient of Concordance (W).The nutritional and health qualities of the each treatment were compared using Duncan's Multiple Rank Test (DMRT) and relative change.

# RESULTS

# 4. RESULTS

The results of the present study entitled "Standardisation and quality evaluation of millet based designer vermicelli" are presented in this chapter under following headings.

4.1. Standardisation of germination for preparation of barnyard millet flour

4.2. Standardisation of barnyard millet vermicelli with functional ingredient

4.3. Quality evaluation of selected barnyard millet based vermicelli

- 4.3.1. Nutritional qualities
- 4.3.2. Health studies
- 4.3.3. Sensory qualities
- 4.3.4. Enumeration of total microflora
- 4.3.5. Insect infestation

4.4. Development of instant *uppuma* mix

- 4.4.1. Cooking time for instant *uppuma* mix
- 4.4.2. Organoleptic qualities of instant *uppuma* mix

4.5. Cost of production for selected barnyard millet vermicelli and instant *uppuma* mix

## 4.1. Standardisation of germination for preparation of barnyard millet flour

Barnyard millet soaked in water (1:3 proportion) for varying time intervals (4, 6, 8, 10, 12, 14, 16 and 18 hrs) were germinated, dried and powdered to obtain a uniform flour (Plate 1). The organoleptic evaluation for the prepared barnyard millet flour ($T_0$ to $T_8$) was carried out. The treatment ($T_0$), ungerminated barnyard millet flour served as control. The mean score for different treatments were ranked statistically using Kendall's coefficient of concordance and presented in Table 4.

**Table 4: Mean scores for organoleptic evaluation of germinated barnyard millet flour**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | **Appearance** | **Colour** | **Flavour** | **Texture** | **Taste** | **Overall acceptability** |
| $T_0$ | 6.66 (3.77) | 6.00 (2.40) | 6.73 (3.33) | 6.26 (2.37) | 6.66 (2.87) | 6.16 (3.57) |
| $T_1$ | 6.73 (4.00) | 6.66 (5.37) | 6.73 (3.00) | 6.70 (3.47) | 7.16 (5.10) | 6.30 (3.70) |
| $T_2$ | 6.93 (5.00) | 6.53 (4.37) | 6.96 (4.20) | 7.03 (5.07) | 7.10 (4.57) | 6.43 (4.53) |
| $T_3$ | 6.90 (4.77) | 6.73 (5.60) | 7.26 (5.47) | 6.80 (3.77) | 6.80 (3.33) | 6.63 (5.73) |
| $T_4$ | 7.40 (6.63) | 7.16 (7.10) | 7.80 (7.00) | 7.83 (7.67) | 7.53 (6.50) | 6.90 (6.40) |
| $T_5$ | 7.10 (5.53) | 6.83 (5.87) | 7.40 (5.93) | 7.10 (5.87) | 7.20 (5.07) | 6.59 (5.80) |
| $T_6$ | 7.00 (5.67) | 6.66 (5.10) | 7.20 (5.50) | 6.83 (4.97) | 7.40 (6.17) | 6.70 (5.93) |
| $T_7$ | 6.80 (4.57) | 6.46 (4.43) | 7.13 (4.93) | 7.00 (5.60) | 7.26 (5.43) | 6.46 (4.50) |
| $T_8$ | 6.86 (5.07) | 6.53 (4.77) | 7.36 (5.63) | 7.10 (6.23) | 7.33 (5.97) | 6.53 (4.83) |
| **Kendalls W** | 0.199** | 0.315** | 0.293** | 0.394** | 0.270** | 0.182** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

The mean score obtained for the organoleptic evaluation varied from 6.66 to 7.40 in appearance. The colour and flavour had a mean score ranging from 6.00 to 7.16 and 6.73 to 7.80. The texture and taste of the barnyard millet flour obtained a mean score of 6.26 to 7.83 and 6.66 to 7.53 respectively. The mean

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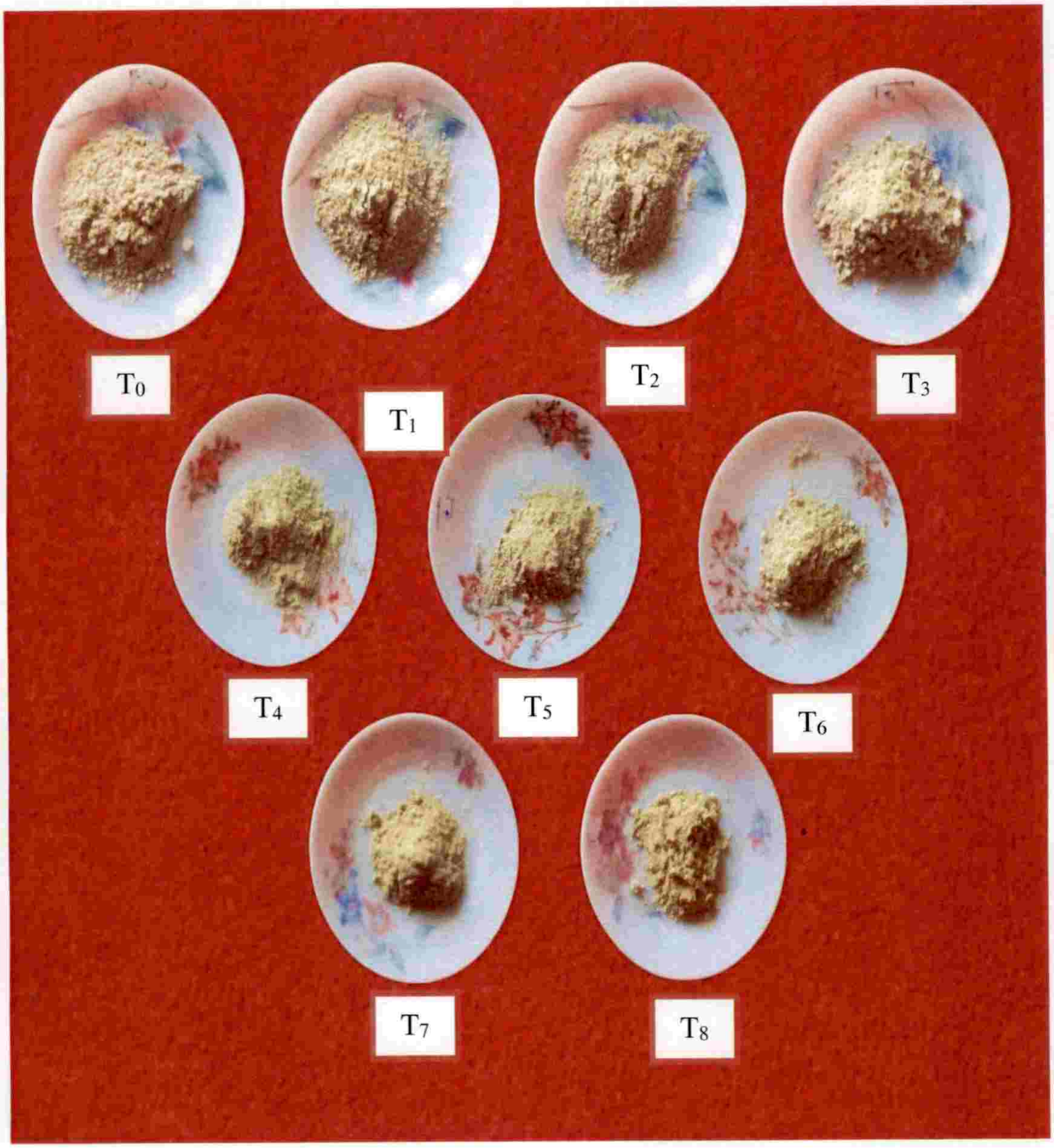


**Plate 1. Barnyard Millet Flour with different soaking time**

score for over all acceptability differs from 6.16 to 6.90. Based on the mean rank score treatment ($T_0$ to $T_8$) varied from 3.77 to 6.63 (appearance), 2.40 to 7.10 (colour), 3.00 to 7.00 (flavour), 2.37 to 7.67 (texture), 2.87 to 6.50 (taste) and 3.57 to 6.40 (overall acceptability).

The treatment $T_4$ with the highest mean score of 7.40 (appearance), 7.16 (colour), 7.80 (flavour), 7.83 (texture), 7.53 (taste) and 6.90 (overall acceptability) was selected as the best treatment and was used to prepare barnyard millet flour for further studies. The Kendall's value showed a significant agreement among the judges for all quality attributes of barnyard millet flour.

**4.2. Standardisation of barnyard millet vermicelli with functional ingredient**

Barnyard millet based vermicelli were prepared with varying proportions of germinated barnyard millet flour, whole wheat flour and functional ingredients namely fenugreek seed, garden cress seed, *Brahmi* leaves and *Ekanayakam* root barks. The refined wheat flour vermicelli which served as control was compared with barnyard millet based vermicelli incorporated with functional ingredients. Organoleptic evaluation of barnyard millet based vermicelli were carried out by scoring for sensory parameters like appearance, colour, flavour, texture, taste and overall acceptability by a panel of 15 judges using a nine point hedonic scale. The mean scores obtained for the barnyard millet based vermicelli using functional ingredients were ranked statistically using Kendall's coefficient of concordance and the results are presented below.

**4.2.1. Sensory evaluation of barnyard millet based vermicelli incorporated with fenugreek seed**

Barnyard millet vermicelli incorporated with germinated fenugreek seed flour were prepared in various proportions and was compared with the control vermicelli. The prepared vermicelli was subjected to organoleptic evaluation. Their mean score, mean rank score and Kendall's value obtained for all the sensory parameters are presented in Table 5.

**Table 5. Mean scores for organoleptic evaluation of fenugreek incorporated barnyard vermicelli**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.80 (10.77) | 8.66 (11.00) | 8.60 (10.83) | 8.55 (10.73) | 8.95 (10.80) | 8.55 (11.00) |
| $T_1$ | 6.37 (3.60) | 6.44 (3.00) | 5.57 (2.37) | 5.84 (3.57) | 6.42 (3.80) | 5.86 (2.93) |
| $T_2$ | 6.31 (3.27) | 6.35 (2.60) | 5.77 (2.93) | 5.84 (3.43) | 6.37 (3.37) | 5.75 (2.43) |
| $T_3$ | 6.75 (2.97) | 6.44 (2.83) | 5.95 (3.40) | 5.80 (3.10) | 6.82 (4.07) | 5.93 (2.90) |
| $T_4$ | 6.28 (2.33) | 6.48 (2.90) | 5.77 (3.33) | 5.84 (3.13) | 6.31 (2.20) | 5.95 (2.93) |
| $T_5$ | 7.02 (4.60) | 6.91 (4.83) | 6.20 (4.23) | 6.22 (4.40) | 7.02 (4.57) | 6.53 (4.97) |
| $T_6$ | 7.24 (5.63) | 7.13 (5.97) | 6.44 (5.40) | 6.15 (4.37) | 7.22 (5.47) | 6.82 (6.20) |
| $T_7$ | 7.44 (6.73) | 7.44 (7.57) | 7.11 (6.83) | 6.62 (6.33) | 7.44 (6.67) | 7.22 (7.37) |
| $T_8$ | 7.77 (7.57) | 7.42 (7.43) | 7.48 (7.77) | 7.35 (7.97) | 7.77 (7.50) | 7.37 (7.67) |
| $T_9$ | 8.04 (8.37) | 7.68 (8.87) | 8.02 (9.03) | 7.84 (9.43) | 8.08 (8.43) | 7.62 (8.53) |
| $T_{10}$ | 8.44 (9.17) | 7.77 (9.00) | 8.20 (9.87) | 8.00 (9.53) | 8.40 (9.13) | 7.77 (9.07) |
| **Kendalls W** | .729** | .866** | .822** | .855** | .781** | .866** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

Based on the organoleptic evaluation, treatment $T_1$ to $T_{10}$ had a mean score ranging from 6.28 to 8.44 and the mean rank score of 2.33 to 9.17 in terms of appearance. For colour, the mean score varied from 6.35 to 7.77 with a mean rank score of 2.60 to 9.00. In case of flavour, the mean score and mean rank score varied from 5.57 to 8.20 and 2.37 and 9.87. For texture, the mean score and mean rank score differs from 5.80 to 8.00 and 3.10 to 9.53. For taste, the mean score and mean rank differs from 6.31 to 8.40 and 2.20 to 9.13. The overall acceptability had a mean score and mean rank score ranging from 5.75 to 7.77 and 2.43 to 9.07.

The highest mean score and mean rank was obtained for control ($T_0$) followed by treatment $T_{10}$ which contained 40 per cent barnyard millet, 58 per cent of whole wheat flour and 2 per cent of germinated fenugreek powder. The best selected barnyard millet based vermicelli incorporated with fenugreek seed ($T_{10}$) are shown in Plate 2.

The Kendall's value obtained had a significant agreement among the judges for all the sensory parameters in fenugreek incorporated barnyard vermicelli.

**4.2.1.1. Sensory evaluation of barnyard millet based *uppuma* incorporated with fenugreek seed**

The sensory score of the barnyard millet based *uppuma* prepared from vermicelli incorporated with fenugreek seed are presented in Table 6.

The appearance of *uppuma* of various treatments $T_1$ to $T_{10}$ had a mean score and mean rank score of 6.20 to 8.04 and 2.77 to 9.30. In case of colour and flavour, the mean score varied from 6.20 to 7.80 and 6.06 to 8.82 whereas mean rank score varied from 2.73 to 9.30 and 2.57 to 9.80. *Uppuma* had a mean score and mean rank score for texture as 5.93 to 8.46 and 2.28 to 9.47. For taste, mean score and mean rank score varied from 5.91 to 7.55 and 2.82 to 9.29. The overall acceptability of the *uppuma* mean score and mean rank score varied from 6.20 to 7.88 and 2.62 to 9.34 respectively.

The treatment $T_{10}$ showed a high mean score of 7.88 with a mean rank score of 9.34 after control in terms of overall acceptability was shown in Plate 2. Based on Kendall's value there was a significant agreement among the judges for all the quality attributes of *uppuma*.

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**Table 6. Mean scores for organoleptic evaluation of fenugreek incorporated barnyard *uppuma***

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.86 (10.97) | 8.75 (10.87) | 8.55 (10.43) | 9.17 (10.59) | 8.26 (10.96) | 8.75 (10.81) |
| $T_1$ | 6.57 (4.20) | 6.37 (3.30) | 6.11 (2.67) | 5.93 (2.28) | 6.24 (4.18) | 6.37 (3.34) |
| $T_2$ | 6.20 (2.90) | 6.20 (2.73) | 6.06 (2.57) | 6.17 (2.84) | 5.97 (3.04) | 6.20 (2.62) |
| $T_3$ | 6.31 (3.97) | 6.37 (3.30) | 6.51 (4.03) | 6.28 (3.50) | 5.97 (3.93) | 6.37 (3.38) |
| $T_4$ | 6.20 (2.77) | 6.37 (3.13) | 6.37 (3.63) | 6.14 (3.28) | 5.91 (2.82) | 6.37 (3.06) |
| $T_5$ | 6.57 (3.80) | 6.55 (4.20) | 6.57 (3.80) | 6.62 (4.06) | 6.76 (3.86) | 6.55 (4.12) |
| $T_6$ | 6.84 (4.60) | 6.93 (5.63) | 6.82 (4.73) | 7.06 (5.47) | 6.44 (4.50) | 6.93 (5.66) |
| $T_7$ | 7.40 (6.53) | 7.15 (6.40) | 7.44 (7.20) | 7.48 (6.97) | 6.95 (6.50) | 7.15 (6.47) |
| $T_8$ | 7.77 (8.27) | 7.51 (7.97) | 7.75 (8.33) | 7.95 (8.12) | 7.31 (8.29) | 7.51 (7.99) |
| $T_9$ | 7.91 (8.70) | 7.77 (9.20) | 7.88 (8.80) | 8.40 (9.41) | 7.42 (8.64) | 7.77 (9.22) |
| $T_{10}$ | 8.04 (9.30) | 7.80 (9.30) | 8.22 (9.80) | 8.46 (9.47) | 7.55 (9.29) | 7.88 (9.34) |
| **Kendalls W** | .791** | .866** | .822** | .855** | .781** | .866** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

Vermicelli

*Uppuma*

**Plate 2. Fenugreek incorporated barnyard vermicelli and *uppuma***

Vermicelli

*Uppuma*

**Plate 3. Garden cress seed incorporated barnyard vermicelli and *uppuma***

### 4.2.2. Sensory evaluation of barnyard millet based vermicelli incorporated with garden cress seed

The vermicelli prepared with a combination of (40-80%) barnyard millet, (15-58%) whole wheat and (2-5%) garden cress seed. The mean scores of organoleptic evaluation of the barnyard millet based garden cress seed incorporated vermicelli with control is depicted in Table 7.

**Table 7. Mean scores for organoleptic evaluation of garden cress seed incorporated barnyard vermicelli**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.68 (10.67) | 8.73 (10.87) | 8.55 (10.80) | 8.68 (10.93) | 8.55 (11.00) | 8.66 (10.97) |
| $T_1$ | 5.77 (2.17) | 6.13 (2.47) | 6.46 (3.33) | 5.60 (2.13) | 5.75 (2.37) | 5.71 (2.61) |
| $T_2$ | 5.68 (2.00) | 6.06 (2.63) | 6.42 (2.80) | 7.33 (3.23) | 5.86 (2.97) | 5.80 (2.72) |
| $T_3$ | 6.08 (3.07) | 6.62 (4.27) | 6.48 (3.20) | 5.86 (3.03) | 5.91 (2.90) | 5.84 (3.00) |
| $T_4$ | 6.22 (3.44) | 6.64 (4.20) | 6.55 (3.30) | 5.53 (2.27) | 6.06 (3.47) | 6.13 (3.97) |
| $T_5$ | 6.78 (5.07) | 6.84 (4.87) | 6.93 (5.37) | 6.53 (5.67) | 6.60 (5.60) | 6.64 (5.62) |
| $T_6$ | 7.04 (5.77) | 7.24 (5.67) | 7.28 (7.20) | 6.71 (5.73) | 6.68 (5.67) | 7.71 (5.75) |
| $T_7$ | 7.35 (6.83) | 7.37 (6.53) | 7.35 (7.53) | 7.40 (7.50) | 7.15 (7.20) | 7.06 (6.59) |
| $T_8$ | 7.64 (7.70) | 7.51 (7.10) | 7.24 (6.20) | 7.48 (7.83) | 7.33 (7.93) | 7.37 (7.69) |
| $T_9$ | 8.00 (9.20) | 7.80 (8.73) | 7.53 (7.90) | 7.66 (8.47) | 7.33 (7.57) | 7.53 (8.09) |
| $T_{10}$ | 8.06 (9.53) | 7.80 (8.77) | 7.60 (8.37) | 7.78 (8.60) | 7.68 (9.33) | 7.88 (9.44) |
| **Kendalls W** | .885** | .703** | .667** | .808** | .795** | .779** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

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Among all the treatments, $T_{10}$ vermicelli prepared with 40 per cent barnyard millet, 58 percent whole wheat flour and 2 per cent of garden cress seed were highly acceptable in all the sensory qualities, after control (Plate 3). The treatment $T_{10}$ had a mean score and mean rank score of 8.06 and 9.53 in appearance, 7.80 and 8.77 in colour, 7.60 and 8.37 in flavour, 7.78 and 8.60 in texture, 7.68 and 9.33 in taste and 7.88 and 9.44 in overall acceptability. The Kendall's W showed a significant agreement among the judges for vermicelli prepared with a combination of barnyard millet flour, whole wheat flour and garden cress seed.

#### 4.1.2.1. Sensory evaluation of barnyard millet based *uppuma* incorporated with garden cress seed

*Uppuma* prepared from the barnyard millet vermicelli in combination with whole wheat flour and garden cress seed is presented in Plate 3. Barnyard millet based garden cress seed *uppuma* were subjected to sensory evaluation and Table 8 shows the mean score for all the sensory parameters.

*Uppuma* prepared with various treatments had a mean score ranging from 5.71 to 8.40 in appearance, 5.71 to 8.24 in colour, 6.37 to 8.04 in flavour, 5.62 to 7.91 in texture, 5.44 to 8.06 in taste and 5.75 to 8.31 in overall acceptability. The control $T_0$ had the highest mean score for appearance (8.82), colour (8.75), flavour (8.55), texture (8.62), taste (8.73) and overall acceptability (8.73). Among the various barnyard millet incorporated garden cress seed *uppuma* the mean score was highest in treatment $T_{10}$ (40 per cent barnyard millet flour, 58 percent whole wheat flour and 2 per cent of garden cress seed) in all the parameters like appearance (8.40), colour (8.24), flavour (8.04), texture (7.91), taste (8.06) and overall acceptability (8.31), which was selected as the best treatment for further studies. The Kendall's value showed a significant agreement among the judges for all quality attributes of barnyard *uppuma* incorporated with garden cress seed.

**Table 8. Mean scores for organoleptic evaluation of garden cress seed incorporated barnyard *uppuma***

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.82 (10.67) | 8.75 (10.60) | 8.55 (10.40) | 8.62 (10.83) | 8.73 (10.70) | 8.73 (10.60) |
| $T_1$ | 5.77 (2.43) | 5.91 (2.77) | 6.37 (2.53) | 5.62 (2.03) | 5.48 (2.17) | 5.77 (2.33) |
| $T_2$ | 5.71 (1.77) | 5.71 (1.87) | 6.42 (2.63) | 5.62 (2.00) | 5.44 (1.73) | 5.75 (2.17) |
| $T_3$ | 6.08 (2.77) | 6.20 (2.70) | 6.48 (2.97) | 6.06 (3.43) | 6.00 (3.60) | 6.20 (3.50) |
| $T_4$ | 6.37 (3.73) | 6.55 (3.90) | 6.48 (3.23) | 6.13 (3.70) | 6.00 (3.97) | 6.04 (3.13) |
| $T_5$ | 7.00 (5.33) | 7.02 (5.50) | 7.00 (5.23) | 6.62 (5.13) | 6.71 (5.77) | 6.86 (5.30) |
| $T_6$ | 7.20 (6.50) | 7.24 (6.47) | 7.13 (6.25) | 6.77 (5.77) | 6.66 (5.27) | 6.91 (5.59) |
| $T_7$ | 7.48 (6.57) | 7.51 (6.83) | 7.44 (7.27) | 7.33 (7.40) | 7.20 (6.50) | 7.33 (7.03) |
| $T_8$ | 7.73 (7.77) | 7.68 (7.51) | 7.51 (7.20) | 7.42 (7.53) | 7.64 (8.20) | 7.44 (7.50) |
| $T_9$ | 8.17 (8.93) | 8.11 (9.00) | 7.91 (9.13) | 7.77 (8.83) | 7.88 (8.93) | 7.84 (8.80) |
| $T_{10}$ | 8.40 (9.53) | 8.24 (9.40) | 8.04 (9.17) | 7.91 (9.33) | 8.06 (9.17) | 8.31 (10.07) |
| **Kendalls W** | .875** | .870** | .790** | .858** | .833** | .857** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

### 4.2.3. Sensory evaluation of barnyard millet based vermicelli incorporated with *Brahmi*

The vermicelli prepared with treatments ($T_1$ to $T_{10}$) with different proportion of barnyard millet, whole wheat flour and *Brahmi* were compared with the control ($T_0$) and is shown in Table 9. Among treatment $T_0$ to $T_{10}$, control was most acceptable followed by $T_{10}$ in case of all the sensory parameters. The



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treatment $T_{10}$ had a mean score of 8.04 (9.40) in appearance, 7.97 (9.00) in colour, 7.91 (9.13) in flavour, 8.06 (9.73) in texture, 8.06 (9.77) in taste. The overall acceptability of the developed vermicelli obtained a mean score of 8.02 (9.77). The Kendall's value showed a significant agreement among the judges for all the sensory parameters of *Brahmi* incorporated barnyard vermicelli.

**Table 9. Mean scores for organoleptic evaluation of *Brahmi* incorporated barnyard vermicelli**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.77 (10.73) | 8.53 (10.50) | 8.33 (9.53) | 8.42 (9.30) | 8.42 (10.30) | 8.55 (10.57) |
| $T_1$ | 5.88 (2.63) | 6.73 (3.27) | 6.82 (4.07) | 6.31 (3.40) | 6.17 (3.40) | 6.37 (3.93) |
| $T_2$ | 5.64 (2.20) | 6.31 (2.90) | 6.68 (3.93) | 6.04 (3.30) | 5.80 (2.13) | 6.11 (3.27) |
| $T_3$ | 6.02 (3.70) | 6.66 (4.23) | 6.77 (4.40) | 6.22 (4.63) | 6.02 (2.63) | 6.11 (2.87) |
| $T_4$ | 5.59 (3.03) | 6.44 (2.80) | 6.62 (2.53) | 6.11 (3.20) | 6.37 (4.10) | 6.44 (3.93) |
| $T_5$ | 6.26 (4.17) | 6.66 (3.10) | 6.73 (3.93) | 6.62 (5.23) | 6.51 (4.83) | 6.35 (5.30) |
| $T_6$ | 6.73 (5.53) | 7.17 (6.00) | 7.08 (5.47) | 6.97 (5.97) | 6.95 (5.57) | 6.86 (5.67) |
| $T_7$ | 7.15 (7.00) | 7.26 (6.73) | 7.08 (5.67) | 6.91 (5.23) | 7.15 (6.57) | 6.93 (5.23) |
| $T_8$ | 7.82 (8.27) | 7.82 (8.63) | 7.68 (8.53) | 7.68 (8.30) | 7.51 (8.20) | 7.55 (7.77) |
| $T_9$ | 8.06 (9.33) | 7.91 (8.83) | 7.82 (8.80) | 7.77 (8.10) | 7.64 (8.50) | 7.86 (9.10) |
| $T_{10}$ | 8.04 (9.40) | 7.97 (9.00) | 7.91 (9.13) | 8.06 (9.73) | 8.06 (9.77) | 8.02 (9.77) |
| **Kendalls W** | .822** | .805** | .645** | .609** | .772** | .738** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

#### 4.2.3.1. Sensory evaluation of barnyard millet based *uppuma* incorporated with *Brahmi*

The organoleptic evaluation of various combination of *Brahmi* incorporated barnyard millet based *uppuma* along with control is presented in Table 10. The best selected *Brahmi* incorporated barnyard millet based *uppuma* is represented in Plate 4.

**Table 10. Mean scores for organoleptic evaluation of *Brahmi* incorporated barnyard *uppuma***

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.77 (10.80) | 8.57 (10.57) | 8.44 (10.83) | 8.62 (10.43) | 8.64 (10.43) | 8.55 (9.93) |
| $T_1$ | 5.20 (2.37) | 6.11 (3.43) | 6.04 (3.02) | 5.44 (2.30) | 5.46 (2.27) | 5.60 (2.77) |
| $T_2$ | 5.04 (2.53) | 5.80 (2.13) | 5.84 (2.90) | 5.44 (2.57) | 5.40 (1.93) | 5.60 (2.77) |
| $T_3$ | 5.31 (3.30) | 6.02 (2.90) | 5.86 (2.10) | 5.55 (2.73) | 5.55 (2.80) | 5.57 (2.40) |
| $T_4$ | 5.66 (4.30) | 6.15 (3.77) | 6.22 (3.70) | 5.75 (3.43) | 5.73 (3.70) | 5.82 (4.17) |
| $T_5$ | 6.24 (5.10) | 6.60 (5.10) | 6.71 (6.07) | 6.44 (5.76) | 6.33 (4.96) | 6.37 (4.80) |
| $T_6$ | 6.42 (5.57) | 6.60 (4.83) | 6.55 (4.97) | 6.28 (4.83) | 6.42 (5.57) | 6.48 (5.70) |
| $T_7$ | 6.84 (6.10) | 6.93 (6.27) | 7.04 (6.77) | 7.04 (7.33) | 7.24 (7.57) | 6.77 (5.87) |
| $T_8$ | 7.35 (7.80) | 7.53 (8.57) | 7.26 (7.37) | 7.42 (8.30) | 7.46 (8.20) | 7.37 (8.33) |
| $T_9$ | 7.93 (9.53) | 7.88 (9.33) | 7.60 (8.67) | 7.84 (9.03) | 7.84 (8.90) | 7.97 (9.47) |
| $T_{10}$ | 7.95 (9.60) | 7.95 (9.40) | 7.77 (9.43) | 7.84 (9.13) | 8.13 (9.73) | 8.22 (9.80) |
| **Kendalls W** | .900** | .809** | .800** | .855** | .898** | .812** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

The organoleptic evaluation result revealed that among the *Brahmi* incorporated *uppuma*, treatment $T_{10}$ had a maximum mean score and mean rank score in appearance (7.95 and 9.60), colour (7.95 and 9.40), flavour (7.77 and 9.43), texture (7.84 and 9.13), taste (8.13 and 9.73) and overall acceptability (8.22 and 9.80). The most acceptable treatment $T_{10}$ with a high mean score in *Brahmi* incorporated vermicelli was selected for further studies. The mean score of various treatments were statistically analysed using Kendall's test. The result showed that there was a significant agreement among the judges in all the sensory parameters of the barnyard millet based *uppuma* incorporated with *Brahmi*.

### 4.2.4. Sensory evaluation of barnyard millet based vermicelli incorporated with *Ekanayakam* root barks

The mean scores for barnyard millet vermicelli incorporated with *Ekanayakam* root bark along with control was tabulated in Table 11. The organoleptic evaluation of *Ekanayakam* vermicelli revealed that, mean score was highest in the case of control for all the sensory parameters followed by $T_{10}$ (40 per cent barnyard millet, 58 per cent whole wheat flour and 2 per cent *Ekanayakam* root barks) is shown in Plate 5.

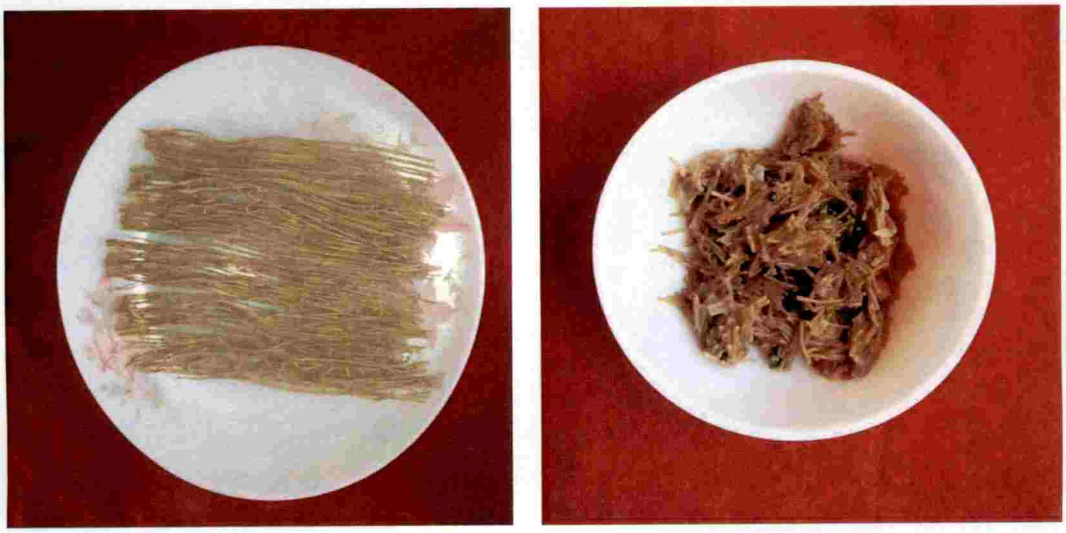
The Table 11 showed that $T_{10}$ had the mean score for appearance (7.77), colour (7.91), flavour (7.80), texture (7.73), and taste (7.81) and the overall acceptability (7.75). The mean rank score of $T_{10}$ was observed as 9.00 for appearance, 9.23 for colour, 8.07 for flavour, 8.87 for texture, 9.40 for taste and 9.67 for overall acceptability. The statistical analysis revealed that there was a significant agreement among the judges for all the sensory attributes of the prepared vermicelli with a combination of barnyard millet flour, whole wheat flour and *Ekanayakam*.

**Table 11. Mean scores for organoleptic evaluation of *Ekanayakam* incorporated barnyard vermicelli**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.84 (10.93) | 8.86 (10.80) | 8.71 (10.53) | 8.84 (10.67) | 8.77 (10.71) | 8.82 (10.53) |
| $T_1$ | 5.16 (3.13) | 5.46 (3.17) | 6.28 (3.10) | 5.98 (3.37) | 5.51 (3.50) | 5.55 (2.60) |
| $T_2$ | 5.31 (3.30) | 5.35 (4.13) | 6.15 (3.17) | 5.98 (3.53) | 5.71 (3.60) | 5.71 (3.37) |
| $T_3$ | 5.44 (4.40) | 5.57 (3.83) | 6.20 (4.17) | 6.04 (4.17) | 5.88 (3.90) | 5.82 (3.37) |
| $T_4$ | 5.75 (4.10) | 5.91 (3.27) | 6.51 (4.63) | 6.11 (4.13) | 6.02 (4.00) | 6.24 (4.50) |
| $T_5$ | 6.13 (4.63) | 6.08 (3.57) | 6.57 (4.93) | 6.22 (4.87) | 6.64 (4.17) | 6.11 (4.33) |
| $T_6$ | 6.86 (6.08) | 6.48 (5.60) | 6.91 (6.30) | 6.67 (4.90) | 6.77 (6.20) | 6.60 (5.93) |
| $T_7$ | 6.44 (5.23) | 6.57 (6.07) | 6.93 (6.40) | 6.88 (5.77) | 7.22 (5.03) | 6.84 (5.67) |
| $T_8$ | 7.28 (6.70) | 7.08 (7.77) | 7.33 (6.97) | 7.15 (6.90) | 7.48 (7.20) | 7.02 (7.73) |
| $T_9$ | 7.71 (8.53) | 7.64 (8.57) | 7.46 (7.73) | 7.62 (8.83) | 7.66 (8.83) | 7.44 (8.70) |
| $T_{10}$ | 7.77 (9.00) | 7.91 (9.23) | 7.80 (8.07) | 7.73 (8.87) | 7.81 (9.40) | 7.75 (9.67) |
| **Kendalls W** | .630** | .729** | .520** | .613** | .612** | .724** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level



Vermicelli

*Uppuma*

**Plate 4. *Brahmi* incorporated barnyard vermicelli and *uppuma***

Vermicelli

*Uppuma*

**Plate 5. *Ekanayakam* incorporated barnyard vermicelli and *uppuma***

#### 4.2.4.1. Sensory evaluation of barnyard millet based *uppuma* incorporated with *Ekanayakam* root barks

From *Ekanayakam* incorporated barnyard millet vermicelli, *uppuma* were prepared and they were analysed for their organoletic qualities. The best selected barnyard millet based *uppuma* prepared by incorporating *Ekanayakam* root barks is given in Plate 5.

The organoleptic evaluation showed that mean score for the appearance varies from 5.11 to 7.71. For colour and flavour the mean score differs from 5.40 to 7.84 and 6.02 to 7.67. The texture and taste of the *uppuma* had a mean score varied from 6.00 to 7.71 and 5.51 to 7.06. The overall acceptability of *uppuma* were highest in control followed by $T_{10}$ with a mean score of 7.73 where as $T_1$ had a lowest mean score of 5.55. The mean rank score was found to be highest in $T_{10}$ of 9.27 for appearance and colour, 8.80 for flavour, 9.23 for texture, 9.37 for texture and 9.40 for overall acceptability.

Among all the treatments with *Ekanayakam* root barks, $T_{10}$ had highest score and was selected for storage studies. The Kendall's value showed a significant agreement among the judges for all the sensory attributes in barnyard millet based *uppuma* incorporated with *Ekanayakam* root barks.

**Table 12. Mean scores for organoleptic evaluation of *Ekanayakam* incorporated barnyard *uppuma***

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_0$ | 8.22 (10.97) | 8.86 (10.67) | 8.71 (10.60) | 8.82 (10.73) | 8.77 (10.70) | 8.22 (10.80) |
| $T_1$ | 5.11 (2.13) | 5.40 (2.80) | 6.15 (3.63) | 6.08 (3.60) | 5.51 (2.33) | 5.55 (2.07) |
| $T_2$ | 5.17 (2.27) | 5.42 (3.07) | 6.02 (3.03) | 6.00 (2.73) | 5.71 (2.50) | 5.71 (2.60) |



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Table 12 Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| $T_3$ | 5.37 (2.27) | 5.44 (3.37) | 6.06 (3.23) | 6.06 (3.37) | 5.88 (3.37) | 5.82 (3.07) |
| $T_4$ | 5.68 (3.63) | 5.77 (3.77) | 6.37 (4.07) | 6.08 (3.30) | 6.02 (4.23) | 6.24 (4.60) |
| $T_5$ | 6.06 (4.93) | 6.02 (4.77) | 6.44 (4.53) | 6.15 (3.70) | 6.08 (3.87) | 6.11 (4.00) |
| $T_6$ | 6.62 (6.47) | 6.42 (5.77) | 6.91 (6.60) | 6.60 (6.13) | 6.64 (6.30) | 6.60 (6.43) |
| $T_7$ | 6.51 (6.03) | 6.57 (6.30) | 6.86 (6.17) | 6.84 (6.70) | 6.77 (6.47) | 6.84 (6.80) |
| $T_8$ | 7.22 (7.81) | 7.06 (7.17) | 7.20 (7.13) | 7.11 (7.60) | 7.22 (7.90) | 7.02 (7.27) |
| $T_9$ | 7.64 (9.17) | 7.60 (9.07) | 7.40 (8.20) | 7.57 (8.90) | 7.48 (8.97) | 7.42 (8.97) |
| $T_{10}$ | 7.71 (9.27) | 7.84 (9.27) | 7.67 (8.80) | 7.71 (9.23) | 7.06 (9.37) | 7.73 (9.40) |
| **Kendalls W** | .863** | .729** | .628** | .728** | .809** | .829** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

### 4.2.5. Selection of barnyard millet based designer vermicelli

Based on organoleptic evaluation, best combination of barnyard millet based vermicelli, one each from all the functional ingredients was selected along with the control and is represented in Table 13 (Plate 6).


**Plate 6. Selected vermicelli for storage**

**Table 13. Selected vermicelli for storage**

| Treatments | Combinations |
|---|---|
| TC | Refined wheat flour vermicelli (control) |
| TF | 40% germinated barnyard millet flour + 58% whole wheat flour + 2% germinated fenugreek seed flour |
| TG | 40% germinated barnyard millet flour + 58% whole wheat flour + 2% garden cress seed |
| TB | 40% germinated barnyard millet flour + 49.5% whole wheat flour + 0.5% *Brahmi* leaf powder |
| TE | 40% germinated barnyard millet flour + 58% whole wheat flour + 2% *Ekanayakam* root bark powder |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

### 4.3. Quality evaluation of selected barnyard millet based vermicelli

The selected four barnyard millet based vermicelli from each functional ingredient along with control (Table 13) were packed in polyethylene pouches of 250 gauge and kept in ambient conditions for a period of four months. The quality evaluation of the stored vermicelli was assessed initially, and during the second and fourth month of storage period.

#### 4.3.1. Nutritional qualities

The nutritional qualities of selected barnyard vermicelli in comparison with control were done and the details are as follows.

##### 4.3.1.1. Moisture

The moisture content of the selected barnyard based vermicelli with each functional ingredient in comparison with control was tabulated and presented in Table 14.

The moisture content of the vermicelli, initially varied from 7.70 to 8.06 per cent and was found to be the highest in vermicelli TC (8.06%) and lowest in TB (7.70%). During second and fourth month moisture content was found to be highest in control, which was 8.10% and 8.32% respectively and lowest in treatment TF of 7.81% and 8.01% respectively. There was a significant difference in the moisture content of control and barnyard millet based vermicelli's throughout storage. As per DMRT initially there was no significant difference observed among the barnyard millet based vermicelli. During second month treatment TF was on par with TG and TB was on par with TE. During fourth month of storage treatment TB obtained high moisture content of 8.14 per cent and remaining treatment TF, TG and TE was on par with a moisture content of 8.01, 8.03 and 8.04 per cent which was lower than control. In all the treatment there was gradual increase in moisture content throughout the storage period.

**Table 14. Moisture content of selected barnyard millet based vermicelli on storage**

| Treatments | Moisture (%) | | |
|---|---|---|---|
| | Initial | 2nd month | 4th month |
| TC | 8.06$^{a}$ | 8.10$^{a}$ (0.49) | 8.32$^{a}$ (2.71) |
| TF | 7.79$^{b}$ | 7.81$^{c}$ (0.25) | 8.01$^{c}$ (2.56) |
| TG | 7.80$^{b}$ | 7.86$^{c}$ (0.76) | 8.03$^{c}$ (2.16) |
| TB | 7.70$^{b}$ | 7.95$^{b}$ (3.34) | 8.14$^{b}$ (2.38) |
| TE | 7.78$^{b}$ | 7.97$^{b}$ (2.44) | 8.04$^{c}$ (0.87) |
| C.D (0.05) | 0.138* | 0.043* | 0.103* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.1.2. TSS

The TSS of the selected barnyard millet based vermicelli in comparison with control was assessed using a hand refractometer and presented in Table 15.

As revealed in Table 13, initially TSS content of barnyard millet based vermicelli varied from $2.4^0$ to $3.6^0$ brix. High TSS content was noted in control vermicelli of $10^0$ brix whereas garden cress incorporated vermicelli (TG) had a low TSS content of $2.4^0$ brix. The TSS content of barnyard vermicelli differs from $2.6^0$ to $4.0^0$ brix and $2.9^0$ to $4.2^0$ brix on second and fourth month of storage. For all the selected vermicelli there was a gradual increase in TSS content on storage. There was a significant difference between control and barnyard millet based vermicelli in TSS content during initial, second and fourth month of storage. Among selected vermicelli, TSS content of treatment TB was on par with TE, throughout the storage period form a homogenous group.

**Table 15. TSS content of selected barnyard millet based vermicelli on storage**

| Treatments | TSS ($^0$ brix) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $10^a$ | $10.6^a$ (6.00) | $10.9^a$ (2.83) |
| TF | $3.6^b$ | $4.0^b$ (11.11) | $4.2^b$ (5.00) |
| TG | $2.4^d$ | $2.6^d$ (8.33) | $2.9^d$ (11.53) |
| TB | $3.0^c$ | $3.2^c$ (6.66) | $3.3^c$ (3.12) |
| TE | $3.1^c$ | $3.4^c$ (9.67) | $3.5^c$ (2.94) |
| C.D (0.05) | 0.150* | 0.412* | 0.340* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

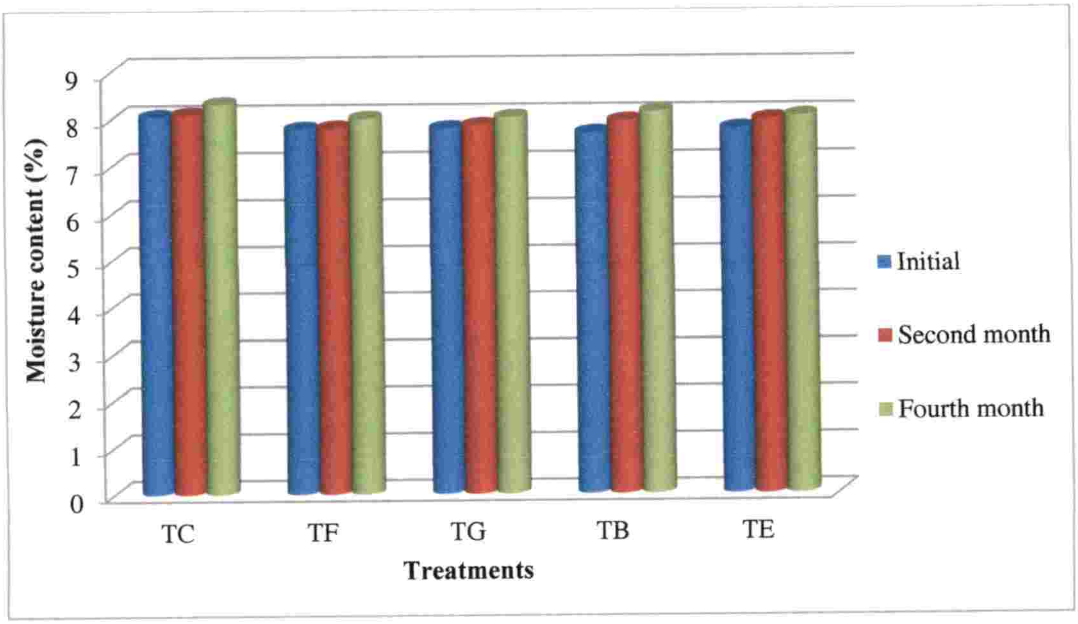


**Figure 1. Moisture content of selected barnyard millet based vermicelli on storage**

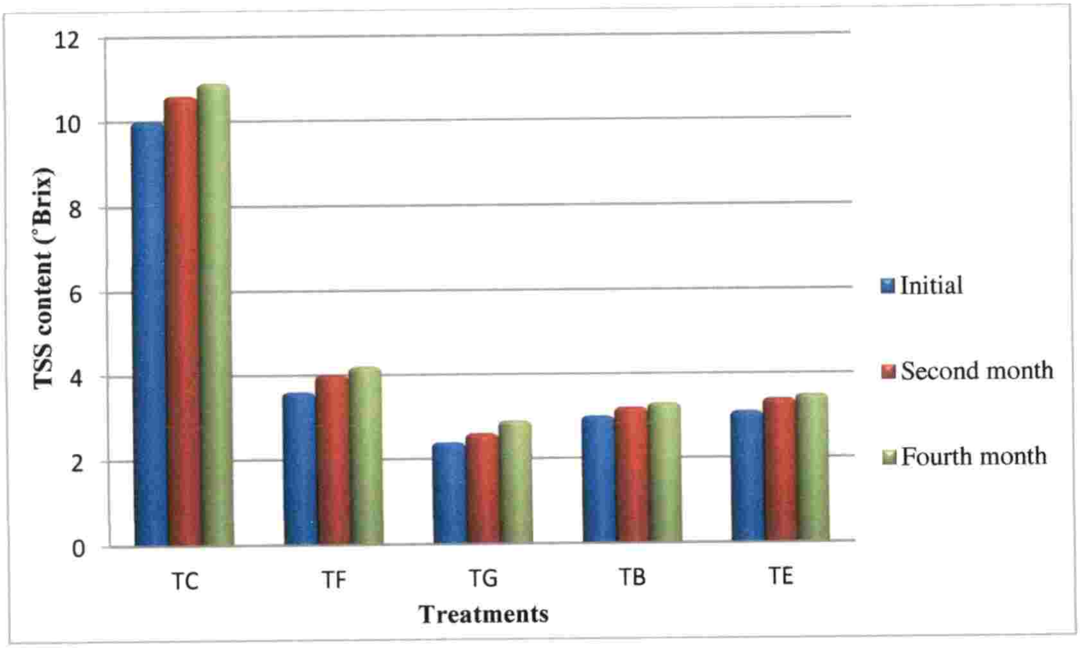


**Figure 2. TSS content of selected barnyard millet based vermicelli on storage**

### 4.3.1.3. Carbohydrate

The carbohydrate content of the various barnyard millet based vermicelli and control are presented in Table 16.

The carbohydrate content of control vermicelli was high (78.10g 100 $g^{-1}$ initially, 77.86g 100 $g^{-1}$ in second month and 77.53 g 100 $g^{-1}$ in fourth month) throughout the storage. The initial carbohydrate content of barnyard millet based vermicelli prepared with fenugreek, garden cress, *Brahmi* and *Ekanayakam* was 50.53g 100 $g^{-1}$, 53.25g 100 $g^{-1}$, 51.25g 100 $g^{-1}$ and 50.47g 100 $g^{-1}$ which gradually decreased to 49.67g 100 $g^{-1}$, 52.94g 100 $g^{-1}$, 50.91g 100 $g^{-1}$ and 50.13g 100 $g^{-1}$ at fourth month of storage. The Table 16 revealed a significant difference in the carbohydrate content of barnyard millet based vermicelli and control throughout the storage period. During entire period of storage treatment TF was on par with TE and treatment TG was on par with TB.

**Table 16. Carbohydrate content of selected barnyard millet based vermicelli on storage**

| Treatments | Carbohydrate (g 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $78.10^{a}$ | $77.86^{a}$ (0.307) | $77.53^{a}$ (0.423) |
| TF | $50.53^{c}$ | $50.32^{c}$ (0.415) | $49.67^{c}$ (1.291) |
| TG | $53.25^{b}$ | $53.01^{b}$ (0.450) | $52.94^{b}$ (0.139) |
| TB | $51.25^{b}$ | $50.98^{b}$ (0.526) | $50.91^{b}$ (0.137) |
| TE | $50.47^{c}$ | $50.27^{c}$ (0.396) | $50.13^{c}$ (0.270) |
| C.D (0.05) | 1.378* | 1.289* | 0.495* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.1.4. Protein

The protein content present in selected barnyard millet based vermicelli were compared with control and is presented in Table 17.

The protein content of selected barnyard millet initially varied from 7.96 g 100 $g^{-1}$ to 9.34g 100 $g^{-1}$ which is significantly higher than control of 1.53g 100 $g^{-1}$. The protein content present in selected vermicelli's decreased on storage. During second and fourth month vermicelli's prepared with barnyard millet decreased to a range of 7.76 g 100 $g^{-1}$ to 9.06g 100 $g^{-1}$ and 7.52 g 100 $g^{-1}$ to 9.03 g 100 $g^{-1}$ respectively. Among the barnyard millet based vermicelli, treatment TF obtained highest protein content and lowest protein content was observed in TB throughout the storage. All the treatment had a significant difference during initial, second and fourth month of storage.

**Table 17. Protein content of selected barnyard millet based vermicelli on storage**

| Treatments | Protein (g 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $1.53^{e}$ | $1.34^{e}$ (5.88) | $1.23^{e}$ (4.16) |
| TF | $9.34^{a}$ | $9.06^{a}$ (2.99) | $9.03^{a}$ (0.33) |
| TG | $8.24^{b}$ | $8.04^{b}$ (2.42) | $8.01^{b}$ (0.37) |
| TB | $7.96^{d}$ | $7.76^{d}$ (2.51) | $7.52^{d}$ (1.15) |
| TE | $8.09^{c}$ | $7.87^{c}$ (2.71) | $7.67^{c}$ (0.88) |
| C.D (0.05) | 0.194* | 0.104* | 0.112* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

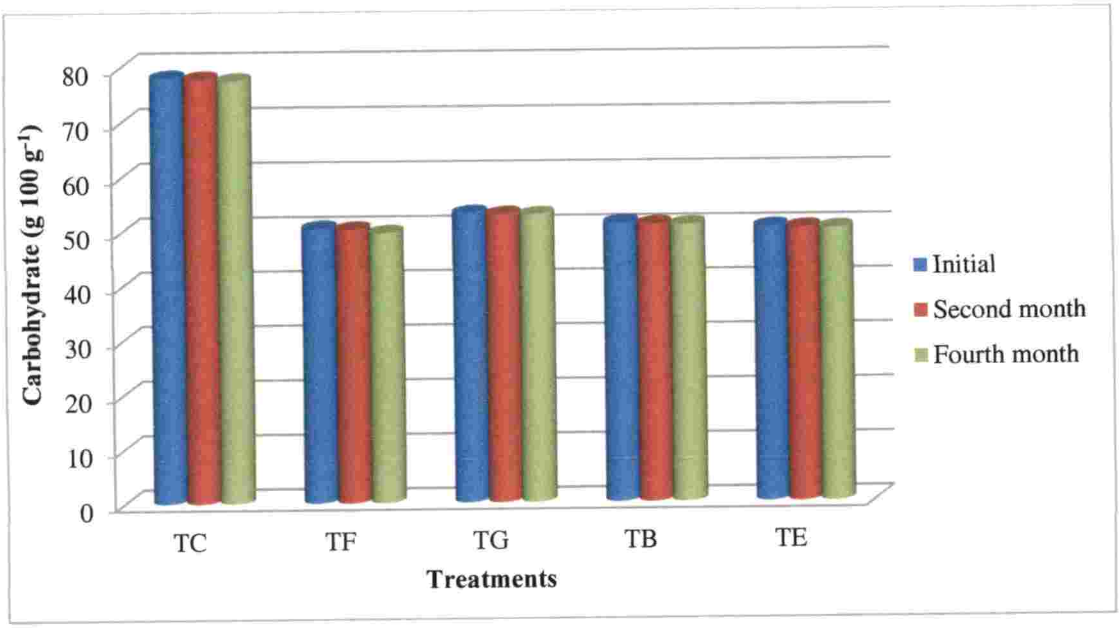


**Figure 3. Carbohydrate content of selected barnyard millet based vermicelli on storage**

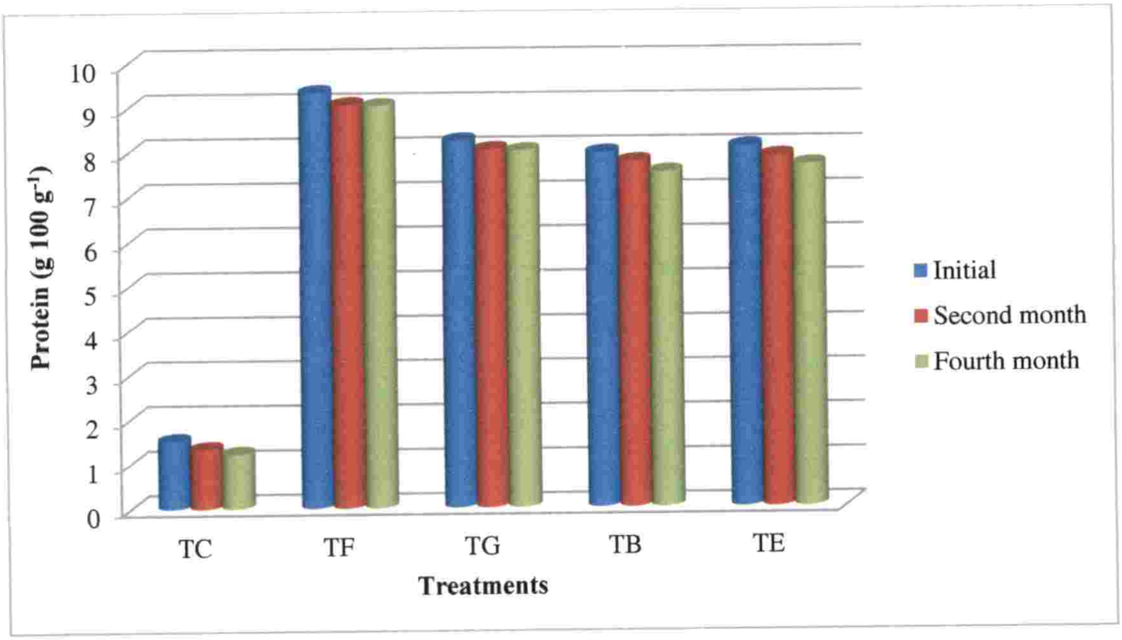


**Figure 4. Protein content of selected barnyard millet based vermicelli on storage**

#### 4.3.1.5. Fat

The fat content present in selected vermicelli were estimated and presented in Table 18.

As in Table 18 there was a decrease in fat content for all the treatment during storage. Initially the fat content present in the selected barnyard millet based vermicelli varied from 1.91 to 2.16g 100 $g^{-1}$ during second and fourth month of storage, the fat content ranging from 1.84 to 2.07g 100 $g^{-1}$ and 1.73 to 2.01g 100 $g^{-1}$. There was significant variation between barnyard millet based vermicelli and control initially and during the second and fourth month of storage. The barnyard millet based vermicelli had higher value than control during the entire period of storage. The relative change was observed to be more in treatment TG (7.94) and TB (9.59) during the second and fourth month of storage.

**Table 18. Fat content of selected barnyard millet based vermicelli on storage**

| Treatments | Fat (g 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $0.40^{d}$ | $0.38^{c}$ (5.00) | $0.36^{d}$ (5.26) |
| TF | $2.16^{a}$ | $2.07^{a}$ (4.16) | $2.01^{a}$ (2.89) |
| TG | $2.14^{a}$ | $1.97^{a}$ (7.94) | $1.85^{b}$ (6.09) |
| TB | $2.09^{b}$ | $1.98^{a}$ (5.26) | $1.79^{bc}$ (9.59) |
| TE | $1.91^{c}$ | $1.84^{b}$ (3.66) | $1.73^{b}$ (5.97) |
| C.D (0.05) | 0.023* | 0.116* | 0.103* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.1.6. Energy

The energy present in selected vermicelli was tabulated and presented in Table 19.

Initially the calorific value of the selected barnyard millet vermicelli was observed to be lowest as 256.93 Kcal in TG and highest in treatment TF of 272.17 Kcal. The control vermicelli had higher calorific value compared to barnyard millet based vermicelli. During fourth month of storage calorific value decreased in all the barnyard millet based vermicelli which varied from 247.32 to 251.03 Kcal. There was significant difference between control and barnyard millet based vermicelli during initial, second and fourth month of storage. Among all treatment, relative change was more in TF (5.45 per cent) during second month whereas energy value decreased much in TE (5.35 per cent) during fourth month of storage.

**Table 19. Energy of selected barnyard millet based vermicelli on storage**

| Treatments | Energy (Kcal/100g) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $322.14^{a}$ | $320.15^{a}$ (0.61) | $318.28^{a}$ (0.58) |
| TF | $272.17^{b}$ | $257.31^{bc}$ (5.45) | $251.03^{b}$ (2.44) |
| TG | $256.93^{b}$ | $254.67^{c}$ (0.87) | $248.48^{c}$ (2.43) |
| TB | $263.69^{b}$ | $260.96^{b}$ (1.03) | $249.82^{c}$ (4.26) |
| TE | $263.44^{b}$ | $261.26^{b}$ (0.82) | $247.32^{d}$ (5.35) |
| C.D (0.05) | 18.35* | 4.32* | 2.06* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

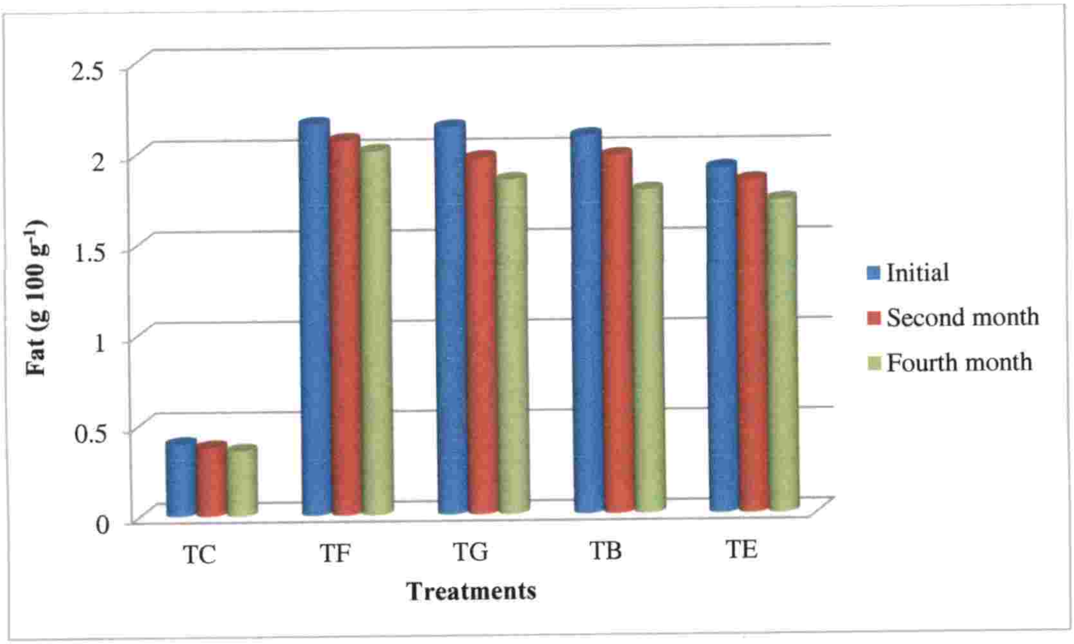


**Figure 5. Fat content of selected barnyard millet based vermicelli on storage**

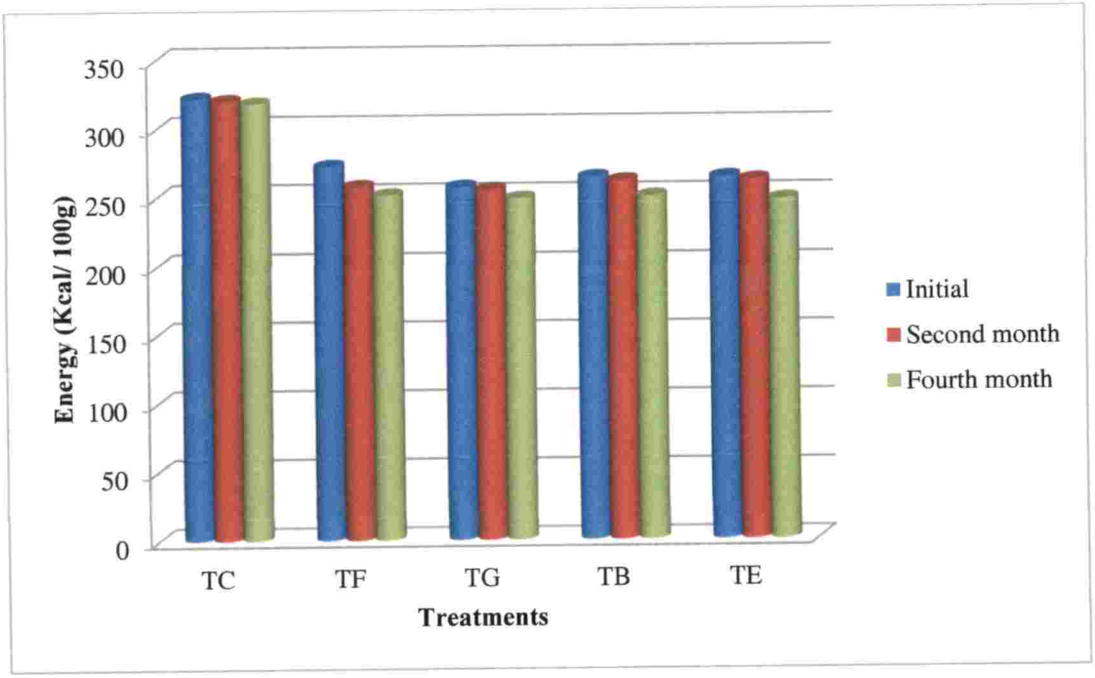


**Figure 6. Energy of selected barnyard millet based vermicelli on storage**

#### 4.3.1.7. Fibre

The changes in the fibre content of selected vermicelli during storage were tabulated and presented in Table 20.

As revealed in Table 20, the fibre content in the selected barnyard millet based vermicelli initially ranged from 3.45 g 100 $g^{-1}$ to 4.62 g 100 $g^{-1}$ with the highest fibre content in TF (4.62 g 100 $g^{-1}$) and lowest in TE (3.45 g 100 $g^{-1}$). During second month and fourth month of storage, TF had a high fibre content of 4.01g 100 $g^{-1}$ and 3.52g 100 $g^{-1}$ whereas TB obtained a lowest fibre content of 3.21 g 100 $g^{-1}$ and 3.01 g 100 $g^{-1}$ respectively. Among all the treatments, control was observed to have lowest fibre content (0.67 to 0.51) throughout the storage. There was a significant difference in the fibre content among all the treatments during initial, second and fourth month on storage with C.D value of 0.107, 1.191 and 1.44.

**Table 20. Fibre content of selected barnyard millet based vermicelli on storage**

| Treatments | Fibre (g 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $0.67^{e}$ | $0.59^{d}$ (11.94) | $0.51^{d}$ (13.55) |
| TF | $4.62^{a}$ | $4.01^{a}$ (13.20) | $3.52^{a}$ (12.21) |
| TG | $3.53^{c}$ | $3.46^{b}$ (1.98) | $3.23^{b}$ (6.64) |
| TB | $3.92^{b}$ | $3.21^{c}$ (18.11) | $3.01^{c}$ (6.23) |
| TE | $3.45^{d}$ | $3.41^{b}$ (1.15) | $3.34^{b}$ (2.05) |
| C.D (0.05) | 0.107* | 0.191* | 0.144* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.1.8. Starch

The starch content present in selected barnyard millet based vermicelli and control are detailed in Table 21.

Initially, the starch content was highest in TC (83.48 per cent). The starch content of barnyard millet based selected vermicelli (TF, TG, TB and TE) varied from 58.50 to 65.40 per cent with a highest in TF and lowest in TG. The starch present in barnyard millet vermicelli was significantly lower than control. During second and fourth month of storage barnyard millet based vermicelli varied from 58.12 to 67.02 per cent and 57.45 to 66.81 per cent with highest starch content in TF and lowest in TG. The starch content declined in all treatments on storage. The starch content present in selected vermicelli have a significant difference between all the treatments during initial, second and fourth month of storage.

**Table 21. Starch content of selected barnyard millet based vermicelli on storage**

| Treatments | Starch (%) | | |
|---|---|---|---|
| | Initial | 2nd month | 4th month |
| TC | 83.48[a] | 82.57[a] (1.09) | 81.63[a] (1.13) |
| TF | 67.52[b] | 67.02[b] (0.74) | 66.81[b] (0.31) |
| TG | 58.50[e] | 58.12[e] (0.64) | 57.45[e] (1.15) |
| TB | 65.40[c] | 64.75[c] (0.99) | 64.67[c] (0.12) |
| TE | 62.15[d] | 61.84[d] (0.49) | 61.14[d] (1.13) |
| C.D (0.05) | 1.437* | 0.682* | 0.573* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

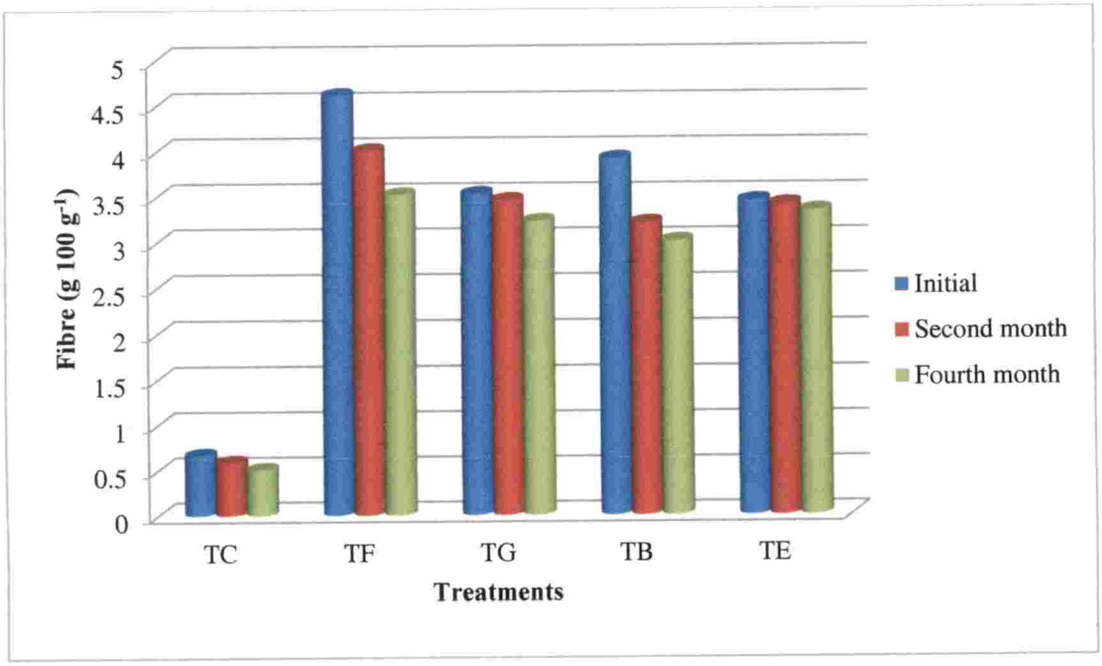


**Figure 7. Fibre content of selected barnyard millet based vermicelli on storage**

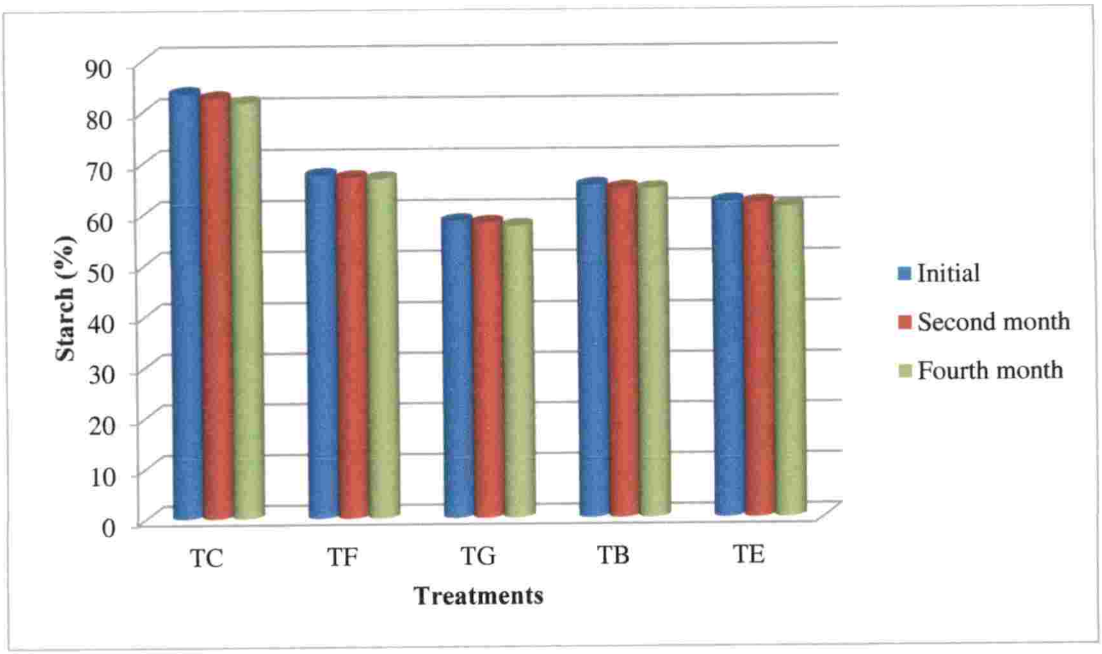


**Figure 8. Starch content of selected barnyard millet based vermicelli on storage**

### 4.3.1.9. Reducing sugar

The reducing sugar present in selected barnyard millet based vermicelli was compared with control as detailed in Table 22.

Among all treatments reducing sugar content was found to be lowest in TG (0.95%) followed by TE (1.15%), TB (1.29%), TF (2.03%) and TC (4.12%) during initial month of storage. During fourth month of storage reducing sugar content increased as 1.10 per cent in TG, 1.31 per cent in TE, 1.38 per cent in TB, 2.25 per cent in TF and 4.17 per cent in TC. There was a gradual increase in the per cent of reducing sugar during storage. Among all the vermicelli, TC shown a highest reducing sugar content and TG had lowest reducing sugar content throughout storage. There was a significant difference between barnyard millet based vermicelli and control throughout the storage period.

**Table 22. Reducing sugar content of selected barnyard millet based vermicelli on storage**

| Treatments | Reducing sugar (%) | | |
|---|---|---|---|
| | Initial | 2nd month | 4th month |
| TC | 4.12$^{a}$ | 4.15$^{a}$ (0.72) | 4.17$^{a}$ (0.48) |
| TF | 2.03$^{b}$ | 2.21$^{b}$ (8.86) | 2.25$^{b}$ (1.80) |
| TG | 0.95$^{d}$ | 1.02$^{d}$ (7.36) | 1.10$^{d}$ (7.84) |
| TB | 1.29$^{c}$ | 1.35$^{c}$ (4.65) | 1.38$^{c}$ (2.22) |
| TE | 1.15$^{c}$ | 1.23$^{c}$ (6.95) | 1.31$^{c}$ (6.50) |
| C.D (0.05) | 0.156* | 0.175* | 0.127* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

### 4.3.1.10. Total sugar

The total sugar content was estimated for the selected combination of vermicelli and is presented in Table 23. Among all the treatments, the initial total sugar content was high in TC with 4.43 per cent followed by TF with 2.47 per cent. The total sugar content of the treatments TG, TB and TE was on par during initial period. During second and fourth month of storage, highest total sugar content was shown in TC (4.45 and 4.51 per cent). Among the barnyard millet based vermicelli, total sugar was found to be high in TF (2.25 and 2.73) with respective of second and fourth month of storage. During storage, the total sugar content increased for all the treatments. As per DMRT there was a significant variation between control and barnyard millet based vermicelli. Among the barnyard millet based vermicelli, TG was on par with TB and TE upto second month of storage whereas TG and TE were on par during the entire storage period.

**Table 23. Total sugar content of selected barnyard millet based vermicelli on storage**

| Treatments | Total sugar (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $4.43^{a}$ | $4.45^{a}$ (0.45) | $4.51^{a}$ (1.34) |
| TF | $2.47^{b}$ | $2.55^{b}$ (3.23) | $2.73^{b}$ (7.05) |
| TG | $1.38^{c}$ | $1.42^{c}$ (2.89) | $1.59^{d}$ (11.97) |
| TB | $1.41^{c}$ | $1.47^{c}$ (4.25) | $1.71^{c}$ (16.32) |
| TE | $1.46^{c}$ | $1.52^{c}$ (4.10) | $1.56^{d}$ (2.63) |
| C.D | 0.144* | 0.121* | 0.092* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

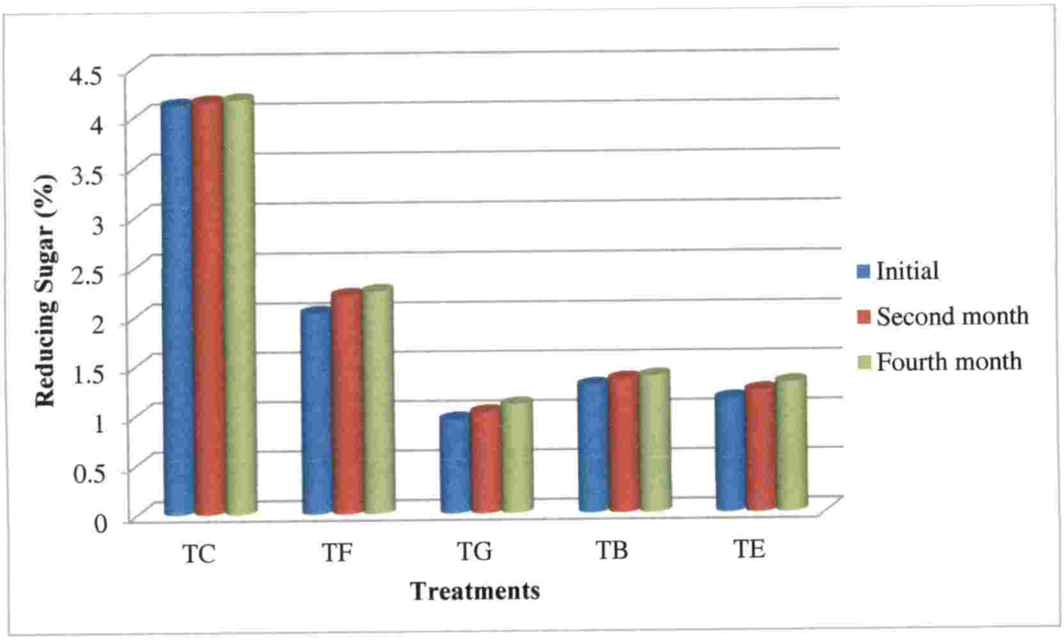


**Figure 9. Reducing sugar content of selected barnyard millet based vermicelli on storage**

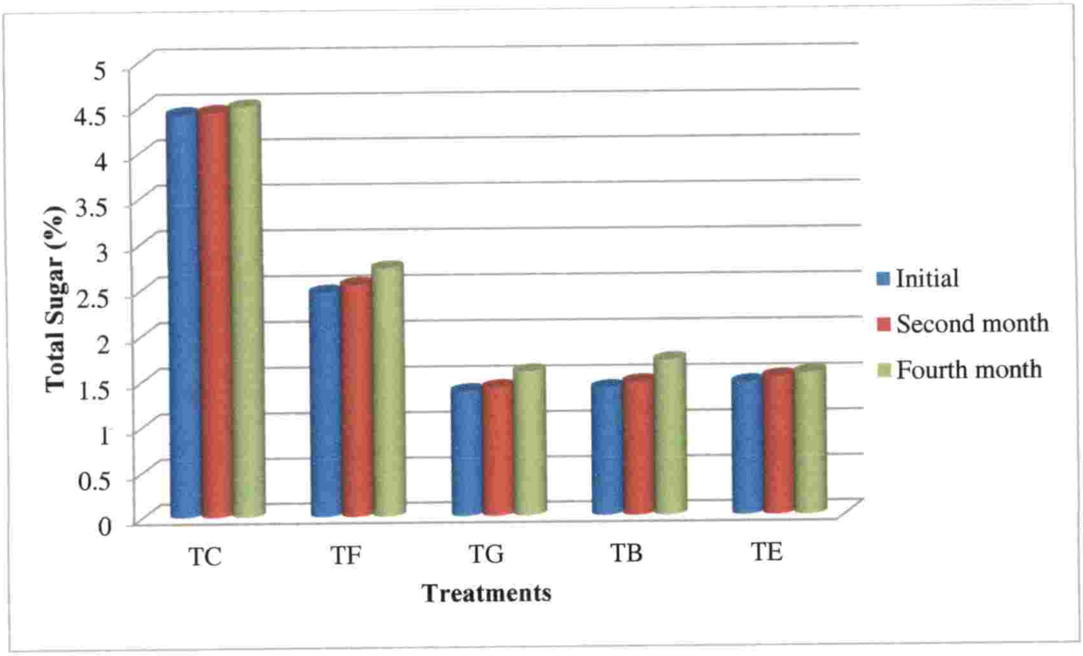


**Figure 10. Total sugar content of selected barnyard millet based vermicelli on storage**

### 4.3.1.11. Calcium

The calcium content of the vermicelli was estimated and their results were tabulated and given in Table 24.

Initially among all the treatments, the highest calcium content was observed in TG (73.52 mg 100 $g^{-1}$) and the lowest in TC (10.14 mg 100 $g^{-1}$). During second and fourth month storage, the calcium content varied from 10.0 mg 100 $g^{-1}$ (TC) to 73.02 mg 100 $g^{-1}$ (TG) and 9.85 mg 100 $g^{-1}$ (TC) to 72.34 mg 100 $g^{-1}$ (TG) respectively. The calcium content was observed to be lowest in control compared to barnyard millet based vermicelli. There was a significant difference between all the treatments for the calcium content initially and during the second and fourth month of storage. There was a reduction in calcium content for all the selected vermicelli on storage.

**Table 24. Calcium content of selected barnyard millet based vermicelli on storage**

| Treatments | Calcium (mg 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | 2nd month | 4th month |
| TC | $10.14^{e}$ | $10.02^{e}$ (1.18) | $9.85^{e}$ (1.69) |
| TF | $69.24^{b}$ | $68.71^{b}$ (0.76) | $68.62^{b}$ (0.13) |
| TG | $73.52^{a}$ | $73.02^{a}$ (0.68) | $72.34^{a}$ (0.93) |
| TB | $67.66^{d}$ | $67.42^{c}$ (0.35) | $66.58^{d}$ (1.24) |
| TE | $67.90^{c}$ | $67.17^{d}$ (1.07) | $66.91^{c}$ (0.38) |
| C.D (0.05) | 0.020* | 0.071* | 0.085* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

### 4.3.1.12. Iron

The iron content of the selected vermicelli were estimated and presented in Table 25.

Among the treatments, iron content was found to be the highest in barnyard based vermicelli with a variation of 13.99 mg 100 $g^{-1}$ in TE to 15.80 mg 100 $g^{-1}$ in TG and at the fourth month of storage the iron varied from 12.38 mg 100 $g^{-1}$ in TE to 14.93 mg 100 $g^{-1}$ in TG. The treatment TG showed a highest iron content among the selected vermicelli's throughout the storage. In control (TC), iron content was found to be lowest of 2.60 mg 100 $g^{-1}$ on comparing with all the other treatments. There was a reduction in the iron content throughout the storage. The critical difference (C.D) value showed a significant difference between the treatments during the entire storage period.

**Table 25. Iron content of selected barnyard millet based vermicelli on storage**

| Treatments | Iron (mg 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $2.60^{e}$ | $2.41^{e}$ (7.31) | $2.10^{e}$ (12.86) |
| TF | $14.96^{b}$ | $14.53^{b}$ (2.87) | $13.76^{b}$ (5.29) |
| TG | $15.80^{a}$ | $15.32^{a}$ (3.03) | $14.93^{a}$ (2.54) |
| TB | $14.75^{c}$ | $14.41^{c}$ (2.30) | $13.54^{c}$ (6.03) |
| TE | $13.99^{d}$ | $12.86^{d}$ (8.07) | $12.38^{d}$ (3.73) |
| C.D (0.05) | 0.171* | 0.079* | 0.101* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

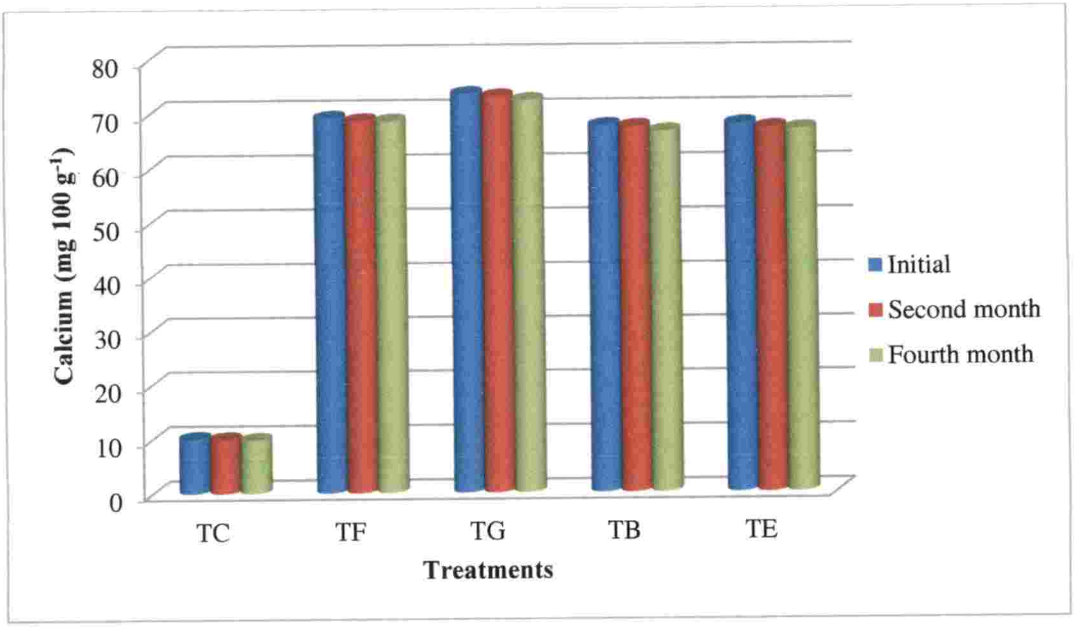


**Figure 11. Calcium content of selected barnyard millet based vermicelli on storage**

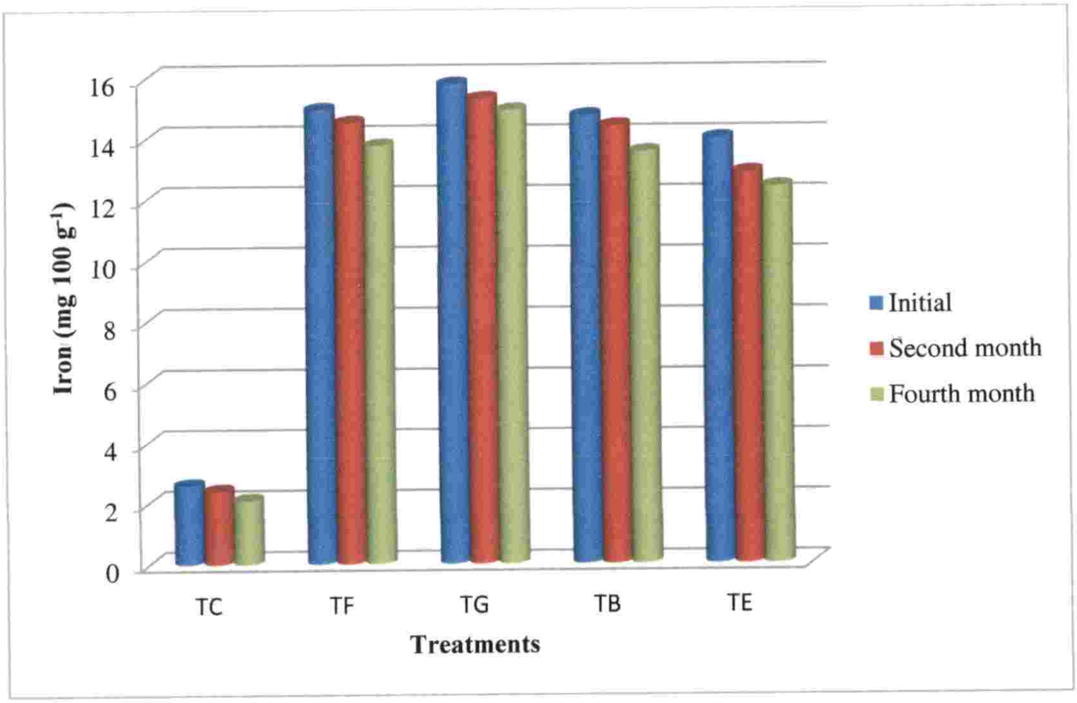


**Figure 12. Iron content of selected barnyard millet based vermicelli on storage**

### 4.3.1.13. Magnesium

The changes in magnesium content of the selected barnyard millet based vermicelli and control is presented in Table 26.

As revealed in Table 26, magnesium content present in barnyard millet based vermicelli was observed to be the highest in TG (108.30 mg 100 $g^{-1}$) and the lowest in TB (101.72 mg 100 $g^{-1}$). On comparing all the treatments, control (TC) was found to be the lowest in magnesium content of 57.65 mg 100 $g^{-1}$. There was gradual decrease in magnesium content in all the treatments during storage. At the end of fourth month the magnesium content varied from 101.24 mg 100 $g^{-1}$ to 107.76 mg 100 $g^{-1}$ in barnyard millet based vermicelli and in control, it decreased to 57.23 mg 100 $g^{-1}$. There was significant variation in the magnesium content among the selected vermicelli during the storage period.

**Table 26. Magnesium content of selected barnyard millet based vermicelli on storage**

| Treatments | Magnesium (mg 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $57.65^{e}$ | $57.63^{e}$ (0.03) | $57.23^{e}$ (0.69) |
| TF | $103.39^{b}$ | $102.97^{b}$ (0.40) | $102.59^{b}$ (0.36) |
| TG | $108.30^{a}$ | $108.19^{a}$ (0.101) | $107.76^{a}$ (0.39) |
| TB | $101.72^{d}$ | $101.63^{d}$ (0.88) | $101.24^{d}$ (0.38) |
| TE | $102.50^{c}$ | $102.32^{c}$ (0.17) | $102.13^{c}$ (0.18) |
| C.D (0.05) | 0.371* | 0.067* | 0.171* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.1.14. Zinc

The zinc content present in the vermicelli's during storage were analysed and tabulated in Table 27.

The zinc content present in vermicelli varied from 1.6mg 100 $g^{-1}$ to 5.04mg 100 $g^{-1}$. Among the barnyard millet based vermicelli, initially the zinc content in TG (5.04mg 100 $g^{-1}$) was found to be the highest followed by TF (4.74 mg 100 $g^{-1}$). The zinc content present in TC (1.60mg 100 $g^{-1}$) was lower than barnyard millet based vermicelli. During the entire storage period, the zinc content was highest in the treatment TG whereas control (TC) was found to be lowest in zinc content. There was a significant variation among the control vermicelli and barnyard millet based vermicelli during storage. The zinc content was observed to be least during the fourth month of storage in all the treatments.

**Table 27. Zinc content of selected barnyard millet based vermicelli on storage**

| Treatments | Zinc (mg 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $1.60^{d}$ | $1.57^{d}$ (1.87) | $1.48^{d}$ (5.73) |
| TF | $4.74^{b}$ | $4.51^{b}$ (4.85) | $4.47^{b}$ (0.88) |
| TG | $5.04^{a}$ | $4.82^{a}$ (4.36) | $4.75^{a}$ (1.45) |
| TB | $3.69^{c}$ | $3.63^{c}$ (1.62) | $3.51^{c}$ (3.30) |
| TE | $3.82^{c}$ | $3.70^{c}$ (3.14) | $3.59^{c}$ (2.97) |
| C.D (0.05) | 0.169* | 0.102* | 0.078* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

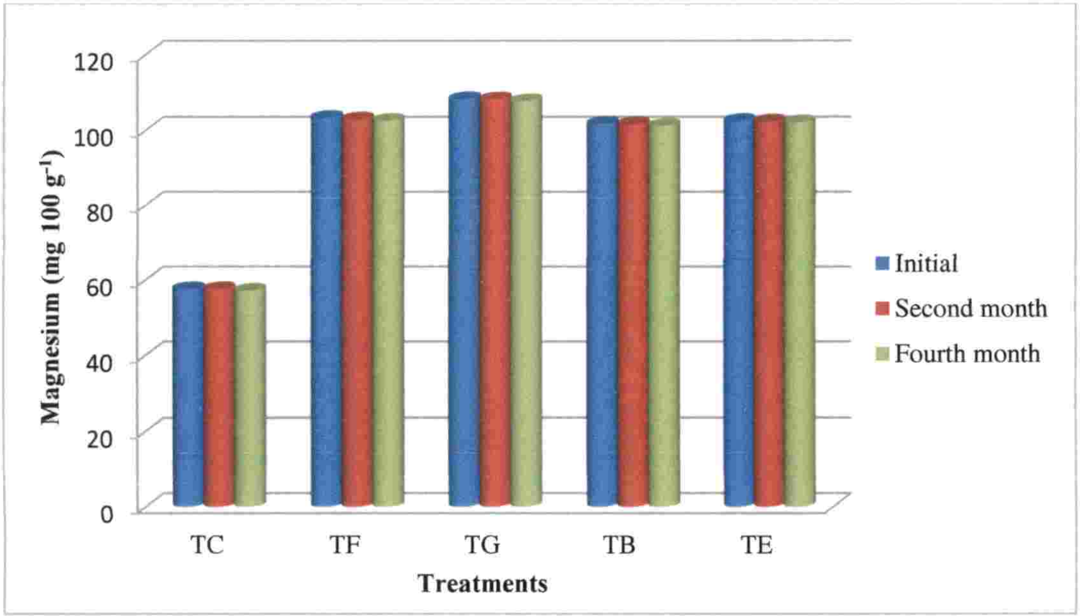


**Figure 13. Magnesium content of selected barnyard millet based vermicelli on storage**

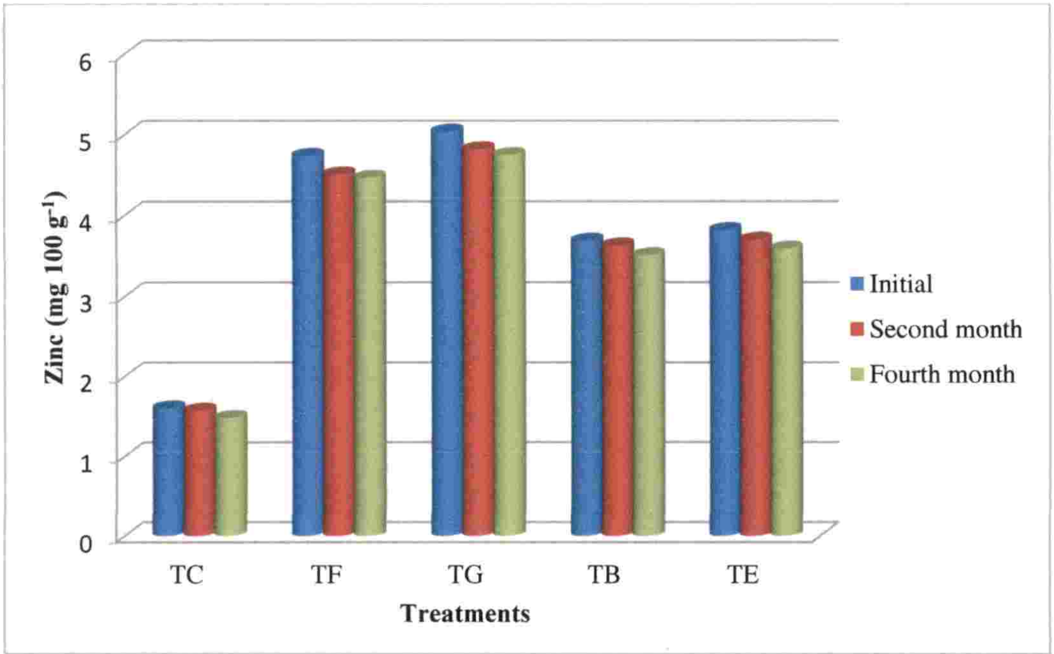


**Figure 14. Zinc content of selected barnyard millet based vermicelli on storage**

#### 4.3.1.15. Sodium

The sodium content observed during initial, second and fourth month of storage is represented in Table 28.

The sodium content of selected barnyard based vermicelli in the different treatments varied from 12.15mg 100 $g^{-1}$ to 13.40mg 100 $g^{-1}$. During second and fourth month, the sodium content decreased and they varied from 12.02mg 100 $g^{-1}$ to 13.16mg 100 $g^{-1}$ and 11.84 mg 100 $g^{-1}$ to 12.91mg 100 $g^{-1}$ respectively. Among all the treatments TG was found to be the highest followed by TF throughout the storage period. The control had the lowest calcium content of 5.50 mg 100 $g^{-1}$ which decreased upon storage to 4.82 mg 100 $g^{-1}$. The barnyard millet based vermicelli and control was found to have a significant variation during initial, second and fourth month of storage.

**Table 28. Sodium content of selected barnyard millet based vermicelli on storage**

| Treatments | Sodium (mg 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $5.50^{c}$ | $5.14^{c}$ (6.54) | $4.82^{c}$ (6.22) |
| TF | $12.62^{b}$ | $12.03^{b}$ (4.67) | $11.96^{b}$ (0.58) |
| TG | $13.40^{a}$ | $13.16^{a}$ (1.79) | $12.91^{a}$ (1.90) |
| TB | $12.20^{c}$ | $11.99^{b}$ (1.72) | $11.84^{b}$ (1.25) |
| TE | $12.15^{d}$ | $12.02^{b}$ (1.07) | $11.91^{b}$ (0.91) |
| C.D (0.05) | 0.265* | 0.073* | 0.149* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.1.15. Potassium

The potassium content of the vermicelli's of different treatments during storage is detailed in Table 29.

As revealed in Table 29, the potassium content was found to be the highest in treatment TF of 254.62mg 100 $g^{-1}$ initially which decreased to 253.67mg100 $g^{-1}$ on fourth month of storage. In control, it was found to be 56.01mg 100 $g^{-1}$ initially and reduced to 46.45 mg 100 $g^{-1}$. There was a significant variation in all the treatments during the initial, second and fourth month of storage. There was a reduction in the potassium content of the selected vermicelli on storage. Among all the treatments, control was found to have high relative change in potassium content during second and fourth month of storage.

**Table 29. Potassium content of selected barnyard millet based vermicelli on storage**

| Treatments | Potassium (mg 100 $g^{-1}$) | | |
|---|---|---|---|
| | Initial | 2nd month | 4th month |
| TC | $56.01^{e}$ | $50.12^{e}$ (10.51) | $46.45^{e}$ (7.32) |
| TF | $254.62^{a}$ | $254.43^{a}$ (0.07) | $253.67^{a}$ (0.29) |
| TG | $235.27^{b}$ | $234.82^{b}$ (0.19) | $234.41^{b}$ (0.17) |
| TB | $232.13^{c}$ | $232.01^{c}$ (0.05) | $231.59^{c}$ (0.18) |
| TE | $228.76^{d}$ | $228.73^{d}$ (0.01) | $228.51^{d}$ (0.09) |
| C.D (0.05) | 0.725* | 0.064* | 0.128* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group



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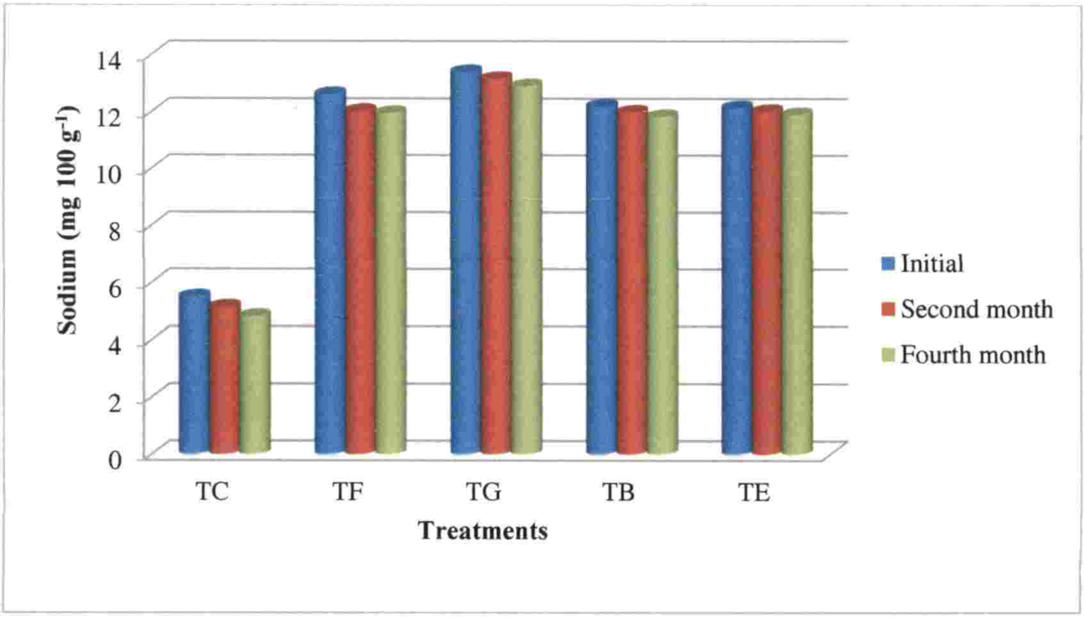


**Figure 15. Sodium content of selected barnyard millet based vermicelli on storage**

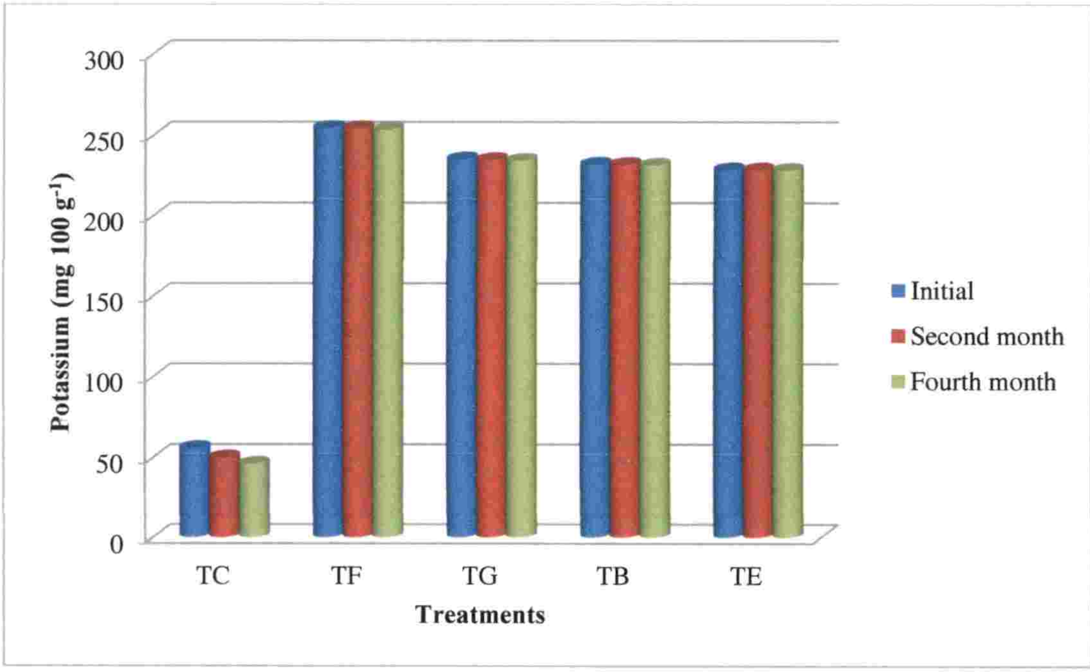


**Figure 16. Potassium content of selected barnyard millet based vermicelli on storage**

### 4.3.2. Health studies

#### 4.3.2.1. *In vitro* starch digestibility (IVSD)

IVSD in selected barnyard based vermicelli's were compared with control and detailed in Table 30.

Initially among the barnyard millet based vermicelli IVSD was found to be the highest in TB (48.46%) and the lowest in TG (42.19%). IVSD of refined wheat flour vermicelli (TC) was higher (63.52%) compared to barnyard millet based vermicelli. IVSD decreased in all the treatments, TC (63.52 to 63.02%), TF (46.12 to 46.01%), TG (42.19 to 41.92%), TB (48.46 to 48.27%) and TE (46.38 to 46.19%) during the storage period. During initial, second and fourth month of storage, there was a significant variation among all the treatments. The relative change was observed to be highest in TC (0.67%) and TG (0.45%) during second month and fourth month of storage.

**Table 30. *In vitro* starch digestibility of vermicelli on storage**

| Treatments | *In vitro* starch digestibility (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $63.52^{a}$ | $63.09^{a}$ (0.67) | $63.02^{a}$ (0.03) |
| TF | $46.12^{c}$ | $46.04^{c}$ (0.17) | $46.01^{d}$ (0.06) |
| TG | $42.19^{d}$ | $42.11^{d}$ (0.18) | $41.92^{e}$ (0.45) |
| TB | $48.46^{b}$ | $48.45^{b}$ (0.02) | $48.27^{b}$ (0.37) |
| TE | $46.38^{c}$ | $46.31^{c}$ (0.15) | $46.19^{c}$ (0.25) |
| C.D | 0.571* | 0.592* | 0.078* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.2.2. *In vitro* protein digestibility (IVPD)

IVPD of selected barnyard millet based vermicelli (TF, TG, TB and TE) was compared with control (TC) and is presented in Table 31.

Among the selected barnyard millet based vermicelli, initially IVPD was highest in treatment TF (83.16%) and lowest in TG (77.83%). The *in vitro* protein digestibility decreased gradually on storage. During second and fourth month of storage, IVPD varied from 77.03 per cent to 78.96 per cent and 76.81 per cent to 78.63 per cent which was the lowest in TG and the highest in TF. Among all the treatments, control had the lowest with a range of 67.83% (initially) to 66.86% (fourth month). There was a significant difference among the treatments in IVPD throughout the storage period. During second and fourth month, relative change was observed to high in TB of 5.05% and 0.41%.

**Table 31. *In vitro* protein digestibility of vermicelli on storage**

| Treatments | *In vitro* protein digestibility (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $67.83^{d}$ | $67.01^{c}$ (1.20) | $66.86^{c}$ (0.22) |
| TF | $83.16^{a}$ | $78.96^{a}$ (5.05) | $78.63^{a}$ (0.41) |
| TG | $77.83^{c}$ | $77.03^{b}$ (1.02) | $76.81^{b}$ (0.28) |
| TB | $78.21^{b}$ | $77.16^{b}$ (1.34) | $77.01^{b}$ (0.19) |
| TE | $78.27^{b}$ | $78.14^{b}$ (0.16) | $77.98^{ab}$ (0.20) |
| C.D (0.05) | 0.344* | 1.489* | 1.389* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

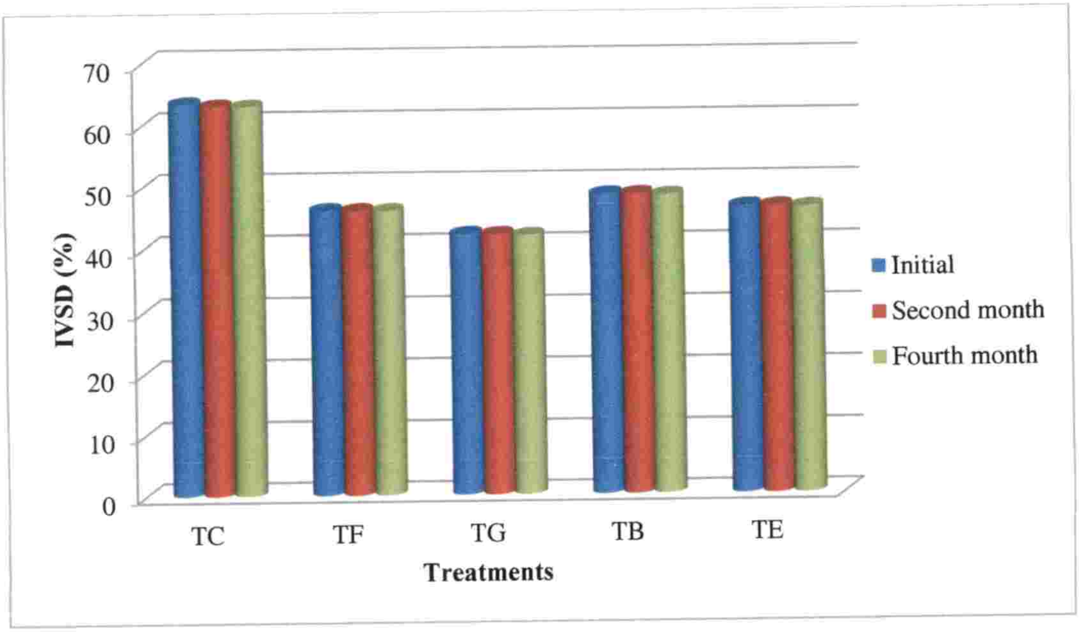


**Figure 17.** ***In vitro*** **starch digestibility of vermicelli on storage**

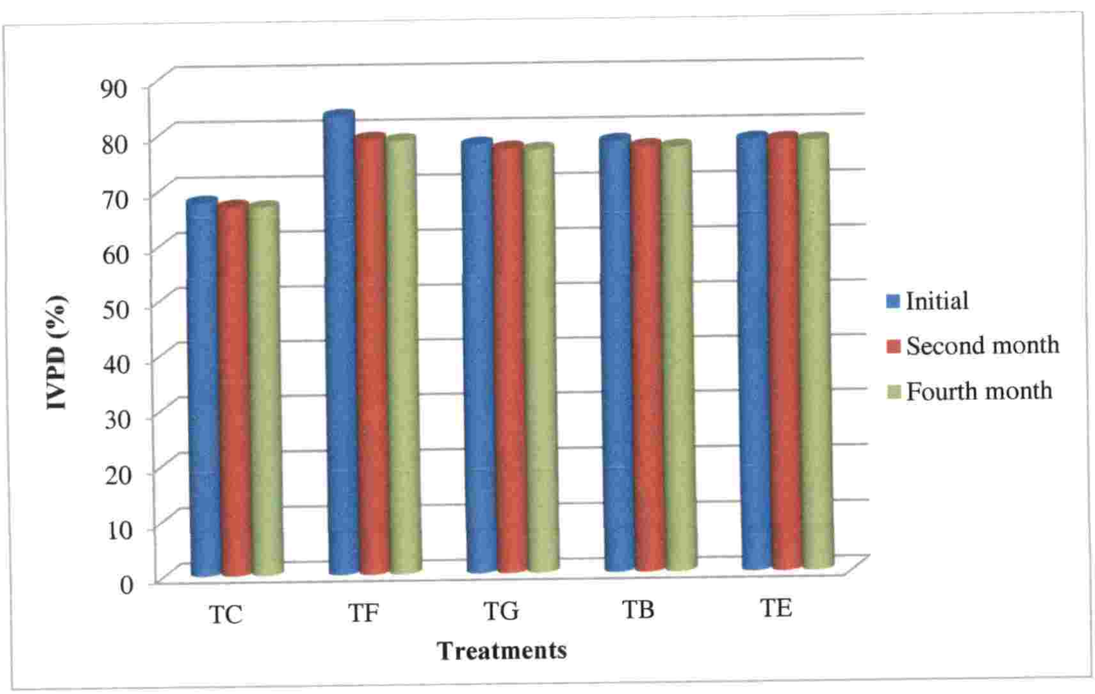


**Figure 18.** ***In vitro*** **protein digestibility of vermicelli on storage**

### 4.3.2.3. *In vitro* availability of calcium

The *in vitro* availability of calcium in selected vermicelli's is presented in Table 32.

The *in vitro* availability of calcium from different treatment initially ranged from 58.95 (TE) to 70.81 (TG) per cent in barnyard based vermicelli whereas in control (TC) it was found to be 22.59 per cent. During storage the *in vitro* availability of calcium for the vermicelli's decreased to 22.48 per cent in TC, 58.74 per cent in TE, 58.78 per cent in TB, 67.63 per cent in TF and 67.71 per cent in TG. Among the vermicelli, *in vitro* calcium availability was observed to be the highest in TG and the lowest in TC throughout the storage. There was a significant difference observed in barnyard millet based vermicelli and control with regard to *in vitro* availability of calcium upon storage. The relative change was observed to be the highest in TB (3.22%) and TG (3.18%) on second and fourth month of storage.

**Table 32. *In vitro* availability of calcium in the vermicelli on storage**

| Treatments | *In vitro* availability of calcium (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $22.59^{e}$ | $22.50^{e}$ (0.39) | $22.48^{c}$ (0.08) |
| TF | $67.90^{b}$ | $67.86^{b}$ (0.05) | $67.63^{a}$ (0.33) |
| TG | $70.81^{a}$ | $69.94^{a}$ (1.22) | $67.71^{a}$ (3.18) |
| TB | $61.02^{c}$ | $59.05^{c}$ (3.22) | $58.78^{b}$ (0.45) |
| TE | $58.95^{d}$ | $58.91^{d}$ (0.06) | $58.74^{b}$ (0.28) |
| C.D | 0.442* | 0.131* | 0.075* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group



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#### 4.3.2.4. *In vitro* availability of iron

The *in vitro* availability of iron in the selected barnyard millet based vermicelli's and control is presented in Table 33.

The availability of iron in the selected barnyard millet based vermicelli's ranged from 55.44 to 64.08 per cent (initially), 54.76 to 63.46 per cent (during second month) and 54.35 to 61.65 per cent (during fourth month). The calcium availability of selected vermicelli was found to be the highest in TG and the lowest in TE during four months of storage. In the control (TC) it was observed to be 24.15 per cent initially which decreased to 23.94 per cent and 23.23 per cent during the second and fourth month of storage. There was a significant difference among all the treatments with regard to *in vitro* availability of iron throughout the storage period. Among all treatments, relative change was higher in TE (1.22%) and TC (2.96%) on second and fourth month of storage.

**Table 33. *In vitro* availability of iron in the vermicelli on storage**

| Treatments | *In vitro* availability of iron (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $24.15^{e}$ | $23.94^{e}$ (0.86) | $23.23^{e}$ (2.96) |
| TF | $61.24^{b}$ | $61.03^{b}$ (0.34) | $59.89^{b}$ (1.86) |
| TG | $64.08^{a}$ | $63.46^{a}$ (0.96) | $61.65^{a}$ (2.85) |
| TB | $59.16^{c}$ | $58.96^{c}$ (0.33) | $58.54^{c}$ (0.71) |
| TE | $55.44^{d}$ | $54.76^{d}$ (1.22) | $54.35^{d}$ (0.74) |
| C.D (0.05) | 0.152* | 0.063* | 0.179* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

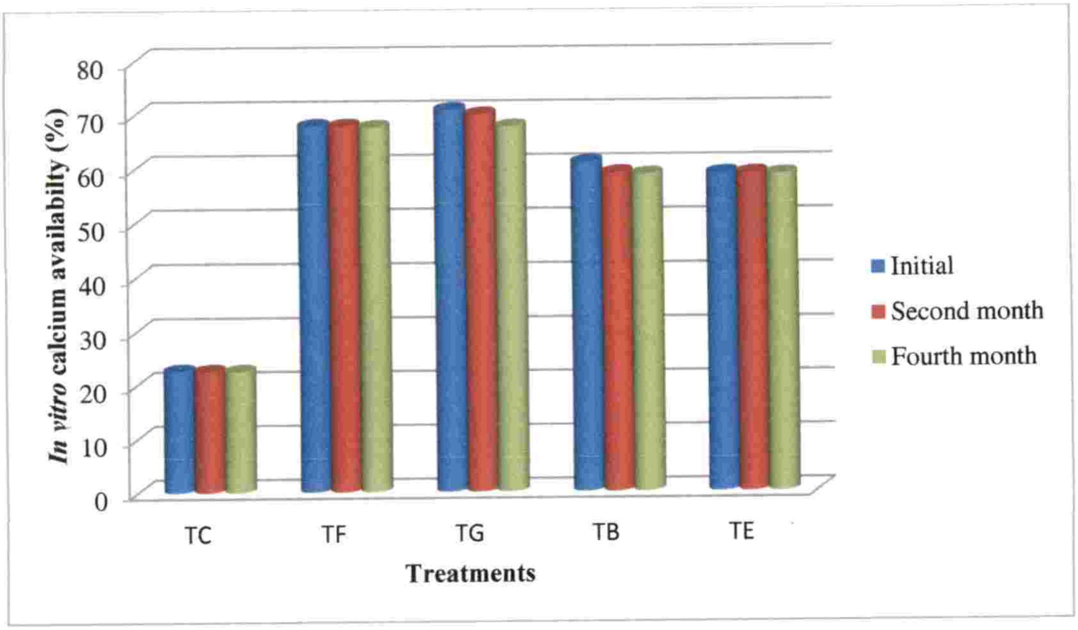


**Figure 19.** ***In vitro* availability of calcium in the vermicelli on storage**

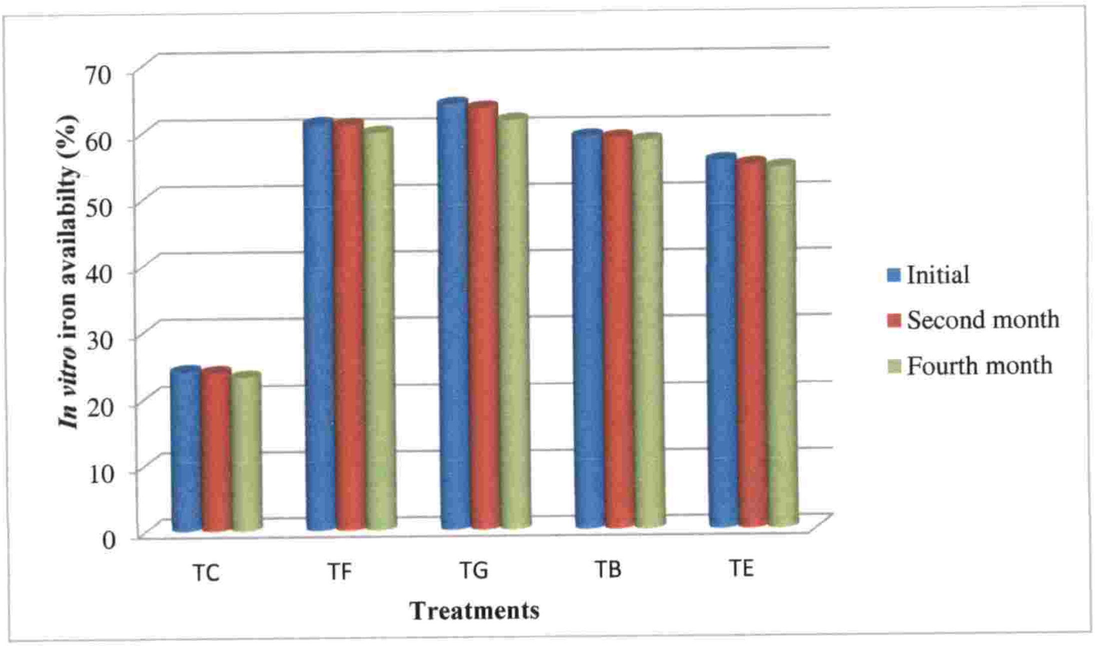


**Figure 20.** ***In vitro* availability of iron in the vermicelli on storage**

#### 4.3.2.5. *In vitro* availability of magnesium

The *in vitro* availability of magnesium present in four combinations of barnyard millet based vermicelli was compared with control and is presented in Table 34.

Among barnyard millet based vermicelli with different treatments, *in vitro* availability of magnesium varied from 67.81 to 72.20 per cent initially and it decreased to the range of 67.56 to 71.93 per cent during fourth month of storage. The treatment TG showed the highest value and lowest magnesium availability was noted in TB during the entire period of storage. The control (TC) was observed to be lower than barnyard millet based vermicelli (TF, TG, TB and TE). There was a significant difference among barnyard millet based vermicelli and control for the *in vitro* availability of magnesium throughout the storage period. During second and fourth month of storage, relative change varied from 0.06 to 0.49 per cent and 0.10 to 0.30 per cent respectively.

**Table 34. *In vitro* availability of magnesium in the vermicelli on storage**

| Treatments | *In vitro* availability of magnesium (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $38.43^{e}$ | $38.33^{e}$ (0.26) | $38.27^{e}$ (0.15) |
| TF | $68.93^{b}$ | $68.59^{b}$ (0.49) | $68.46^{b}$ (0.18) |
| TG | $72.20^{a}$ | $72.15^{a}$ (0.06) | $71.93^{a}$ (0.30) |
| TB | $67.81^{d}$ | $67.74^{d}$ (0.10) | $67.56^{d}$ (0.26) |
| TE | $68.33^{c}$ | $68.18^{c}$ (0.21) | $68.11^{c}$ (0.10) |
| C.D (0.05) | 0.214* | 0.098* | 0.060* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.2.6. *In vitro* availability of zinc

The *in vitro* availability of zinc for the selected vermicelli throughout the storage is tabulated and detailed in Table 35.

Initially *in vitro* availability of zinc of the selected barnyard millet based vermicelli ranged from 46.34 to 56.94 per cent. During second month and fourth month of storage *in vitro* availability of zinc differs from 46.29 to 56.89 per cent and 45.97 to 56.38 per cent. Among barnyard millet based vermicelli, TG showed the highest zinc availability and TB lowest. In the control (TC), 37.18 per cent of *in vitro* availability of zinc initially decreased to 37.17 per cent and 37.01 per cent during second and fourth month of storage. There was a significant difference among all the treatments in the *in vitro* availability of zinc during the entire storage period.

**Table 35. *In vitro* availability of zinc in the vermicelli on storage**

| Treatments | *In vitro* availability of zinc (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $37.18^{e}$ | $37.17^{e}$ (0.02) | $37.01^{e}$ (0.43) |
| TF | $47.89^{c}$ | $47.65^{c}$ (0.50) | $45.97^{d}$ (3.52) |
| TG | $56.94^{a}$ | $56.89^{a}$ (0.08) | $56.38^{a}$ (0.89) |
| TB | $46.34^{d}$ | $46.29^{d}$ (0.10) | $46.08^{c}$ (0.45) |
| TE | $52.09^{b}$ | $52.05^{b}$ (0.07) | $51.78^{b}$ (0.51) |
| C.D (0.05) | 0.150* | 0.091* | 0.106* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

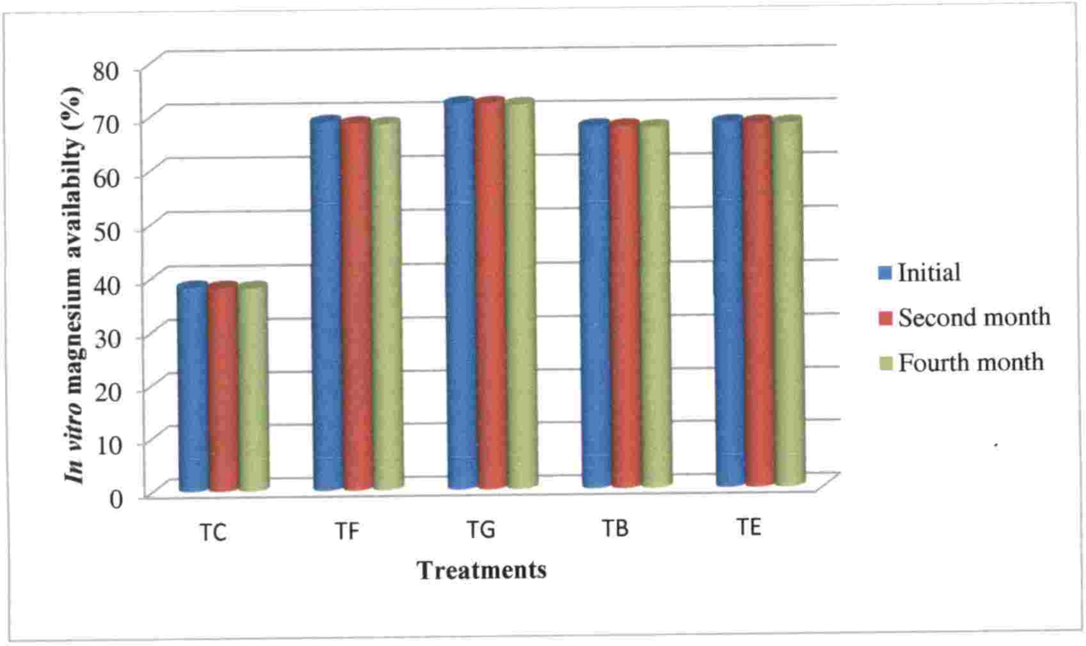


**Figure 21.** ***In vitro*** **availability of magnesium in the vermicelli on storage**

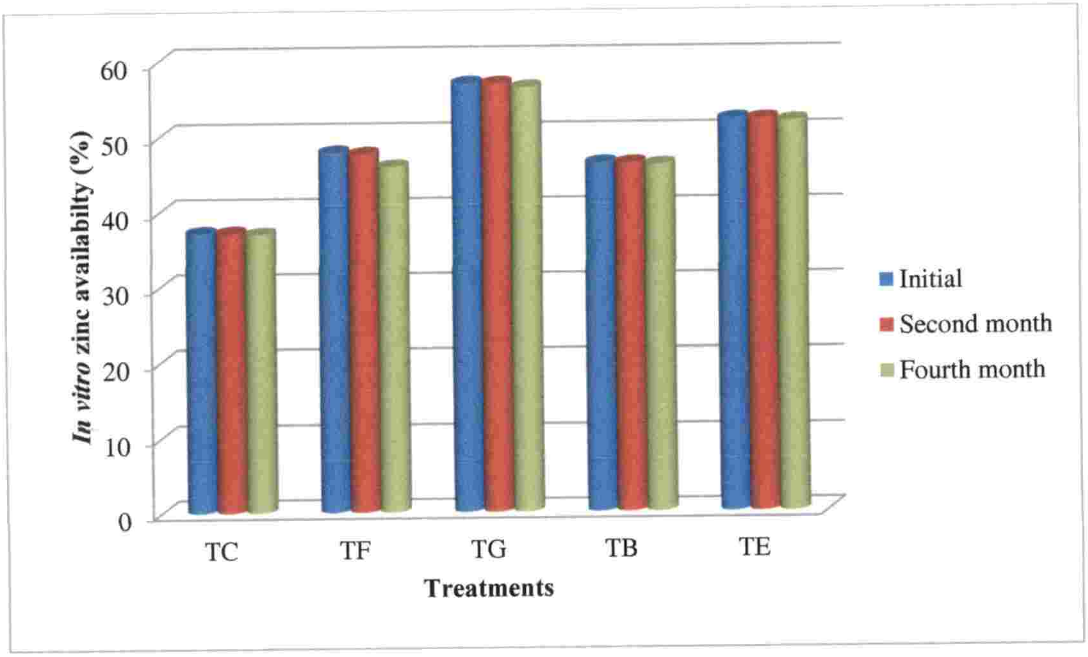


**Figure 22.** ***In vitro*** **availability of zinc in the vermicelli on storage**

### 4.3.2.7. *In vitro* availability of potassium

The *in vitro* availability of potassium of the selected vermicelli during four months of storage is tabulated and given in Table 36.

The *in vitro* availability of potassium present in selected barnyard millet based treatments was compared with control in Table 36. Among the barnyard millet based vermicelli initially treatment TF was found to be highest in 63.65 per cent and the lowest in TE of 57.45 per cent. The control was observed to be lowest on comparison with all the treatments. The treatment TF was the highest in potassium availability of 63.42 per cent and 63.27 per cent and lowest of 57.40 per cent and 56.84 per cent in TE during second and fourth month of storage. There was a significant variation among all the treatment throughout storage. There was a decrease in availability of potassium content during storage which was observed to high relative difference in TC.

**Table 36. *In vitro* availability of potassium in the vermicelli on storage**

| Treatments | *In vitro* availability of potassium (%) | | |
|---|---|---|---|
| | Initial | 2nd month | 4th month |
| TC | 28.97$^{d}$ | 28.84$^{d}$ (0.44) | 28.53$^{e}$ (1.07) |
| TF | 63.65$^{a}$ | 63.42$^{a}$ (0.36) | 63.27$^{a}$ (0.23) |
| TG | 58.81$^{b}$ | 58.73$^{b}$ (0.13) | 58.18$^{c}$ (0.93) |
| TB | 58.98$^{b}$ | 58.81$^{b}$ (0.28) | 58.68$^{b}$ (0.22) |
| TE | 57.42$^{c}$ | 57.40$^{c}$ (0.03) | 56.84$^{d}$ (0.97) |
| C.D (0.05) | 0.54* | 0.136* | 0.177* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.2.8. *In vitro* availability of phosphorus

The *in vitro* availability of phosphorus of the selected barnyard millet based vermicelli and control is tabulated and detailed in Table 37.

The *in vitro* availability of phosphorus initially varied from 43.16 per cent in TC to 67.09 per cent in TF. During second and fourth month of storage, all the treatments showed a gradual decrease in the *in vitro* availability of phosphorus. The *in vitro* availability of phosphorus on second and fourth month was observed to be highest in TF (65.45 and 64.98 per cent) and lowest in TC (42.59 and 41.20 per cent). Significant variation was observed among all the treatments for *in vitro* availability of phosphorus in selected vermicelli on storage. The relative change over previous month varied from 0.07 to 1.32 per cent and 0.43 to 3.52 per cent during second and fourth month of storage.

**Table 37. *In vitro* availability of phosphorus in the vermicelli on storage**

| Treatments | *In vitro* availability of phosphorus (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $43.16^{e}$ | $42.59^{e}$ (1.32) | $41.20^{e}$ (0.43) |
| TF | $67.09^{a}$ | $65.45^{a}$ (0.50) | $64.98^{b}$ (3.52) |
| TG | $62.48^{c}$ | $61.68^{c}$ (0.08) | $61.21^{a}$ (0.89) |
| TB | $58.63^{d}$ | $58.46^{d}$ (0.10) | $58.32^{c}$ (0.45) |
| TE | $65.37^{b}$ | $65.07^{b}$ (0.07) | $64.38^{d}$ (0.51) |
| C.D (0.05) | 0.135* | 0.111* | 0.157* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

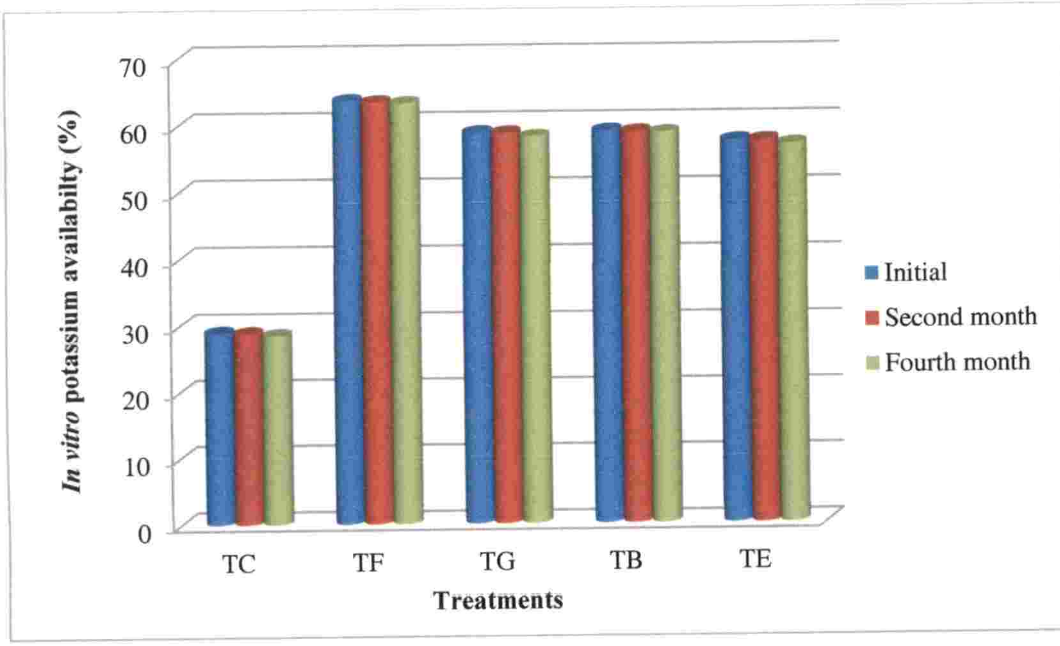


**Figure 23.** ***In vitro*** **availability of potassium in the vermicelli on storage**

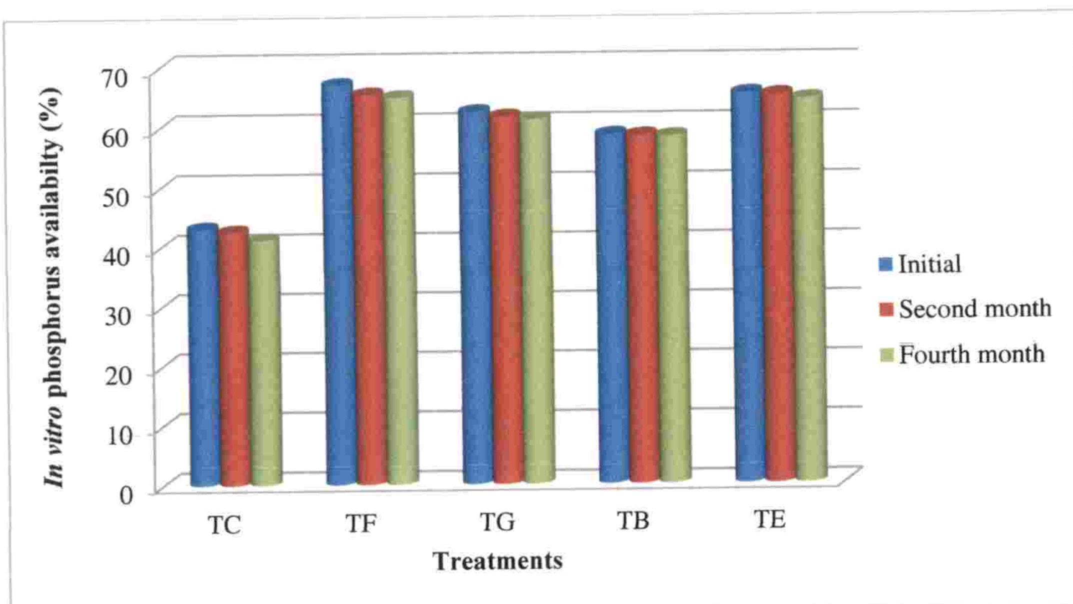


**Figure 24.** ***In vitro*** **availability of phosphorus in the vermicelli on storage**

### 4.3.2.9. Total antioxidant activity

The antioxidant activity of selected barnyard millet based vermicelli was higher than control and the details are presented in Table 38.

Initially, the antioxidant activity of selected barnyard millet based vermicelli varied from 23.28 to 27.18 per cent which was highest in TF and lowest in TE. There was a gradual decrease in antioxidant activity of the selected vermicelli on storage. During second month, antioxidant activity was the highest in TF (26.98%) and lowest in TE (23.09%). The antioxidant activity of vermicelli varied from 22.94 per cent (TG) to 26.74 per cent (TF) during fourth month of storage. Among all the vermicelli, control (TC) attained a lowest antioxidant activity of 13.68 per cent initially which decreased to 13.37 per cent at the end of storage. There was a significant variation among all the treatments during the entire period of storage.

**Table 38. Total antioxidant activity of selected vermicelli on storage**

| Treatments | Total antioxidant activity (%) | | |
|---|---|---|---|
| | Initial | $2^{nd}$ month | $4^{th}$ month |
| TC | $13.68^{e}$ | $13.52^{e}$ (1.14) | $13.37^{e}$ (1.10) |
| TF | $27.18^{a}$ | $26.98^{a}$ (0.72) | $26.74^{a}$ (0.88) |
| TG | $24.73^{b}$ | $24.63^{b}$ (0.55) | $24.56^{b}$ (0.32) |
| TB | $23.47^{c}$ | $23.32^{c}$ (0.65) | $23.21^{c}$ (0.47) |
| TE | $23.28^{d}$ | $23.09^{d}$ (0.80) | $22.94^{d}$ (0.64) |
| C.D (0.05) | 0.045* | 0.087* | 0.049* |
| Significance | S | S | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli

Figure in parenthesis indicates per cent relative change over the previous month

Values with same alphabet for different treatments represented in each column form a homogenous group

#### 4.3.2.10. Glycemic index

The quantity of test food equivalent to 75 g of carbohydrate was given to five non diabetic respondents. The glycemic index of selected vermicelli is presented in Table 39. The glycemic index of control was the highest on comparing with selected barnyard millet based vermicelli's. Among the barnyard millet based vermicelli, treatment TB had a lowest glycemic index of 48.25 followed by TF (55.65), TG (56.40) and TE (57.51). All the treatment had a significant variation in glycemic index whereas TF was on par with TG.

**Table 39. Glycemic index of the selected vermicelli**

| Treatments | Quantity (g) (equivalent to 75 g of CHO) | Glycemic index |
|---|---|---|
| TC | 96.03 | 74.89[a] |
| TF | 148.42 | 55.65[c] |
| TG | 140.84 | 56.40[c] |
| TB | 146.34 | 48.25[d] |
| TE | 148.60 | 57.51[b] |
| C.D (0.05) | | 0.991* |
| Significance | | S |

TC – Refined wheat vermicelli, TF – Barnyard millet + Fenugreek vermicelli, TG – Barnyard millet + Garden cress seed vermicelli, TB – Barnyard millet + *Brahmi* vermicelli, TE – Barnyard millet + *Ekanayakam* vermicelli
Figure in parenthesis indicates per cent relative change over the previous month
Values with same alphabet for different treatments represented in each column form a homogenous group

### 4.3.3. Sensory qualities

The organoleptic evaluation of the selected vermicelli was assessed initially and during the second and fourth month of storage. The mean scores for the organoleptic evaluation of selected vermicelli and *uppuma* prepared is presented in Table 40 and 41.

#### 4.3.3.1. Organoleptic evaluation of selected vermicelli on storage

The mean scores for the appearance of barnyard millet based vermicelli initially varied from 7.82 (TE) to 8.40 (TF) which gradually decreased in the second and fourth month of storage to 7.80 (TE) to 8.36 (TF) and 7.26 (TE) to 8.08 (TF) respectively. The control (TC) had an initial score of 8.84 which decreased to 8.53 at the end of storage. In case of appearance, control was observed to have a higher score than barnyard millet based vermicelli.

The colour of the barnyard millet vermicelli varied from 7.75 (TE) to 8.48 (TF) initially and that of control (TC) was 8.51. During second and fourth month of storage treatment TF was found to have high mean scores of 8.20 and 7.97 whereas lowest mean scores was seen in TE (7.62 and 7.40).

The highest mean scores for the flavour of barnyard millet based vermicelli initially was 8.20 in TF and lowest in TG of 7.60. During second month of storage treatment TF was highest of 8.16 and lowest in TG of 7.58 whereas at the end of storage, the mean scores was highest in TF (7.71) and lowest in TE (7.17). The mean score for control ranged from 8.33 to 8.15.

The texture and taste of barnyard millet based vermicelli was varied from 7.73 to 8.13 and 7.67 to 8.40 (initially), 7.47 to 8.07 and 7.51 to 8.33 (second month), 6.88 to 7.93 and 6.80 to 7.71 (fourth month) respectively. The texture and taste of barnyard millet based vermicelli, shows that treatment TF have the highest mean score and TE attained a lowest mean score throughout the storage.

The overall acceptability was high in treatment TF (8.04, 7.96 and 7.73) and lowest in TE (7.76, 7.58 and 6.95) during initial, second and fourth month of storage. The control (TC) was high in all the sensory parameters in comparison with barnyard millet vermicelli. Even though there was a gradual decrease in mean score during storage. All the treatments maintained a mean score within the acceptable levels.

**4.3.3.1. Organoleptic evaluation of *uppuma* prepared from selected vermicelli on storage**

Among the *uppuma* prepared with the selected vermicelli along with control, organoleptic evaluation was carried out initially and during the second and fourth month of storage. Initially mean score for organoleptic evaluation of *uppuma* varied from 7.71 to 8.22 (appearance), 7.84 to 8.29 (colour), 7.76 to

**Table 40. Mean scores for organoleptic evaluation of selected vermicelli during storage**

| Treatments | Appearance | | | Colour | | | Flavour | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month |
| TC | 8.84 | 8.78 | 8.53 | 8.51 | 8.48 | 8.44 | 8.33 | 8.29 | 8.15 |
| TF | 8.40 | 8.36 | 8.08 | 8.48 | 8.20 | 7.97 | 8.20 | 8.16 | 7.71 |
| TG | 8.07 | 8.04 | 7.64 | 7.95 | 7.78 | 7.73 | 7.60 | 7.58 | 7.51 |
| TB | 8.04 | 7.98 | 7.71 | 7.97 | 7.86 | 7.64 | 7.91 | 7.87 | 7.44 |
| TE | 7.82 | 7.80 | 7.26 | 7.75 | 7.62 | 7.40 | 7.80 | 7.78 | 7.17 |

| Treatments | Texture | | | Taste | | | Overall acceptability | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month |
| TC | 8.53 | 8.47 | 8.33 | 8.67 | 8.60 | 8.46 | 8.56 | 8.51 | 8.28 |
| TF | 8.13 | 8.07 | 7.93 | 8.40 | 8.33 | 7.71 | 8.04 | 7.96 | 7.73 |
| TG | 7.78 | 7.78 | 7.40 | 7.93 | 7.80 | 7.62 | 7.89 | 7.87 | 7.55 |
| TB | 8.07 | 7.91 | 7.48 | 8.00 | 7.80 | 7.44 | 7.87 | 7.80 | 7.51 |
| TE | 7.73 | 7.47 | 6.88 | 7.67 | 7.51 | 6.80 | 7.76 | 7.58 | 6.95 |

TC – Refined wheat vermicelli, TF – Barnyard + Fenugreek vermicelli, TG – Barnyard + Garden cress seed vermicelli, TB – Barnyard + *Brahmi* vermicelli, TE – Barnyard + *Ekanayakam* vermicelli

**Table 41. Mean scores for organoleptic evaluation of selected vermicelli based *uppuma* during storage**

| Treatments | Appearance | | | Colour | | | Flavour | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month |
| TC | 8.82 | 8.71 | 8.41 | 8.87 | 8.80 | 8.61 | 8.64 | 8.58 | 8.21 |
| TF | 8.22 | 8.16 | 8.02 | 8.29 | 8.20 | 8.00 | 8.22 | 8.00 | 7.81 |
| TG | 8.16 | 8.07 | 7.72 | 8.24 | 8.11 | 7.91 | 8.04 | 7.98 | 7.74 |
| TB | 7.96 | 7.87 | 7.53 | 7.96 | 7.89 | 7.69 | 7.78 | 7.71 | 7.51 |
| TE | 7.71 | 7.58 | 7.29 | 7.84 | 7.78 | 7.54 | 7.76 | 7.65 | 7.50 |

| Treatments | Texture | | | Taste | | | Overall acceptability | | |
|---|---|---|---|---|---|---|---|---|---|
| | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month |
| TC | 8.82 | 8.74 | 8.47 | 8.78 | 8.70 | 8.52 | 8.82 | 8.80 | 8.24 |
| TF | 7.98 | 7.91 | 7.58 | 8.09 | 8.04 | 7.96 | 8.22 | 8.16 | 7.72 |
| TG | 7.91 | 7.86 | 7.47 | 8.07 | 8.00 | 7.88 | 8.18 | 8.02 | 7.57 |
| TB | 7.84 | 7.78 | 7.41 | 7.93 | 7.89 | 7.43 | 8.20 | 8.04 | 7.49 |
| TE | 7.71 | 7.64 | 7.32 | 7.84 | 7.67 | 7.01 | 7.73 | 7.54 | 6.91 |

TC – Refined wheat vermicelli, TF – Barnyard + Fenugreek vermicelli, TG – Barnyard + Garden cress seed vermicelli, TB – Barnyard + *Brahmi* vermicelli, TE – Barnyard + *Ekanayakam* vermicelli

(flavour), 7.71 to 7.98 (texture), 7.84 to 8.09 (taste), 7.73 to 8.22 (overall acceptability) which was highest in TF followed by TG, TB and lowest in TE.

The mean score for organoleptic evaluation decreased on further months of storage. During second month, the mean score for appearance, colour, flavour, texture, taste and overall acceptability for *uppuma* prepared from selected vermicelli varied from 7.58 to 8.16, 7.78 to 8.20, 7.65 to 8.00, 7.64 to 7.91, 7.67 to 8.04 and 7.54 to 8.16 respectively and the highest mean score was obtained for TF and lowest for TE.

The mean score was highest in control when compared with barnyard millet based *uppuma* in the fourth month. During fourth month of storage the treatment TF was found to have the highest mean score of 8.02 (appearance), 8.00 (colour), 7.81 (flavour), 7.58 (texture), 7.96 (taste) and 7.72 (overall acceptability) followed by TG of 7.72 (appearance), 7.91 (colour), 7.74 (flavour), 7.47 (texture), 7.88 (taste) and 7.57 (overall acceptability).

**4.3.4. Enumeration of total microflora**

The selected barnyard millet based vermicelli and control was evaluated for microbial enumeration (bacteria, fungi and yeast) and the results are presented in Table 42.

As revealed in Table 42, the bacterial count present in selected vermicelli varied from 0.02 x $10^6$ cfu/g (TB) to 0.37 x $10^6$ cfu/g (TG) initially. In second and fourth month bacterial count of selected vermicelli varied from 0.24 x $10^6$ cfu/g to 1.61 x $10^6$ cfu/g and 0.46 x $10^6$ cfu/g to 1.94 x $10^6$ cfu/g respectively where bacterial load was high in TC (0.66 to 2.34 x $10^6$ cfu/g). There was increase in bacterial colony during fourth month of storage. The bacterial count was identified more in control (TC), on comparing with barnyard millet based vermicelli.

The initial fungi count in the selected vermicelli was not detected. During second month fungal count with a range of 0.31 x $10^3$ cfu/g to 0.46 x $10^3$ cfu/g was noticed in all the barnyard millet based vermicelli except treatment TB. The fungal count of the selected vermicelli was observed from 0.13 x $10^3$ cfu/g to 0.81 x $10^3$ cfu/g at fourth month of storage. The fungal count was increased throughout

**Table 42. Total microbial count of the selected vermicelli during storage**

| Treatments | Microbial population (cfu/g) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Bacteria ($10^6$cfu/g) | | | Fungi ($10^3$cfu/g) | | | Yeast($10^3$cfu/g) | | |
| | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month | Initial | 2nd month | 4th month |
| TC | 0.66 | 1.67 | 2.34 | ND | 0.64 | 1.12 | ND | ND | ND |
| TF | 0.23 | 1.44 | 1.92 | ND | 0.31 | 0.66 | ND | ND | ND |
| TG | 0.37 | 1.59 | 1.86 | ND | 0.46 | 0.77 | ND | ND | ND |
| TB | 0.02 | 0.24 | 0.46 | ND | ND | 0.13 | ND | ND | ND |
| TE | 0.36 | 1.61 | 1.94 | ND | 0.44 | 0.81 | ND | ND | ND |

TC – Refined wheat vermicelli, TF – Barnyard + Fenugreek vermicelli, TG – Barnyard + Garden cress seed vermicelli, TB – Barnyard + *Brahmi* vermicelli, TE – Barnyard + *Ekanayakam* vermicelli

storage which was higher in control than barnyard millet based vermicelli. The yeast count was not detected in any of the vermicelli during the entire storage period.

### 4.3.5. Insect infestation

The selected vermicelli and control was packed in polyethylene pouches and stored in ambient condition. The insect infestation of the selected vermicelli was assessed initially and during the second and fourth month of storage. There was no insect infestation in any of the vermicelli throughout the storage period.

## 4.4. Development of instant *uppuma* mixes

Based on organoleptic evaluation four selected barnyard based vermicelli with different functional ingredients (fenugreek seed, garden cress seed, *Brahmi and Ekanayakam*) were used for preparing instant *uppuma* mix. The cooking time of barnyard millet based instant *uppuma* mix and control was noted. Instant *uppuma* mix was prepared using 100g vermicelli with five different ($T_1$ to $T_5$) volume of water (200ml, 250ml, 300ml, 350ml and 400ml). In all the treatment 5g spice mix, 5g toasted mustard and 2g toasted curry leaves were added.

### 4.4.1. Cooking time for instant *uppuma* mix preparation

Cooking time is the time required for cooking 100gm of vermicelli with various levels of water (200ml, 250ml, 300ml, 350ml and 400ml). Cooking time was observed for all the prepared instant *uppuma* mix and their result are presented in Table 43.

As revealed in Table 43, when the volume of water increased there was a relative increase in cooking time of fenugreek incorporated instant *uppuma* from 3.07 to 4.21 minutes whereas garden cress seed based instant *uppuma* varied from 3.02 to 4.25 minutes and 3.20 to 4.12 minutes in case of *Brahmi* based instant *uppuma* mix. *Ekanayakam* instant *uppuma* attained a low cooking time compared to other treatments with increase in water content. Cooking time of *Ekanayakam* instant *uppuma* ranged from 2.96 to 4.02 minutes. The cooking time of control vermicelli varied from 1.46 to 2.47 minutes which was lower than all the barnyard millet based vermicelli.

In all the combinations of instant *uppuma* mix cooking time increased significantly with increase in amount of water used for cooking. Statistically, prepared instant *uppuma* mixes showed significant difference among the treatments. The desired amount of water and their cooking time directly influences the product sensory qualities.

**Table 43. Cooking time of instant *uppuma* mixes**

| Treatments | Volume of water (ml) | Cooking time of instant *uppuma* (minutes) | | | | |
|---|---|---|---|---|---|---|
| | | Control | Fenugreek | Garden cress | *Brahmi* | *Ekanayakam* |
| $T_1$ | 200 | 1.46 | 3.07 | 3.02 | 3.20 | 2.96 |
| $T_2$ | 250 | 2.01 | 3.52 | 3.46 | 3.38 | 3.21 |
| $T_3$ | 300 | 2.15 | 3.94 | 3.82 | 3.84 | 3.46 |
| $T_4$ | 350 | 2.34 | 4.06 | 3.96 | 3.95 | 3.69 |
| $T_5$ | 400 | 2.47 | 4.21 | 4.25 | 4.12 | 4.02 |
| C.D (0.05) | | 0.019* | 0.029* | 0.025* | 0.018* | 0.020* |

* Significant at 5 per cent

Values with same alphabet for different treatments represented in each column from a homogenous group

**4.4.2. Organoleptic qualities of instant *uppuma* mix**

The organoleptic evaluation of *uppuma* prepared with the instant *uppuma* mix with varying amount of water and constant quantity of ingredients was carried out. For different combinations of instant *uppuma* mix, organolpetic evaluation was carried out separately and the results are detailed below.

**4.4.2.1. Organoleptic qualities of fenugreek incorporated barnyard instant *uppuma* mix**

The selected fenugreek incorporated barnyard millet vermicelli (40% barnyard millet flour: 58% whole wheat flour: 2% fenugreek seed powder) was used to prepare instant *uppuma* mix. The quality parameters like appearance, colour,



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flavour, texture, taste and overall acceptability were assessed by a panel of selected judges. The mean score for the fenugreek incorporated barnyard instant *uppuma* mixes are depicted in Table 44.

**Table 44. Mean scores for organoleptic evaluation of fenugreek incorporated barnyard millet instant *uppuma* mix**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_1$ | 7.00 (2.53) | 7.07 (2.30) | 7.02 (2.37) | 7.16 (2.80) | 6.96 (2.43) | 6.93 (2.20) |
| $T_2$ | 7.42 (3.37) | 7.31 (3.23) | 7.31 (3.13) | 7.29 (3.00) | 7.33 (3.17) | 7.27 (2.97) |
| $T_3$ | 7.91 (4.57) | 7.89 (4.50) | 7.96 (4.23) | 7.91 (4.43) | 7.87 (4.17) | 7.82 (4.27) |
| $T_4$ | 7.13 (2.87) | 7.22 (2.97) | 7.11 (2.77) | 7.04 (2.67) | 7.16 (3.13) | 7.10 (2.97) |
| $T_5$ | 6.62 (1.67) | 6.93 (2.00) | 7.07 (2.50) | 6.73 (2.10) | 6.71 (2.10) | 6.89 (2.60) |
| **Kendalls W** | .506** | .441** | .252** | .334** | .275** | .257** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

The mean score for the appearance of fenugreek incorporated barnyard millet instant *uppuma* prepared with different volume of water (200 to 400ml), $T_3$ had a highest score of 7.91 and lowest score of 6.62 was obtained by $T_5$ with a mean rank score of 4.57 and 1.67 respectively. The colour of the instant *uppuma* with treatment $T_3$ had the highest mean score and mean rank score of 7.89 and 4.50. In $T_5$, colour was found to have lowest mean score and mean rank score of 6.93 and 2.00 respectively. In case flavour the mean score and mean rank score for instant *uppuma* mix found to be the highest in $T_3$ (7.96 and 4.23) and lowest in $T_1$ (7.02 and 2.37). The highest mean score for the texture and taste of the *uppuma* prepared was in $T_3$ (7.91 and 7.87) with a mean rank score of 4.43 and 4.17 respectively. For texture and taste was observed to have a mean rank score of 2.10 in $T_5$. The overall acceptability was highest in $T_3$ (7.82) having a mean rank score of 4.27. The lowest mean score and mean rank score was observed for $T_5$ (6.89) and $T_1$ (2.20) in terms of overall acceptability. The Kendall's value showed a significant agreement among the judges in all sensory attributes for the prepared fenugreek incorporated instant *uppuma* mix.

#### 4.4.2.2. Organoleptic qualities of garden cress seed incorporated barnyard instant *uppuma* mix

The best selected garden cress seed incorporated barnyard vermicelli (40 per cent barnyard millet flour, 58 per cent whole wheat flour and 2 per cent garden cress seed) were taken for preparing instant *uppuma* mix. The *uppuma* were prepared with 200 to 400ml of water along with spice mix are shown in Plate 8. The mean scores based on organoleptic evaluation are detailed in Table 45.

The mean scores for appearance varied from 6.60 to 7.93. For colour, mean score of treatment $T_1$ to $T_5$ was ranging from 7.07 to 8.24. The mean score for parameters like flavour, texture and taste differs from 7.20 to 8.04, 6.91 to 8.02 and 6.67 to 7.91. The overall acceptability was found to be in the range of 6.53 to 7.78.

Among all the treatments $T_3$ (100g vermicelli with 300ml water) were found to be high in mean score and mean rank score for all the sensory parameters such as appearance (7.93 and 4.10), colour (8.24 and 4.13), flavour (8.04 and 4.00), texture (8.02 and 3.97), taste (7.91 and 4.17) and overall acceptability (7.78 and 4.07) respectively.

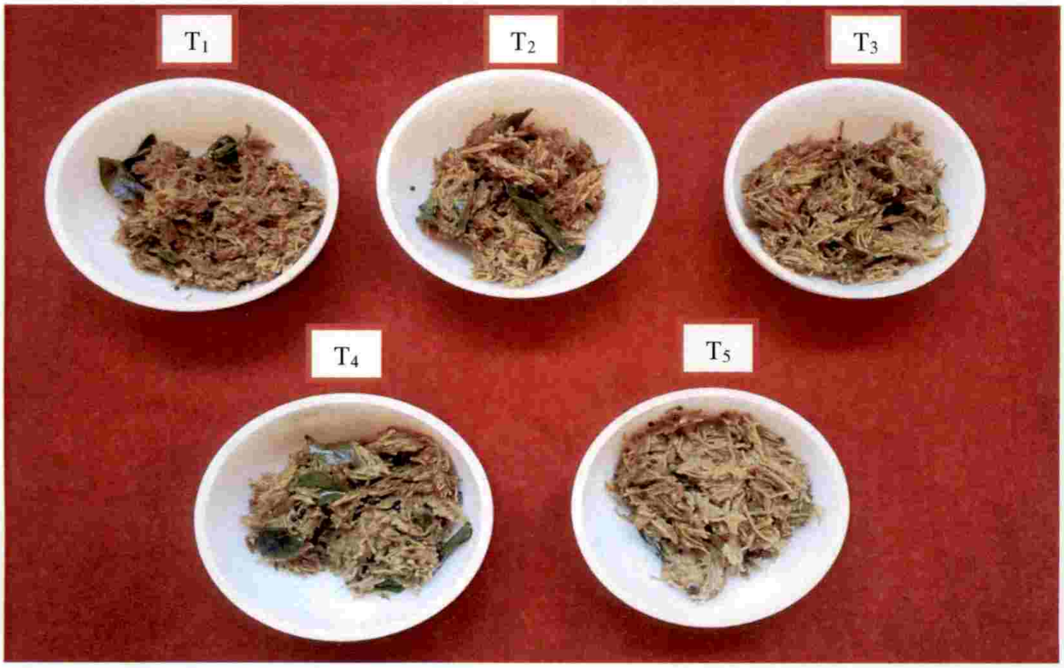


**Plate 7. Fenugreek incorporated barnyard millet instant *uppuma***

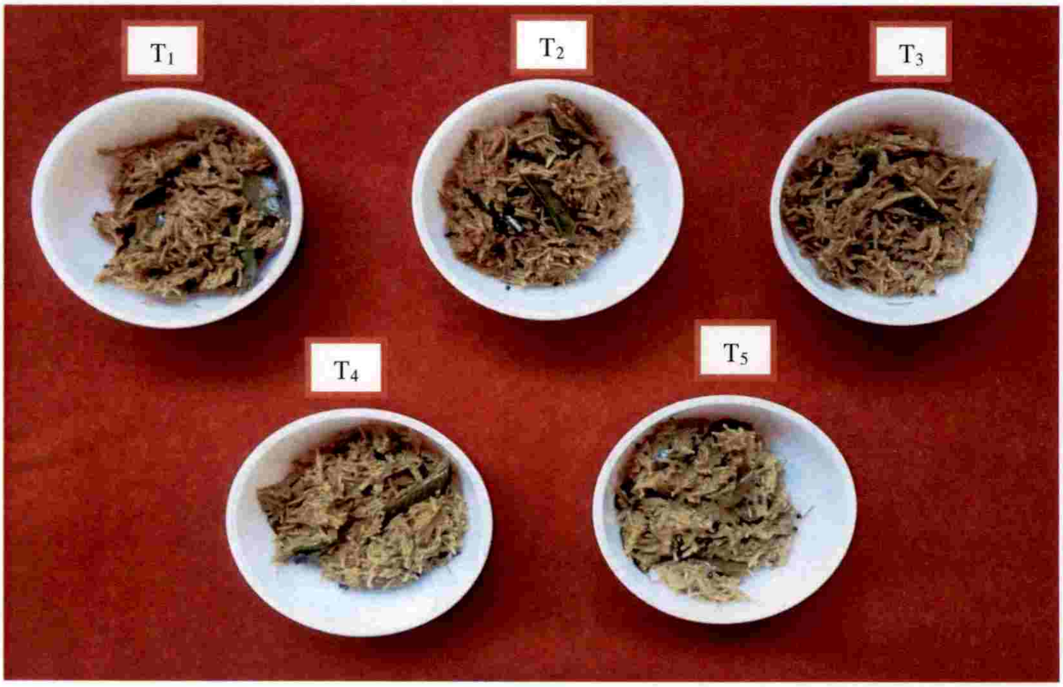


**Plate 8. Garden cress seed incorporated barnyard millet instant *uppuma***

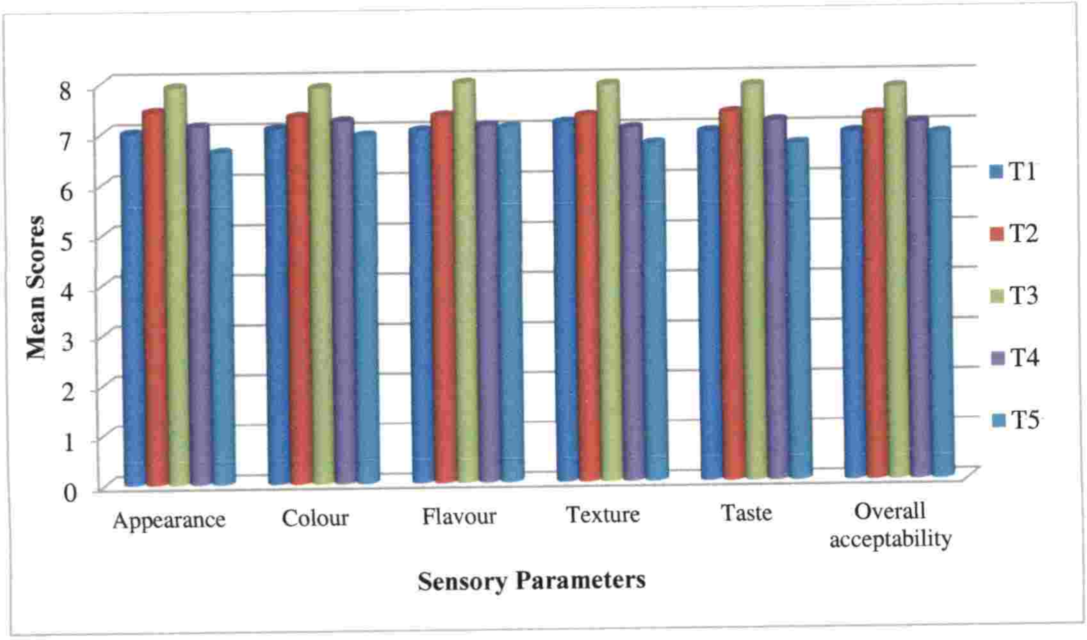


**Figure 25. Mean scores for organoleptic evaluation of Fenugreek seed incorporated barnyard millet instant *uppuma* mix**

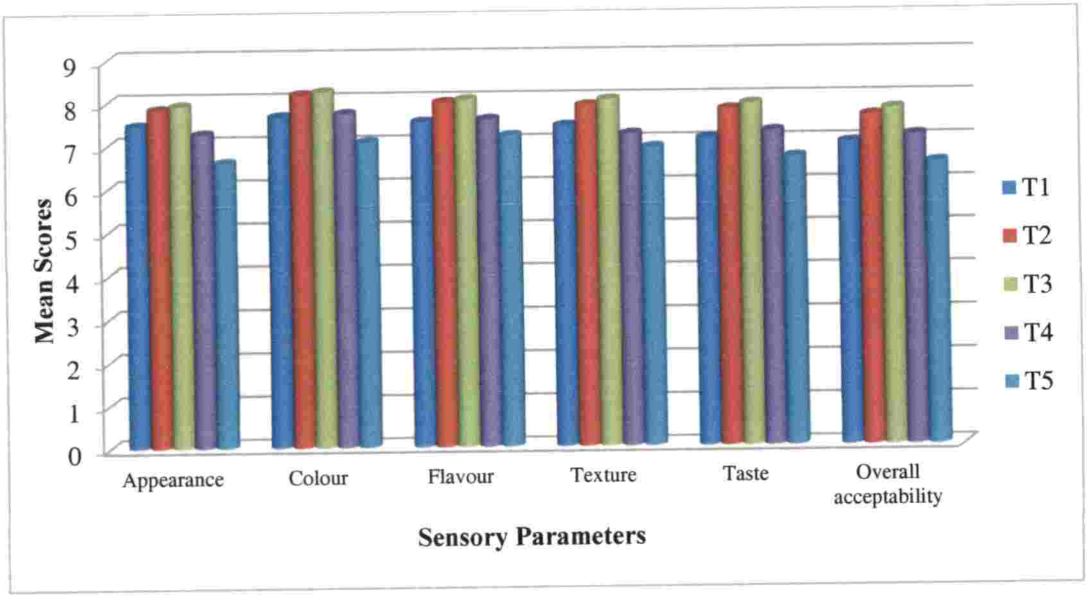


**Figure 26. Mean scores for organoleptic evaluation of garden cress seed incorporated barnyard millet instant *uppuma* mix**

**Table 45. Mean scores for organoleptic evaluation of garden cress seed incorporated barnyard millet instant *uppuma* mix**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_1$ | 7.47 (3.17) | 7.67 (2.53) | 7.53 (2.50) | 7.42 (2.97) | 7.11 (2.70) | 7.00 (2.77) |
| $T_2$ | 7.84 (3.90) | 8.18 (3.87) | 7.98 (3.90) | 7.89 (3.80) | 7.78 (3.83) | 7.62 (3.77) |
| $T_3$ | 7.93 (4.10) | 8.24 (4.13) | 8.04 (4.00) | 8.02 (3.97) | 7.91 (4.17) | 7.78 (4.07) |
| $T_4$ | 7.27 (2.43) | 7.73 (2.80) | 7.58 (2.90) | 7.22 (2.70) | 7.27 (2.77) | 7.16 (2.83) |
| $T_5$ | 6.60 (1.40) | 7.07 (1.67) | 7.20 (1.70) | 6.91 (1.57) | 6.67 (1.53) | 6.53 (1.57) |
| **Kendalls W** | .526** | .472** | .478** | .434** | .465** | .421** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

### 4.4.2.3. Organoleptic qualities of *Brahmi* incorporated barnyard instant *uppuma* mix

*Brahmi* incorporated barnyard instant *uppuma* mix were prepared from the best selected vermicelli (40% barnyard millet flour, 49.5% whole wheat flour and 0.5% *Brahmi*). The *Brahmi* incorporated barnyard instant *uppuma* mix were prepared with various proportions of water as shown in Plate 9. The sensory evaluation for the prepared instant *uppuma* was carried out and their mean score was tabulated and presented in Table 46.

Among all the treatments *uppuma* prepared with $T_3$ (100g vermicelli with 300ml water) had a maximum mean score and mean rank score of 8.00 (3.97) for appearance, 7.93 (3.60) for colour, 7.53 (4.07) for flavour, 7.73 (3.93) for taste, 7.73 (4.17) for texture and 7.89 (4.30) for overall acceptability. The *uppuma* prepared with $T_5$ had a minimum mean score and mean rank score of 7.27 (1.90) in appearance, 7.56 (2.43) in colour, 7.02 (2.33) in flavour, 6.64 (1.60) in texture, 6.76 (1.83) in taste and 6.69 (1.67) in overall acceptability. The Kendall's value revealed a significant agreement among the panel of judges for all the sensory parameters of *Brahmi* incorporated barnyard instant *uppuma* mix.

**Table 46. Mean scores for organoleptic evaluation of *Brahmi* incorporated barnyard millet instant *uppuma* mix**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_1$ | 7.76 (3.13) | 7.67 (2.87) | 7.07 (2.53) | 7.20 (3.00) | 7.09 (2.57) | 7.18 (2.57) |
| $T_2$ | 7.87 (3.53) | 7.89 (3.67) | 7.33 (3.40) | 7.64 (3.83) | 7.47 (3.50) | 7.51 (3.23) |
| $T_3$ | 8.00 (3.97) | 7.93 (3.60) | 7.53 (4.07) | 7.73 (3.93) | 7.73 (4.17) | 7.89 (4.30) |
| $T_4$ | 7.49 (2.47) | 7.60 (2.43) | 7.11 (2.67) | 7.16 (2.63) | 7.22 (2.93) | 7.29 (3.23) |
| $T_5$ | 7.27 (1.90) | 7.56 (2.43) | 7.02 (2.33) | 6.64 (1.60) | 6.76 (1.83) | 6.69 (1.67) |
| **Kendalls W** | .410** | .285** | .271** | .392** | .344** | .409** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

### 4.4.2.4. Organoleptic qualities of *Ekanayakam* incorporated barnyard instant *uppuma* mix

The best combination of vermicelli selected (40% barnyard millet flour, 58% whole wheat flour and 2% *Ekanayakam* root bark) was used for the preparation of barnyard instant *uppuma* mix with *Ekanayakam*. The *Ekanayakam* incorporated barnyard instant *uppuma* prepared is shown in Plate 10. The organoleptic evaluation was carried out for the *Ekanayakam* based barnyard instant *uppuma* and their results are revealed in Table 47.

**Table 47. Mean scores for organoleptic evaluation of *Ekanayakam* incorporated barnyard millet instant *uppuma* mix**

| Treatments | Sensory Attributes | | | | | |
|---|---|---|---|---|---|---|
| | Appearance | Colour | Flavour | Texture | Taste | Overall acceptability |
| $T_1$ | 7.22 (2.60) | 7.31 (2.50) | 7.16 (2.43) | 7.07 (2.27) | 6.98 (2.50) | 7.02 (2.40) |
| $T_2$ | 7.58 (3.87) | 7.62 (3.67) | 7.51 (3.67) | 7.60 (3.83) | 7.51 (4.10) | 7.62 (4.10) |
| $T_3$ | 7.44 (3.47) | 7.51 (3.30) | 7.44 (3.67) | 7.58 (3.77) | 7.22 (3.23) | 7.31 (3.43) |
| $T_4$ | 7.27 (2.83) | 7.36 (2.60) | 7.20 (2.57) | 7.13 (2.73) | 7.04 (2.93) | 7.09 (2.63) |
| $T_5$ | 7.07 (2.23) | 7.29 (2.93) | 7.13 (2.67) | 7.02 (2.40) | 6.91 (2.23) | 7.00 (2.43) |
| **Kendalls W** | .191** | .129** | .170** | .264** | .227** | .240** |

Value in parentheses is mean rank score based on Kendall's W

** Significant at 1% level

As revealed in Table 47, the mean score for appearance in five treatments varied from 7.07 to 7.58, colour of the prepared *uppuma* lies between a score of 7.29 to 7.62, flavour differs from 7.13 to 7.51. The texture and taste were varied from the range of 7.02 to 7.60 and 6.91 to 7.51. The overall acceptability of the *uppuma* had a acceptable score of 7.00 to 7.62.

All the sensory attributes like appearance (7.58), colour (7.62), flavour (7.51), texture (7.60), taste (7.51) and overall acceptability (7.62) was highest mean score in $T_2$ (100g vermicelli with 250ml water) followed by $T_3$ with a mean score of 7.44 for appearance, 7.51 for colour, 7.44 for flavour, 7.58 for texture, 7.22 for taste and 7.31 for overall acceptability.

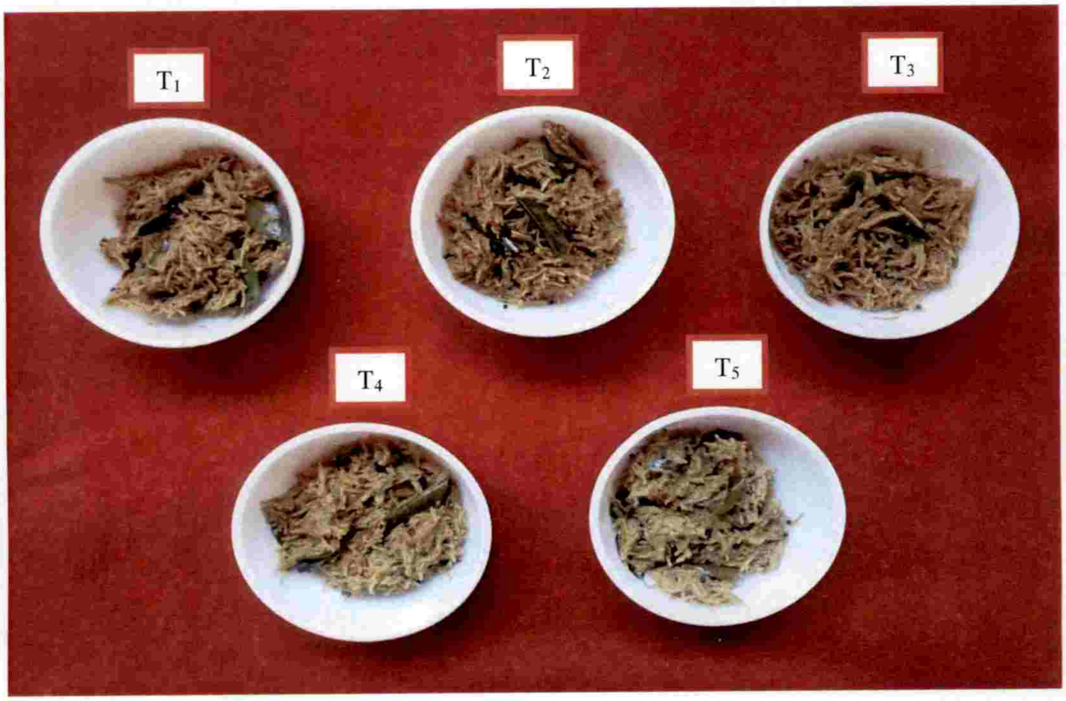


**Plate 9.** ***Brahmi*** **incorporated barnyard millet instant** ***uppuma***

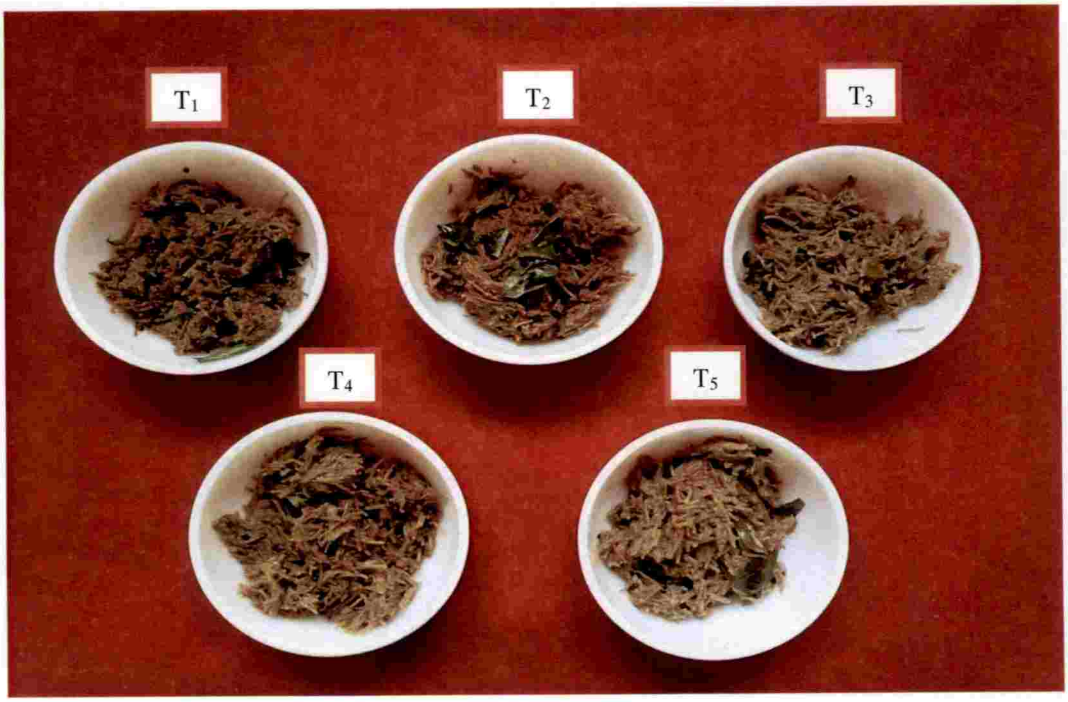


**Plate 10.** ***Ekanayakam*** **incorporated barnyard millet instant** ***uppuma***

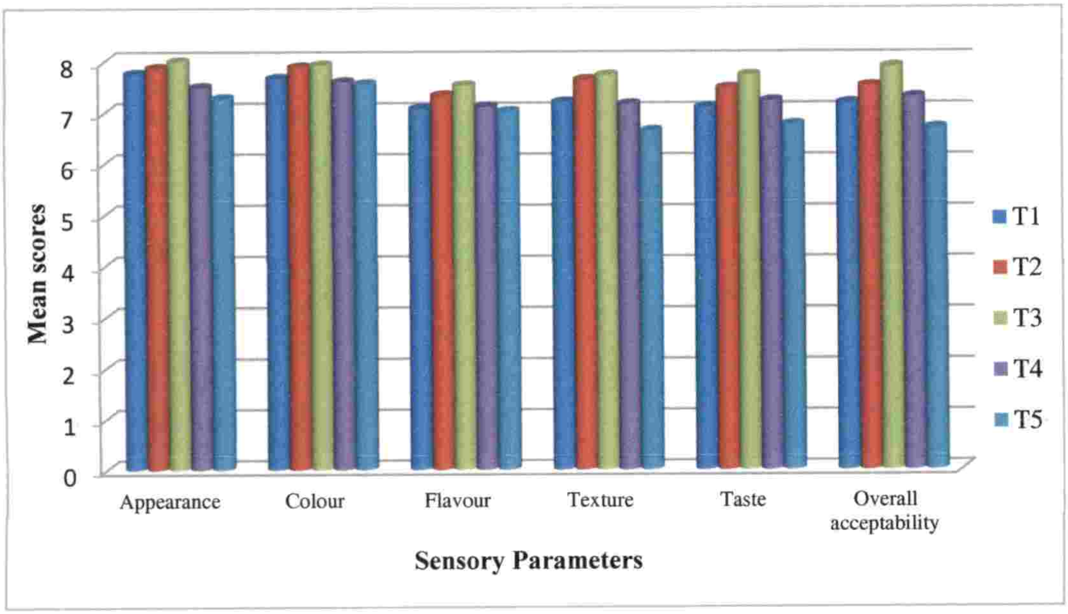


**Figure 27. Mean scores for organoleptic evaluation of *Brahmi* incorporated barnyard millet instant *uppuma* mix**

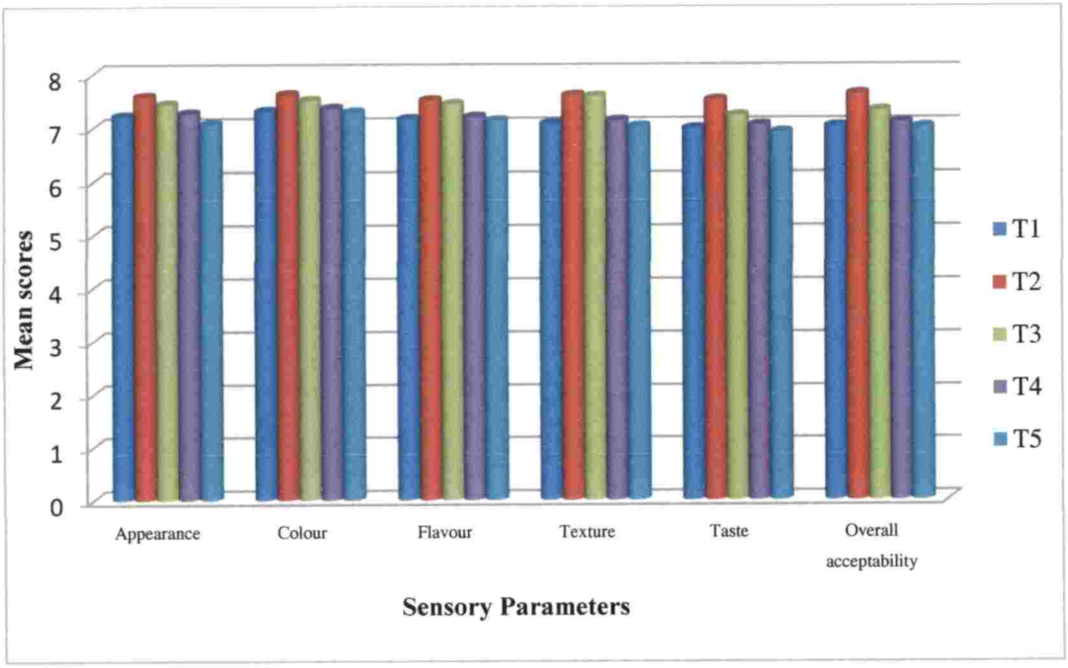


**Figure 28. Mean scores for organoleptic evaluation of *Ekanayakam* incorporated barnyard millet instant *uppuma* mix**

Statistical analysis on the score obtained from the panel of judges was undergone Kendall's coefficient of concordance. The Kendall's value showed significant agreement among judges for all the sensory parameter of *Ekanayakam* incorporated barnyard instant *uppuma* mix.

## 4.5. Cost of production for selected barnyard millet vermicelli and instant *uppuma* mix

The cost of production for the selected barnyard based vermicelli and instant *uppuma* mixes along with their control was calculated for one kg and presented in Table 48.

**Table 48. Cost of production for selected barnyard millet vermicelli and instant *uppuma* mix**

| Treatments | Cost (Rs/Kg) | |
|---|---|---|
| | Vermicelli | Instant *uppuma* mix |
| Control (Refined wheat flour) | 72.51 | 85.56 |
| Barnyard + Fenugreek | 113.91 | 126.96 |
| Barnyard + Garden cress seed | 114.61 | 127.66 |
| Barnyard + *Brahmi* | 113.81 | 126.86 |
| Barnyard + *Ekanayakam* | 128.61 | 141.66 |

The cost of production of control vermicelli (72.51 Rs/Kg) and instant *uppuma* (85.56 Rs/Kg) was lower compared to barnyard millet based vermicelli's. The cost of selected barnyard based vermicelli varied from 113.81 Rs/Kg to 128.61 Rs/Kg and barnyard millet based instant *uppuma* mix range from 126.86 Rs/Kg to 141.66 Rs/Kg. Among the barnyard millet based vermicelli and instant *uppuma* mix, *Brahmi* incorporated products was found to have the lowest price whereas cost of the products formulated with *Ekanayakam* was observed to be the highest.

# DISCUSSION

# 5. DISCUSSION

Barnyard millet is underutilised minor millet rich in B vitamins, minerals, dietary fibre and phytochemicals. Barnyard millet is a low glycemic index food with slowly digestible carbohydrate and highly digestible protein. Hence, they are considered to be ideal food for the consumers who are engaged in sedentary activities. Barnyard millet can be utilised for the preparation of various value added products for health conscious consumers (Verma *et al.*, 2015). Hence, present investigation entitled as "Standardisation and quality evaluation of millet based designer vermicelli was conducted and the results obtained are discussed in this chapter under the following headings.

5.1. Standardisation of germination for preparation of barnyard millet flour

5.2. Standardisation of barnyard millet based vermicelli with different functional ingredients

5.3. Quality attributes of selected barnyard millet based vermicelli on storage

5.4. Standardization of instant *uppuma* mix

5.5. Cost of production for selected barnyard based vermicelli and instant *uppuma* mix

## 5.1. Standardisation of germination for preparation of barnyard millet flour

Processing methods like soaking, germination, malting, fermentation, thermal and mechanical treatments of grains are said to increase the nutrient value, improves flour shelf life, decrease the anti nutritional factors and reduce bitterness (Ahmed, 2013).

Germination is considered to be a processing method which activates the enzymes of the grains which converts the cereal sugars to fermented sugars. Germination improves nutritive value and bioavailability of the nutrients (Platel *et al.*, 2010). Barnyard millets are nutritionally rich but the whole grain and the bi-product utilisation in product development is limited. The millet flour can be utilised in making value added products. The barnyard millet flour is slightly bitter in taste due to the presence of phenolic compounds (Sarker, 2015). Hence, barnyard millet were germinated to improve the sensory and nutritional properties for the development of value added products.

In the present study, germinated barnyard millet flour prepared with 10 hrs soaking followed by 24 hrs of germination ($T_4$) was highly acceptable with a mean score of 7.40 (appearance), 7.16 (colour), 7.80 (flavour), 7.83 (texture), 7.53 (taste) and 6.90 (overall acceptability) with reduced bitter taste. The reduction of antinutritional factors during germination was considered to be reason to improve taste of the germinated barnyard millet flour.

Rao and Prabhavati (1982) reported that on germination tannins and phytic acid reduced by 54 per cent and 49.2 per cent. Parameswaran and Sadasivam (1994) carried out a study on effect of germination of cereals and millets. They reported that malt obtained after germination improved nutritional profile and can be used to prepare various value added products. Soaking for more than 10 hrs developed an off flavour and bitter taste.

Malleshi and Desikachar (1986) found that germination activates alpha amylases which help in degradation of starch to free sugars. The germinated seeds with a high sugar content unmask the bitter taste and improve the sensory properties. In the present study, barnyard millet flour decreased the bitter taste upto $T_4$ (10 hrs of soaking and 24 hrs of germination). From the treatment $T_4$, bitter taste was gradually increased due to prolonged time of soaking and germination. Nomura *et al.* (1969) reported that germination helps to reduce the phenolic content and increase the free sugars. Sarker (2015) reported that sweetness of proso millet increased significantly as the germination time increased with increase in soaking time, there was an off flavour and bitter taste. This may have been due to protein degradation occurring during this process. Partial protein digestion by proteolytic enzymes can produce bitter peptides. These bitter peptides are known to impart a bitter taste that decreases the sensory quality of a food (Maehashi and Huang, 2009).

Platel *et al.* (2010) reported that germination was an process to reduce antinutritional factors which improved nutritional content and digestibility. The sensory evaluation of germinated barnyard millet products were highly acceptable with improved functional properties (Sharma *et al.*, 2016).

Nazni and Devi (2016) carried out a study on the antinutritional factors during different processing techniques (boiling, germination, pressure cooking, roasting). The study revealed that on comparing all the processing methods, germination was found to be effective in reducing antinutritional factors with improved functional properties. Hence, the germinated millet flour can be recommended to use in various food products.

**5.2. Standardisation of barnyard millet based vermicelli with different functional ingredients**

Barnyard millet based vermicelli in different combinations along with various functional ingredients (fenugreek seeds, garden cress seeds, *Brahmi* and *Ekanayakam*) were formulated. Devi *et al.* (2012) prepared barnyard millet based extruded product with a proportion of 50 per cent barnyard millet flour and 50 per cent whole wheat flour was highly acceptable with a mean score of 7.24. Barnyard millet was considered to be an appropriate replacer for wheat flour for the development of extruded products with functional and nutraceutical properties.

Agarwal *et al.* (2013) standardised vermicelli with barnyard millet flour, wheat flour and defatted soya flour in the ratio of 45: 45:10 was highly acceptable with a mean score of 7.80 (appearance and colour), 7.90 (taste), 7.50 (texture), 8.00 (flavour) and 7.84 (overall acceptability).

Ranganna *et al.* (2014) formulated small millet based vermicelli. The barnyard millet, kodo millet, proso millet, foxtail millet and little millet based vermicelli with the combination of 50 per cent millet flour, 40 per cent wheat flour and 10 per cent soya flour was highly acceptable.

Devi *et al.* (2015) formulated a gluten free sweet vermicelli using pearl millet, sorghum, green gram with good sensory and nutritional properties for the patients suffering from gluten intolerance.

Devika and Banu (2016) standardised multigrain based vermicelli with a combination of millets, pulses and cereals as a functional food for HIV people. The prepared multigrain was most acceptable in sensory and nutritional qualities.

Vimalarani *et al.* (2016) formulated extruded products from pearl millet. The pearl millet based vermicelli prepared with a proportion of 30 per cent of pearl millet, 50 per cent wheat flour and 20 per cent of soya or bengal gram flour was found to have highest mean score of 8.00 in terms of overall acceptability.

Functional ingredients may improve the sensory and nutritional profile of the formulated product which help to prevent various degenerative diseases (Jideani and Onwubali, 2009). Millet based vermicelli when incorporated with functional ingredients may improve the nutritional profile of the product. The study was thus undertaken to incorporate different functional ingredients to barnyard millet based vermicelli and their results are discussed below.

### 5.2.1. Sensory evaluation of barnyard millet based vermicelli and *uppuma* incorporated with fenugreek seed

Barnyard millet vermicelli were prepared with varying proportion of whole wheat flour and germinated fenugreek seed flour and compared with control (refined wheat flour vermicelli). From fenugreek incorporated barnyard millet vermicelli, *uppuma* was prepared and subjected to organoleptic evaluation and the results revealed that vermicelli and *uppuma* prepared with 58 per cent whole wheat flour, 40 per cent germinated barnyard millet flour and 2 per cent of germinated fenugreek seed ($T_{10}$) was highly acceptable after control ($T_0$).

The results of sensory evaluation reported that mean score obtained for fenugreek based barnyard vermicelli were 8.44 for appearance, 7.77 for colour, 8.20 for flavour, 8.00 for texture, 8.40 for taste and 7.77 for overall acceptability.

The mean scores of *uppuma* prepared were 8.04 for appearance, 7.80 for colour, 8.22 for flavour, 8.46 for texture, 7.55 for taste and 7.88 for overall acceptability.

Shirani and Ganesharanee (2008) formulated chickpea based extruded product by substituting fenugreek seed powder and fenugreek polysaccharides. Chickpea based extruded product developed with 2 per cent fenugreek seed and 15 per cent of fenugreek polysaccharide were selected as the best in all the sensory attributes. They concluded that inclusion of more than the prescribed limit developed a bitter product.

Ibrahim and Hegazy (2009) prepared wheat flour biscuit by incorporating fenugreek seed flour. Fenugreek seed flour prepared using two treatments, one is soaking for 12hrs and the other is germination for 48hrs. The soaked and germinated fenugreek seeds were dried and powdered. Based on sensory evaluation, the biscuits prepared with 5 per cent soaked and germinated fenugreek seed powders were highly desirable. The biscuit prepared with 5 per cent soaked fenugreek seed powder had a mean score of 7.89 (appearance), 7.89 (colour), 7.98 (flavour), 7.61 (texture), 7.98 (taste), and 7.79 (overall acceptability). The formulated biscuit with 5 per cent of germinated fenugreek seed powder obtained a mean score of 7.97 (appearance), 7.89 (colour), 7.98 (flavour), 8.12 (taste) and 7.69 (overall acceptability) respectively.

Pandey (2013) developed foxtail millet based vermicelli with 1 to 3 per cent of fenugreek seed flour. The result revealed that foxtail millet based vermicelli prepared with varying proportion of fenugreek seed flour were firm, strong with separate strands and creamish white in colour. But foxtail millet based vermicelli prepared with 2 and 3 per cent of fenugreek seed flour were not acceptable due to the strong flavour and bitter taste

Wani and Kumar (2015b) conducted a study on extruded products prepared by incorporating fenugreek in various proportions of composite flour, barley flour and dry green pea flour. The result revealed that extruded products prepared by incorporating 2 per cent fenugreek seed flour and 3 per cent fenugreek leave flour had a high mean score of 7.44 and 7.00. It clearly indicated that as the fenugreek incorporation decreases, there will be significant increase in the overall acceptability of the developed product.

Favier *et al.* (1995) carried out a study on the effect of fenugreek seed powder on 60 diabetic individuals. Fenugreek seed consist of galactomannans which helps to control blood glucose and cholesterol level. Hence they concluded that consumption of fenugreek seed powder in our daily diet reduces blood glucose and LDL cholesterol.

### 5.2.2. Sensory evaluation of barnyard millet based vermicelli and *uppuma* incorporated with garden cress seed

Barnyard vermicelli and *uppuma* incorporated with garden cress seed were prepared along with control. The organoleptic evaluation of vermicelli and *uppuma* prepared with control had a high score followed by germinated barnyard millet flour, whole wheat flour and garden cress seed in the combination of 40:58:2 ($T_{10}$).

In the present study, vermicelli and *uppuma* prepared with treatment $T_{10}$ had a highest mean score in all the sensory attributes like appearance (8.06 and 8.40), colour (7.80 and 8.24), flavour (7.60 and 8.04), texture (7.78 and 7.91), taste ( 7.68 and 8.06) and overall acceptability (7.88 and 8.31).

Paranjape and Mehta (2005) carried out an investigation to study the effect of garden cress seed to cure asthma. Garden cress powder of 1gm thrice a day was administered to 30 patients with bronchial asthma for a period of 4 weeks. The consumption of garden cress seed improved lung function by reducing dyspnoea, wheezing, tightness in chest and cough. They also reported that no adverse effect was noted in patients during the study. Hence, garden cress seed can be used effectively as a food supplement to treat diseases.

Barnyard millet products prepared with garden cress seeds along with nuts and dry fruits were highly acceptable with excellent texture (Ballolli, 2010).

Kurahatti (2010) developed little millet and multigrain based composite mix and conducted sensory evaluation of the porridges prepared with these mixes, by incorporating 2 per cent of garden cress seed flour which showed an acceptable total mean score of 35.02/45 and 35.90/45 respectively.

Mohite *et al.* (2012) standardised health drink enriched with garden cress seed powder (1 to 5gm). Based on sensory evaluation the overall acceptability was more in 3gm garden cress seed powder incorporated health drink with a mean score of 8.75.

Vijayanchali and Devi (2013) formulated iron rich antioxidant mix with an addition of 2% garden cress seed flour and antioxidant rich foods like millets, cereals and green leafy vegetables. From the formulated mix, porridge and nutriballs were prepared with good acceptability score to meet the nutritional needs of adolescents and women.

Elizabeth and Poojara (2014) prepared with five types of cookies and muffins by incorporating 10gm to 30gm of garden cress seed. They concluded that cookies and muffins incorporated with 10gm of garden cress seeds were highly acceptable. Garden cress seed were incorporated to various products to improve the micronutrients.

Patil *et al.* (2015) developed garden cress seed biscuits by incorporating 5 to 20 per cent garden cress seed in whole wheat flour. The mean score obtained for garden cress incorporated biscuits varies from 7 to 9. They concluded that garden cress seed can be added upto a level of 10 per cent in wheat flour to develop various value added products without affecting the sensory parameters.

Rana and Kaur (2016) prepared various value added products like biscuit, *ladoo* and *namakpare* (deep fried snack) by incorporating germinated garden cress seed upto 15 per cent. Garden cress seed incorporated in biscuits, *ladoo* and *namakpare* upto 10 per cent were desirable in terms of all the sensory attributes with improved nutrients.

Anaveri (2016) formulated functional ingredients (garden cress seed and flax seed) incorporated cookies and buns made with tuber flours. The cookies and buns prepared with 2 per cent and 6 per cent of functional ingredient (equal proportion of garden cress sees and flax seed) were highly acceptable.

### 5.2.3. Sensory evaluation of barnyard millet based vermicelli and *uppuma* incorporated with *Brahmi*

Organoleptic evaluation of barnyard millet vermicelli incorporated with *Brahmi* showed that treatment $T_{10}$ (40% germinated barnyard millet flour, 49.5% whole wheat flour and 0.5% *Brahmi)* was highly acceptable both in terms of vermicelli and *uppuma* after control (TC). The mean score obtained for treatment $T_{10}$ vermicelli was 8.40 for appearance, 8.24 for colour, 8.04 for flavour, 7.91 for texture, 8.06 for taste and 8.31 for overall acceptability. In case of *uppuma* prepared with $T_{10}$ with a combination of germinated barnyard millet, whole wheat flour and *Brahmi* (40: 59.5:0.5) was selected as best treatment for further storage studies. The selected treatment had a mean score of 7.95 (appearance and colour), 7.77 (flavour), 7.84 (texture), 8.13 (taste) and 8.22 (overall acceptability).

*Brahmi*, an effective herb to treat various health problems is bitter in taste. Formulation of value added product with *Brahmi* with acceptable sensory attributes may improve the health of mankind.

*Bacopa monnieri* contains active components like saponins and bacoside A which contribute bitter taste to the products (Singh and Dhawan, 1997). Joshi and Parle (2006) prepared *Brahmi rasayana* which was given in doses of 100 and 200 mg for eight successive days to the mice. The result shown that, *Brahmi rasayana* intake reduced amnesia and cognitive disorder. Edward (2013) reported that consumption of 400 to 500mg of *Brahmi* extract per day helps to enhance memory power.

Zaker *et al.* (2014) prepared biscuit with a combination of composite flour and ayurvedic herbs (*Brahmi*, lemon grass, *Shilajit*). The herbal biscuit formulated with 0.5 g of *Brahmi*, lemon grass and *Shilajit* were most acceptable by a panel of

25 judges. In case of *Brahmi* incorporated biscuits mean score was 8.28 (appearance), 8.27 (flavour), 8.11 (flavour), 8.65 (texture), 8.48 (taste) and 8.35 (overall acceptability).

Anand *et al.* (2013) formulated bacoside enriched date syrup juice by extracting bascosides from *Brahmi*. The bacoside enriched date syrup juice prepared with a proportion of bacoside (0.075%), date syrup (10%) and sugar (2.5%) was most acceptable. The prepared juice was subjected to rats for a period of 14 weeks. The consumption of bascoside enriched juice increased physical endurance in rats due to reduced malondialdehyde levels of 16.50 per cent in brain, 17.88 per cent in liver and 30.20 per cent in muscle tissues. The result revealed that bacoside was considered to be good supplement to persons involved in strenuous exercise.

Mishra *et al.* (2013a) standardised *Brahmi vati*, an herbal formulation used to prevent epilepsy and cognitive disorder. *Brahmi vati* were formulated by addition of thirty five medicinal herbs. He reported that 250mg *Brahmi vati* contains 18mg of *Brahmi*.

Anand *et al.* (2016) carried out an investigation to treat neurodegenerative disease on consumption of formulated *Brahmi* based health drink. The formulated health drink had a overall acceptability of 7.30 due to incorporation of date syrup, lemon juice, honey and ginger which helped to mask the bitterness of the product. To the selected mice, 100mg of aluminium chloride were administered daily for a time period of 23 which cause cognitive impairment. The prepared *Brahmi* health drink was introduced to mice loaded with aluminium chloride. The result revealed that Brahmi health drink supplementation contains bacoside which decreased acetylcholine esterase activity and reversed aluminium induced memory and learning deficits in mice.

### 5.2.4. Sensory evaluation of barnyard millet based vermicelli incorporated with *Ekanayakam* root barks

Barnyard vermicelli and *uppuma* prepared with *Ekanayakam* root barks were compared with control. Among *Ekanayakam* incorporated barnyard vermicelli and *uppuma* with a combination of 40 per cent germinated barnyard vermicelli, 58 per cent whole wheat flour and 2 per cent *Ekanayakam* were considered to be the most acceptable formulation.

Jayawardena *et al.* (2005) formulated *Salacia reticulata* based herbal tea and conducted a clinical trial on administering the herbal tea prepared with a dose of 2.25mg *Salacia reticulata* for a period 3 months to diabetic patients. Jayawardena and co workers proved that *Salacia reticulata* based herbal tea was safe and effective for the treatment of diabetes mellitus. Li *et al.* (2008) reported that *Ekanayakam* (*Salacia reticulata*) root and stem was effective medicinal herb with functional properties to treat diabetes and obesity.

Radha and Amrithaveni (2009) carried out a study on *Salacia reticulata* to treat diabetes. They proved that consumption of 2gm of *Salacia reticulata* powder per day for 3 months helps to manage diabetes. Yoshino *et al.* (2009) carried out a study, in which 1mg of *Salacia reticulata* extract was given to mice for a period of six weeks and he proved that *Salacia reticulata* extracts can be utilized as one of the ingredients in food to treat diabetes.

Ediriweera and Ratnasooriya (2009) prepared decoction with 60 gm of dried root bark of *Salacia reticulata*. They reported that consumption of 120 ml of prepared *Salacia reticulata* decoction twice a day helps to recover from diabetes.

Jayakumar *et al.* (2010) carried out a study to treat disease using traditional plant therapy in two southern regions (Kollam and Thiruvanathapuram) of Kerala. They reported that consumption of root decoction of *Salacia reticulata* regularly helps to treat against diabetes.

Venkatasubramanian *et al.* (2011) carried out an investigation on the effect of dehydrated *Ekanayakam* powder. The preliminary clinical study was carried out by administering 1 to 5gm of dehydrated *Ekanayakam* powder in 250 ml of buttermilk to six patients. They concluded that administering upto 5gm of *Ekanayakam* powder was well tolerated by human subjects without any side effects. When the level increased to more than 5gm, patients experienced nausea.

Rajalakshmy *et al.* (2014) formulated anti diabetic ayurvedic herbal product *diajith*, prepared with parts of common medicinal herbs (*Salacia recticulata* roots, *Tribulus terrestris* and *Emblica officinali* fruits, *Curcuma longa* rhizomes). The organoleptic attributes of formulated herbal product exhibits yellow colour with turmeric flavour. The product was found to be fibrous in texture, bitter and astringent in taste.

The present study shows that, barnyard millet based vermicelli and *uppuma* prepared with *Ekanayakam* root barks was observed to have a least acceptable combination in comparison with fenugreek seed, garden cress seed and *Brahmi* based barnyard millet vermicelli and *uppuma.* The fibrous texture of the *Ekanayakam* vermicelli and *uppuma* may be affected the sensory qualities of the products.

**5.3. Quality attributes of selected barnyard millet based vermicelli on storage**

The selected barnyard millet vermicelli (TF, TG, TB and TE) along with control (Refined wheat vermicelli- TC) were packed in polyethylene pouches (250 gauges) for a period of four months. The packed vermicelli was analysed for nutritional, health, sensory and keeping qualities during initial, second and fourth month of storage.

**5.3.1. Effect of storage on the nutritional qualities of selected barnyard millet based vermicelli**

The moisture content of the selected barnyard millet based vermicelli initially varied between 7.70 to 7.80 per cent with the lowest in treatment TB and highest in TG. The moisture content in control was found to be the highest among all the treatments. During fourth month of storage, moisture content increased with a range of 8.01 to 8.14 per cent with the highest in TB and lowest in TF. The moisture content of the product increased due to the high relative humidity of the storage conditions. The moisture intake was influenced by temperature and time of storage. Jacob (1982) reported that, polyethylene pouches can act as an excellent water barrier whereas they are poor barriers to nitrogen, oxygen and carbon dioxide. He and Hoseney (1990) reported that temperature, humidity and permeability of the packing material is an important parameter to increase the moisture absorption capacity of the product. Vani and Manimegalai (2004) formulated mixed pulse flour based noodles and packed in polyethylene pouches showed an increasing trend in moisture content during six month of storage. Sugasini (2003) reported that kodo millet and wheat based vermicelli packed in polyethylene and metalized polyester polyethylene pouches for a period four months observed an increase in moisture content upon storage. Veena *et al.* (2005) reported that moisture content present in barnyard millet varied from 8.15 to 9.84 per cent. Mogra and Midha (2013) stated that malted wheat based vermicelli had a moisture content of 6.9 (initially) increased to 8.0 per cent (during second month of storage). The results are in agreement with the findings of Ranganna *et al.* (2014), who formulated foxtail millet, barnyard millet and refined wheat flour based vermicelli and observed a moisture content of 6.88 per cent, 8.85 per cent and 9.74 per cent respectively.

The TSS content in selected barnyard millet vermicelli initially was observed to be in the range of $2.4^0$ to $3.6^0$ brix on comparison with control. The TSS of the stored vermicelli increased from $2.9^0$ to $4.2^0$ brix during fourth month of storage. Agarwal *et al.* (2004) stated that, product formulated with higher proportion of millet flour increases the TSS content of the product. The TSS of the pearl millet grain during different storage conditions varied from $4.02^0$ to $4.16^0$ brix (Mali and Satyavir, 2005). In the present study TSS content of the barnyard millet based vermicelli and control increased on storage. The findings are in agreement with the results of Arthey and Philip (2005) reported that TSS content increased due the transformation of starch into simpler sugars on storage. Satkar *et al.* (2012) also stated that polysaccharides present in the products undergo a transformation to monosaccharides and disaccharides during storage.

The carbohydrate content present in selected barnyard millet based vermicelli was lower than control. The carbohydrate content of the barnyard millet based vermicelli varied from 50.47 (TE) to 53.25 g 100 $g^{-1}$ (TG) whereas control was high in carbohydrate content of 78.10 g 100 $g^{-1}$. Poongodi *et al.* (2010) also stated that carbohydrate content present in 20 per cent kodo and barnyard millet incorporated noodles was 48.0 ± 1.41g 100 $g^{-1}$ whereas in branded noodles it was observed to be high as 67.5±0.56 g 100 $g^{-1}$. The carbohydrate content present in millet and soybean based extruded product varied from 63.34 to 63.62 per cent (Abdoulaye *et al.,* 2012). Ranganna *et al.* (2014) reported that carbohydrate content present in refined wheat vermicelli (78.95g 100 $g^{-1}$) was higher than millet incorporated vermicelli (71.14 to 75.20g 100 $g^{-1}$) whereas barnyard millet vermicelli was observed to be low in carbohydrate content on comparison with other minor millet. There was a decrease in the carbohydrate content of the products with the range of 49.67 (TF) to 52.94 g 100 $g^{-1}$ (TG) on four months of storage. The decrease in carbohydrates on storage may be due to the decomposition of complex molecule present in vermicelli to simpler sugars (Hayakawa *et al.*, 2004).

In the present study, initial protein content of selected barnyard millet based vermicelli varied from 7.96 to 9.34g 100 $g^{-1}$, the maximum protein content was observed in treatment TF and minimum protein content in TB. The protein content of control vermicelli (TC) was 1.53 g 100 $g^{-1}$. Sowbhagya *et al.* (2000) formulated maize noodles which had a protein content of 6.5 per cent. Suhendro *et al.* (2000) reported that sorghum noodles had a protein content ranged from 7.3 to 8.9 per cent. Surekha *et al.* (2007) formulated barnyard millet based health mix had observed a protein content of 12 per cent. Kulkarni *et al.* (2012) formulated noodles by incorporating malted finger millet flour and observed a protein content of 7.60g 100 $g^{-1}$ in malted flour and 15.66g 100 $g^{-1}$ in malted ragi noodles. A similar finding of Ranganna *et al.* (2014) reported that vermicelli prepared with millet flours supplements is a good source of protein (10.62 to 15.08 g 100 $g^{-1}$). During fourth month of storage, protein content in barnyard millet based vermicelli varied from 7.52 to 9.03 g 100 $g^{-1}$ which was significantly higher than control. Goldin (1998) stated that, on storage protein content decreases which may be due to the increase in the moisture absorption and production of free amino acids. There was a reduction in protein content on storage due to the moisture uptake from atmosphere and protein degradation of the stored product (Shazad *et al.*, 2005). Sugasini (2003) reported that wheat and kodo millet based vermicelli observed a gradual decrease in protein content on 120 days of storage.

The fat content of selected barnyard millet based vermicelli was significantly higher than control. The fat content of selected barnyard millet vermicelli varied from 1.91 g 100 $g^{-1}$ to 2.16g 100 $g^{-1}$ which was lower in control of 0.40 g 100 $g^{-1}$. Surekha *et al.* (2007) developed barnyard millet based health mix with a fat content of 4 per cent. Desai *et al.,* (2012) reported that ragi noodles formulated with (70%) wheat flour and (30%) malted ragi flour had higher fat content of 0.98 per cent and 0.86 per cent in control. Agrawal *et al.* (2013) reported that barnyard millet fortified with fenugreek seed flour had a fat content of 2.58 per cent. During fourth month of storage fat content of barnyard vermicelli varied from 1.73g 100 $g^{-1}$ to 2.01g 100 $g^{-1}$. There was a decrease in fat content throughout the storage period. Rao *et al.* (1984) stated that decrease in fat content on storage may be due to the enzymatic activity of lipase and lipoxidase which was produced by microorganism. As a similar finding of Sugasini (2003) proved that fat content of kodo millet based vermicelli observed to be decreased during storage period. Shazad *et al.* (2005) reported that fat content decreased during storage which may be due to the development of oxidative rancidity.

In the present study, calorific value of the selected barnyard vermicelli varied from 256.93 to 272.17 Kcal 100 $g^{-1}$ initially which decreased to 248.48 to 251.03 Kcal 100 $g^{-1}$ during fourth month of storage which was lower than control. The calorific value decreased on storage due to the direct influence of protein, carbohydrate and fat. Veena *et al.* (2004) carried a study on nine varieties of barnyard millet and reported that calorific value of barnyard millet varied from 287-358 Kcal 100 $g^{-1}$. Kalpana *et al.* (2013) standardised barnyard millet papad by incorporating fenugreek and observed a energy value of 272.57 Kcal 100 $g^{-1}$. Begum *et al.* (2017) reported that finger millet vermicelli prepared with a 50 per cent finger millet, 40 per cent whole wheat flour and 10 per cent defatted soya flour obtained a low calorific value of 214 Kcal 100 $g^{-1}$. They also prepared *uppuma* with finger millet vermicelli which had a calorific value of 221.8 Kcal 100 $g^{-1}$.

The fibre content present in selected barnyard millet based vermicelli varied from 3.45g 100 $g^{-1}$ (TE) to 4.62g 100 $g^{-1}$ (TF) which was found to higher than control (TC) vermicelli of 0.67g 100 $g^{-1}$. During fourth month, fibre content decreased and they varied from 3.01g 100 $g^{-1}$ to 3.52 g 100 $g^{-1}$. The fibre content present in vermicelli decreased during storage due to the degradation of polysaccharide into simple compounds. There was reduction in fibre content during storage which may due to the moisture absorption (Ahmad, 1996). Pathak and Srivastava (1998) formulated *dhokla*, *uppuma* and *laddu* with foxtail millet by incorporating fenugreek seeds and legumes and observed that a crude fibre content of 2.74, 3.34 and 6.08 per cent respectively. Anju and Sarita (2010) carried out a study on the nutritional composition of flour and prepared millet based biscuit and compared with control. They reported that flour and biscuits developed from barnyard millet had higher crude fibre content of 8.13 and 2.03 per cent on comparing with control of 0.46 (flour) per cent and 0.23 (biscuit) per cent. Nousheen (2013) reported a similar study on the pasta product developed with millet flour, cassava modified starch and green gram dhal with a crude fibre content of 5.21 to 6.92 g 100 $g^{-1}$ and the pasta with wheat flour (control) had a fibre content of 2.00 g 100 $g^{-1}$. Malathi *et al.* (2012) prepared barnyard millet based *uppuma* and their findings reported that fibre content was 6.55g 100 $g^{-1}$. Ranganna *et al.* (2014) reported vermicelli prepared with small millet flour had a fibre content of 1.06 to 1.46g 100 $g^{-1}$. They observed a reduction in fibre content on storage.

The starch content of the selected barnyard vermicelli varied from 58.50 to 67.52 per cent with the lowest starch content in TG (40% germinated barnyard millet flour: 58% whole wheat flour: 2% garden cress seed) and the highest in TF (40% germinated barnyard millet flour: 58% whole wheat flour: 2% garden cress seed). Among all treatments starch content present in TC (100% refined wheat flour vermicelli) was the highest with 83.48 per cent. However there was a decrease in the starch content of vermicelli on storage this may be due to breakdown of starch molecule into simpler sugars. A study on millet flour by Poongodi *et al.* (2010) reported that as the millet flour incorporation increases there will be significant reduction in the starch content. The millet based product showed lower starch digestibility which can be recommended for diabetic and obese patients due to the low rate of enzymatic hydrolysis of carbohydrates. Nousheen (2013) carried out a study on the noodles prepared with a combination of modified cassava starch and green gram dhal with a starch content varying from 41.70 to 51.58 per cent. Thilagavathi (2015) reported that the starch content of noodles, spaghetti and macaroni prepared with millets, soya bean and horse gram varied from 36.58 to 50.76 g 100 $g^{-1}$, 36.65 to 50.85 g 100 $g^{-1}$and 36.07 to 50.74 g 100 $g^{-1}$ were stored for a period of four months. They observed a reduction in starch content on storage.

The changes in reducing sugar and total sugar content during storage period of selected barnyard millet based vermicelli were compared with control. The reducing and total sugar content initially varied from 0.95 to 2.03 per cent and 1.38 to 2.47 per cent which was found to be the highest in TF and the lowest in TG. During fourth month of storage, total and reducing sugar content varied from 1.10 to 2.25 per cent and 1.56 to 2.73 per cent. The reducing and total sugars were higher in control throughout the entire period. There was increase in reducing and total sugars content on storage period due to the formation of simpler sugar like sucrose, glucose and fructose on starch degradation and protein hydrolysed to soluble amino acid. Hemalatha (2004) reported that reducing and total sugars were gradually increased on storage for millet based noodles. Mogra and Midha (2013) showed that vermicelli standardised with malted wheat flour had a total sugars of 8.91 per cent and reducing sugars of 2.41 per cent. The reducing sugar and total sugar content present in millet based extruded products shown as 0.72 ± 0.14 and 4.6 ± 0.14 g per cent (Poongodi *et al.*, 2010). Thilagavathi *et al.* (2015) stated that increased level of air and moisture content in formulated products hasten the breakdown of total sugars to reducing sugars.

The mineral content of the selected barnyard millet based vermicelli were compared with control. Among the selected barnyard based vermicelli calcium, iron, magnesium, zinc and sodium content was observed to be highest in TG of 73.52 mg 100 $g^{-1}$, 15.80 mg 100 $g^{-1}$, 108.30mg 100 $g^{-1}$, 5.04mg 100 $g^{-1}$, 13.40mg 100 $g^{-1}$ and potassium content was shown to be highest in TF of 254.62mg 100 $g^{-1}$ initially. The mineral content of control (TC) was lower than barnyard millet based vermicelli. The mineral content decreased on storage. Rangaswami and Bagyaraj (2000) reported that mineral content of the products decreased on storage due to the utilization of available nutrients by the microbes present in the formulated products. A similar result was observed in Sharon (2010), Lakshmy (2011), Mohan (2014) and Anaveri (2016). They reported that mineral content of the products decreased on storage. Patil (2006) reported barnyard millet rich source of iron (15mg 100 $g^{-1}$) and phosphorus (280mg 100 $g^{-1}$). Functional ingredients like garden cress seeds are rich in calcium, iron and phosphorus and the consumption of value added products with functional ingredients helps to reduce life style diseases (Patel *et al.*, 2009). Abdoulaye *et al.* (2012) carried out a study on the extruded products prepared with germinated millet flour and soyaflour had calcium, phosphorous, iron and magnesium content ranged from 133.62 to 159.62mg 100 $g^{-1}$, 548.87 to 576.11mg 100 $g^{-1}$, 5.99 to 8.99 mg 100 $g^{-1}$ and 139.40 to 162.94 mg 100 $g^{-1}$. Malathi *et al.* (2012) reported that *uppuma* prepared from barnyard millet had a calcium content of 52.1mg 100 $g^{-1}$ and phosphorus content of 213mg 100 $g^{-1}$. A similar finding of Thilagavathi (2015) reported that noodles and spaghetti prepared with a combination of millets, soya bean, horse gram and egg albumin had a calcium content ranging from 51.70 to 180.65mg 100 $g^{-1}$, iron content varing from 5.86 to 7.82mg 100 $g^{-1}$, sodium content differs from 37.48 to 41.05mg 100 $g^{-1}$, zinc content varying from 5.39 to 6.39mg 100 $g^{-1}$, magnesium ranging from 125.97 to 137.45mg 100 $g^{-1}$, phosphorus and potassium varying 310.48 to 391.16 mg and 238.31 to 290.60mg 100 $g^{-1}$ in noodles. The prepared spaghetti was found to be rich in minerals like calcium (51.72 to 180.67mg 100 $g^{-1}$), iron (5.85 to 7.80mg 100 $g^{-1}$), magnesium (125.95 to 137.40mg 100 $g^{-1}$), zinc (5.41 to 6.43mg 100 $g^{-1}$), sodium (37.50 to 41.10mg 100 $g^{-1}$), potassium (238.36 to 290.65mg 100 $g^{-1}$) and phosphorus (310.50 to 391.20mg 100 $g^{-1}$). Shobha *et al.* (2015) formulated maize based vermicelli with a proportion of 50 per cent maize flour and 50 per cent wheat flour. The formulated maize based vermicelli was found to have a calcium content of 108.8mg 100 $g^{-1}$, magnesium content of 89mg 100 $g^{-1}$ and zinc content of 3.13mg 100 $g^{-1}$ respectively.

### 5.3.2. Effect of storage on the health qualities of selected barnyard millet based vermicelli

Veena *et al.* (2005) carried out a study on the physico chemical and nutritive value of barnyard millet and their results revealed that IVSD varied from 20.7 to 28.8 per cent. Germination is an effective way to improve the *in vitro* starch and protein digestibility of the products by partial hydrolysis of protein and carbohydrates (Khetarpaul and Chauhan, 1990). In the present study, the germinated barnyard millet flour was used for preparing vermicelli. Archana *et al.* (2001) reported that germination of pearl millet flour improved *in vitro* starch digestibility by 14-26 per cent. The present study shows that, IVSD of the selected barnyard millet based vermicelli were significantly lower when compared to control (refined wheat flour vermicelli). The IVSD was maximum in control (63.52%) followed by TB (48.46%) and minimum in TG (42.19%) initially. Oghbaei and Prakash (2013) reported that 51% and 42% *in vitro* starch digestibility in refined and whole wheat flour respectively. The reduction in bran during milling may leads to improved starch digestibility. There was decrease in the IVSD on storage for all vermicelli. IVSD of selected barnyard millet vermicelli varied from 41.92 per cent (TG) to 48.27 per cent (TB) during fourth month of storage. Rathi *et al.* (2004) reported that pearl millet based pasta products was found to have an high IVSD (68.8 to 74.0 per cent). Awada *et al.* (2005) stated that starch digestibility may be increased due to rupturing of starch granules. The starch digestibility decreased on storage may be due to conversion of starch molecules into simpler sugars. Raj (2010) reported that, IVSD decreased on storage in pearl millet based weaning food. Hymavathi *et al.* (2014) prepared pearl millet based vermicelli and their findings revealed that IVSD varied from 31 ± 0.50% to 39 ± 0.45%. Wadikar *et al.* (2014) prepared multi millet ready to eat extruded snacks with an IVSD of 4.65mg/g. Rachid *et al.* (2014) carried out a investigation on the *in vitro* starch digestibility of sorghum flour and observed it was in a range of 89.30 to 96.22 per cent. A similar study of Thilagavathi (2015) found that starch digestibility of pasta products prepared with millet and pulse ranged from 90.0 to 94.5 per cent in noodles and 87.0 to 90.5 per cent in spaghetti. Ren *et al.* (2016) carried out a study on the raw and processed millet flour and their results proved that starch digestibility of millet flour (both raw and processed) was lower than wheat flour.

Veena *et al.* (2005) reported that IVPD of barnyard millet was 74.9 to 84.7 per cent. The results of present study shows that, IVPD were observed to be high in all the treatment of barnyard millet based vermicelli incorporated with functional ingredients (TF, TG, TB and TE) whereas in control it was minimum (67.83%). IVPD of barnyard millet based vermicelli varied from 77.88 to 83.16 per cent (initially) and 76.81 to 78.63 per cent (during fourth month). IVPD was observed to reduce on storage from 83.16 to 78.63 per cent (TF), 77.83 to 76.81 per cent (TG), 78.21 to 77.01 per cent (TB), 78.27 to 77.98 per cent (TE) and 67.83 to 66.86 per cent (TC). Rehman and Shan (1999) observed that there was decrease in IVPD by 5% at 25°C and 10.28% at 45°C of wheat grains stored for a period of six months. Dahlin and Lorenz (1993) reported that protein digestibility improved on heat treatment due to protein denaturation and elimination of antinutritional factors. In present study, also IVPD increased during germination (Gahalawat and Sehgal, 1994). Kurahatti *et al.* (2010) formulated little millet based mix by incorporating amaranthus and garden cress seed which had an IVPD of 64.5 per cent. Roopa (2011) prepared little millet based mix which exhibited 79.15 per cent of IVPD. *In vitro* protein digestibility of extruded products prepared with millet and soyabean ranged from 73.94 to 82.17 per cent (Abdoulaye *et al.,* 2012). Jesus *et al.* (2012) carried a study on the *in vitro* protein digestibility of the extruded product with a mixture of whole maize flour (60%) and chick pea flour (40%) having an IVPD of 89.1 ± 1.01 per cent. Susanna and Prabhasankar (2013) prepared gluten free pasta by blending sorghum flour, soya flour, channa flour and observed an *in vitro* protein digestibility of 95.18 ± 0.89. Mannuramath (2013) reported that *in vitro* protein digestibility of little millet grains decreased on storage. Bora (2013) reported that IVPD of pearl millet and proso millet based porridge was 62.9 ± 0.3 and 52 ± 0.2 per cent respectively. IVPD of little millet grains were 71 per cent initially which decreased to 63 per cent during 18 month of storage. The pearl millet based vermicelli varied from 69 ± 0.86 to 73 ± 0.55 per cent (Hymavathi *et al.*, 2014).

The bioavailability is the amount of nutrients available to our body. Bioavailability of minerals improved through the destruction of phytic acid. In the present study, *in vitro* availability of minerals (calcium, iron, magnesium, zinc, potassium and phosphorus) was observed to be higher in selected barnyard millet based vermicelli when compared to control. Among the selected barnyard millet based vermicelli, treatment TG was found to have the highest *in vitro* availability of calcium (70.81 to 67.71%), iron (64.08 to 61.65%), magnesium (72.20 to 71.93%), zinc (56.94 to 56.38%) whereas potassium (63.65 to 63.27%) and phosphorus (67.09 to 64.98%) availability was found to be high in TF during initial and fourth month of storage. Samia *et al.* (2005) carried out an investigation on the effect of processing on pearl millet and their findings shows that germination reduces antinutritional factors and improves the bioavailability.

Appukuttan (2010) reported that during germination tannin content reduced by 26 per cent which significantly improved the availability of minerals. The germinated pulses observed a calcium availability of 23 to 29 per cent, iron availability of 22 to 64 per cent, phosphorus availability of 17 to 43 per cent, potassium availability of 17 to 43 per cent and zinc availability of 10 to 34 per cent respectively. Thilagavathi *et al.* (2015) prepared extruded products (noodles, spaghetti and macaroni) with addition of millet and pulse flour. They modified millet by heat treatment which significantly reduced phytochemicals and improved bioavailability of minerals. The calcium availability varied from 35.16 to 68.07 per cent (noodles), 34.20 to 67.01 per cent (spaghetti) and 37.12 to 69.53 per cent (macaroni). The bioavailability of iron differs from 43.69 to 53.60 per cent in noodles, 42.74 to 52.63 per cent in spaghetti and 44.73 to 54.26 per cent in macaroni. The per cent of zinc availability varied from 46.51 to 50.61 per cent in noodles, 45.67 to 49.92 per cent in spaghetti and 47.39 to 51.01 per cent in macaroni. The noodles, spaghetti and macaroni contain *in vitro* availability of magnesium ranging from 57.25 to 69.78 per cent, 56.80 to 70.00 per cent and 58.21 to 70.90 per cent. The *in vitro* availability of phosphorus varied from 62.96 to 71.11 per cent in noodles, 63.09 to 71.61 per cent in spaghetti and 63.23 to 71.76 per cent in macaroni. The bioavailability of potassium present in noodles, spaghetti and macaroni ranged from 67.29 to 70.20 per cent, 66.82 to 69.66 per cent and 67.59 to 70.45 per cent respectively.

The antioxidant activity of the selected barnyard millet based vermicelli was significantly higher than control throughout the storage period. The total antioxidant activity of the selected barnyard millet based vermicelli varied from 23.28 (TE) to 27.18 per cent (TF) during initial period of the study. The selected barnyard vermicelli and control decrease in antioxidant activity during storage. The antioxidant activity decreased on storage may be due to increased moisture uptake and oxidation. The antioxidant property of millets contributes hypoglycaemic effect and reduces oxidative stress (Hegde *et al.,* 2005). Sridevi *et al.* (2008) reported that phytochemicals present in whole grains are responsible for higher antioxidant activity. Kundgol *et al.* (2012) formulated little millet based products (cookies, flakes and sports mix) and they reported an antioxidant activity of 17.77 per cent in cookies, 21.68 per cent in flakes and 34.08 per cent in sport mixes. Devi and Nazni (2016) stated that, among millets barnyard millet flour shown a higher antioxidant activity. They also formulated barnyard millet based chapatti with a antioxidant activity of 47 to 53 per cent. Dar *et al.* (2016) reported that, in bran enriched extruded snacks there was a decrease in antioxidant activity from 38.99 per cent (initial) to 32.15 per cent (6 month of storage).

The glycemic index of the selected barnyard millet based vermicelli (TF, TG, TB and TE) was lower than control. Among the selected products, treatment TB (48.25) had a lowest glycemic index followed by TF (55.65), TG (56.40), TE (57.51) and control (74.89) had highest glycemic index. Salmeron *et al.* (1997) reported inclusion of low glycemic foods in the diet of diabetic patients help to reduce the blood glucose level. Arora and Srivastava (2002) prepared *khichadi* and *laddu* with combination of barnyard millet, legumes and fenugreek seeds. The glycemic index of *khichadi* and *laddu* was observed to be 34.68 and 36.71. Ugare *et al.* (2014) carried out a study on the consumption of dehulled and heat treated barnyard millet grains to type II diabetes patients. They found that barnyard millet exhibited a low glycemic index of 50 (dehulled grains) and 41.7 (heat treated grains) in diabetic patients. Shukla and Srivastava (2014) reported that finger millet noodles and refined wheat noodles had a glycemic index of 45.13 and 62.59. They proved that millet incorporated noodles show a low glycemic index than refined wheat noodles. Surekha *et al.* (2013b) formulated a barnyard millet based health mix for diabetic patients. The formulated product showed a glycemic index of 51. Itagi *et al.* (2013) formulated little millet based mix and observed a glycemic index of 58.72. Joshi and Srivastava (2016) prepared barnyard millet and rice based *khichdi.* The glycemic index was evaluated by serving the prepared *khichdi* to ten healthy volunteers. The result showed that glycemic index of barnyard millet based *khichdi* was $34.96 \pm 1.22$

whereas in rice based *khichdi* it was 62.5 ± 1.38. Shanmugam *et al.* (2017) formulated value added product from finger millet. They observed that glycemic index of finger millet based flakes, vermicelli, extruded snack with fenugreek was 82.3 ± 6.4, 65.5 ± 5.1 and 65.0 ± 6.6 respectively.

### 5.3.3. Effect of storage on the sensory qualities of selected barnyard millet based vermicelli and *uppuma*

The selected barnyard millet based vermicelli were evaluated for the organoleptic evaluation and compared with control. The mean score obtained for barnyard millet based vermicelli and *uppuma*, initially varied from 7.82 to 8.40 and 7.71 to 8.22 (appearance), 7.75 to 8.48 and 7.84 to 8.29 (colour), 7.60 to 8.20 and 7.76 to 8.22 (flavour), 7.73 to 8.13 and 7.71 to 7.98 (texture), 7.67 to 8.40 and 7.84 to 8.09 (taste) and 7.76 to 8.04 and 7.73 to 8.22 (overall acceptability) respectively. During storage, sensory qualities of selected barnyard millet based vermicelli decreased. But all vermicelli and *uppuma* obtained a mean score of above 6.90 for all the sensory parameters which indicates that barnyard millet based vermicelli and *uppuma* was highly acceptable throughout the storage.

Sowbhagya *et al.* (2000) formulated maize based vermicelli and packed in polypropylene and polyethylene packs. They reported that maize based vermicelli was found to be highly acceptable in sensory properties upto 100 days of storage.

Devi *et al.* (2014) carried out a study on the sensory qualities of kodo millet based pasta (60 per cent kodo millet and 40 per cent wheat flour) stored for a period of 3 months. They observed that mean score for overall acceptability was 7.62 initially which decreased to 7.40 at the end of storage.

Devaraju *et al.* (2006) prepared pasta from finger millet were stored in polyethylene pouches and subjected to organoleptic evaluation. The result shows that, finger millet pasta was highly acceptable with a mean score of above 3.80 out of 5.00 during third month of storage.

Karpagavalli and Amutha (2015) carried out organoleptic evaluation on cereal pulse blended spaghetti. They reported a mean score varying from 8.27 to 8.60 (initially) and 7.95 to 8.25 (180 days of storage). It clearly state that, mean score for sensory attributes of cereal pulse blended spaghetti decreased on storage.

**5.3.4. Effect of storage on the total micro flora of selected barnyard millet based vermicelli**

In the present study, the selected barnyard millet and refined wheat flour based vermicelli were evaluated for bacteria, fungi and yeast. The bacterial load present in selected barnyard based vermicelli varied from 0.02 x $10^6$ cfu/g to 0.37 x $10^6$ cfu/g which was lower than in control vermicelli of 0.66 x $10^6$ cfu/g. The bacterial load increased in second and fourth month of storage. The fungal colony for the selected barnyard millet vermicelli was not observed in initial period. During second and fourth fungal colony was observed with a variation of 0.31 x $10^3$ cfu/g (TF) to 0.46 (TE) x $10^3$ cfu/g and 0.13 x $10^3$ cfu/g (TB) to 0.81 x $10^3$ cfu/g (TE). There was no yeast in any of the vermicelli throughout the storage period. Shanti *et al.* (2000) stated that small quantity of free water present in dried food product doesn't support the growth of microorganisms. The low moisture content and water activity shows better storability of the period. In the present study microbial growth increased on storage it may due to moisture absorption capacity of the product. Bera *et al.* (2001) stated that moisture content, relative humidity, storage temperature are the parameters which directly influence the microbial load. Vijayalakshmi (2004) formulated noodles enriched with β - carotene and carried out storage study for a period of 360 days and found that a bacterial load of 0.32 x $10^3$ cfu/g initially and 2.94 x $10^3$ cfu/g by end of storage. Shobha *et al.* (2015) carried out a study on the microbial load of maize based vermicelli. They reported that bacterial load varied from 2.33 to 2.86 x $10^4$ cfu/g whereas yeast and mould was found to be absent in maize vermicelli. Gull *et al.* (2016) formulated millet based functional pasta and the microbial analysis of pasta show that yeast and mould was not observed for a period of four months.



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### 5.3.4. Effect of storage on the insect infestation of selected barnyard millet based vermicelli

Insect infestation was not observed in the entire period of storage in any of the vermicelli, this may due to the low moisture content of the selected vermicelli. Ugare (2008) reported that barnyard millet grains and flour storage for period of six month without insect infestation. Latha *et al.* (2015) carried out storage study on ragi based vermicelli against *Sitophilus oryzae* and *Tribolium castaneum*. The study revealed that vermicelli stored in steel container observed more shelf life without insect infestation for six months of storage.

### 5.4. Development of instant *uppuma* mix

The term instant food refers to simple, fast and easily accessible product with extended shelf life. They are effective means to prepare food with less time, energy and labour. The instant mixes are ready to cook products which undergo major processing by the manufacturers. The demand on ready to cook food products have increased now a days due to the changing life style and food habits in developing countries. Cereals based traditional instant mixes like instant *uppuma*, instant idli mix, and instant dosa mix are widely available in market for large number of consumers. In present the study, an attempt was made to standardise barnyard millet based instant *uppuma* mix with functional ingredients to improve the nutritional profile of consumers.

Instant *uppuma* mixes using barnyard millet based vermicelli with various functional ingredients namely fenugreek, garden cress seed, *Brahmi* and *Ekanayakam* were standardised with different volume of water (200 to 400ml) along with 5g spice mix, 5g toasted mustard and 2g toasted curry leaves.

### 5.4.1. Cooking time for instant *uppuma* mix preparation

Cooking time is an important parameter for instant *uppuma* mix. Normally for preparing *uppuma* 15-25 minutes is required. Hence, for the formulation of instant *uppuma* mix less time is required by eliminating several procedures of *uppuma* preparation.

In the present study, cooking time of control instant *uppuma* was observed to be lower than selected barnyard millet based vermicelli. The time required for the preparation of 100g fenugreek incorporated barnyard instant *uppuma* varied from 3.07 to 4.21. In case of garden cress seed incorporated instant *uppuma* cooking time differs from 3.02 to 4.25. The cooking time of *Brahmi* and *Ekanayakam* based instant *uppuma* varied from 3.20 to 4.12 and 2.96 to 4.02 respectively.

Premavalli *et al.* (1987) formulated instant sooji *uppuma* mix (100g), which can be reconstituted in boiling water with 4 to 5 minutes. Sowbhagya and Ali (2001) conducted a study on instant noodles and found that volume of water and weight of noodles increased upon cooking.

Suhendro *et al.* (2000) conducted a study on the preparation of sorghum noodles. They reported that, 100g of sorghum noodles was observed to have a cooking time of 4.0 to 5.5 minutes. They also reported that, mixed pulse flour incorporated at a level of 40 per cent increased cooking time (7 to 8 minutes).

Agarwal *et al.* (2004) carried out a study on the cooking quality of foxtail millet noodles. They reported that as the incorporation level of millet flour increased there will be gradual decrease in the cooking time and water absorption. Vijayalakshmi (2004) carried out the study on the cooking time of spaghetti (extruded product). They reported that cooking time was directly proportional to the density of the products

Shah *et al.* (2005) formulated instant soup mixes with various cooking time (1 to 5 minutes). The formulated soup mix (100g) can be reconstituted with boiling water (1:10) for 4 minutes were desirable.

Singh (2008) formulated various types of instant porridges like sweet porridge, salty porridge, vegetable supplemented porridge, pulse supplemented and cereal mixed porridges. They observed that cooking time for sweet, salty, cereal mixed porridges were 4.30 minutes whereas pulse supplemented and vegetable supplemented porridges cooked with 5 and 6 minutes.

Fernandes *et al.* (2013) prepared rice based pasta by incorporating modified rice flour and egg albumin in rice flour. They reported that all the formulated pasta had an optimum cooking time of 3 minutes.

Pandey (2013) carried out a study on the value addition of foxtail millet based vermicelli. The foxtail millet vermicelli were formulated with a combination of semolina, unprocessed foxtail millet, steamed foxtail millet, black gram dhal flour and fenugreek seed flour. The cooking time for 100g of foxtail millet based vermicelli varied from 4.34 to 8.37 minutes. They reported that utilisation of processed foxtail millet flour in foxtail millet vermicelli reduced cooking time.

Karpagavalli and Amutha (2015) formulated pasta product by incorporating 5 to 10 per cent of cereal pulse blend in wheat semolina flour. The prepared pasta (100g) cooked with 209.2 to 288.50 ml of water within a time period of 6.40 to 10.30 minutes.

### 5.4.2. Organoleptic evaluation of instant *uppuma* mixes

The instant *uppuma* mixes were standardised from the best selected vermicelli with fenugreek, garden cress seed and *Ekanayakam* using 40% barnyard millet flour, 58% whole wheat flour and 2% fenugreek/ garden cress seed/ *Ekanayakam*, where as *Brahmi* based vermicelli formulated with 40% barnyard millet flour, 58.5% whole wheat flour and 0.5% *Brahmi*. *Uppuma* were prepared from instant *uppuma* mixes using optimum volume of water. The organoleptic evaluation of *uppuma* prepared from fenugreek, garden cress seed and *Brahmi* based instant *uppuma* mixes with 300ml of water, 5g spice mix, 5g toasted mustard and 2g toasted curry leaves were highly acceptable for all sensory characters (appearance, colour, flavour, texture, taste and overall acceptability). The overall acceptability of 100g barnyard millet based instant *uppuma* with fenugreek, garden cress seed and *Brahmi* was found to have highly acceptable mean score of 7.82, 7.78 and 7.89 respectively, when cooked in 300ml water.

Prabhakar (2006) formulated instant *uppuma* mix with a combination of 25 per cent cereals and 75 per cent foxtail millet. The instant dry mix pack contained a pack of roasted bengal gram dhal, mustard seeds, dehydrated curry leaves, chillies and ginger. They prepared instant *uppuma* with 300ml of water which was highly acceptable in all the sensory attributes.

Anitha and Rajyalakshmi (2014) prepared instant *uppuma* mix with a combination of wheat semolina and popular low grade variety rice (NLR 34449). The other ingredients used in their *uppuma* mix were bengal gram dhal, mustard seeds, citric acid, dried curry leaves, green chilli and ginger. They found that 300ml of water can be used for preparing 100g of *uppuma* mix.

Khan *et al.* (2014) standardised instant wheat porridge (Dalia) mix with precooked broken wheat, skimmed milk powder and sugar and they optimized quantity of water used for reconstituting the porridges mix. They reported that instant wheat porridge mix were reconstituted with 303ml of water and the prepared porridges had a mean score of 7.58 (consistency), 7.59 (taste) and 7.58 (overall acceptability).

The results of organoleptic evaluation of *Ekanayakam* incorporated barnyard millet based instant *uppuma* mix were found to be acceptable with 250ml of water and constant amount of other ingredients (5g spice mix, 5g toasted mustard and 2g toasted curry leaves). The *Ekanayakam* incorporated barnyard millet based instant *uppuma* mix prepared with $T_2$ (100g vermicelli with 250 ml of water) had a mean score of 7.58 for appearance, 7.62 for colour, 7.51 for flavour, 7.60 for texture, 7.51 for taste and 7.62 for overall acceptability.

Balasubramanian *et al.* (2014) proved that 100g of pearl millet *uppuma* dry mix required 244.6ml of water for cooking *uppuma* with desired consistency. They stated that, while preparing *uppuma* mix as the water rehydration ratio increases, the fat content increases which increase in the reconstitution time.

*Ekanayakam* was less in fat content and fibrous in nature. Hence, the amount of water absorption may be reduced to 250 ml compared to other functional ingredients within the reduced reconstitution time.

Vijayakumar and Deepa (2010) standardised a cereal based mix incorporated with green leafy vegetables and spices. They reported that for cereal based mix, the predicted response value for water absorption capacity was about 242.5 ml, which obtained a good sensory score of 15.3.

Kaur *et al.* (2012) formulated pasta by incorporating 5 to 25 per cent of cereal bran (wheat bran, rice bran and oats bran). All the formulated pasta was cooked with 250ml of water. The cereal bran based pasta enriched with 15 per cent level of wheat, rice and oat bran and 10 per cent barley bran was most acceptable with a storage period of 4 months.

Latha *et al.* (2014) prepared oryzanol enriched instant *bisibele bhath* mixes, a delicious Karnataka. They reported that 100g of mix needed 250 ml of water for cooking to acquire a desirable consistency.

### 5.5. Cost of production for selected barnyard based vermicelli's and instant *uppuma* mix

The cost of barnyard millet based vermicelli varied from 113.81 to 128.61 Rs/Kg which higher than control (refined wheat flour vermicelli) of 72.51 Rs/Kg. The cost of barnyard millet based instant *uppuma* mix differs from 126.86 to 141.66 Rs/Kg whereas lower cost was found in control instant *uppuma* mix of 85.56 Rs/Kg. The cost of prepared vermicelli was lower than the market price. The market price of ragi vermicelli, rice vermicelli, refined wheat vermicelli and instant *uppuma* mix was observed as 150 Rs/Kg, 118 Rs/Kg, 90 Rs/Kg and 170 Rs/Kg respectively. Kulkarni *et al.* (2011) reported that millets based value added products was highly nutritious and low cost. Now a days consumers are much emphasised on the healthy foods with low calorific value which increased the demand on instant food mixes (Jafersadhiq, 2014). Thilagavathi (2015) carried out a study on consumer's preference in millet based extruded products (noodles, spaghetti and macaroni) and proved that formulated pasta products were well accepted by the consumers. Ahmed *et al.* (2016) reported that noodles formulated with gluten free millets was highly preferred by the consumers and they are mainly preferred to patients suffering with diabetics, celiac disease and those who are, susceptible to allergies.

# SUMMARY

# 6. SUMMARY

The present study entitled "Standardisation and quality evaluation of millet based designer vermicelli" was proposed to formulate barnyard millet based designer vermicelli with a combination of germinated barnyard millet flour, whole wheat flour and various functional ingredients like fenugreek seeds, garden cress seeds, *Brahmi* and *Ekanayakam*. The study also assessed the nutritional, health, sensory and microbial qualities of the standardised products for a period of four months. The study also aimed to standardise instant *uppuma* mix with functional ingredients.

The barnyard millet was soaked (10hrs), germinated (24hrs) and powdered to obtain an uniform flour. The functional ingredients like fenugreek seeds (germinated), garden cress seeds, *Ekanayakam root bark* and *Brahmi* leaves (dried) were also powdered.

The barnyard millet vermicelli was prepared with a combination of 40 to 80 per cent of germinated barnyard millet flour, 15 to 48 per cent whole wheat flour by incorporating with 2 and 5 per cent of functional ingredients like fenugreek seed flour, garden cress seed and *Ekanayakam* where as *Brahmi* was incorporated in less quantity due to its bitter taste. The *Brahmi* incorporated vermicelli was tried with 40 to 80 per cent germinated millet flour, 19 to 59.5 per cent whole wheat flour incorporated with 0.5 and 1 per cent *Brahmi*.

Based on organoleptic evaluation, barnyard millet based vermicelli and *uppuma* incorporated with each functional ingredient showed a highest mean score in treatment $T_{10}$ for all sensory attributes. Fenugreek, garden cress seed and *Ekanayakam* based vermicelli and *uppuma* prepared with 40 per cent germinated barnyard millet flour, 58 per cent whole wheat flour and 2 per cent functional ingredients were found to be high in overall acceptability with a mean score of 7.77 and 7.88 (fenugreek), 7.88 and 8.31 (garden cress seed) and 7.75 and 7.73 (*Ekanayakam*) respectively, whereas *Brahmi* based vermicelli formulated with (40: 59.5: 0.5) germinated barnyard millet, whole wheat flour and *Brahmi* was highly acceptable with an overall acceptability of 8.02 and 8.22 respectively.

The best selected barnyard based vermicelli were TF (Barnyard millet + fenugreek based vermicelli), TG (Barnyard millet + garden cress seed based vermicelli), TB (Barnyard millet + *Brahmi* based vermicelli) and TE (Barnyard millet + *Ekanayakam* based vermicelli) along with control (TC) was packed in polyethylene pouches of 250 gauge and kept in ambient condition for a period of four months. The selected vermicelli was evaluated for nutritional qualities, health studies, sensory and microbial evaluation initially and during the second and fourth month of storage.

The moisture content of the selected barnyard millet varied from 7.70 to 7.80 per cent which was lower than control. There was a significant difference between barnyard millet vermicelli and control and the moisture content increased throughout storage. The TSS content varied from $2.4^0$ to $3.6^0$ brix in selected barnyard millet based vermicelli which increased to $2.9^0$ to $4.2^0$ brix at the end of storage.

Initially, barnyard millet vermicelli observed to have a carbohydrate content of 50.47 to 53.25 g 100 $g^{-1}$, protein of 7.96 to 9.34 g 100 $g^{-1}$ and the fat content varied from 1.91 to 2.16 g 100 $g^{-1}$ which decreased on storage. The low calorific value was observed in barnyard millet based vermicelli, when compared with control. The barnyard millet vermicelli had a calorific of 256.93 to 272.17 Kcal 100 $g^{-1}$ initially and declined to 247.32 to 251.03 Kcal 100 $g^{-1}$ at fourth month of storage. The energy value was highest in TF and lowest in TE throughout the storage period.

There was gradual decrease in fibre content of selected barnyard millet based vermicelli and control. Initially fibre content varied from 3.45g 100 $g^{-1}$ (TE) to 4.62g 100 $g^{-1}$ (TF) which decreased to 3.01g 100 $g^{-1}$ to 3.52 g 100 $g^{-1}$ at the end of storage. The starch content was found to have significant variation among the selected barnyard and refined wheat flour vermicelli. The starch content was highest in control of 83.48 per cent and it was lower in barnyard millet vermicelli (58.50% to 67.52%). There was a gradual decrease in starch content during second and fourth month of 58.12 per cent (TG) to 67.02 per cent (TF) and 57.45 per cent (TG) to 66.81 per cent (TF).

The reducing and total sugar content present in selected vermicelli was increased during storage. The reducing and total sugar content of barnyard vermicelli, initially ranged from 0.95 (TG) to 2.03 per cent (TF) and 1.38 (TG) to 2.47 per cent (TF) respectively and it was observed to be lower than in control (4.12% and 4.43%). During the fourth month, reducing sugar and total sugar increased with a variation of 1.10 (TG) to 2.25 per cent (TF) and 1.56 (TE) to 2.73(TF) per cent respectively which was lower than control (4.17% and 4.51%)

The mineral content of the selected barnyard millet based vermicelli was lower than control. Initially, the selected barnyard based vermicelli was noted with a variation of 67.66 to 73.52 mg 100 $g^{-1}$ (calcium) , 13.99 to 15.80 mg 100 $g^{-1}$ (iron), 101.72 to 108.30 mg 100 $g^{-1}$, (magnesium), 3.69 to 5.04mg 100 $g^{-1}$ (zinc) and 12.15 to 13.40mg 100 $g^{-1}$ (sodium) and 228.76 to 254.62mg 100 $g^{-1}$ (potassium). The mineral content decreased on storage. During fourth month calcium and iron content varied from 66.58 to 72.34 mg 100 $g^{-1}$ and 12.38 to 14.93 mg 100 $g^{-1}$ The magnesium, zinc, sodium, and potassium content differs from 101.24 to 107.76 mg 100 $g^{-1}$, 3.51 to 4.75 mg 100 $g^{-1}$, 11.84 to 12.91 mg 100 $g^{-1}$ and 228.51 to 253.67 mg 100 $g^{-1}$ respectively.

The *in vitro* starch digestibility for selected vermicelli varied from 42.19 to 48.46 per cent initially, which decreased to 41.92 to 46.19 per cent at the end of storage. IVPD of selected vermicelli varied from 77.83 to 83.16 per cent at initial period of storage. During second and fourth month of storage, *in vitro* protein digestibility differed from 77.03 to 78.96 per cent and 77.01 to 78.63 per cent.

The mineral bioavailability of the selected barnyard millet based vermicelli was assessed and the availability of calcium ranged from 58.95 to 70.81 per cent, iron availability ranged from 55.44 to 64.08 per cent, magnesium availability ranged from 67.81 to 72.20 per cent, zinc availability varied from 46.34 to 56.94, potassium availability differs from 57.42 to 63.65 per cent and phosphorus availability ranged from 58.63 to 67.09 per cent during initial period of storage. The *in vitro* availability of minerals (calcium, iron, magnesium, zinc, potassium and phosphorus) was observed to higher in selected barnyard millet based vermicelli when compared to control. The *in vitro* availability of minerals decreased during storage. During fourth month of storage, the mineral bioavailability was observed as 58.74 to 67.71 per cent (calcium), 54.35 to 61.65 per cent (iron), 67.56 to 71.93 per cent (magnesium), 45.97 to 56.38 per cent (zinc), 56.84 to 63.27 per cent (potassium) and 58.32 to 64.98 per cent (phosphorus).

The antioxidant activity of the selected barnyard millet based vermicelli initially varied from 23.28 (TE) to 27.18 (TF) per cent which decreased with a range of 22.94 (TE) to 26.74 (TF) per cent at fourth month of storage. The antioxidant activity of selected barnyard millet based vermicelli was observed to be lower than control. The glycemic index of the selected barnyard millet based vermicelli varied from 48.25 in TB to 57.91 in TE which was lower than in control (74.89).

Based on organoleptic evaluation, the mean scores of barnyard millet based vermicelli and *uppuma* was lower than control throughout the storage period. The organoleptic evaluation for the selected barnyard millet vermicelli and *upumma* shows that TF (Barnyard millet + fenugreek based vermicelli), TG (Barnyard millet + garden cress seed based vermicelli), TB (Barnyard millet + *Brahmi* based vermicelli) and TE (Barnyard millet + *Ekanayakam* based vermicelli) was acceptable upto fourth month of storage with gradual decline in all the sensory attributes. Even though, all the selected barnyard vermicelli and *uppuma* was acceptable, *Ekanayakam* incorporated products observed to have least score throughout the storage. During storage, the mean score was observed to be slightly decreasing in all the treatments.

The bacterial load was initially highest in TC (0.66 x $10^6$ cfu/g) in the selected barnyard millet based vermicelli. Among, the selected vermicelli bacterial load was found to be high in TG (0.37 x $10^6$ cfu/g) whereas bacterial count was detected to be low in TB ($0.02 \times 10^6$ cfu/g) initially. During fourth month of storage bacterial count was high in TE ($1.94 \times 10^6$ cfu/g) and low in TB ($0.46 \times 10^6$ cfu/g). The fungal count was absent at initially and during fourth month it varied from $0.13 \times 10^3$ cfu/g (TB) to $0.81 \times 10^3$ cfu/g (TE). The yeast count was not detected during the storage. No insect infestation was seen in stored vermicelli during four month of storage.

In the present study, selected barnyard vermicelli was used to standardise instant *uppuma* mixes with different volume of water (200 to 400ml), 5g of spice mix, 5g of toasted mustard and 2g of toasted curry leaves. The cooking time of the selected barnyard millet based varied from 3.07 to 4.21 minutes (TF), 3.02 to 4.25 minutes (TG), 3.20 to 4.12 minutes (TB) and 2.96 to 4.02 minutes (TE) respectively. The organoleptic evaluation for the instant *uppuma* was carried out and the barnyard millet based instant *uppuma* prepared with fenugreek, garden cress seed and *Brahmi* was found to be highly acceptable in treatment $T_3$ (100g vermicelli in 300ml of water) for all the sensory parameters whereas *Ekanayakam* based instant *uppuma* was highly acceptable in treatment $T_2$ (100g vermicelli in 250ml of water).

The cost of production of barnyard millet based vermicelli varied from 113.81 to 128.61 Rs/Kg whereas control vermicelli cost was 72.51 Rs/Kg. The barnyard millet based instant *uppuma* mix cost differs from 126.86 to 141.66 Rs/Kg which was higher than control instant *uppuma* mix of 85.56 Rs/Kg.

From the study, it was clear that barnyard millet based vermicelli prepared with functional ingredients like 0.5 per cent *Brahmi* to 2 per cent fenugreek seeds, garden cress seeds and *Ekanayakam* root barks was highly acceptable. The formulated vermicelli and *uppuma* was observed to have good nutritional profile. The barnyard millet based vermicelli was considered to be low glycemic food with high antioxidant activity and mineral bioavailability. The instant *uppuma* mix formulated with selected barnyard millet based vermicelli was most acceptable in $T_3$ (300ml of water) for fenugreek seed, garden cress seed and *Brahmi* whereas *Ekanayakam* based instant mix prepared, $T_2$ (250ml of water) was highly acceptable in terms of the sensory parameters.

The present study concluded that barnyard millet is an underutilised grain which can be effectively used in development of millet based designer vermicelli incorporated with functional ingredients (2% germinated fenugreek seed / garden cress seed/ *Ekanayakam* root barks and 0.5% *Brahmi* leave powder). The selected barnyard millet based products was observed to have good nutritional and health qualities. The developed products were shelf stable without any deterioration upto four month of storage in polyethylene pouches (250 gauges).

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# APPENDICES

## APPENDIX – I

**Score card for the organoleptic evaluation of barnyard millet vermicelli**

Name :

Date :

| S No | Parameter | Treatments | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ |
| 1 | Appearance | | | | | | | | | | | |
| 2 | Colour | | | | | | | | | | | |
| 3 | Flavour | | | | | | | | | | | |
| 4 | Texture | | | | | | | | | | | |
| 5 | Taste | | | | | | | | | | | |
| 6 | Overall acceptability | | | | | | | | | | | |

**9 point hedonic scale**

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

**Signature**

## APPENDIX – II

**Score card for the organoleptic evaluation of barnyard millet *uppuma***

Name :

Date :

| S No | Parameter | Treatments | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ | $T_9$ | $T_{10}$ |
| 1 | Appearance | | | | | | | | | | | |
| 2 | Colour | | | | | | | | | | | |
| 3 | Flavour | | | | | | | | | | | |
| 4 | Texture | | | | | | | | | | | |
| 5 | Taste | | | | | | | | | | | |
| 6 | Overall acceptability | | | | | | | | | | | |

**9 point hedonic scale**

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

**Signature**

## APPENDIX – III

**Score card for the organoleptic evaluation of barnyard millet based instant *uppuma***

Name :

Date :

| S No | Parameter | Treatments | | | | |
|---|---|---|---|---|---|---|
| | | $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ |
| 1 | Appearance | | | | | |
| 2 | Colour | | | | | |
| 3 | Flavour | | | | | |
| 4 | Texture | | | | | |
| 5 | Taste | | | | | |
| 6 | Overall acceptability | | | | | |

**9 point hedonic scale**

| | |
|---|---|
| Like extremely | 9 |
| Like very much | 8 |
| Like moderately | 7 |
| Like slightly | 6 |
| Neither like nor dislike | 5 |
| Dislike slightly | 4 |
| Dislike moderately | 3 |
| Dislike very much | 2 |
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**Signature**

# STANDARDISATION AND QUALITY EVALUATION OF MILLET BASED DESIGNER VERMICELLI

By

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ABSTRACT OF THE THESIS

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## ABSTRACT

Barnyard millet is a minor millet which consist of fair amount of highly digestible protein coupled with low amount of slowly digestible carbohydrate. It is also rich in dietary fibre, iron, phytochemicals and antioxidants. Due to this, barnyard millet may be considered as a functional food. Functional foods provide an additional physiological benefit beyond their basic nutrition. Functional ingredients (fenugreek seed, garden cress seed, *Brahmi leaves* and *Ekanayakam root barks*) can be incorporated to various food products to improve their sensory, nutritional and health quality. They can be utilised to develop convenient products like vermicelli, which carry nutraceutical properties. Hence, the present study entitled "Standardisation and quality evaluation of millet based designer vermicelli" was undertaken to develop functional/designer vermicelli and to evaluate its quality aspects. The study also aims to develop acceptable instant *uppuma* mix with the standardised vermicelli.

Fenugreek seed, garden cress seed and *Ekanayakam* based vermicelli and *uppuma* were prepared in different combination. Among this, 40% germinated barnyard millet flour incorporated to 58% whole wheat flour and 2% functional ingredient was highly acceptable with a mean organoleptic scores of 7.77 and 7.88 (fenugreek seed), 7.88 and 8.31 (garden cress seed), 7.75 and 7.73 (*Ekanayakam*) respectively. *Brahmi* based vermicelli and *uppuma* formulated with 40% germinated barnyard millet, 59.5% whole wheat flour and 0.5% *Brahmi* was highly acceptable with an overall acceptability of 8.02 and 8.22 respectively. The best selected barnyard based vermicelli with each functional ingredient along with control was packed in polyethylene pouches of 250 gauge and kept in ambient condition for a period of four months.

The moisture and TSS of the selected vermicelli varied from 7.70 to 7.80% and $2.4^0$ to $3.6^0$ brix, which increased on storage. The selected barnyard millet vermicelli were observed to have a carbohydrate content of 50.47 to 53.25 g 100 $g^{-1}$, protein of 7.96 to 9.34 g 100 $g^{-1}$, fat of 1.91 to 2.16 g 100 $g^{-1}$, energy of 256.93 to 272.17 Kcal 100 $g^{-1}$, fibre of 3.45 to 4.62g 100 $g^{-1}$ and starch of 58.50 to

67.52% initially which decreased on storage. Initially reducing and total sugar content varied from 0.95 to 2.03% and 1.38 to 2.47% which increased to a range of 1.10 to 2.25% and 1.56 to 2.73% respectively on storage.

The minerals like calcium, iron, magnesium, zinc and sodium, initially were highest in garden cress seed based barnyard vermicelli of 73.52 mg 100 $g^{-1}$, 15.80 mg 100 $g^{-1}$, 108.30 mg 100 $g^{-1}$, 5.04 mg 100 $g^{-1}$ and 13.40 mg 100 $g^{-1}$ respectively. The potassium content was shown to be highest in fenugreek based barnyard vermicelli of 254.62 mg 100 $g^{-1}$. There was a gradual decrease in the mineral content on storage.

*In vitro* starch and protein digestibility of barnyard millet based vermicelli initially varied from 42.19 to 48.46% and 77.83 to 83.16% which decreased on storage. Among the selected vermicelli, the highest *in vitro* availability of calcium (70.81%), iron (64.08%), magnesium (72.20%) and zinc (56.94%) was found in garden cress seed incorporated vermicelli whereas potassium (63.65%) and phosphorus (67.09%) availability was found to be highest in fenugreek based vermicelli throughout the storage period. The barnyard millet based vermicelli was found to have a high antioxidant activity (23.28 to 27.18%) and lower glycemic index (48.25 to 57.51).

Microbial enumeration of the selected vermicelli was done and found to be within the permissible limits throughout the storage. The mean score for sensory qualities of selected barnyard millet based vermicelli and *uppuma* were highest in fenugreek incorporated vermicelli. Initially, the mean score for overall acceptability of barnyard millet based vermicelli and *uppuma* varied from 7.76 to 8.04 and 7.73 to 8.22 which were lower than the control. The products were shelf stable without any deterioration upto four months of storage, in polyethylene pouches (250 gauge).

Instant *uppuma* mixes were standardised using 5g spice mix, 5g toasted mustard and 2g toasted curry leaves in different volume of water (200 to 400ml). The cooking time of instant *uppuma* mix increases as the volume of water increases. The overall acceptability of barnyard millet based instant *uppuma* incorporated with fenugreek seed, garden cress seed and *Brahmi* standardised with 300ml of water was highly acceptable with a mean score of 7.82, 7.78 and 7.89 respectively, whereas *Ekanayakam* incorporated barnyard millet based instant *uppuma* prepared with 100g vermicelli in 250ml of water had a highest mean score of 7.62.

The development of barnyard millet vermicelli with functional ingredients will help to improve human health. Hence, there is immense scope for the development of various designer foods from barnyard millet.