STANDARDISATION AND QUALITY EVALUATION OF MILLET BASED PROBIOTIC YOGHURTS

By

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(2019-16-003)

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COLLEGE OF AGRICULTURE

VELLANIKKARA, THRISSUR - 680 656

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THESIS

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DECLARATION

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

Amrutha U. A.

Place: Vellanikkara
Date : 2.3.2023

CERTIFICATE

Certified that the thesis entitled **"Standardisation and quality evaluation of millet based probiotic yoghurts"** is a bonafide record of research work done independently by **Ms. Amrutha U. A.** 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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Date : 2. 3. 2023

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We, the undersigned members of the advisory committee of **Ms. Amrutha U. A. (2019-16-003)**, a candidate for the degree of **Master of Science** in **Community Science** with a major field in **Food Science and Nutrition**, agree that the thesis entitled **"Standardisation and quality evaluation of millet based probiotic yoghurts"** may be submitted by **Ms. Amrutha U. A**. in partial fulfillment of the requirement for the degree.

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Introduction

I. INTRODUCTION

Millets are small grained cereals belonging to the grass family and are one of the oldest foods known to humans but were discarded in favour of wheat and rice. Millets are highly tolerant of extreme weather conditions such as drought. They are the reservoirs of nutrition for better health and are rich in B vitamins, calcium, iron, potassium, magnesium, zinc, dietary fibre and phytochemicals. Millets act as therapeutic food in controlling blood pressure, diabetes, heart diseases etc. Millets act as nutraceuticals and due to the health benefits they are known as nutricereals. There are a wide variety of millets such as pearl millet, finger millet, little millet, kodo millet, foxtail millet, barnyard millet and proso millet.

Barnyard millet (*Echinochloan sp.*) is one of the oldest domesticated millets in the semiarid tropics of Asia and Africa. It is an important minor millet because of its fair amounts of protein (12%) that is highly digestible (81.13%) coupled with low carbohydrate content (58.56%) of slow digestibility (25.88%). The dietary fibre content of barnyard millet can be considered in the management of disorders like diabetes mellitus, obesity, hyperlipidemia etc. They are a good source of micronutrients and nutraceutical components.

Finger millet (*Eleusine coracana*) is also a widely grown cereal crop in the arid and semiarid areas. It is known for several health benefits and some of the health benefits are attributed to its polyphenol and dietary fibre contents. Nutritionally it is high in calcium and phenolic com pounds and is also recognised for beneficial health effects like anti-diabetic, anti- tumorogenic, antioxidant and atherosclerogenic effects.

Fermented millet products serve as a natural probiotic. Probiotics are live microorganisms that when administered in adequate amounts confer a health benefit on the host. Probiotic microorganisms inhibit pathogenic microorganisms, enhance the immune system and decrease the blood cholesterol level. Prebiotics are non-digestible ingredients that enhance the activity of colon bacteria and the viability of probiotics.

Synbiotics involve the combination of probiotics and prebiotics. The length of life of probiotic bacteria extends in this combination and colonises better in the colon. Millet based fermented foods and beverages are potential prebiotics and can enhance the functionality of probiotics with significant health benefits. The most common prebiotics used are inulin, its derivatives fructo-oligosaccharides and galacto-oligosaccharides, polydextrose, soluble corn fibre, pyrodextrin, lactosucrose, lactulose *etc*.

Dairy foods are the main types of food matrices supplemented with probiotic bacteria and they have a positive reputation among consumers. Yoghurt a milk-based product is a healthy food which offers high nutritional value with concentrated amounts of protein, carbohydrates and fats. The added value of yoghurt over milk lies on the presence of beneficial bacteria as well as certain bioactive components. The nutrient profile of yoghurt makes it an important dairy food which is widely accepted worldwide and associated with a healthy diet.

Hence, the present study entitled "Standardisation and quality evaluation of millet based probiotic yoghurts" was undertaken with the following objectives

1. To develop probiotic and synbiotic yoghurts incorporating barnyard millet and finger millet.
2. To evaluate its acceptability, nutritional, health and shelf life qualities.

Review of Literature

2. REVIEW OF LITERATURE

The relevant literature of the study entitled “Standardisation and quality evaluation of millet based probiotic yoghurts” is briefly discussed under the following headings.

2.1. Millet: An overview

- 2.1.1. Finger millet
- 2.1.2. Barnyard millet
- 2.1.3. Millet based yoghurts

2.2. Definition and history of yoghurts

2.3. Types of yoghurts

2.4. Probiotic yoghurts

2.1. Millet: An overview

Millets, also known as coarse grains or grasses, are widely farmed around the world for a variety of uses, including fodder and primarily for human food due to their high nutritional content. In dry and arid parts of the developing world, particularly in Africa and Asia, millets constitute a significant source of food for impoverished farmers (McDonough *et al*., 2000). The term millet was derived from "*mille*" (French term) means a handful of millet containing thousands of seed grains (Taylor and Emmambux, 2008).

Around 97 per cent of the world's millets are produced and consumed in developing nations, while just a small portion is imported. According to average statistics on millet production throughout the continents between 1961 and 1963, Asia produced the most millets (13.2 Mt), followed by Africa (6.9 Mt), Europe (2.3 Mt), America (0.32 Mt) and Oceania (0.32 Mt) (0.03 Mt). Millets (pearl millet and minor millets) are grown in more than 93 nations worldwide (Obilana and Manyasa, 2002). Throughout Asia, India, China and Nepal produce the majority of the world's millet. The greatest producer of millets is India, accounting for 37.5 per cent of the world's output, followed by Sudan and Nigeria.

Millets are divided into two types: major millets and small millets, depending on the size of the grain. According to use, it is divided into three categories: major millets, minor millets and pseudo millets. Sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and finger millet (*Eleusine coracana*) constitute the major millet. Little millet (*Panicum sumatrance*), foxtail millet (*Setaria italica*), kodo millet (*Paspalum scrobiculatum*), proso millet (*Panicum miliaceum*) and barnyard millet (*Echinochloa frumentacea*) are the five species that make up the minor millets. Amaranth and buck wheat are pseudo millets, which are not members of the *Poaceae* genus of plants. So it is categorised as pseudo millets. Minor millets are renowned for their climate resilient characteristics, which include their greater ecological adaptability, lower water needs, decreased incidence of insect pests and illnesses and less susceptibility to environmental shocks.

Millets have long been a staple of tribal cuisine in India, particularly in the tribal regions of Odisha, Maharashtra, Gujarat, Madhya Pradesh, Tamil Nadu, Bihar and Uttar Pradesh (Vanniarajan *et al*., 2018). The majority of millet production occurs in dry areas with irregular and little rainfall. The most widely produced millet is pearl millet, which makes up 56 per cent (9 Mt) of all millets produced in India. It is primarily grown in the states of Rajasthan, Uttar Pradesh, Gujarat, Madhya Pradesh and Haryana. With a yield of 1.79 Mt from a total cropped area of 1.17 M hectare, finger millet is the most extensively produced minor millet in India. More than 90 per cent of the country's output of finger millet is produced in the major finger millet growing states of Karnataka, Uttarakhand, Maharashtra, Tamil Nadu, Odisha and Andhra Pradesh. The second most frequently cultivated minor millet in India is kodo millet. In tropical regions of the world, including India, China, Japan and Korea, barnyard millet is grown for consumption. With an area, production and productivity of 0.146 million hectare, 0.147 million and 1034 kg ha^{-1}, India is the world's largest producer of barnyard millet (IIMR, 2019).

However, because of their incredible nutraceutical potential, they have recently started to gain popularity in urban areas as well.

Asia saw the greatest area reduction in millet cultivation among the continents (148 %), while Africa experienced the least. Lack of concerted crop development efforts, a shift to high value cash crops, a lack of government programmes and low farm profitability may be to blame for this drop. Millets now have the position of marginal or underused grains due to the ongoing fall in the global cultivated area under millets in recent decades (Obilana and Manyasa, 2002).

Millets are an abundant source of energy; their main nutrients include 60 - 70 per cent carbohydrates, 7 - 11 per cent proteins, 1.5 - 5 per cent fat and 2 - 7 per cent crude fibre, minerals and vitamins. Iron and phosphorus are abundant in millets. Millets stand out from other cereals due to their abundance of calcium, dietary fibre, polyphenols and protein (Devi *et al*., 2011).

Methionine and cysteine, two important amino acids that contain sulphur, are notably abundant in millets, which also have a greater fat content than maize, rice and sorghum (Obilana and Manyasa, 2002).

The phytic acid concentration of unmalted pearl millet grain was found to range from 2.91 per cent to 3.30 per cent (Badau *et al*., 2005). The total dietary fibre (22 %) of finger millet grain was observed to be substantially greater than that of several other cereal grains, such as wheat, rice, maize and sorghum, which had total dietary fibre contents of 12.6 per cent, 4.6 per cent, and 12.8 per cent, respectively (Shobana and Malleshi, 2007; Siwela *et al*., 2010).

The health benefits of nutrients such as vitamins, minerals, essential fatty acids, and fibre were once thought to be caused by these nutrients, but recent research suggests that some bioactive substances combined with nutrients, such as oligosaccharides, lipids, antioxidants (phenolic acids, avenanthramide, flavonoids), hormonally active substances (lignans, phytosterols) and anti-nutrients (such as phytic acid, tannins, *etc*.), could produce more beneficial health effects. Millet foods' phytates, polyphenols, and tannins can help with antioxidant activity, which is crucial for preventing metabolic illness, ageing, and other problems (Bravo, 1998). Globally, the number of cases of diabetes and obesity is rapidly rising. To fight the aforementioned health problems, foods strong in fibre and phytochemicals have become increasingly popular (Shobana *et al*., 2007). Because they are abundant sources of dietary fibre and phytochemicals that have good impacts on health, whole grain cereals are being included in more food formulations across the world (Jones and Engleson, 2010).

2.1. Finger millet

Finger millet (*Eleusine coracana*) is considered a minor cereal in the native of Ethiopia but is widely farmed across India and Africa. It is a staple meal that provides the greatest amount of calories and proteins to vast portions of the population in these nations, especially those from low income groups (Kennedy *et al*., 2006). After wheat, rice, maize, sorghum and bajra, finger millet is the sixth most important crop in India and Karnataka is the country's largest producer of this grain.

Finger millet is also said to be *ragi* and *mandua* in India, *kaddo* in Nepal, *fingerhirse* in Germany, *bulo* in Uganda, *kambale* in Zambia, *lupoko* in Zimbabwe, *mawele* in Ethiopia, *koracan* in England, *barankiya* in Ethiopia. In portions of eastern and Central Africa, as well as India, it is a significant staple food.

Finger millet has high source of calcium (344 mg/100 g), phosphorus (283 mg), iron (3.9 mg), vitamin B (1.71 mg), vitamin E (22 mg) and other minerals in addition to its proximity components (Rajasekaran *et al*., 2004). The high content of calcium (0.38 %), protein (6 - 13 %), dietary fibre (18 %), carbohydrates (65 - 75 %), minerals (2.5 - 3.5 %), phytates (0.48 %), tannins (0.61 %), phenolic compounds (0.3 - 3 %) and trypsin inhibitory factors, as well as its known anti-diabetic, anti-tumorogenic, anti-diarrhoeal antiulcer properties, make finger millet important nutritionally (Chethan and Malleshi, 2007). It has several therapeutic benefits because of its high dietary nutritional profile.

The significant levels of calcium and iron, protect the body against anaemic illnesses and build bones.

Additionally, finger millet helps manage several physiological conditions, including diabetes mellitus, hypertension, vascular fragility, hypercholesterolemia and the prevention of low density lipoprotein (LDL) oxidation. It also promotes digestive health (Scalbert *et al*., 2005).

The tryptophan present in finger millet can suppress hunger and maintains weight (Kakade and Hathan, 2015). The seed coat part can inhibits intestine pancreatic amylase and α-glucosidase and helps in the reduction of hyperglycemia. Therefore, by maintaining a healthy blood glucose level, frequent use of finger millet as a staple diet and whole meal based products would aid in treating bodily problems. Diabetes patients have reduced wound healing due to damage to nerve growth factors and finger millet extracts can improve this impairment by increasing the synthesis of nerve growth factors and antioxidant levels (Chandra *et al*., 2016).

Finger millet consumption has shown to increase the skin antioxidant status, nerve growth factor (NGF) production and wound healing parameters in early diabetic rats with impaired wound healing. In diabetic rats, delayed wound healing is caused by elevated levels of oxidative stress indicators and reduced antioxidant levels. However, feeding diabetic animals finger millet for four weeks reduced glucose levels and increased antioxidant status, which sped up the healing of cutaneous wounds (Rajasekaran *et al*., 2004).

In comparison to white rice and sorghum fed rats, finger millets and proso millets have also been demonstrated to dramatically reduce blood triglyceride concentrations. By lowering plasma triglycerides in hyperlipidemic rats, finger millet and proso millet may prevent cardiovascular diseases (Lee *et al*., 2010).

Because of their ability to chelate metals and inhibit enzymes, it was once thought that the polyphenols, phytates, tannins and dietary fibre found in finger millet acted as anti-nutrients (Thompson, 1993; Bravo, 1998). However, it has since been proven that these constituents can also contribute to antioxidant activity, which is a crucial component in preventing ageing and metabolic diseases.

In some regions of Karnataka, finger millet are added to papad at a rate of up to 60 per cent (Begum, 2007). Millet growing regions of South India, it has become customary to use finger millet as one of the fundamental components at a rate of 15 - 20 per cent (w / w), along with other necessary ingredients like rice and spices (Verma and Patel, 2013).

Vidyavati *et al*. (2004) produced millet based papad (rolled, round and thin sheets) by replacing half of the combination of black gram dhal flour and sago flour with finger millet flour and compared the results to black gram (Phaseolus mungo) dhal papad. In comparison to black gram dhal papad, the finger millet flour papad had a highersensory score of 4.7 on a five point hedonic scale and was richer in calcium (102 mg/100g in roasted and 109 mg/100 g in fried) (82 mg/100 g in roasted and 99.6 mg/100 g in fried). The number of nutrients decreased somewhat, but the quality of the protein increased as a result of the addition of millet and pulse proteins. After being stored for awhile, finger millet's popularity among consumers was quite high, indicating that it canbe an excellent food.

Naikare *et al*. (2003) made a comparable attempt to create papad using malted sorghum and finger millet flour as well as composite flours in various ratios of 80:20, 60:40 and 40:60. With a 4.6 out of 5 on the hedonic scale for acceptance, the crispest, appealing taste and excellent appearance, the finger millet papad received the top ranking.

The most popular fermented alcoholic beverage made from dried finger millet seeds is called "*kodo ko jaanr*" and is produced in the Eastern Himalayan areas of India's Darjeeling hills and Sikkim. Additionally, the Ladakh area of India is home to the fermented finger millet beverage chhang. Ethnic communities in Tamil Nadu consume koozh, another fermented beverage made with rice and pearl or finger millet flour (Ilango and Antony, 2014). Ambali is the name of the conventional, organically fermented finger millet product.

Zacharia (2020) developed nutriflakes with finger millet flour, tapioca flour and jackfruit seed flour. Among the different treatments, the best combinations were 60 per cent finger millet flour + 30 per cent tapioca flour + 10 per cent other ingredients and 60 per cent finger millet flour + 30 per cent jackfruit flour + 10 per cent other ingredients which had overall acceptability of 7.92 and 7.85, respectively.

2.2. Barnyard millet

In Asia, notably in India, China, Japan and Korea, barnyard millet (*Echinochloa* species) is a common millet crop that has been produced for centuries. It is the fourth most produced minor millet and provides many hungry people with food security all around the world.

Echinochloa esculenta (Japanese barnyard millet) and *Echinochloa frumentacea* (Indian Barnyard millet) commonly known as barnyard millet, is a crop grown for food and fodder. Japanese barnyard millet, *ooda*, *oodalu*, *sawan*, *sanwa* and *sanwank* are some of the other names for it. The family *Poaceae*, tribe *Paniceae* and subfamily *Panicoideae* all contain the genus *Echinochloa* (Clayton and Renvoize, 2006). One of the first domesticated millets in the semi-arid tropical regions of Asia and Africa is barnyard millet (*Echinochloa sp*.).

Major and minor millets are inferior to barnyard millet in terms of nutritional content. The grains of barnyard millet are an excellent source of nutritional fibre, iron, zinc, calcium, protein, magnesium, lipids, vitamins and several necessary amino acids (Singh *et al*., 2010; Saleh *et al*., 2013; Chandel *et al*., 2014). Compared to other major and minor millets, barnyard millet has a lower average carbohydrate content, ranging from 51.5 to 62.0 g/100 g (Saleh *et al*., 2013). According to Ugare *et al*. (2014) barnyard millet has the highest crude fibre content of any crop, ranging from 8.1 to 16.3 per cent.

The high carbohydrate to crude fibre ratio promotes a delayed release of glucose into the blood, which helps to keep blood sugar levels stable.

Evidence already in existence suggested that barnyard millet had a protein level (11.2 - 12.7 %) that was comparatively greater than that of other main cereals and millets. Iron level of barnyard millet was noticeably greater than that of other grains, even though its total mineral, ash, lipid and amino acid contents were equivalent to those of other cereals and millets. For instance, the iron concentration of barnyard millet grain is logically greater than that of main cereals and millets at 15.6–18.6 mg/100 g (Saleh *et al*., 2013; Renganathan *et al*., 2017; Vanniarajan *et al*., 2018).

Phytic acids are greatly reduced as a result of the dehulling process and a lower phytate content (3.30 - 3.70 mg/100 g) in grains (Panwar *et al*., 2016), which favours the bioavailability of minerals. Because of this, anaemic individuals, particularly women in impoverished nations and persons with lifestyle disorders can all benefit from eating barnyard millet.

The quantity of crude protein in barnyard millet was equivalent to foxtail millet, which had the highest level of all the millets examined. Millet oil are a useful source of naturally occurring oil that is high in tocopherols and linoleic acid (Liang *et al*., 2010). Magnesium and phosphorus are both abundant in millets. While phosphorus is a crucial part of adenosine triphosphate (ATP), the body's precursor to energy, magnesium has the power to lessen the impact of migraines and heart attacks (Devi *et al*., 2011).

When compared to rice and other minor millets, rats fed on a diet of native and processed starch from barnyard millet had the lowest levels of blood sugar, serum cholesterol and triglycerides (Kumari and Thayumanavan 1998).

The blood glucose, serum cholesterol and triglyceride levels are decreased due to the presence of resistant starch in barnyard millet (Kumari and Thayumanavan, 1998). Ugare *et al*. (2014) confirmed a lower glycemic index (GI) in type 2 diabetic groups during regular consumption of barnyard millet meal in a clinical study with human volunteers.

The alkaloids, steroids, carbohydrates, glycosides, tannins, phenols and flavonoids found in barnyard millet have a variety of ethnomedical qualities like being an antioxidant, anti-carcinogenic, anti-inflammatory, antimicrobial, having the ability to heal wounds, biliousness and alleviating diseases related to constipation (Kim *et al*., 2011; Ajaib *et al*., 2013; Moreno –Larrazabal *et al*., 2015; Borkar *et al*., 2016; Nguyen *et al*., 2016; Sharma *et al*., 2016; Sayani and Chatterjee, 2017).

In comparison to finger millet, barnyard millet contains two times more polyphenols and carotenoids, which are recognised to have various possible health advantages for people (Panwar *et al*., 2016). All of these qualities make barnyard millet a safe and ideal diet for modern customers in terms of their entire nutritional and physical wellbeing.

The finest ready to eat (RTE) food was created by Dhumal *et al*. (2014) using various combinations of potato and barnyard millet. The cold extrudate was the first treatment, followed by microwave puffing and oven toasting. The cold extrudates were made from potato mash and barnyard millet flour in a ratio of 55:45, with moisture contents of 0.6168 kg/kg dm. Then it was steamed in a kitchen pressure cooker for 15 minutes and after kneading for 10 to 15 minutes in a Dolly Mini P3 Pasta machine could be used for further processing. Convection heating at 22° C for 5 min followed by microwave heating with 80 per cent of total power 1350 W for 60 s might be used to perform the best microwave puffing of the steamed cold extrudate.

Chandraprabha (2017) standardized barnyard millet based vermicelli and uppuma with an overall acceptability of 7.75 and 7.73 respectively with 40 per cent barnyard millet flour, 58 per cent whole wheat flour and 2 per cent ekanayakam root bark powder. The physico chemical properties of the barnyard millet vermicelli incorporated with ekanayakam root bark were moisture (7.78 %), protein (8.09 g/100 g),fat (1.91 g/100 g), fibre (3.45 g/100 g), carbohydrate (50.47 g/100 g), energy (263.44

Kcal/100 g). The minerals which include calcium (67.90 mg/100 g), iron (13.99 mg/100 g), magnesium (101.72 mg/100 g) and potassium (228.76 mg/100 g).

Zacharia (2020) developed nutriflakes with barnyard millet flour, tapioca flour and jackfruit seed flour. Among the different treatments, the best combinations were 40 per cent barnyard millet flour + 50 per cent tapioca flour + 10 per cent other ingredients and 40 per cent barnyard millet flour + 50 per cent jackfruit flour + 10 per cent other ingredients which had an overall acceptability of 7.61 and 7.72 respectively.

2.1.3. Millet based yoghurts

India and other emerging nations rely heavily on agriculture. In a nation like India, pre-and post-processed foods are quite important. The major established industry includes dairy businesses. Yoghurt has always been a crucial component of Indian food. One of the first known crops utilised in the human diet is millet (*Panicum miliaceum*). Because millets are far richer in antioxidants than the other cereal crops, they are employed as nutraceuticals and provide a variety of health advantages. They are said to be helpful in treating heart attacks, migraines, blood pressure, diabetic heart disease and atherosclerosis. Compared to popular cereals like rice, the concentration of protein, fibre and minerals is significantly higher. Thus, adding millet to plain yoghurt enhances its nutritious content.

To improve the organoleptic and nutritional value of yoghurt, kodo millet milk was added to cow's milk. When compared to the 3:1 (3 parts (300 ml) of water and 1 part (100 ml) of kodo millet) variant, the 4 : 1 (4 parts (400 ml) of water and 1 part (100 ml) of kodo millet) type was well accepted. The concentration of probiotic bacteria in the 4 : 1 (61×10^8 cfu/ml) variation was also revealed by the microbiological study, making the yoghurt healthy and it maintained a good consistency (Kumari and Nazni, 2021).

Cow milk, buffalo milk, finger millet milk and foxtail millet milk were utilised in a study to make composite yoghurt powder which had 10.05 log cfu/ml of *L. brevis*. Energy (236 Kcal), total ash (2.0 %), pH (4.7), titrable acidity (0.63 %), protein content

(4.8 g), crude fibre (1.68 %) and carbohydrate (8.42 %) are the characteristics that were examined. The use of finger millet and foxtail millet milk in the preparation of yoghurt powder has been shown to be better in terms of nutrition and flavour than cow and buffalo milk in most qualitative parameters (Prabha *et al*., 2020).

The nutritional and energy value of the fermented millet based beverage was assessed in a millet based drinkable yoghurt developed (Ziarno *et al*., 2019). The millet based beverages had an energy content of 293 kJ/100 g. (67 kcal per 100 g). There were 1.1 gram of fat per 100 gram, of which 0.1 gram were saturated fat. 13.4 g of carbohydrates, including 7.0 g of sugars, were present per 100 g. 0.7 g of protein were present per 100g. 0.09 g of salt were estimated for every 100 gram.

Finger millet enriched probiotic fermented milk products were made using two types of finger millet flour: malted and un-malted. The probiotic bacteria *L. helveticus* MTCC 5463 and *S. thermophiles* MTCC 5460 were used with yoghurt culture for the fermentation of each treatment (10 per cent, 15 per cent and 20 per cent of finger millet flour (both malted and un-malted finger millet flour) in toned milk). From this 30 per cent of malted finger millet flour added yoghurt was found to be the best treatment with *L. helveticus* count of 10.97 log cfu/ml and the streptococcal count of 10.92 cfu/ml. The overall acceptability of the yoghurt was 7.58 (Shaikh *et al*., 2017).

Narayana and Kale (2019) prepared stirred yoghurts with malted finger millet flour (upto 4 %), after inoculating the mixture with 2 per cent (w / w) commercial yoghurt culture containing *S. thermophilus* and *L. delbruekii ssp. bulgaricus* (1 : 1), incubated at 42° C. The results revealed that when the concentration of malted finger millet flour increased, syneresis of the product increased from 17.1 to 28.5 per cent andthe water holding capacity (74.9 to 62.4 %) and viscosity (1.51 to 1.01) decreased. So the addition of more millet flour to yoghurt reduced its physical stability and consistency,which made it less appealing to customers.

Di-Stefano *et al*. (2017) studied whether millet may ferment when one gram of the Fiti sachet containing *L. rhamnosus* GR-1 and *S. thermophilus* C106 consortium was introduced. A formulation with 4 per cent millet (pearl millet) in milk, 60 minutes of millet pre-treatment and 5 per cent sugar addition and 12 hours of fermentation at 40° C was preferred in the sensory assessment. The growth of *L. rhamnosus* was 9.0 log cfu/ml and the growth of *S. thermophilus* was 1.67 log cfu/ml.

Sukarminah *et al*. (2019) studied the optimum sorghum flour content for making goat milk synbiotic yoghurt. The four treatments which they used were 2 per cent, 3 per cent, 4 per cent and 5 per cent (w/v) of sorghum flour. The best one selected in accordance with its microbial count and its physicochemical properties was 5 per cent. The total lactic acid bacteria (*L. acidophilus*) was found to be 11.41 log cfu/g.

Ramawickrama (2012) prepared yoghurt with rice flour and finger millet flour. A mixture of 60 per cent rice flour and 40 per cent finger millet flour contributed to a yoghurt with good sensory rating. The mean score of selected finger millet based drinkable yoghurt was 8.23 for appearance, 8.56 for colour, 8.36 for mouth feel, 8.64 for taste, 8.48 for texture and 8.57 for overall acceptability.

2.1 Definition and history of yoghurts

Yoghurt is derived from the Turkish word “Yogurmak” which means to coagulate or precipitate or curdle. Yoghurt is a fermented milk product processed by fermentation, which enhances nutrients like vitamins, proteins, essential amino acids and fatty acids and it also helps to decrease the toxicity of food. Due to these reasons, yoghurt has been in consumption in many countries since ancient times (Krista *et al*., 2015).

The milk from different species can make different types of yoghurt. The higher acceptability of yoghurt is mainly because of its sensory qualities (Saint-Eve *et al*., 2006). According to Tamime and Robinson (2007), yoghurt is defined as a dairy product that use microorganisms from the milk of cow, buffalo, goat, sheep or other mammals either by homogenisation or pasteurisation and then fermentation.

According to WHO (2010) yoghurt is defined as the product processed by the fermentation of milk by the action of microorganisms which reduces pH with or without coagulation and the condition is that the starter microorganism should be active.

Yoghurt is one of the tangled gel structures consisting of protein polysaccharides and lipids (Marshall, 1993). Yoghurt is the three dimensional casein network formed by the isoelectric precipitation by the action of lactic acid bacteria and the denaturation of proteins and fat globules (Ebdali *et al*., 2013).

Across the world, yoghurt is regarded to be a fermented milk product that contains digested lactose and particular, live bacterial strains, such as *S. thermophilus* and *L. bulgaricus*. Protein, calcium, potassium, phosphorus and vitamins B_2 and B_{12} are just a few of the necessary elements found in it and it also acts as a vehicle for fortification (Bodot *et al.,* 2013).

Milk products are thought to have entered the human diet about 10,000 – 5000 BC, when milk producing animals (cows, sheep and goats, as well as yaks, horses, buffalo and camels) were domesticated (Aznar *et al*., 2013). Milk, on the other hand, deteriorated quickly, making it impossible to use. Herdsmen in the Middle East carried milk in pouches made of the intestinal gut at the time. It was discovered that exposing milk to digestive secretions caused it to curdle and sour, preserving it and enabling the long term storage of dairy products.

Fermentation is the process of chemical breakdown of substances by microorganisms such as bacteria and yeast and is a technique used by people for the preservation of milk. There is a belief that fermented dairy products originated in the Middle East area even before the Phoenician era. The fermented milk products like *laban rayeb* and *laban khad* in Egypt were popular from 7000 BC (Mohran *et al*., 2019).

The health advantages of fermented milk products are mentioned in Indian Ayurvedic writings dating back to around 6000 BC (Brothwell and Brothwell, 1997). There are around 700 yoghurt and cheese products available in Indian cuisine nowadays. Other than drying milk, producing yoghurt was the only known safe way of storing milk for millennia.

Yoghurt was well known throughout the Greek and Roman empires and the Greeks were the first to record it in writing around 100 BC, noting that barbarian cultures consumed it. In the 11^{th} century, the Turks were the first to examine yoghurt's medical usage for several ailments and symptoms, including diarrhoea and cramps, as well as to relieve the agony of burnt skin (Kashgari *et al*., 1984).

Genghis Khan, the Mongol Empire's founder, is said to have fed his troops yoghurt, a staple of the Mongolian cuisine, with the idea that it created bravery in them. After being supplied yoghurt as a remedy by the country's Turkish allies for spells of acute diarrhoea, King Francoise I of France brought it to Western Europe in 1542. Later, it was blended with a variety of ingredients, including cinnamon, honey, fruits and sweets and served as a dessert (McGee *et al*., 2004).

The word yoghurt was first used by Turkey in the 8^{th} century. Another belief is that it was first prepared by the Balkan people including Greeks, Albanians, Macedonians, Bulgarians, Romanians, Serbs, Montenegrins and Bosnian Muslims. The largest producers and consumers of fermented dairy products are South Asian regions for example India, Pakistan, Nepal and Bangladesh, as well as South West Asia regions such as Iran, Iraq, Turkey and Syria. The information about yoghurt production spread by the invasion of Mongols, Tartars and other Asian rulers to Russia and Europe.

Yoghurt is an ancient food item known by different names in different countries for example *katyk* (Armenia), *dahi* (India), *zabadi* (Egypt), *mast* (Iran), *leben raib* (Saudi Arabia), *laban* (Iraq and Lebanon), *roba* (Sudan), *iogurte* (Brazil), *cuajada* (Spain), *coalhada* (Portugal), *dovga* (Azerbaijan) and *matsoni* (Georgia, Russia and Japan) (Moreno-Larrazabal *et al*., 2015; Aznar *et al*., 2013). Now yoghurt is an important part of the diet in almost all parts of the world. In many regions, traditional ways of yoghurt production are in vogue.

Researchers did not propose an explanation for the health benefits connected with yoghurt eating until the twentieth century. Stamen Grigorov, a Bulgarian medical student, discovered *Bacillus bulgaricus* (now *L. bulgaricus*), a lactic acid bacteria that is being used in yoghurt cultures today, in 1905. Based on Grigorov's results, Yllia M*etc*hnikoff of the Pasteur Institute in Paris, a Russian Nobel winner, proposed in 1909 that lactobacilli in yoghurt were linked to lifespan in the Bulgarian peasant population.

Yoghurt became well known for its therapeutic advantages in the early twentieth century and it was offered as a medication in pharmacies. When Isaac Carasso of Barcelona started making yoghurt with jams, it became a commercial hit. The first yoghurt laboratory and plant debuted in France in 1932, while the first laboratory and factory opened in the United States in 1941 (Brothwell and Brothwell, 1997). Plain yoghurt proved too sour for the American palate and in 1966 sweetened yoghurt with added fruit preserves, creating a "fruit on the bottom" style of yoghurt was developed. This was successful and company sales soon exceeded (Denker, 2003). Yoghurt's popularity in the United States was enhanced in the 1950s and 1960s (Smith, 2013). By the late 20^{th} century, yoghurt became a common American food item. Because of its high nutritive and therapeutic effect, the popularity of yoghurt increased drastically everywhere.

Yoghurt, known as Dahi in India, has been a part of the human diet for several millennia. In the Indian subcontinent, yoghurt or fermented milk, is the product often made from cows, buffalo or goat's milk. Yoghurt is a significant dairy food that is often regarded as being connected with a healthy diet and having a high nutritional profile as well as therapeutic properties. Greek yoghurt was originally introduced in India by Drum Food International, under the name of Epigamia. The first yoghurt based delivery chain in India was Cocoberry which established in 2009. Then after, Nestle and Danon came in 2016 and 2017, respectively. GCMMF, Mother Dairy, Nestle India and Parang milk foods account for 50 per cent of the market in India for commercially accessible yoghurts. The Yoghurt service chain market, Flavours 24, Cocoberry and Red mango contributed 30 per cent of the commercially accessible yoghurts (Dublin, 2021). Flavoured and frozen yoghurt sales increased by 30 per cent between 2014 and 2019 and the average per capita consumption was 8.3 kg in 2021 in India. Globally, spoonful yogurt is projected to grow around 20 per cent from 2017-18 to 2022 - 23 (IMARC, 2022).

2.2. Types of yoghurts

Yoghurt is divided into two types: (i) Standard culture yoghurt and (ii) Bio or probiotic yoghurt. Standard culture yoghurt refers to normal yoghurt including *L. bulgaricus* and *S. thermophilus*. Bio yoghurt, also known as probiotic yoghurt, is made when microorganisms are added to encourage the bacteria found in regular yoghurt and promote gastrointestinal health.

Mckinley (2005) classified yoghurt based on

- **a)** Chemical composition
- **b)** Physical nature
- **c)** Flavour of the product
- **d)** Market availability of yoghurt
- **e)** Others.

a) Based on the chemical composition

Yoghurt can be classified according to its fat content. The three varieties are regular, low fat and non-fat yoghurt. High fat yoghurt is regular yoghurt. Low fat yoghurt is made from half skimmed milk and non-fat yoghurt from skimmed milk (Weerathilake *et al*., 2014).

b) Based on the physical nature

Based on its physical features, yoghurt can be classed as solid yoghurt, semi fluid yoghurt and fluid.

1. Solid yoghurt : Set yoghurt is an example of solid yoghurt, which is solid or jelly. It is prepared by incubation and then is stored in the refrigerator only after packaging (Dairy Consultant, 2013).
2. Semifluid yoghurt : When compared to set yoghurt, stirred yoghurt is less firm, with a texture like a thick cream and has a little reformation after packaging

(Aswal *et al*., 2012). Stirred yoghurt is an example of semi fluid yoghurt. Before cooling and packaging the yoghurt mixture is stirred (Dairy Consultant, 2013).

3. Fluid yoghurt : If the yoghurt is in the form of a fluid it is drinking yoghurt. It undergoes homogenisation for the reduction of particle size for the distribution of hydrocolloids and stabilisation of protein suspension (Weerathilake *et al*., 2014).

c) Based on flavour of the product

This categorization is based on the addition of flavour to the yoghurt, which boosts the consumer accessibility of the yoghurt. Yoghurts are classed as plain and fruit or flavoured yoghurts depending on the flavour added to them.

1. Plain yoghurt : The yoghurt prepared by the fermentation of lactic acid bacteria without any adulteration is said to be plain yoghurt. So that it helps to improve its texture and flavour. Here there is no added colour and additives. According to Dowden (2013) plain yoghurt has a normal taste.
2. Flavoured yoghurt : The yoghurt is prepared by the addition of flavouring agents like fruits (apple, blueberry, apricot, lemon, black cherry, black currant, peach, strawberry), vegetables, cereals, chocolate, caramel, vanilla, *etc*. This can be added either before incubation or before packaging (Aswal *et al*., 2012).

d) Based on market availability of yoghurts

The major varieties of yoghurt available in the market are discussed below.

1. Balkan style yoghurt : It is also known as set style yoghurt, is a thick textured yoghurt prepared in small, individual batches after being poured in the warm cultured mix into a container and incubated for 12 hours or more without stirring until the appropriate creaminess and thicknessare obtained. This is usually used as a salad dressing or topping for Mediterranean foods such as *moussaka*, *spanakopita* and *pita sandwiches* with meat or chicken slices in Balkan meat based recipes. It may also be served as regular yoghurt with granola for breakfast,

sweetened with chopped fruits, sugar or honey (Aswal *et al*., 2012).

2. Greek style yoghurt : It is also known as Mediterranean yoghurt, is thicker and creamier than regular yoghurt and is created with partly condensed milk or strained whey from plain yoghurt. This type of yoghurt has a high saturated fat content (Aswal *et al*., 2012).
3. Stirred curd yoghurt : It is also known as European style yoghurt and is distinguished by its smooth, creamy texture. This yoghurt is made by incubating the yoghurt mixture in a large vessel rather than individual cups, then cooling and stirring in fruits to make a flavoured and creamy yoghurt. Because of its thin texture, it may be used in cold beverages and desserts (Aswal *et al*., 2012).
4. French style yoghurt : It is also known as custard type yoghurt. Here, the yoghurt culture is immediately put into the pot. The texture is similar to that of pudding. Fruits (strawberries and blueberries) are sometimes added as flavoured yoghurt and it is an excellent source of vitamin A, iron and protein (Aswal *et al*., 2012).
5. Non-dairy yoghurt : These yoghurts are mostly consumed by those with milk allergies, gastrointestinal issues or who refuse to consume dairy products due to religious or personal views. Yoghurts made with soy milk are already on the market. Because the nutrients are fortified before preparation, the nutritional profile of the non-dairy is the same as normal yoghurt (calcium and vitamin D) (Aswal *et al*., 2012).

e) Others

1. Frozen yoghurt : Frozen yoghurt is similar to stirred yoghurt. Here the pasteurised milk is frozen. The remaining procedure is the same as for the production of stirred Yoghurt (Aswal *et al*., 2012).
2. Concentrated yoghurt : Concentrated yoghurt is also similar to stirred yoghurt. The difference is that there is a breakdown of coagulum and the concentration is increased by the removal of water under vacuum conditions. Low pH formed by heating protein for denaturation produces a rough and gritty texture (Aswal *et al*.,

2012).

3. Pasteurised yoghurt : This is mainly done by increasing the shelf life of the yoghurt and it also decreases the natural tartness of the yoghurt. But the disadvantage is that there will be the elimination of microbes that include live and active culture (Weerathilake *et al*., 2014).

2.3. Probiotic yoghurts

The term“probiotika” was proposed by Kollath (1953) which means the substance is active and necessary for life. Lilly and Stillwell (1965), reported that the probiotic was a substance secreted by microorganisms and it also helps to encourage the growth of other microorganisms. Sperti (1971) and Nutini *et al.* (1982) said that probiotics were a factor that helps to stimulate health. According to Parker (1974) substances and microorganisms that help to balance intestinal microbes are said to be probiotic. Then ‘substance’ was removed from this definition. So probiotics were said to be a supplement to live microbial feed which is beneficial for the host animals since they improve their intestinal microbial balance (Fuller., 1989). After that, this definition interchanged into the micro flora of other habitats like the upper respiratory tract or the urogenital tract (Havenaar *et al.*, 1992). Orally given probiotics are defined as the living microorganisms that provide health benefits by the addition of these organisms in certain amounts (Guarner and Schaafsma, 1998).

According to Rad *et al.* (2012) the following standards must be met for a microbe to be probiotic.

(1) The cultures are often factory made and associated with the nursing industrial scale.
(2) The culture will live throughout production and storage.
(3) The culture will tolerate the gut condition of the host.
(4) The culture will exert healthy effects once consumed.

The normal probiotic organism can resist hydrochloric acid and pancreatic juice. So this can be tolerated in the stomach and duodenum conditions and gastric transport. It also produces anticarcinogenic and antipathogenic activity by the action of probiotics with pathogens by producing lactic acid. The strains can also have the capacity to live during the period of processing and storage (Lin *et al.*, 2006).

The addition of probiotics in the yoghurt in a certain amount can improve health benefits in hosts such as improvement in lactose tolerance, immunity, metabolic disorder and prevention of gastrointestinal disorders. Due to these health benefits, probiotic yoghurt is considered the fastest growing dairy product in the global market and a lot of variations in the production of yoghurt can be seen.

It also prevents lactose intolerance diseases by improving lactose digestion. There are so many studies related to the viability and metabolic activity of yoghurt bacteria in the human intestine (Martini *et al*., 1987; Pochart *et al*., 1989; Marteau *et al*., 1990). So it is administered for the management of acute diarrhoeal disorders (WHO, 1995). *S. thermophilus* and most *L. bulgaricus* have the capacity for lactase activity (Sanders *et al*., 1996). The improvement of lactose digestion was proved in the case of *in vivo* animal models also (Lick *et al*., 2001; Drouault *et al*., 2002). The researchers detected yoghurt bacteria in human faeces after consumption of yoghurt (Brigidi *et al*., 2003; Callegari *et al*., 2004).

A jackfruit incorporated probiotic yoghurts were standardised by Remya (2020) and the yoghurt with 30 per cent jackfruit pulp was found to be the most acceptable. The maximum total viable count of *L. acidophilus* ranged from 10.84 to 10.92 log cfu/ml when 25 gram of the yoghurt were fermented with 100 µl of inoculum at 38º C.

Rice based yoghurt was produced using various combinations of rice slurry and its microbiological count was assessed. The count of both *S. salivarius ssp. thermophilus* (8.06 log cfu/ml) and *L. delbrueckii ssp. bulgaricus* (8.35 log cfu/ml) bacteria was found to be greater in the combination with less milk (i.e. 25 per cent milkand 75 per cent rice slurry). On the second day of the study, both bacteria exhibited the largest concentration and as the storage time went on, the count decreased. Nandakumar*et al*. (2022) selected rice based yoghurt supplemented with 20 per cent annona fruit pulp and 5 per cent papaya fruit pulp and was extremely good, according to the judges. Additionally, with an overall acceptability score of 9.33 for 20 per cent, annonaenhanced yoghurt and 4.8 for 5 per cent papaya enriched yoghurt.

This backs up Tarakci (2010) finding that yoghurts with kiwi marmalade fruit were determined to be satisfactory in terms of overall acceptability. Probiotic yoghurt products including spices offer good sensory attributes, according to Illupapalayam *et al.* (2014). Senadeera *et al*. (2018) found that soursop enriched yoghurt had higher sensory scores treatments and Othman *et al.* (2019) yoghurt containing papaya puree received higher ratings than plain yoghurt.

If the yoghurt is produced with a probiotic organism the nutrients will be enhanced to get health benefits to the host (Ranadheera *et al*., 2012 and Sloan, 2014). When compared with traditional yoghurt, the yoghurt with Bifidobacteriae has more desired qualities.

The normal bacteria in yoghurt can also protect the intestine from pathogenic microorganisms (Metchnikoff, 1908). The probiotic organisms include *Lactobacillus*, *Bifidobacterium*, *Escherichia*, *Enterococcus*, *Bacillus*, *Streptococcus* and some fungal *Saccharomyces* strains (Parvez *et al*., 2006; Gupta and Garg, 2009). For people who have lactose intolerance, the intake of probiotics will increase the absorption and digestion of lactose (Parvez *et al*., 2006). Akin *et al.* (2007) recommended that the daily intake of probiotic count should be > 10^6 cfu/ml. The daily intake of probiotic yoghurt helps to strengthen the gastrointestinal tract and the functioning of the immune system.

Women who consumed yoghurt treated with *B. lactis* Bb12 produced more secretory IgA in their faeces, indicating that probiotics can help to prevent gastrointestinal and lower respiratory tract infections (Kabeerdoss *et al*., 2011). Salarkia *et al.* (2013) found that probiotic yoghurt containing *L. acidophilus* SPP and *B. bifidum* reduced the number of episodes of respiratory infections and the duration of various symptoms such as dyspnea and ear discomfort in young adult female endurance swimmers. In a 12 week study, Pu *et al.* (2017) found that oral administration of *L. paracasei* N1115 (3.6×10^7 cfu/ml) yoghurt supplemented with *L. paracasei* N1115 (3.6×10^7 cfu/ml) decreased the incidence of acute upper tract infections in older persons.

Vijayalakshmi (2005) found that replacing cereal for skimmed milk powder (rice, wheat, corn and oat (25, 50, 75 and 100 %)) with probiotic culture (1.0, 1.5 and 2.0 %) and fruit pulp (mango, apple, banana and sapota (10, 15 and 20 %) when making yoghurt improved the quality of the yoghurt. The finest yoghurt was produced with 75 per cent cornflour, 10 per cent mango pulp and 1.0 per cent *L. acidophilus*. The sensory, chemical, microbiological, rheological and microstructural aspects of this product were studied.

Microencapsulation of four different probiotic cultures (*L. acidophilus, L. helveticus*, *B. longum* and *B lactis*) was done using two different wall materials (alginate + starch and alginate + starch + gelatin) in two different ways (extrusion and emulsion). When compared to the control, the probiotic count was found to be greater in the yoghurt with extrusion containing alginate (2.0 per cent w / v) + gelatin (2.0 per cent w / v) + starch (0.5 per cent w / v) as wall material having highest viability (9 log units) after 21 days of storage (Jayalalitha *et al*., 2011).

Yoghurts containing glucose oxidase are beneficial in controlling oxidative stress and maintaining optimal probiotic bacterial counts. The microbial count was high *(S. thermophilus* having values above 10^9 cfu/mL and *L. bulgaricus*, *L. acidophilus* and *Bifidobacterium* having values above 10^8 cfu/mL) with the addition of glucose oxidase in commercial yoghurts after 30 days of refrigerated storage (Batista *et al*., 2015).

In NAFLD patients, consumption of *L. acidophilus* La5 and *Bifidobacterium lactis* Bb12 incorporated yoghurt reduced serum levels of alanine aminotransferase, aspartate aminotransferase, total cholesterol and low-density lipoprotein cholesterol by 4.67, 5.42, 4.10 and 6.92 per cent, respectively, compared to the control group (Nabavi *et al*., 2014). Non-alcoholic fatty liver disease (NAFLD), which comprises simple steatosis, non- alcoholic steatohepatitis and fibrosis, is the most prevalent kind of liver disease. Cirrhosis and ultimately hepatocellular carcinoma can develop from this (Lomonaco *et al*., 2015).

Infections of the gastrointestinal tract and the loss of microbial products from the gut have a significant impact on the immune system's deterioration in people living with the human immunodeficiency virus (HIV). Consumption of probiotic yoghurt supplemented with *L. rhamnosus* GR-1 has been shown to improve productivity, nutritional intake, antiretroviral treatment tolerance and immune function (CD4 count) in HIV-infected people (an additional increase of 0.28 cells / mL / day versus 0.13 cells / mL / day) (Irvine *et al*., 2010).

Materials and Methods

3. MATERIALS AND METHODS

The methods which were followed and the materials used for the thesis entitled 'Standardisation and quality evaluation of millet used probiotic yoghurts' are discussed in the following headings.

3.1. Collection of raw materials

3.2. Standardisation of the proportion of ingredients in yoghurt

3.2.1. Pretreatment

3.2.2. Standardisation of yoghurt using millets

3.2.3. Acceptability of the prepared millet based yoghurts

3.2.3.1. Selection of panel members for organoleptic evaluation

3.2.3.2. Preparation of score cards for organoleptic evaluation

3.2.3.3. Organoleptic evaluation of prepared millet based yoghurt

3.2.3.4. Selection of the most acceptable millet based yoghurt

3.3. Optimisation of conditions for the growth of *Lactobacillus acidophilus* in yoghurt

3.3.1. Optimisation of substrate concentration

3.3.2. Optimisation of time of incubation

3.3.3. Optimisation of temperature

3.3.4. Optimisation of population of *L. acidophilus* for incubation

3.4. Development of millet based probiotic yoghurt

3.4.1. Incorporation of culture to the selected yoghurt

3.5. Storage studies of the developed millet based probiotic yoghurt

3.5.1. Physico-chemical composition of the selected probiotic yoghurt

3.5.2. Health studies of the selected yoghurt

3.5.3. Organoleptic evaluation of the probiotic yoghurt

3.5.4. Population of *L. acidophilus* in millet based probiotic yoghurt

3.5.5. Enumeration of total micro flora

3.6. Preparation of synbiotic yoghurt

3.6.1. Standardising the proportion of prebiotic in the selected yoghurt

3.6.2. Acceptability of the prepared synbiotic yoghurt

3.6.2.1. Selection of panel members for organoleptic evaluation

3.6.2.2. Preparation of score cards for organoleptic evaluation

3.6.2.3. Organoleptic evaluation of prepared synbiotic yoghurt

3.6.2.4. Selection of the most acceptable synbiotic yoghurt

3.7. Quality evaluation of the developed millet based synbiotic yoghurt

3.7.1. Physico-chemical composition of the selected synbiotic yoghurt

3.7.2. Health studies of the selected yoghurt

3.7.3. Organoleptic evaluation of the synbiotic yoghurt

3.7.4. Population of *L. acidophilus* in millet based synbiotic yoghurt

3.7.5. Enumeration of total micro flora

3.8. Cost of production of the developed millet based probiotic and synbiotic yoghurts

3.8. Statistical analysis

3.1. Collection of raw materials

The cow's milk required for the preparation of yoghurt was procured from the dairy plant of Kerala Veterinary and Animal Science University, Mannuthy, Thrissur. Barnyard millet, finger millet and all other ingredients were purchased from the local market. The yoghurt culture was purchased from the Department of Dairy Microbiology, College of Dairy Science and Technology, Kerala Veterinary and Animal Science University, Mannuthy and the probiotic culture *L. acidophilus* were procured from IMTECH, Chandigarh.

3.2. Standardisation of the proportion of ingredients in yoghurt

3.2.1. Pretreatment

The millets purchased from the local market were washed, cleaned and oven dried (65 - 75º C) for 4 - 5 hours. It was then powdered in a local mill and sieved in a fine mesh sieve with mesh size of 0.5 mm. The slurry was prepared by adding 7 - 8 gram of millet flour (barnyard or finger millet) to 100 ml of distilled water.

3.2.2 Standardisation of yoghurt using millet

Millet based yoghurts were prepared by the modified standard procedure suggested by Sarabhai (2012) (Fig. 1) Plain yoghurt was served as control. The different proportions of ingredients are shown in Table 1. There were two sets of yoghurt, set I barnyard millet based yoghurt (T_1 - T_5) and set II finger millet based yoghurt (T_6 - T_{10}). From each set, the best yoghurt was selected for further studies.

3.2.3. Acceptability of the prepared millet based yoghurt

3.2.3.1. Selection of panel members for the organoleptic evaluation

A panel of fifteen judges (between 18 - 35 years) was selected by using a triangle test suggested by Jellinek (1985) carried out in the laboratory. The acceptability trials of the yoghurt were done by this panel.

3.2.3.2. Preparation of score cards for the organoleptic evaluation

According to Jones *et al*. (1955) the nine-point hedonic scale, originally

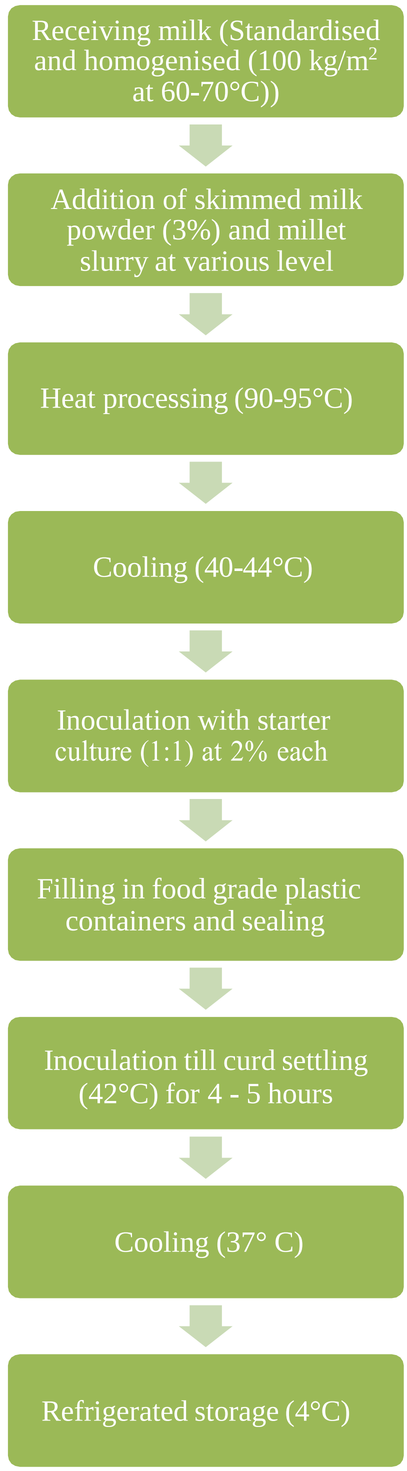


Fig 1. Flow chart for the preparation of millet based yoghurt

Table 1. Proportion of ingredients in millet based yoghurts

Treatments	Quantity	
	Milk (ml)	Millet slurry (ml)
T_0 (Control)	100	-
Set I (Barnyard millet flour)		
T_1	80	20
T_2	70	30
T_3	60	40
T_4	50	50
T_5	40	60
Set II (Finger millet flour)		
T_6	80	20
T_7	70	30
T_8	60	40
T_9	50	50
T_{10}	40	60

Plate 1. Preparation of millet based yoghurts

developed by the US Army was used for the organoleptic evaluation of the food mixtures by the panel members. The score card is given in Appendix I.

3.2.3.1. Organoleptic evaluation of prepared millet based yoghurts

The prepared yoghurts underwent a series of sensory evaluation by a panel of 15 selected judges using the nine-point hedonic scale. The sensory evaluation was carried out and quality attributes like appearance, colour, flavour, texture, taste and overall acceptability was evaluated.

3.2.3.2. Selection of the most acceptable millet based yoghurts

On the basis of organoleptic scores using nine-point hedonic scale, the yoghurts with maximum quality attributes were selected for further studies.

3.3. Optimisation of conditions for the growth of *L. acidophilus* in yoghurt

3.3.1. Optimisation of substrate concentration

From the chosen millet yoghurt combination (best combination from both barnyard millet flour and finger millet flour) 25 g, 50 g and 75 g were weighed and inoculated with 100 µl of probiotic culture and 200 µl of yoghurt culture. The mixture was then incubated for 4 hours at 38° C. The inoculum should be standardised to have 10^9 cells/ml.

MRS medium was used to test the viability of probiotic species in the yoghurt. One gram of the sample was weighed and placed in a test tube with 9 ml sterile distilled water (10^{-1} dilution).The sample was then serially diluted up to a dilution of 10^{-9}. The results of the microbial enumeration were expressed as 10^9 cfu/g and were obtained using the pour plate method with MRS agar.

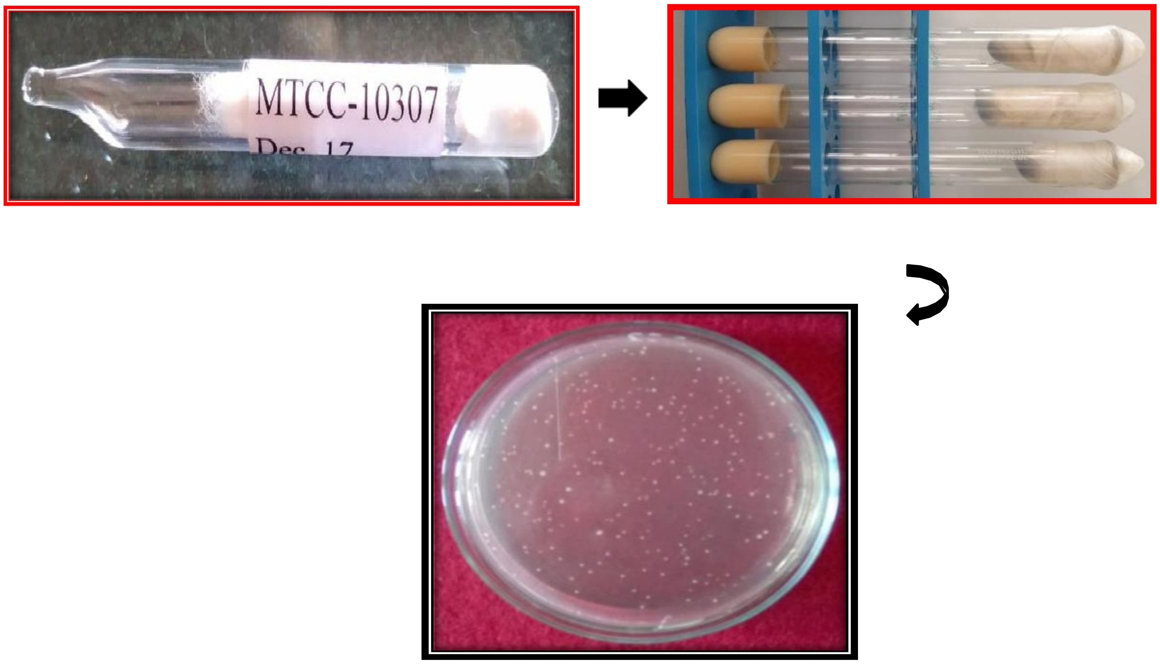


Plate 2. Sub culturing of probiotic strain

3.3.2. Optimisation of time of incubation

The maximum viable substrate concentration was chosen and inoculated with 100 µl of probiotic culture and 200 µl of yoghurt culture. After that, the mixture was incubated at 38º C for 4, 5 and 6 hours. The viability of probiotic organisms was then determined.

3.3.3. Optimisation of temperature

The optimal substrate concentration was used, and probiotic and yoghurt strains were mixed and incubated at 38º C, 40º C and 42º C for the optimal fermentation time. After incubation the samples were analysed for *L. acidophilus* viability.

3.3.4. Optimisation of population of ***L. acidophilus for incubation***

Each yoghurt combination was taken and mixed with 100 µl, 200 µl and 300 µl probiotic culture and yoghurt culture 200 µl. This mixture was then incubated at the optimum temperature for the optimum fermentation. The prepared yoghurts were then enumerated for the total number of viable cells of *L. acidophilus.*

3.4. Development of millet based probiotic yoghurts

3.4.1. Incorporation of culture to the selected yoghurt

The chosen treatments, T_4 (50 % milk and 50 % barnyard millet slurry) from the first set and T_9 (50 % milk and 50 % finger millet slurry) from the second set, were inoculated with 100 µl of *L. acidophilus* and 200 µl of yoghurt culture for the preparation of probiotic yoghurt. It was then incubated at 38˚ C for 6 hours. Once the yoghurt was set, it was kept in the refrigerator.

3.5. Storage studies of the developed millet used probiotic yoghurt

The millet based yoghurts were packaged in food grade plastic containers and kept refrigerated for 15 days. Throughout the storage period, quality elements of the yoghurts were investigated. The physico - chemical composition, health studies, organoleptic evaluation and population of *L. acidophilus* and enumeration of total micro flora were studied at the interval of 5 days. The procedures for each parameter were discussed below.

3.5.1. Physico-chemical composition of the selected probiotic yoghurts

Analysis of each parameter was carried out in three replications and the methods used are discussed below.

3.5.1.1. Moisture

The method suggested by AOAC (1994) was followed to assess the moisture content of the developed millet based yoghurt.

Five gram of the test sample was placed in a petri dish and dried in a hot air oven at 60- 70° C, cooled in a desiccator and weighed to determine the moisture content. The drying and cooling processes were repeated until the weight remained unchanged. The weight lost during thedrying process was used to determine the sample's moisture content.

$$\textbf{Moisture \%} = \frac{\textbf{I} - \textbf{F}}{\textbf{I}} \times \textbf{100}$$

I- Initial weight of the sample

F- Final weight of the sample

3.5.1.2. Acidity

The approach proposed by Ranganna (1986) was used to calculate the acidity of the yoghurt. The titratable acidity of the food sample extract was determined by titrating it against 0.1N sodium hydroxide (NaOH) using 1% phenolphthalein solution as an indicator. A measured amount of the yoghurt was boiled in distilled water to make the extract. When the solution turns pink, the titre value was recorded. The formula was used to calculate titratable acidity as per cent citric acid equivalent.

$$\textbf{\% Titratable acidity} = \frac{\textbf{Titre value} \times \textbf{Normality of NaOH} \times \textbf{Volume made up} \times \textbf{Equivalent weight of acid}}{\textbf{Volume of sample taken for estimation} \times \textbf{Weight of sample taken} \times \textbf{1000}} \times \textbf{100}$$

3.5.1.3. pH

Five gram of yoghurt were homogenised in 100ml of hot distilled water for 30 seconds before being vacuum filtered through Whatman filter paper. The pH of the products were calculated using a pH metre after a 25 ml aliquot was pipetted into a beaker.

3.5.1.4. Water holding capacity

Guzman-Gonzalez *et al*. (1999) recommended procedures for determining the water holding capacity. At 4° C, a weighted amount of sample 20 g (Y) was centrifuged for 10 minutes at 1250 rpm. The whey expelled (W) was removed and the weight was recalculated. The water holding capacity (g/kg) was computed using the following formula :

$$\textbf{WHC} = \frac{(Y - W) \times 100}{Y}$$

3.5.1.5. Syneresis

The procedure suggested by Gaston *et al.* (2007) was used to assess the syneresis of preparedyoghurts. Yoghurt samples (35 g) were centrifuged at 1100 rpm for 10 min at 5 ± 2° C. The clear supernatant was poured off and weighed. This was recorded as syneresis (%).

3.5.1.6. Viscosity

The viscosity of yoghurt was measured using a Brookfield viscometer model BM type. The observed value was based on a three reading average. The measurements were taken at 10º C (the temperature at which the yoghurt is consumed). The spindle speed was modified basedon the sample's firmness. In this case, the specification combination was speed 12 (revolutions per second) and spindle number 4. A factor of 400 was used to multiply the obtained figure to get the final viscosity in centipoises.

3.5.1.7. Texture analysis

A texture profile analyser (TPA) with a load cell of five kg and a cylindrical probe (25 mm in diameter) was used to determine the texture analysis of yoghurt samples. The samples were kept at 25° C for TPA analysis. TPA was carried out by compressing the probe twice to make a 10 mm penetration at a speed of five mm/s. TPA was tested for hardness, springiness, adhesiveness, cohesiveness, chewiness, gumminess and resilience applying software. For each sample, all parameters were measured in triplicate.

3.3.1.1. Carbohydrate

The carbohydrate content was determined by colourimetrically using an anthrone reagent (Sadasivam and Manickam, 1992). The residue was neutralised with solid sodium carbonate after 0.1 ml of yoghurt was hydrolysed with five ml of 2.5 N HCl and cooled. Centrifuged the contents of a 100 ml standard flask. 1 ml distilled water and four ml anthrone reagent were pipetted into 0.1 ml of supernatant. The intensity of colour from green to dark green was measured at 630 nm after thecontents were heated for eight minutes and then cooled. The total carbohydrate content of the sample was calculated using the standard graph and expressed in gram.

3.3.1.2. Protein

The AOAC (1994) recommended approach was used to ascertain the protein content of thesamples. A digestion flask was used to hold the 0.5 g sample. This was mixed with five gram of Kjeldahl reagent (9 parts K_2SO_4 and 1 part $CuSO_4$) and 200 milliliters of concentrated K_2SO_4. After digestion, it was diluted with distilled water and pumped with 25 ml of 40 % NaOH. In a receiver with two percent, the distillate was collected. The distillate was extracted in a receiver containing 2 % boric acid, mixed with indicators, and then titrated against 40 % NaOH with standard acid (0.2 N HCl).

$$\textbf{Protein (\%)} = \frac{\textbf{(A-B)} \times \textbf{N} \times \textbf{1.4007}}{\textbf{W}} \times \textbf{6.25}$$

Where

A = Volume (ml) of 0.2 N HCl used in the sample titration

B = Volume (ml) of 0.2 N HCl used in the blank titration

N = Normality of HCl

W = Weight (g) of the sample

1.4007 = Atomic weight of nitrogen

6.25 = Protein-nitrogen conversion factor

3.3.1.1. Fat

In a small beaker, ten gram of the sample was weighed. To this, 10 ml of concentrated hydrochloric acid was added and heated on a Bunsen burner. A glass rod was used to stir the sample constantly until the contents turned dark brown. After that, the contents were able to come up to room temperature.

The contents were then transferred to a Mojonnier fat extraction flask. Ethyl alcohol (10 ml) was added to the beaker and then to the Mojonnier fat extraction flask. Mixedwell. Similarly, 25 ml of ethyl ether was added to the Mojonnier flask, which was then corked andvigorously shaken for one minute. Shaking was repeated for one minute after adding 25 ml of petroleum ether. For 3 minutes, the Mojonnier flask was centrifuged at 600 rpm**.**

The extraction'stip and the extraction's stopper flask were cleaned with an equal parts mixture of the two solvents (ethyl alcohol and ethyl ether) and the washings were added to the weighing flask. The extractionof the remaining liquid in the flask was repeated several times with 15 ml of each solvent. The solvent was entirely evaporated on a water bath after extraction (at a temperature that does not cause sputtering or bumping).

Fat was dried to a constant weight in an oven at 102 ± 2° C. Weighingthe cooled flask. The container was weighed again after the fat was fully removed from the container with warm petroleum ether (Sadasivam and Manickam., 1992).

$$\textbf{Fat \% (w/w)} = \frac{\textbf{100 (W1-W2)}}{\textbf{W3}}$$

Where,

W_1 = Weight in g of contents in the flask before removal of fat

W_2 = Weight in g of contents in the flask after removal of fat

W_3 = Weight in g of material taken for the test

3.3.1.2. TSS

Total soluble solids (TSS) of the yoghurt was determined using a hand refractometer. The readings were taken at room temperature and expressed as degree brix (Ranganna, 1986).

3.3.1.3. Reducing sugar

A conical flask was filled with 25 gram of yoghurt and 100 milliliters of distilled water. In the presence of phenolphthalein, it was then neutralised with a 0.1 N sodium hydroxide solution. The neutralised mixture was clarified with the addition of two ml of lead acetate. By adding two ml potassium oxalate to the excess lead acetate, the excess was eliminated. It was then set aside for 10 minutes to allow the precipitate to settle. Whatman's No. 1 filter paper was used to filter the solution. After that, it was made up to 250 ml. Using methylene blue as an indication, an aliquot of the solution was titrated against a boiling mixture of Fehling’s solution A and B. The reaction comes to a halt when a brick red colour appears (Ranganna, 1986). The following formula was used to calculate the amount of reducing sugars in the food mixtures.

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

3.3.1.3. Total sugar

Ranganna (1986) procedure was used to compute the total sugar. 50 ml of the clarified solution used for lowering sugar estimation was taken. After adding citric acid and water, the solution was lightly boiled. After neutralising the solution with sodium hydroxide, the volume wasincreased to 250 ml. Fehling's solution A and B were used to titrate an aliquot of this solution. Fehling's solution A and B were used to titrate an aliquot of this solution. The total sugar content was calculated as a percentage of the total sugar content.

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

3.3.1.4. Crude fibre

Crude fibre is the organic matter that remains after the sample has been digested with dilute sulphuric acid and sodium hydroxide. In a crucible, two g of the sample (yoghurt) were placed and cooked for 30 minutes with H_2SO_4 (200 ml). After boiling, the sample was carefully cleaned in boiling water and boiled for another 30 minutes with 200 ml of NaOH. The sample was carefully cleaned with boiling water and rinsed in alcohol under vacuum after digestion. The difference in weight between the weight of the dried crucible and the weight of crude fibre present in the samplewas calculated (ASTA, 1968).

$$\textbf{Crude fibre content (\%)} = \frac{\textbf{(A-B)}}{\textbf{W}} \times \textbf{100}$$

Where

A = Weight of crucible with dry residue (g)

B = Weight of crucible with ash (g)

W = Weight of the sample

3.3.1.1. Total ash

The AOAC (1994) process discovered for total ash. First, a clean and dry crucible was properly weighed and recorded. To get the exact weight of the sample, about two g of it was put in the crucible and weighed again. The sample was put in a partly open crucible in an electricburner for the sample to be burned with initial smoky expulsion. The crucible was then put in a muffle furnace and heated to 60° C for two hours. The crucible was carefully removed from the furnace and allowed to cool to room temperature before being weighed again.

$$\textbf{Ash content (\%)} = \frac{\textbf{(Z-X)}}{\textbf{(Y-X)}} \times \textbf{100}$$

Where,

X- Weight of empty crucible in grams

Y- Weight of crucible + sample in grams

Z- Weight of crucible + ash in grams (after complete ashing)

3.3.1.2. Calcium

Using the diacid extract prepared from the sample, the calcium content of the chosen yoghurt was calculated using the Atomic Absorption Spectrophotometric approach (Perkin-Elmer, 1982). A 0.2 g sample was pre-digested with 10 ml of a 9 : 4 mixture of nitric acid and perchloric acid, then diluted to 50 ml and used directly in an Atomic Absorption Spectrophotometer to determine calcium concentration, which was expressed in mg/100 g of thesample.

3.3.1.3. Iron

The iron content of various food samples was determined using procedure suggested by Perkin-Elmer (1982). A 9:4 mixture of nitric and perchloric acid was used to predigest 0.2 gram of the sample (10 ml). In an Atomic Absorption Spectrophotometer, the prepared di-acid extract of the food sample was used to estimate iron. Iron content present in the sample was expressed as mg/100 g of the sample.

3.3.1.4. Potassium

The potassium content present in the prepared food sample was estimated using the procedure suggested by Jackson (1973). The diacid extract of the food mixture was directly read in the flame photometer and the potassium content was expressed in mg/100 g of the sample.

3.3.1.5. Phosphorus

The method for the estimation of phosphorus was suggested by Jacksons (1973). Phosphorus content was determined using a colorimetric method that uses nitric acid and vandate molybdate reagent to produce a yellow colour.

The sample of 0.2 g was pre-digested with 10 ml of 9: 4 diacid and volume made to 100 milli liters. The volumetric flask was filled to 50 ml with distilled water after adding five ml of pre-digested aliquot, five ml of nitric acid, and fiveml of vandate molybdate reagent. The optical density was red at 470 nm after 10 minutes. The phosphate content was measured in milligram per kilogram of body weight.

3.3.1.6. Zinc

Perkin-Elmer (1982) was used to determine the quantity of zinc contained in the yoghurt. The sample of 0.2 gram of yoghurt was pre-digested in 10 ml of nitric acid and perchloric acid in a 9:4 ratio. In the Atomic Absorption Spectrometer, the diacid extract of the yoghurt sample was used to estimate zinc. The proportion of minerals in the sample was measured in milligram per 100 g.

3.3.1.7. Magnesium

The amount of magnesium in the yoghurt was calculated using the standard procedure suggested by Perkin-Elmer (1982). The sample of 0.2 gram of yoghurt was pre-digested in 10 ml of nitric acid and perchloric acid in a 9:4 ratio. In the Atomic Absorption Spectrometer, the diacid extract of the yoghurt was used to estimate magnesium. The proportion of minerals in the assay was measured in milligram per 100 gram.

3.3.2. Health studies of the yoghurts

3.5.2.1 *In vitro* mineral availability

The method of Duhan *et al.* (2001) was used to determine the availability of calcium, iron, potassium, phosphorus, zinc and magnesium *in vitro*. The HCl extractability of minerals was computed for *in vitro* availability. The chosen yoghurt samples were collected in a shaker for threehours at 37° C with 0.03 N HCl. Whatman no. 40 filter paper was used to filter the sample. The clear extract was dried in an oven at 100° C before being digested with moist acid. The amount of HCl extractable calcium, iron, potassium, phosphorus, zinc and magnesium in the digested sample was then calculated using the above mentioned methods for mineral estimation. To calculate the HCl extractability, the following formula was recommended.

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

3.5.2.2. Total antioxidant activity

According to Blois (1958), 1, 1 - diphenyl - 1- picryl hydrazine (DPPH) spectrometric assay was used to determine the antioxidant capacity of yoghurt. A methanolic solution containing DPPH radicals (0.1 mM) was added to the concentrations of the sample and vigorously shook. In the dark, the reaction mixture was incubated for 30 minutes. In a spectrometer, the absorbance was measured at 517 nm. The following formula was used to calculate the proportion of antioxidant activity:

$$\textbf{\% Inhibition of free radicals} = \frac{\textbf{(absorbance of control - absorbance of sample)}}{\textbf{Control}} \times 100$$

The sample concentration providing 50 % 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.

3.3.3. Organoleptic evaluation of the probiotic yoghurt

The developed yoghurts were subjected to organoleptic evaluation by the panel of selected judges. The procedure of organoleptic evaluation is mentioned in 3.2.3.3.

3.3.4. Population of *L. acidophilus* in millet based probiotic yoghurts

The feasible count of *L. acidophilus* present in the produced millet based yoghurt was determined using Agarwal and Hasija (1986) serial dilution and plate count technique. Ten gram of the yoghurt sample was mixed with 90 ml distilled water and carefully mixed to count the probiotic bacteria (*L. acidophilus*). One milliliter of this mixture was placed in a test tube with 9 milliliters of distilled water. This is a dilution of 10^{-2}. Dilutions up to 10^{-9} were made in the same manner. As indicated in 3.3.1, the viable counts of *L. acidophilus* were counted.

3.3.5. Enumeration of total micro flora

According to Agarwal and Hasija (1986), the microbial population present in the yoghurt was estimated using the serial dilution plate count method. The microbial analysis was performed on selected yoghurt from each set at the starting of storage and at five day intervals after that.

The sample was made by combining 90 ml distilled water with 10 g yoghurt and shaking vigorously with a shaker to achieve suspension. This is a dilution of 10^{-1}. In the prepared water blank, serial dilutions were performed. Transfer one ml of the prepared suspension to nine ml of water blank, resulting in a dilution of 10^{-2}. Using serial dilution procedures, this is then diluted to 10^{-3}, 10^{-4}, 10^{5} and 10^{-6}. The medium used were Nutrient Agar (NA) for bacteria, Potato Dextrose Agar (PDA) for fungi, and Sabouraud's Dextrose Agar (SDA) for yeast, with findings expressed in cfu/g.

3.3.5.1. Enumeration of bacterial colony

In the nutrient agar medium, the total number of bacterial colonies was counted in a 10^{-5} dilution. Using a micropipette, pour one ml of 10^{-5} dilution into a clean petri dish. Pour about 20 ml of the nutrient agar medium into the petri dish, which is equally distributed in the petri dish byspinning clockwise and anticlockwise. The enumerated petri dishes were incubated for 48 hours at room temperature for bacterial colonies. The total number of bacterial colonies were counted and expressed in colony forming units per gram (cfu/g).

3.3.5.2. Enumeration of fungal colony

In Potato Dextrose Agar the total number of fungal colonies was counted in a 10^{-3} dilution. Using a micropipette, pour one ml of 10^{-3} dilution into a clean petri dish. Pour about 20 ml of Potato Dextrose Agar medium into a petri dish and spread evenly. The petri dishes were incubated at room temperature for four to five days to count the fungal colonies. The number of fungal colonies counted in total. The total number of fungal colonies counted and expressed in colony forming units per gram (cfu/g).

3.3.5.3. Enumeration of yeast colony

In Sabouraud's Dextrose Agar medium, the total number of yeast colonies was counted ina 10^{-3} dilution. Using a micro pipette, pour one ml of 10^{-3} dilution into a clean petri dish. Pour about 20 ml of Sabouraud's Dextrose Agar medium into the petri dish, rotating it to evenly distribute themedium. The petri dishes were incubated in room temperature for four to five days to count the yeast population. The total number of yeast colonies was counted and expressed in colony forming units per gram (cfu/g).

3.6 Preparation of synbiotic yoghurts

3.6.1. Standardising the proportion of prebiotic in the selected probiotic yoghurt

The probiotic yoghurt from 3.4.1 was made into synbiotic yoghurt by adding inulin and polydextrose. The various treatments for each probiotic yoghurt is discussed below.

3.6.2. Acceptability of the prepared synbiotic yoghurts

3.6.2.1. Selection of panel members for the organoleptic evaluation

A panel of fifteen judges was selected as mentioned in the 3.2.3.1.

3.6.2.2. Preparation of score cards for the organoleptic evaluation

The score card was prepared as discussed in the 3.2.3.2 and it is given in Appendix 3.

3.6.2.3. Organoleptic evaluation of prepared synbiotic yoghurts

The organoleptic evaluation was done as per the section 3.2.3.3. discussed.

3.6.2.4. Selection of the most acceptable synbiotic yoghurt

On the basis of organoleptic scores the yoghurts with maximum quality attributes were selected for further study.

3.7. Quality evaluation of the developed millet used synbiotic yoghurt

3.7.1. Physico-chemical composition of the selected synbiotic yoghurts

Analysis of each parameter was carried out in three replications and the methods used were followed as mentioned in 3.5.1.

Table 2. Proportions of prebiotics in the selected probiotic yoghurts

Prebiotics	The selected probiotic yoghurt	Treatments		
		1%	2%	3%
Inulin	BF Probiotic yoghurt	T_1	T_2	T_3
	FF Probiotic yoghurt	T_4	T_5	T_6
Polydextrose	BF Probiotic yoghurt	T_7	T_8	T_9
	FF Probiotic yoghurt	T_{10}	T_{11}	T_{12}

(BF - Barnyard millet flour and FF - Finger millet flour)

3.7.2. Health studies of the selected yoghurts

The *in vitro* mineral availability and total antioxidant activities were calculated by the procedure discussed in 3.5.2.

3.7.3. Population of *L. acidophilus* in the selected yoghurts

The probiotic count was enumerated, which was mentioned in section 3.3.1.

3.7.4. Enumeration of total micro flora

The enumeration of total micro flora was done using the methods described in 3.5.6.

3.8 Cost of production of the developed millet based probiotic and synbiotic yoghurts

The cost of production of the selected probiotic and symbiotic yoghurt were calculated by considering the material cost (market value), labour charges, fuel and electricity charges and packing cost. The price was determined based on 100 gram.

3.9. Statistical analysis

The derived data were statistically analysed using methods such as Kendall's coefficient of concordance, Duncan's multiple range test and paired sample "t" test.

Results

4. RESULT

The results of the study entitled "Standardisation and quality evaluation of millet based probiotic yoghurts" were discussed under the following headings.

4.1. Standardisation of proportion of ingredients in the yoghurt

The yoghurts were prepared as per the standard procedure of Sarabhai (2012) as mentioned in section 3.1. Millet based yoghurt was made from barnyard millet flour and finger millet flour. The various quality characteristics were ranked using mean scores and analysed using Kendall's (W) test.

4.1.1. Organoleptic qualities of yoghurt prepared from barnyard millet

The mean scores and mean rank scores obtained for several qualitative parameters of yoghurt made from barnyard millet when compared to plain yoghurt are detailed in Table 3.

The mean scores for the appearance of barnyard millet based yoghurt ranged from 8.38 to 8.67 and 8.62 to 8.76 for colour. For appearance, the mean rank score ranged from 2.7 to 4.27 and for colour, it ranged from 3.03 to 3.83. The treatment T_4 (50 % barnyard millet slurry + 50 % milk) yielded the highest mean score among the several combinations assessed for the preparation of barnyard millet based yoghurt. The mean score for appearance and colour was found to be 8.42 and 8.80 respectively for control yoghurt (T_0).

Treatment T_4 had the highest mean score for flavour (8.60) and taste (8.60) among the five treatments used to make barnyard millet based yoghurt, followed by T_3. For the flavour and taste of barnyard millet based yoghurt, the mean rank score ranged from 2.90 to 4.10 and 2.73 to 4.17, respectively. When compared to barnyard millet based yoghurt, plain yoghurt (T_0) got a higher mean taste (8.67) score.

The texture of barnyard based yoghurt (T_4) made with millet slurry and milk (50:50) obtained the highest mean and mean rank scores of 8.62 and 4.07, respectively. The texture of plain yoghurt (T_0) had an average score of 8.53, with a mean rank score

Table 3. Mean scores for organoleptic evaluation of barnyard millet based yoghurt

Treatments	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability	Total mean score
T_0	8.42 (2.6)	8.80 (4.23)	8.60 (4.23)	8.67 (4.77)	8.53 (4.23)	8.56 (3.37)	8.60
T_1	8.38 (2.7)	8.62 (3.03)	8.38 (2.90)	8.27 (3.03)	8.27 (2.57)	8.40 (2.67)	8.39
T_2	8.53 (3.57)	8.67 (3.43)	8.40 (3.00)	8.29 (2.80)	8.29 (2.77)	8.48 (3.67)	8.44
T_3	8.58 (3.9)	8.69 (3.43)	8.47 (3.37)	8.38 (3.50)	8.44 (3.83)	8.52 (3.77)	8.51
T_4	8.67 (4.27)	8.76 (3.83)	8.60 (4.10)	8.60 (4.17)	8.62 (4.07)	8.69 (4.23)	8.66
T_5	8.60 (3.97)	8.64 (3.03)	8.47 (3.40)	8.29 (2.73)	8.47 (3.53)	8.49 (3.30)	8.49
Kendall's W Value	0.21**	0.189**	0.198**	0.22**	0.167**	0.089*	

Figures in parenthesis indicate mean rank scores
*Significant at 1 % level
**Significant at 5 % level

T_0 - 100% M; T_1 – 80 % M + 20 % BMS; T_2 –70 % M + 30 % BMS; T_3 –60 % M + 40 % BMS; T_4 –50 % M + 50 % BMS; T_5 –60 % M + 40 % BMS

Table 4. Mean scores for organoleptic evaluation of finger millet based yoghurt

Treatments	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability	Total mean score
T_0	8.44 (5.70)	8.95 (5.73)	8.67 (4.17)	8.91 (5.43)	8.84 (5.07)	8.66 (5.73)	8.74
T_6	8.18 (2.67)	8.22 (2.47)	8.69 (3.17)	8.27 (2.07)	8.33 (2.47)	8.15 (2.00)	8.38
T_7	8.24 (2.77)	8.27 (2.80)	8.69 (3.17)	8.40 (3.07)	8.38 (2.73)	8.35 (3.10)	8.31
T_8	8.31 (3.27)	8.29 (2.97)	8.71 (3.10)	8.49 (3.53)	8.58 (4.00)	8.58 (4.00)	8.45
T_9	8.42 (3.70)	8.47 (4.00)	8.82 (3.90)	8.51 (3.70)	8.64 (4.40)	8.53 (4.03)	8.56
T_{10}	8.29 (2.90)	8.29 (3.03)	8.80 (3.50)	8.49 (3.20)	8.31 (2.33)	8.33 (2.73)	8.42
Kendall's W Value	0.437	0.512	0.137	0.430	0.433	0.567	

Figures in parenthesis indicate mean rank scores
*Significant at 1 % level
**Significant at 5 % level

T_0 - 100% M; T_1 – 80 % M + 20 % FMS; T_2 –70 % M + 30 % FMS; T_3 –60 % M + 40 % FMS; T_4 –50 % M + 50 % FMS; T_5 –60 % M + 40 % FMS

of 4.23. The mean texture score of barnyard millet based yoghurt increased to 8.62 as the proportion of millet slurry increased to 50 per cent.

The highest mean and rank score (8.69 and 4.23) for overall acceptance across the five treatments of barnyard millet based yoghurt was for treatment T_4. However, this was shown to be higher than the control's mean and mean scores (8.56 and 3.37). T_1, which was made with an 80 : 20 combination of milk and millet slurry, had the lowest score of 8.40.

The highest total mean score among the five treatments was ranked for T_4 with the score of 8.66 followed by T_3, T_5, T_4 and T_1. The total mean score for the control was 8.60 which was less than T_4 yoghurt.

Significant agreement among the judges was seen in the evaluation of several attributes of barnyard millet based yoghurt as measured by Kendall's (W) value.

4.1.2. Organoleptic qualities of yoghurt prepared from finger millet

In comparison to plain yoghurt, Table 4. represents the mean scores and mean rank scores for several qualitative parameters of finger millet yoghurt.

For finger millet based yoghurt, the mean score for appearance varied from 8.18 to 8.42. In terms of colour, it ranged from 8.22 to 8.47. The mean rank score for appearance varied from 2.67 to 3.70, while the mean rank score for colour was 2.47 to 4.00. Among the several combinations examined for the production of finger millet based yoghurt, the 50 : 50 ratio obtained the highest mean score (T_9). When compared to the control, the mean score for appearance and colour was determined to be high (8.44 and 8.95).

Among the five treatments used to produce finger millet based yoghurt, T_9 got the highest mean scores for flavour (8.82) and taste (8.51), followed by T_8 and T_7. The mean rankscore for the flavour and taste of finger millet based yoghurt varied from 3.17 to 3.90 and 2.07 to 3.70, respectively. Plain yoghurt scored higher than finger millet based yoghurt in terms of taste (8.91) and lower in terms of flavour (8.67).

With mean and rank scores of 8.64 and 4.40, the texture of finger millet based yoghurt (T_9) made with millet slurry and milk (50:50) received the highest mean and rank scores. The mean texture score for plain yoghurt (T_0) was 8.84, with a mean rank score of 5.07.

In the five treatments of finger millet based yoghurt, T9 had the highest mean and rankscore (8.53 and 4.03) for overall acceptability (50:50). However, this was shown to be lower than the mean and mean scores of the control (8.66 and 5.73). The lowest score was 8.15 for T6, which was a 50:50 combination of milk and millet slurry.

The highest total mean score among five treatments was T_9 with the score of 8.56 followed by T_8, T_{10}, T_6 and T_7. The total mean score for the control was 8.74 which was greater than T_9 yoghurt.

The examination of several attributes of millet based fermented dairy products made from millet flour, as evaluated by Kendall's (W) value, revealed significant agreement among the judges.

4.1.3. Selection of the most acceptable treatment for the preparation of millet based yoghurts

Milk and millet slurry were combined in various proportions as explained in section 4.1 for both barnyard and finger millet to make millet based yoghurt. Plain yoghurt made with100 per cent milk served as control. The treatment T_4 (50 % milk and 50 % barnyard millet slurry) and T_9 (50 % milk and 50 % finger millet slurry) had the highest mean score and mean rank score for appearance, colour, flavour, taste, texture and overall acceptability among the several treatments used for the preparation of millet based yoghurts. T_4 had the score of 8.67 for appearance, 8.76 for colour, 8.60 for flavour and taste, 8.62 for texture and 8.69 for overall acceptability.

Treatment T_9 got an average mean score of 8.42 for appearance, 8.47 for colour, 8.82 for flavour, 8.51 for taste, 8.64 for texture and 8.53 for overall acceptability. Hence the treatments T_4 (50 % milk and 50 % barnyard millet slurry) and T_9 (50 % milk and 50 % finger millet slurry) were chosen for further studies.

4.2. Optimisation of conditions for the growth of *L. acidophilus*

For the optimisation procedure, the best millet based yoghurt from each set (50 % milk + 50 % millet slurry) was chosen. *L. acidophilus* (MTCC 10307) was added to probiotic yoghurts under various conditions and the best fermentation conditions were determined based on the findings. For the preparation of millet based probiotic yoghurt, factors such as substrate concentration, incubation time, temperature and *L. acidophilus* population for inoculation were optimised.

4.2.1. Optimisation of substrate concentration

Optimisation studies were conducted using the best millet based yoghurt combination (50 % milk + 50 % millet slurry) from both sets. Twenty five, fifty and seventy five grams of the yoghurts were fermented with 1 ml of *L. acidophilus* and 2 ml of yoghurt culture for 4 h at 38º C. The results of the viable counts of *L. acidophilus* are shown in Table 5.

In both sets of experiments, a substrate concentration of 25 g resulted in an acceptable yoghurt. On serial dilution, the substrate concentration of 25 g produced higher colonies in the MRS medium (6.12 and 6.32 log cfu/ml in barnyard millet based yoghurt and finger millet based yoghurt, respectively). In the 75 g substrate concentration, probiotic growth was minimal (3.32 and 3.87 log cfu/ml in barnyard millet based yoghurt and finger millet based yoghurt, respectively).

4.2.2. Optimisation of time of incubation

The 25 g concentration was chosen for further studies because it gave the highest number of probiotic colonies. This was inoculated for 4, 5 and 6 hours with 1 ml of *L. acidophilus* with 2 ml of yoghurt culture at 38º C. Table 2 shows the results of enumerating the viable count of *L. acidophilus* (Table 6).

The number of probiotic colonies increased with incubation time and the plates containing yoghurt samples incubated for six hours had the highest number of organisms. After six hours of incubation, the number of colonies in the barnyard millet based yoghurt was 5.83 log cfu/ml while the number of colonies in the finger millet based yoghurt was 5.43 log cfu/ml. The lowest was for 4 hours in both cases (4.30 log cfu / mg in barnyard millet based yoghurt and 2.87 log cfu/ml in finger millet based yoghurt).

4.2.3. Optimisation of temperature of incubation

The 25 g concentration was chosen for further studies because it yielded the

Table 5. Viable count of *L. acidophilus* in millet based yoghurts with different substrate concentrations

Treatments \ Quantity of substrates (g)	25 (g)	50 (g)	75 (g)
	Viable counts ($\times 10^9$ cfu/ml)		
Barnyard millet based yoghurt	160 (9.20)	90 (8.95)	60 (8.78)
Finger millet yoghurt	150 (9.18)	79 (8.90)	44 (8.64)

All values are means of three independent enumerations
Figures in parenthesis indicate log cfu/ml

Table 6. Viable count of *L. acidophilus* in millet based yoghurts with different time of incubation

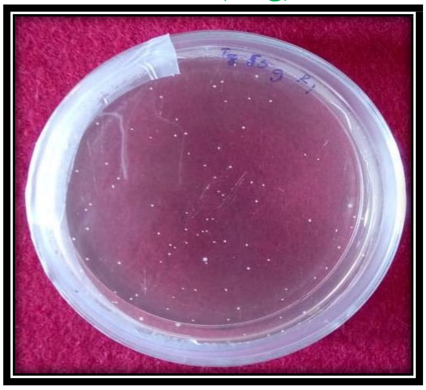
Treatments \ Time of incubation (h)	4 h	5 h	6 h
	Viable counts ($\times 10^9$ cfu/ml)		
Barnyard millet based yoghurt	74 (8.67)	90 (8.95)	136 (9.13)
Finger millet yoghurt	33 (8.52)	90 (8.95)	118 (9.07)

All values are means of three independent enumerations
Figures in parenthesis indicate log cfu/ml

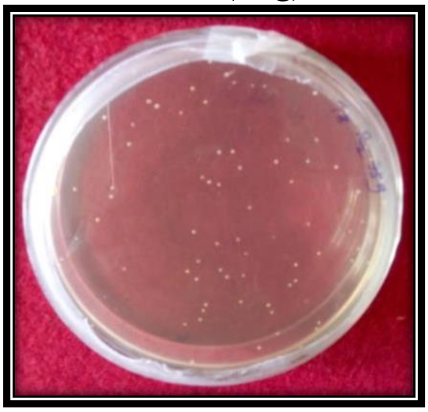
BMPY (25 g)

FMPY (25 g)

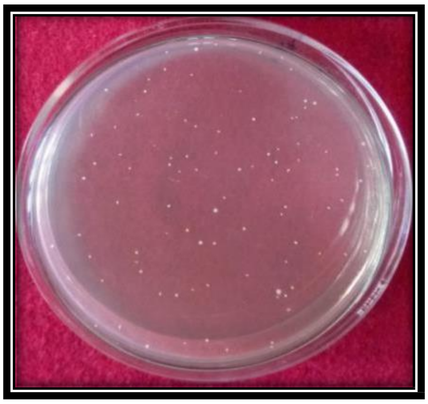
BMPY (50 g)



FMPY (50 g)



BMPY (75 g)

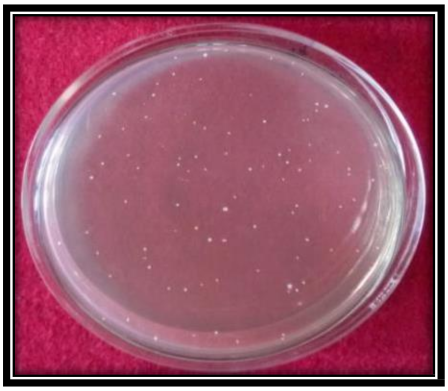


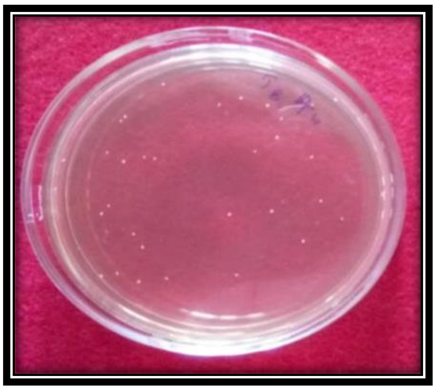
FMPY (75 g)

BMPY: Barnyard millet based probiotic yoghurt

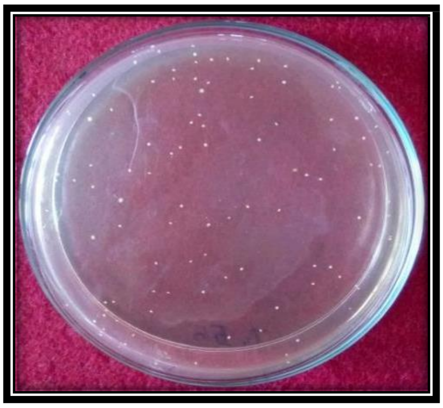
FMPY: Finger millet based probiotic yoghurt

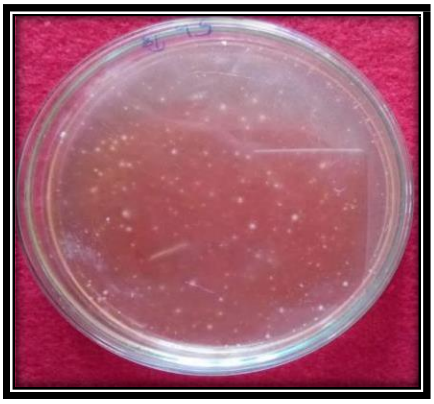
Plate 3. Optimisation of substrate concentration (10^9 dilution)



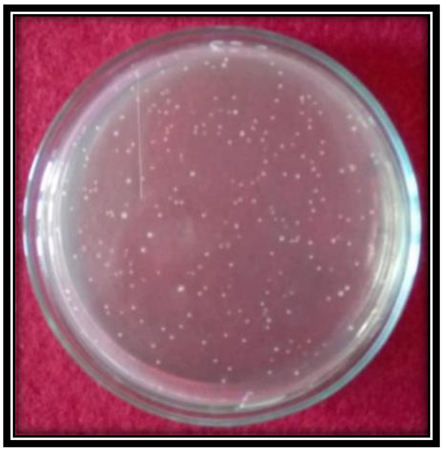


BMPY (4 h) **FMPY (4 h)**





BMPY (5 h) **FMPY (5 h)**



BMPY (6 h) **FMPY (6 h)**

BMPY: Barnyard millet based probiotic yoghurt

FMPY: Finger millet based probiotic yoghurt

Plate 4. Optimisation of time of incubation (10^9 dilution)

most probiotic colonies when incubated for six hours. The next stage was to optimise the incubation temperature. For this, 25 g of substrates was inoculated with 1 ml of probiotic culture with 2 ml of yoghurt culture incubated for six hours at 38º C, 40º C and 42º C. When the incubation was carried out at 38º C, most colonies were detected. The findings of the viable counts of *L. acidophilus* are shown in Table 7.

Table 3, illustrates the viable count of *L. acidophilus* at 38º C, 40º C and 42º C. According to the results, the optimal temperature for probiotic bacteria was 38º C rather than 40º or 42º C. At 42º C, the smallest number of colonies (3 and 2.45 log cfu/ml for barnyard and finger millet based yoghurt, respectively) was seen. The bacterial concentration in log cfu/ml is indicated by the figures in the table's parentheses.

4.2.4. Optimisation of inoculum concentration

The 25 g of yoghurt sample was chosen for further study since it produced the most probiotic colonies when incubated at 38º C for six hours. It was also necessary to optimise the inoculum concentrations. For this experiment, 25 g of the substrate was inoculated with 100 µl, 200 µl and 300 µl of probiotic culture and 200 µl of yoghurt culture, incubated at 38º C for six hours. Over fermentation was generated by inoculation with 200 µl and 300 µl of probiotic strains. As a result, a concentration of 100 µl inoculum was used. Table 8 shows the probiotic count.

For the creation of probiotic yoghurts, a 100 µl inoculum concentration was used. The viability of *L. acidophilus* at a concentration of 100 µl meets the FSSAI (2016) probiotic product standards.

4.3. Development of millet based probiotic yoghurts

Millet based yoghurts were made with the criteria optimised in the preceding portion of this chapter. A probiotic culture of 100 µl and 200 µl of yoghurt culture were added to 25 g of the milk and millet slurry mixture. This combination was then incubated for 6 hours at 38º C. The products were kept refrigerated for fifteen days after incubation for further research.

Table 7. Viable count of *L. acidophilus* in millet based yoghurts with different temperatures

Treatments \ Temperature	38º C	40º C	42º C
	Viable counts (×10^{9} cfu/ml)		
Barnyard millet based yoghurt	106 (9.02)	53 (8.72)	36 (8.56)
Finger millet yoghurt	95 (8.98)	60 (8.78)	24 (8.38)

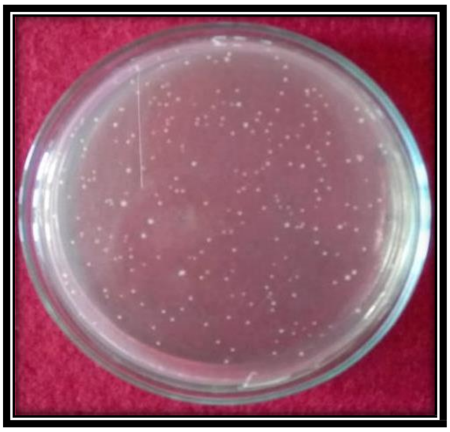
All values are means of three independent enumerations
Figures in parenthesis indicates log cfu/ml

Table 8. Viable count of *L. acidophilus* in millet based yoghurts with 100 µl inoculum concentration

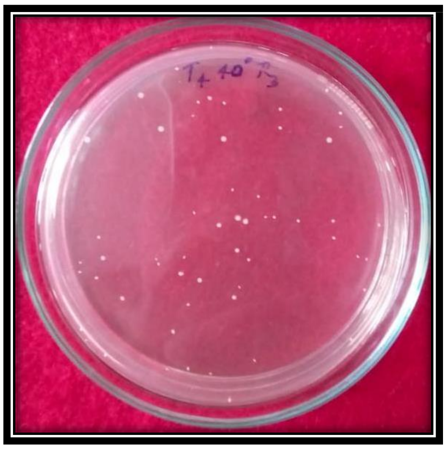
Treatments \ Concentration of inoculum	(1+2) ml
	Viable counts (×10^{9} cfu/ml)
Barnyard millet based yoghurt	106 (9.02)
Finger millet yoghurt	95 (8.98)

All values are means of three independent enumerations
Figures in parenthesis indicates log cfu/ml

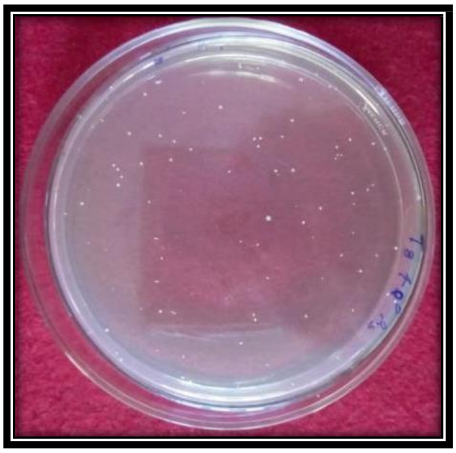
BMPY (38° C)



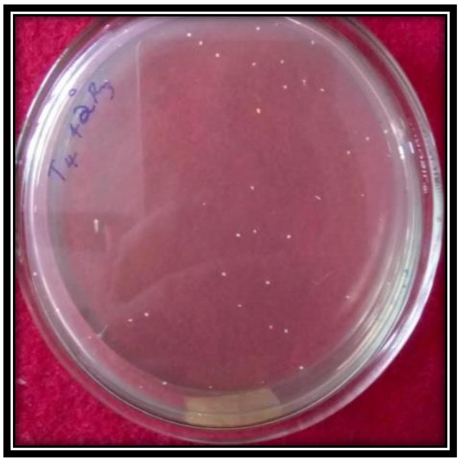
FMPY (38° C)



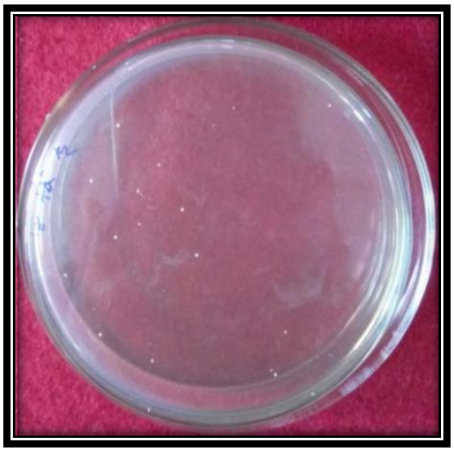
BMPY (40° C)



FMPY (40° C)



BMPY (42° C)



FMPY (42° C)

BMPY: Barnyard millet based probiotic yoghurt

FMPY: Finger millet based probiotic yoghurt

Plate 5. Optimisation of temperature (10^9dilution)

BMPY (1+2 ml) **FMPY (1+2 ml)**

BMPY: Barnyard millet based probiotic yoghurt

FMPY: Finger millet based probiotic yoghurt

Plate 6. Optimisation of inoculum concentration (10^9 dilution)

Non-probiotic barnyard millet yoghurt

Probiotic barnyard millet yoghurt

Non-probiotic finger millet yoghurt

Probiotic finger millet yoghurt

Plate 7. Millet based non-probiotic and probiotic yoghurt

4.3.1. Physico-chemical composition of the developed millet based yoghurts

The physicochemical attributes of the millet based probiotic yoghurts were investigated and the results are furnished below.

4.3.1.1. Moisture

The moisture content of millet based probiotic yoghurts, as well as their control yoghurts, is shown in Table 9. After analysing the data, the control sample of each millet based yoghurt reported lower moisture compared to the probiotic yoghurt. The moisture of the non-probiotic barnyard millet based yoghurt was 85.05 per cent, while the probiotic yoghurt was 87.03 per cent and the moisture of the probiotic yoghurt was 87.42 per cent for finger millet based yoghurt and for non-probiotic yoghurt, it was

Table 9. Moisture content of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	85.05 [a]	85.98 [b]	86.31 [c]	86.81[d]	0.014
	Probiotic Yoghurt	87.03 [a]	87.21 [b]	88.31 [c]	88.52[d]	0.013
	t value	5.88*	5.90*	8.77*	7.09*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	86.38 [a]	86.35 [a]	86.21 [b]	86.01 [c]	0.033
	Probiotic Yoghurt	87.42 [a]	87.43 [b]	87.44 [c]	87.52[d]	0.02
	t value	5.78*	6.99*	5.49*	4.91*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

86.38 per cent. According to the t test, there was significant difference between probiotic and non-probiotic yoghurts in the case of moisture content.

On storage, the moisture of millet based yoghurts was found to be increasing. On the 15th day of storage, the non-probiotic yoghurt made from barnyard millet had a moisture content of 86.81 per cent, while probiotic yoghurt had 88.52 per cent. Non-probiotic yoghurt made from finger millet had a moisture content of 86.01 per cent, while probiotic yoghurt had 87.52 per cent. The statistical analysis (DMRT) of the data showed a significant difference in the moisture of both millet based yoghurts throughout the storage period.

Table 10. Acidity of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	0.72 [a]	0.76 [b]	0.84 [c]	0.96 [d]	0.016
	Probiotic Yoghurt	0.81 [a]	0.82 [b]	0.98 [c]	1.08 [c]	0.014
	t value	9.71*	4.91*	6.39*	7.40*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	0.72 [a]	0.76 [b]	0.82 [c]	0.98 [d]	0.013
	Probiotic Yoghurt	0.78 [a]	0.85 [b]	0.91 [c]	1.02 [d]	0.018
	t value	4.27*	5.68*	4.38*	3.35*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.1.2. Acidity

The acidity of millet based yoghurts on storage is shown in Table 10. The acidity of both millet based probiotic yoghurts was observed to be higher than thenon-probiotic yoghurt. Both millets (barnyard and finger millet) had an initial acidity of 0.72 per cent for non-probiotic yoghurts and probiotic yoghurt had 0.81 for barnyardmillet based yoghurt and 0.78 for finger millet based yoghurt. Each set was significantly different in the case of acidity of probiotic and non-probiotic yoghurts, according to the t test.

The acidity of the prepared yoghurt increased during storage. After 15 days of storage, the acidity of barnyard millet based probiotic yoghurt was 1.08 per cent, whereas the non-probiotic yoghurt was 0.96 per cent. In the case of finger millet based yoghurt the acidity of non-probiotic yoghurt after 15 days was 0.98 per cent and 1.02 per cent for probiotic yoghurt in finger millet based yoghurt. According to the statistical study (DMRT), the data showed a significant difference in both millet based yoghurt throughout the storage period.

4.3.1.3. pH

Table 11. depicts the pH of selected millet based probiotic yoghurt to that of the non-probiotic yoghurt. Non-probiotic yoghurt had an initial pH of 4.02, whereas probiotic yoghurt had an initial pH of 3.88 in barnyard based yoghurt and 3.92 for non-probiotic yoghurt and 3.82 for probiotic yoghurt in finger millet yoghurt. According to t test, each set was significantly different in the case of pH of probiotic and non-probiotic yoghurt.

After the 15th day of storage, the pH of each yoghurt significantly decreased. In the case of barnyard millet based yoghurt, it declined to 3.75 for non-probiotic yoghurt and 3.53 for probiotic yoghurt at the end of storage and to 3.65 for non-probiotic yoghurt and 3.67 for probiotic yoghurt in finger millet based yoghurt at the end of storage. The pH of barnyard and finger millet yoghurts differed significantly in storage, according to statistical analysis (DMRT).

Table 11. pH of millet based yoghurts during storage

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	4.02 [a]	3.98 [b]	3.87 [c]	3.75 [d]	0.019
	Probiotic Yoghurt	3.88 [a]	3.79 [b]	3.65 [c]	3.53 [d]	0.025
	t value	2.95*	2.70*	4.43*	1.66*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	3.92 [a]	3.87 [b]	3.73 [c]	3.65 [d]	0.02
	Probiotic Yoghurt	3.82 [a]	3.69 [b]	3.68 [b]	3.67 [b]	0.071
	t value	9.11*	6.22*	3.19*	5.84*	

DMRT row wise comparison (significant at 5% level)
* Significant at 5 % level

4.3.1.4. Water holding capacity

The rheological parameters like water holding capacity, syneresis, viscosity and texture analysis (cohesiveness, gumminess and resilience) of prepared probiotic yoghurts on storage were analysed and the results are detailed in Tables 10 to12.

The water holding capacity (WHC) of millet based probiotic yoghurts, as well as their control yoghurts, are shown in Table 10. After analysing the data, the control sample of each millet based yoghurt reported the highest WHC compared to the probiotic yoghurt. The WHC of the non-probiotic barnyard millet based yoghurt was

88.30 per cent, while the probiotic yoghurt was 79.75 per cent and the WHC of the probiotic yoghurt was 78.30 per cent for finger millet based yoghurt and for non-probiotic yoghurt, it was 85.80 per cent. According to the t test, there was significant difference in the case of WHC of probiotic and non-probiotic yoghurts.

Table 12. Water holding capacity of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	88.30 ^{a}	83.20 ^{b}	79.10 ^{c}	78.20 ^{d}	0.206
	Probiotic yoghurt	79.75 ^{a}	77.93 ^{b}	73.73 ^{c}	71.27 ^{d}	0.037
	t value	9.65*	5.70*	7.82*	10.90*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	85.80 ^{a}	83.10 ^{b}	79.10 ^{c}	75.20 ^{d}	0.199
	Probiotic yoghurt	78.30 ^{a}	75.10 ^{b}	73.20 ^{c}	71.10 ^{d}	0.217
	t value	17.03*	14.64*	19.00*	14.71*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

On storage, the WHC of millet based yoghurts was found to be decreasing. On the 15th day of storage, the non-probiotic yoghurt made from barnyard millet had a WHC of 78.20 per cent, while probiotic yoghurt had 71.27 per cent. Non-probiotic yoghurt made from finger millet had a WHC of 75.20 per cent, while probiotic yoghurt had 71.10 per cent. The statistical analysis (DMRT) of the data showed a significant difference in the WHC of both millet based yoghurts throughout the storage period.

4.3.1.5. Syneresis

The syneresis of millet based yoghurts on storage are shown in Table 13. The syneresis of both millet based probiotic yoghurts was observed to be higher than the non-probiotic yoghurt. The barnyard millet based non-probiotic yoghurt had an initial syneresis of 4.33 per cent and for probiotic yoghurt syneresis was 5.20 per cent. The finger millet based non-probiotic yoghurt had initial syneresis of 4.33 per cent and for probiotic yoghurt the syneresis was 5.10 per cent. A significant difference was observed in case of syneresis of probiotic and non-probiotic millet based according to the t test.

Table 13. Syneresis of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	CD Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	4.33^{a}	4.45^{b}	4.87^{c}	5.2^{d}	0.162
	Probiotic yoghurt	5.20^{a}	5.60^{b}	5.80^{c}	6.10^{d}	0.205
	t value	14.26*	8.64*	10.82*	7.08*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	4.33^{a}	4.48^{b}	4.98^{c}	5.30^{d}	0.134
	Probiotic yoghurt	5.10^{a}	5.40^{b}	5.80^{c}	6.20^{d}	0.103
	t value	11.10*	10.04*	12.75*	7.80*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

The syneresis of the prepared yoghurt increased during storage. After 15 days of storage, the syneresis of barnyard millet based probiotic yoghurt was 6.10 per cent, whereas the non-probiotic yoghurt was 5.20 per cent. In the case of finger millet based yoghurt the syneresis of non-probiotic yoghurt after 15 days was 5.30 per cent and 6.20 per cent for probiotic yoghurt in finger millet based yoghurt. According to the statistical study (DMRT), the data showed a significant difference in both millet based yoghurt on storage.

4.3.1.6. Viscosity

The viscosity of millet based yoghurts is shown in Table 14. Non-probiotic barnyard millet based yoghurt had a viscosity of 21104 cP, while probiotic yoghurt had 23204 cP and finger millet based yoghurt had a viscosity of 20900 cP for non-probiotic and 22800 cP for probiotic yoghurt. According to the t test, there was significant difference in the case of viscosity of probiotic and non-probiotic of both millet based yoghurts (barnyard and finger millet).

The viscosity of the yoghurt decreased as the storage day rises. When the viscosity of 15 days stored barnyard millet based probiotic yoghurt was 21408 cP and for non-probiotic yoghurt, it was 19302 cP. The non-probiotic finger millet based yoghurt had 17481 cP and for probiotic finger millet based yoghurt was 19881 cP. The viscosity of barnyard and finger millet yoghurts differed significantly throughout the storage period, according to statistical study (DMRT).

Table 14. Viscosity of millet based yoghurts during storage (cP)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	21104 ^{a}	20202 ^{b}	19808 ^{c}	19302 ^{d}	2.925
	Probiotic yoghurt	23204 ^{a}	22201 ^{b}	21908 ^{c}	21408 ^{d}	2.535
	t value	1461*	1428*	1962*	1996*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	20900 ^{a}	19581 ^{b}	18432 ^{c}	17481 ^{d}	3.065
	Probiotic yoghurt	22800 ^{a}	21466 ^{b}	20668 ^{c}	19881 ^{d}	3.176
	t value	1573*	1216*	1623*	1529*	

DMRT row wise comparison (significant at 5 % level), * Significant at 5 % level

4.3.1.7. Cohesiveness

The structural organisation and microstructure of the protein network determine the rheological and textural features of fermented dairy products (Delikanli and Ozcan, 2017). The parameters of texture analysis like cohesiveness, gumminess and resilience are detailed in Table 15 to 17.

Table 15. shows the cohesiveness of millet based yoghurts. Initial cohesiveness was 0.63 N in non-probiotic yoghurt and 0.64 N in probiotic yoghurt in barnyard and for finger millet based probiotic yoghurt the cohesiveness was 0.62 N and for non-probiotic yoghurt it was 0.58 N initially. According to the t test, there was no significant difference in the case of cohesiveness of probiotic and non-probiotic yoghurts of both barnyard and finger millet.

Table 15. Cohesiveness of millet based yoghurts during storage (N)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	0.63 ^{a}	0.57 ^{b}	0.48 ^{c}	0.45 ^{c}	0.022
	Probiotic yoghurt	0.64 ^{a}	0.58 ^{b}	0.49 ^{c}	0.42 ^{c}	0.02
	t value	1.57 ^{NS}	1.09 ^{NS}	0.28 ^{NS}	3.04 ^{NS}	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	0.58 ^{a}	0.55 ^{a}	0.45 ^{b}	0.42 ^{b}	0.023
	Probiotic yoghurt	0.62 ^{a}	0.57 ^{b}	0.48 ^{c}	0.39 ^{d}	0.026
	t value	2.72 ^{NS}	1.02 ^{NS}	2.20 ^{NS}	2.21 ^{NS}	

DMRT row wise comparison (significant at 5 % level)
NS: Non-significant

Cohesiveness of millet based yoghurt was decreased after storage on the 15th day, falling to 0.45 N in non-probiotic yoghurt and 0.42 N for probiotic yoghurt made from barnyard millet and 0.42 N in non-probiotic yoghurt and 0.39 N for probiotic yoghurt made from finger millet. The cohesiveness of millet based yoghurts significant throughout storage in both millets (barnyard and finger millet), according to statistical analysis (DMRT).

Table 16. Gumminess of millet based yoghurts during storage (N)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	55.73 ^{a}	54.81 ^{b}	53.55 ^{c}	52.43 ^{d}	0.027
	Probiotic yoghurt	56.65 ^{a}	55.93 ^{b}	54.63 ^{c}	53.77 ^{d}	0.03
	t value	1.26 ^{NS}	1.39 ^{NS}	1.69 ^{NS}	2.31 ^{NS}	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	62.45 ^{a}	61.64 ^{b}	59.47 ^{c}	58.77 ^{d}	0.021
	Probiotic yoghurt	63.86 ^{a}	61.23 ^{b}	59.88 ^{c}	57.86 ^{d}	0.033
	t value	1.63 ^{NS}	1.31 ^{NS}	1.41 ^{NS}	1.12 ^{NS}	

DMRT row wise comparison (significant at 5 % level), NS: Non-significant

4.3.1.8. Gumminess

The gumminess of millet based yoghurts is represented in Table 16. Set 1 includes yoghurt made with barnyard millet. The probiotic yoghurt (56.65 N) had a higher gumminess, than the non-probiotic yoghurt (55.73 N). In the 2nd set, yoghurt was made with finger millet and is summarised. Probiotic yoghurt (63.86 N) had a higher gumminess content, whereas non-probiotic yoghurt (62.45 N) had the lowest. There was no significant difference in the case of gumminess of probiotic and non-probiotic yoghurt.

The gumminess underwent a decrease during storage. The gumminess was decreased to 52.43 N for non-probiotic yoghurt and 53.77 N for probiotic yoghurt in barnyard millet based yoghurt. In the case of finger millet based yoghurt the gumminess of non-probiotic yoghurt decreased to 58.77 N and 57.86 N in probiotic yoghurt after storage. The statistical analysis (DMRT) of the data showed a significant difference in the gumminess of both millet based yoghurts throughout the storage period.

Table 17. Resilience of millet based yoghurts during storage (N)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	40.45 ^{a}	39.67 ^{b}	37.65 ^{c}	35.98 ^{d}	0.025
	Probiotic yoghurt	41.74 ^{a}	40.67 ^{b}	39.45 ^{c}	38.56 ^{d}	0.023
	t value	2.24 ^{NS}	1.45 ^{NS}	1.11 ^{NS}	1.04 ^{NS}	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	38.77 ^{a}	37.45 ^{b}	36.74 ^{c}	35.53 ^{d}	0.027
	Probiotic yoghurt	39.66 ^{a}	37.56 ^{b}	35.64 ^{c}	34.88 ^{d}	0.026
	t value	1.08 ^{NS}	1.28 ^{NS}	1.70 ^{NS}	0.45 ^{NS}	

DMRT row wise comparison (significant at 5 % level), NS: Non-significant

4.3.1.9. Resilience

Table 17. shows the resilience of millet based yoghurts. Set 1 represents barnyard millet based yoghurts, with the probiotic yoghurt having the highest resilience (41.74 N) and the non-probiotic yoghurt having the lowest (40.45 N). The 2nd set consists of finger millet based yoghurts, with the probiotic yoghurt having higher

resilience than non-probiotic yoghurt. The probiotic yoghurt had resilience of 39.66 N and non-probiotic yoghurt had 38.77 N of resilience. There was no significant difference in the case of resilience of probiotic and non-probiotic yoghurt, according to the t test.

The resilience of the yoghurt decreased as the storage day increased. The resilience on the 15th day of storage in probiotic yoghurt was 38.56 N and for non-probiotic it was 35.98 N in barnyard millet based yoghurt and the resilience was 35.53 N for non-probiotic and 34.88 N for probiotic yoghurt in finger millet based yoghurt. The statistical analysis (DMRT) of the data showed a significant difference in the resilience of both millet based yoghurts throughout the storage period.

Table 18. Carbohydrate content of millet based yoghurts during storage (g/100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	8.76 [a]	8.75 [a]	7.71 [b]	7.59 [c]	0.025
	Probiotic Yoghurt	8.58 [a]	8.43 [b]	7.31 [c]	7.28 [c]	0.023
	t value	3.32*	9.87*	5.09*	3.82*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	8.91 [a]	7.95 [b]	7.92 [c]	7.81 [d]	0.026
	Probiotic Yoghurt	8.32 [a]	7.82 [b]	7.65 [c]	7.59 [d]	0.028
	t value	2.76*	2.80*	2.27*	1.90*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.1.10. Carbohydrate

Table 18. shows the carbohydrate content of each millet based yoghurt compared to its control. The carbohydrate content of the barnyard based non-probiotic yoghurt was 8.76 g/100 g initially and 8.58 g/100 g for probiotic yoghurt. The carbohydrate level of the finger millet based non-probiotic yoghurt was 8.91 g/100 g and 8.32 g/100 g for probiotic yoghurt initially. According to the t test, there was significant difference in the case of carbohydrate content of probiotic and non-probiotic yoghurt.

The decrease in carbohydrate content was observed during storage. In the case of barnyard millet based non-probiotic yoghurt, the carbohydrate content was 7.59 g/100 g and its probiotic yoghurt had 7.28 g/100 g on the 15th day of storage. The carbohydrate content of finger millet based yoghurt was 7.81 g/100 g for non-probiotic and 7.59 g/100 g for probiotic yoghurt on the 15th day of storage. The statistical analysis (DMRT) of the data showed a significant difference in the carbohydrate content of both millet based yoghurts throughout the storage period.

4.3.1.11. Protein

Table 19. shows the protein content of millet based yoghurts. Set 1 lists the protein content of yoghurts made from barnyard millet. The non-probiotic yoghurt (3.49 g/100 g) had the lowest protein than the probiotic yoghurt (3.52 g/100 g). Set 2 shows the protein content of finger millet based yoghurts, with non-probiotic yoghurts (3.89 g/100 g) having considerably lowest protein than probiotic yoghurt (3.91 g/100 g). According to the t test, there was significant difference in the case of the protein content of probiotic and non- probiotic yoghurt.

Protein is hydrolysed during storage, as seen by the lower protein content of yoghurt after storage. The protein content of the 15th day of barnyard millet based non-probiotic yoghurt was 3.27 g/100 g and for probiotic yoghurt, the protein content was 3.38 g/100 g. The protein content of non-probiotic yoghurt was 3.59 g/100 g and 3.62 g/100 g for probiotic yoghurt in the case of finger millet based yoghurt. The statistical study (DMRT) of the data showed a significant difference in the protein content of both millet based yoghurts throughout the storage period.

Table 19. Protein content of millet based yoghurts during storage (g/100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	3.49 [a]	3.42 [b]	3.37 [c]	3.27 [d]	0.02
	Probiotic Yoghurt	3.52 [a]	3.49 [a]	3.42 [b]	3.38 [b]	0.084
	t value	2.80*	4.27*	4.60*	7.00*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	3.89 [a]	3.80 [b]	3.71 [c]	3.59 [d]	0.026
	Probiotic Yoghurt	3.91 [a]	3.86 [b]	3.78 [c]	3.62 [d]	0.018
	t value	3.10*	5.15*	6.21*	4.44*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.1.12. Fat

The fat content of millet based yoghurts is as shown in Table 20. Non-probiotic barnyard millet based yoghurt had a fat content of 2.59 g/100 g, while probiotic yoghurt had 2.63 g/100 g and finger millet based yoghurt had a fat content of 2.80 g/100 g for non-probiotic and 3.29 g/100 g for probiotic yoghurt. According to the t test, there was significant difference in the case of fat content of probiotic and non-probiotic yoghurts.

The fat content of the yoghurt decreased as the storage day increased. When the fat content of 15 days stored barnyard millet based probiotic yoghurt was 2.58 g/100 g and 2.51 g/100 g for non-probiotic yoghurt, it was 1.90 g/100 g for non-probiotic finger millet based yoghurt and 3.21 g/100 g for probiotic finger millet based yoghurt. The fat content of barnyard and finger millet yoghurts differed significantly throughout the storage period, according to statistical analysis (DMRT).

Table 20. Fat content of millet based yoghurts during storage (g/100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	0.59 [a]	0.55 [b]	0.53 [b]	0.51 [c]	0.02
	Probiotic Yoghurt	0.63 [a]	0.62 [a]	0.60 [a]	0.58 [b]	0.022
	t value	5.48*	5.00*	6.77*	5.11*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	0.28 [a]	0.25 [a]	0.23 [b]	0.19 [c]	0.03
	Probiotic Yoghurt	0.39 [a]	0.35 [b]	0.35 [b]	0.31 [c]	0.029
	t value	6.31*	9.52*	9.94*	4.09*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.1.13. TSS

Table 21. shows the TSS of millet based yoghurts. Initial TSS was 12° brix in non-probiotic yoghurt and 11° brix in probiotic yoghurt in both millet (barnyard and finger millet) based yoghurt initially. According to the t test, there was significant difference in the case of TSS content of probiotic and non-probiotic yoghurts.

TSS of millet based yoghurt was decreased after storage on the 15th day, falling to 11° brix in non-probiotic yoghurt made from both millet (barnyard and finger millet) and 10° brix in both millets (barnyard and finger millet) based probiotic yoghurt. The

TSS of millet based yoghurts were no significant difference in storage in both millets (barnyard and finger millet), according to statistical analysis (DMRT).

Table 21. TSS of millet based yoghurts during storage (º brix)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	12 [a]	12 [a]	12 [a]	11 [b]	0.027
	Probiotic Yoghurt	11 [a]	11 [a]	11 [a]	10 [b]	0.089
	t value	4.07*	4.07*	4.07*	2.71*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	12 [a]	12 [a]	12 [a]	11 [b]	0.028
	Probiotic Yoghurt	11 [a]	11 [a]	11 [a]	10 [b]	0.023
	t value	4.07*	4.07*	4.07*	2.71*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.1.14. Reducing sugar

The reducing sugar of millet based yoghurts is represented in Table 22. Set 1 includes yoghurt made with barnyard millet. The probiotic yoghurt (7.55 g/100 g) had the lowest reducing sugar content than the non-probiotic yoghurt (8.33 g/100 g). In the 2nd set, yoghurt made with finger millet is summarised. Probiotic yoghurt (7.38 g/100 g) had the lowest reducing sugar content than non-probiotic yoghurt (8.36 g/100 g). According to the t test, there was significant difference in the case of reducing sugar of probiotic and non-probiotic yoghurt.

Table 22. Reducing sugar of millet based yoghurts during storage (g/100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	8.33 ^{a}	7.35 ^{b}	6.25 ^{c}	5.60 ^{d}	0.104
	Probiotic Yoghurt	7.55 ^{a}	7.12 ^{b}	6.01 ^{c}	5.01 ^{d}	0.054
	t value	5.55*	6.45*	9.39*	7.10*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	8.36 ^{a}	7.62 ^{b}	6.75 ^{c}	6.25 ^{d}	0.032
	Probiotic Yoghurt	7.38 ^{a}	6.81 ^{b}	6.31 ^{c}	6.11 ^{d}	0.027
	t value	4.87*	2.29*	2.71*	3.88*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

The reducing sugar showed a decrease during the storage period. The reducing sugar was decreased to 5.60 g/100 g for non-probiotic yoghurt and 5.01 g/100 g for probiotic yoghurt in barnyard millet based yoghurt. In the case of finger millet based yoghurt the reducing sugar of non-probiotic yoghurt was decreased to 6.25 g/100 g after storage and 6.11 g/100 g in probiotic yoghurt. The statistical analysis (DMRT) of the data showed a significant difference in the reducing sugar of both millet based yoghurts throughout the storage period.

4.3.1.15. Total sugar

Table 23. shows the total sugar of millet based yoghurts. Set 1 represents barnyard millet based yoghurts, with the probiotic yoghurt having the lower total sugar (10.99 g/100 g) than the non-probiotic yoghurt (11.55 g/100 g). The 2nd set consists of finger millet based yoghurts, with the probiotic yoghurt having lower total sugar than

non-probiotic yoghurt. The probiotic yoghurt had total sugar of 10.42 g/100 g and non-probiotic yoghurt had 11.32 g/100 g of total sugar. There was significant difference in the case of total sugar of probiotic and non-probiotic yoghurt, according to the t test.

The total sugar of the yoghurt decreased as the storage day increased. The total sugar on the 15th day of storage in probiotic yoghurt was 10.12 g/100 g and for non-probiotic it was 9.42 g/100 g in barnyard millet based yoghurt and the total sugar was 9.02 g/100 g for non-probiotic and 8.90 g/100 g for probiotic yoghurt in finger millet based yoghurt. The statistical analysis (DMRT) of the data showed a significant difference in the total sugar of both millet based yoghurts throughout the storage period.

Table 23. Total sugar of millet based yoghurts during storage (g/100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	11.55 [a]	10.83 [b]	9.90 [c]	9.42 [d]	0.103
	Probiotic Yoghurt	10.99 [a]	10.81 [b]	10.20 [c]	10.12 [c]	0.085
	t value	9.55*	2.61*	6.87*	3.86*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	11.32 [a]	10.83 [b]	9.60 [c]	9.02 [d]	0.187
	Probiotic Yoghurt	10.42 [a]	9.89 [b]	9.50 [b]	8.90 [c]	0.406
	t value	8.57*	5.78*	4.90*	3.22*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

Table 24. Crude fibre of millet based yoghurts during storage (g / 100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	0.60 [a]	0.60 [a]	0.40 [b]	0.40 [b]	0.012
	Probiotic Yoghurt	0.50 [a]	0.40 [b]	0.40 [b]	0.40 [b]	0.022
	t value	1.68 [NS]	2.08 [NS]	0.81 [NS]	0.81 [NS]	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	1 [a]	0.90 [a]	0.70 [b]	0.70 [b]	0.018
	Probiotic Yoghurt	0.90 [a]	0.80 [b]	0.80 [b]	0.70 [c]	0.020
	t value	1.55 [NS]	1.56 [NS]	0.70 [NS]	0.05 [NS]	

DMRT row wise comparison (significant at 5 % level)
NS: Non-significant

4.3.1.16. Crude fibre

The fibre content of yoghurts is listed in Table 24. Set 1 depicts the fibre content of yoghurts made from barnyard millet. Probiotic yoghurt (0.50 g/100 g) has less crude fibre than non-probiotic yoghurt (0.60 g/100 g). Set 2 depicts the fibre content of finger millet based yoghurt. Non-probiotic yoghurt had a fibre content of 1 g/100 g, while probiotic yoghurt had a fibre content of 0.90 g/100 g. According to the t test, there was no significant difference in the case of crude fibre of probiotic and non-probiotic yoghurt of barnyard millet and non-significant in the case of finger millet based yoghurts.

The crude fibre of both non-probiotic and probiotic yoghurt of barnyard millet based yoghurts was decreased to 0.40 g/100 g after 15 days of storage. In finger millet based yoghurt also both probiotic and non-probiotic yoghurt, the fibre content was decreased to 0.70 g/100 g after storage. The statistical analysis (DMRT) analysis of the data showed a significant difference in the crude fibre content of both millet based yoghurts throughout the storage period.

Table 25. Total ash of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	0.68 [a]	0.65 [b]	0.64 [c]	0.63 [c]	0.02
	Probiotic Yoghurt	0.69 [a]	0.66 [a]	0.65 [b]	0.64 [b]	0.022
	t value	2.10 [NS]	2.19 [NS]	1.64 [NS]	1.00 [NS]	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	0.77 [a]	0.75 [b]	0.74 [b]	0.74 [b]	0.013
	Probiotic Yoghurt	0.78 [a]	0.76 [b]	0.75 [c]	0.74 [d]	0.018
	t value	1.24 [NS]	1.73 [NS]	1.09 [NS]	0.29 [NS]	

DMRT row wise comparison (significant at 5 % level)
NS: Non-significant

4.3.1.17. Total ash

The total ash content of probiotic yoghurts is listed in Table 25. The ash content of non-probiotic barnyard yoghurt was 0.68 per cent, whereas probiotic yoghurt had 0.69 per cent. The ash content of non-probiotic finger millet yoghurt was 0.77 per cent, whereas probiotic yoghurt was 0.78 per cent. According to the t test, there was no significant difference in the case of ash of both probiotic and non-probiotic yoghurt.

The total ash of barnyard millet based yoghurt was decreased to 0.63 in non-probiotic yoghurt and 0.64 per cent in probiotic yoghurt after 15 days of storage. In the case of finger millet based yoghurt the total ash was decreased to 0.74 per cent in both probiotic and non-probiotic yoghurt after 15 days of storage. The statistical analysis (DMRT) of the data showed a significant difference in the total ash of both millet based yoghurts throughout the storage period.

4.3.2. Mineral content of the developed millet based yoghurts

The mineral content in the millet based yoghurts were studied. The minerals analysed were calcium, iron, potassium, phosphorus, zinc and magnesium.

Table 26. Calcium content of millet based yoghurts during storage (mg / 100g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	58.43 [a]	58.38 [b]	58.15 [c]	57.95 [d]	0.026
	Probiotic Yoghurt	59.36 [a]	59.15 [b]	58.95 [c]	58.86 [d]	0.03
	t value	2.70*	4.08*	4.16*	4.74*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	72.06 [a]	72 [a]	71.97 [b]	71.95 [c]	0.04
	Probiotic Yoghurt	73.18 [a]	73.09 [b]	72.96 [c]	72.85 [d]	0.025
	t value	5.41*	3.25*	5.05*	2.65*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.2.1. Calcium

Table 26. depicts the calcium of selected millet based non-probiotic yoghurt and probiotic yoghurt. Non-probiotic yoghurt had initial calcium of 58.43 mg/100 g and probiotic yoghurt had initial calcium of 59.36 mg/100 g for barnyard millet based yoghurt and 72.60 mg/100 g for non-probiotic yoghurt and 73.18 mg/100 g for probiotic

yoghurt in finger millet yoghurt. According to t test, there was significant difference in the case of the calcium content of probiotic and non-probiotic yoghurts.

All yoghurts showed a decreasing trend in calcium with increasing storage days. In the case of barnyard millet based yoghurt, it decreased to 57.95 mg/100 g for non-probiotic yoghurt and 58.86 mg/100 g for probiotic yoghurt and to 71.95 mg/100 g for non-probiotic yoghurt and 72.85 mg/100 g for probiotic yoghurt in finger millet based yoghurt at the end of storage. The calcium content of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 27. Iron content of millet based yoghurts during storage (mg / 100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	0.24 [a]	0.23 [a]	0.23 [a]	0.22 [b]	0.10
	Probiotic Yoghurt	0.25 [a]	0.25 [b]	0.24 [c]	0.23 [c]	0.11
	t value	1.09 [NS]	2.18 [NS]	0.93 [NS]	2.80 [NS]	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	0.23 [a]	0.23 [a]	0.22 [b]	0.22 [b]	NS
	Probiotic Yoghurt	0.24 [a]	0.24 [a]	0.23 [b]	0.23 [b]	NS
	t value	0.31 [NS]	0.31 [NS]	2.55 [NS]	2.55 [NS]	

DMRT row wise comparison (significant at 5 % level), NS: Non-significant

4.3.2.2. Iron

The iron content of various millet based yoghurts is shown in Table 27. Non-probiotic barnyard millet based yoghurt had an iron content of 0.24 mg/100 g, while probiotic yoghurt had an iron level of 0.25 mg/100 g and finger millet based yoghurt had an iron content of 0.23 mg/100 g for non-probiotic and 0.24 mg/100 g for probiotic yoghurt initially. According to t test, there was no significant difference in the case of the iron content of probiotic and non-probiotic yoghurts.

The iron content of the yoghurt decreased as the storage day increased. After 15 days of storage, the iron content of barnyard millet based probiotic yoghurt was 0.23 mg/100 g and 0.22 mg/100 g for non-probiotic yoghurt. In non-probiotic finger millet based yoghurt, the iron content was 0.22 mg/100 g and 0.23 mg/100 g or probiotic finger millet based yoghurt. The iron content of barnyard and finger millet yoghurts differed significantly, according to the DMRT study.

Table 28. Potassium content of millet based yoghurts during storage (mg / 100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	56.33 [a]	56.12 [b]	55.98 [c]	55.76 [d]	0.027
	Probiotic Yoghurt	57.85 [a]	57.63 [b]	57.35 [c]	57.15 [d]	0.025
	t value	5.14*	5.19*	4.49*	6.51*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	53.84 [a]	53.67 [b]	53.29 [c]	51.99 [d]	0.047
	Probiotic Yoghurt	54.67 [a]	54.56 [b]	54.32 [c]	53.98 [d]	0.026
	t value	4.82*	3.21*	5.204*	9.12*	

DMRT row wise comparison (significant at 5 % level), * Significant at 5 % level

4.3.2.3. Potassium

Table 28. shows the potassium content of millet based yoghurts. The initial potassium content of non-probiotic yoghurt was 56.33 mg/100 g and for probiotic yoghurt, it was 57.85 mg/100 g in the case of barnyard millet based yoghurt. The potassium content of non-probiotic yoghurt with finger millet was 53.84 mg/100 g a

54.67 mg/100 g in probiotic yoghurt initially. According to t test, there was significant difference in the case of potassium content of probiotic and non-probiotic yoghurts.

Potassium content decreased after storage, falling to 55.76 mg/100 g for non-probiotic and 57.15 mg/100 g for probiotic yoghurt in barnyard millet based yoghurt and 51.99 mg/100 g for non-probiotic and 53.98 mg/100 g for probiotic yoghurt in finger millet based yoghurt. The potassium content of probiotic yoghurts differed significantly according to statistical analysis (DMRT) throughout the storage period.

Table 29. Phosphorus content of millet based yoghurts during storage (mg / 100g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	51.58 [a]	51.32 [b]	50.96 [c]	50.85 [d]	0.023
	Probiotic Yoghurt	52.68 [a]	52.35 [b]	52.06 [c]	51.98 [d]	0.025
	t value	9.19*	5.16*	5.57*	5.34*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	48.84 [a]	48.65 [b]	48.03 [c]	47.86 [d]	0026
	Probiotic Yoghurt	49.65 [a]	49.38 [b]	49.21 [c]	48.95 [d]	NS
	t value	4.15*	5.29*	3.89*	5.80*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.2.4. Phosphorus

Table 29. shows the phosphorus content of millet based yoghurts. Set 1 lists the phosphorus content of yoghurts made from barnyard millet. The initial phosphorus content of barnyard millet based non-probiotic yoghurt was 51.58 mg/100 g and for probiotic yoghurt was 52.68 mg/100 g and for finger millet based non-probiotic

yoghurt, the phosphorus content was 48.84 mg/100 g and for probiotic yoghurt was 49.65 mg/100 g. According to t test, there was significant difference in the case of phosphorus content of probiotic and non-probiotic yoghurts.

The phosphorus progressively decreased during storage and reached 50.85 mg/100 g for non-probiotic yoghurt and 51.98 mg/100 g for probiotic yoghurt in barnyard millet based yoghurt and 47.86 mg/100 g for non-probiotic yoghurt and 48.95 mg/100 g for probiotic yoghurt in finger millet based yoghurt. The phosphorus content of probiotic yoghurts differed significantly according to statistical analysis (DMRT) throughout the storage period.

4.3.2.5. Zinc

The zinc content of millet based yoghurts is listed in Table 30. The initial zinc content of barnyard millet based non-probiotic yoghurt was 0.24 mg/100 g and for probiotic yoghurt was 0.25 mg/100 g and for finger millet based non-probiotic yoghurt the zinc content was 0.18 mg/100 g and for probiotic yoghurt was 0.19 mg/100 g. According to t test, there was no significant difference in the case of the zinc content of probiotic and non-probiotic yoghurts.

The zinc progressively decreased during storage and reached 0.22 mg/100 g for both non-probiotic yoghurt and probiotic yoghurt in barnyard millet based yoghurt and 0.16 mg/100 g for non-probiotic yoghurt and 0.17 mg/100 g for probiotic yoghurt in finger millet based yoghurt. The zinc content of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 30. Zinc content of millet based yoghurts during storage (mg / 100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	0.24 [a]	0.23 [b]	0.22 [c]	0.22 [c]	0.03
	Probiotic Yoghurt	0.25 [a]	0.24 [b]	0.23 [c]	0.22 [d]	0.031
	t value	0.70 [NS]	1.19 [NS]	0.70 [NS]	0.22 [NS]	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	0.18 [a]	0.17 [b]	0.17 [b]	0.16 [c]	0.02
	Probiotic Yoghurt	0.19 [a]	0.18 [b]	0.18 [b]	0.17 [c]	0.021
	t value	1.09 [NS]	1.10 [NS]	1.10 [NS]	1.09 [NS]	

DMRT row wise comparison (significant at 5 % level), NS: Non-significant

4.3.2.6. Magnesium

Table 31. depicts the magnesium content of selected millet based non-probiotic yoghurt and probiotic yoghurt. Non-probiotic yoghurt had initial magnesium of 5.58 mg/100 g and probiotic yoghurt had initial magnesium of 6.23 mg/100 g for barnyard millet based yoghurt and 8.85 mg/100 g for non-probiotic yoghurt and 9.98 mg/100 g for probiotic yoghurt in finger millet yoghurt. According to t test, there was significant difference in the case of magnesium content of probiotic and non-probiotic yoghurts.

All yoghurts showed a declining trend in magnesium with increasing storage days. In the case of barnyard millet based yoghurt, the magnesium content was decreased to 5.25 mg/100 g for non-probiotic yoghurt and 5.98 mg/100 g for probiotic yoghurt and to 8.54 mg/100 g for non-probiotic yoghurt and 9.62 mg/100 g for probiotic yoghurt in finger millet based yoghurt at the end of storage. The magnesium content of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 31. Magnesium content of millet based yoghurts during storage (mg / 100 g)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	5.58 [a]	5.42 [b]	5.39 [c]	5.25 [d]	0.025
	Probiotic Yoghurt	6.23 [a]	6.15 [b]	6.05 [c]	5.98 [d]	0.02
	t value	3.66*	3.79*	3.65*	3.26*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	8.85 [a]	8.76 [b]	8.69 [c]	8.54 [d]	0.023
	Probiotic Yoghurt	9.98 [a]	9.86 [b]	9.75 [c]	9.62 [d]	0.021
	t value	5.49*	5.30*	5.11*	5.47*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.3.3. Health studies

4.4.3.1. *In vitro* mineral availability the developed millet based yoghurts

The *in vitro* mineral availability of the millet based yoghurts are studied. The minerals are calcium, iron, potassium, phosphorus, zinc and magnesium.

4.4.3.1.1. Calcium

Table 32. depicts the *in vitro* availability of calcium of selected millet based probiotic and non-probiotic yoghurt. Non-probiotic yoghurt had an initial *in vitro* availability of

calcium of 77.73 per cent and probiotic yoghurt had an initial *in vitro* availability of calcium of 78.59 per cent in barnyard based yoghurt and 72.19 per cent for non-probiotic yoghurt and 72.67 per cent for probiotic yoghurt in finger millet yoghurt. According to t test, there was significant difference in the case of *in vitro* availability of calcium content of probiotic and non-probiotic yoghurts.

All yoghurts showed a decreasing trend in *in vitro* availability of calcium with increasing storage days. In the case of barnyard millet based yoghurt, it decreased to 77.13 per cent for non-probiotic yoghurt and 78.07 per cent for probiotic yoghurt and to 71.33 per cent for non-probiotic yoghurt and 72.54 per cent for probiotic yoghurt in finger millet based yoghurt at the end of storage. The *in vitro* availability of calcium of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 32. *In vitro* available calcium content of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	77.73 [a]	77.12 [b]	77.14 [b]	77.13 [c]	0.02
	Probiotic Yoghurt	78.59 [a]	78.25 [b]	78.10 [c]	78.07 [c]	0.021
	t value	2.73*	5.47*	4.83*	4.81*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	72.19 [a]	72.18 [a]	71.77 [b]	71.33 [c]	0.02
	Probiotic Yoghurt	72.67 [a]	72.57 [b]	72.56 [b]	72.54 [c]	0.321
	t value	2.75*	2.66*	4.29*	5.66*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

Table 33. *In vitro* available iron content of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	69.82 [a]	68.31 [b]	67.51 [c]	67.08 [d]	0.022
	Probiotic Yoghurt	70.02 [a]	69.35 [b]	68.98 [c]	68.51 [d]	0.023
	t value	10.31*	11.95*	9.01*	8.08*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	75.96 [a]	75.86 [b]	74.36 [c]	74.35 [c]	0.027
	Probiotic Yoghurt	76.98 [a]	76.95 [b]	75.50 [c]	75.49 [c]	0.022
	t value	4.93*	5.37*	3.53*	3.49*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.4.3.1.2. Iron

The *in vitro* availability of iron content of various millet based yoghurts is shown in Table 33. Non-probiotic barnyard millet based yoghurt had an *in vitro* availability of iron content of 69.82 per cent, while probiotic yoghurt had an *in vitro* availability of iron level of 70.02 per cent and finger millet based yoghurt had an *in vitro* availability of iron content of 75.96 per cent for non-probiotic and 76.98 per cent for probiotic yoghurt. According to t test, there was significant difference in the case of *in vitro* availability of iron content of probiotic and non-probiotic yoghurts.

The *in vitro* availability of iron content of the yoghurt decreased as the storage day increased. When the *in vitro* availability of iron content of 15 days stored barnyard millet based probiotic yoghurt was 68.51 per cent and 67.08 per cent for non-probiotic yoghurt, for non-probiotic finger millet based yoghurt it was 74.35 per cent and 75.50 per cent for probiotic finger millet based yoghurt. The *in vitro* availability of iron content of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 34. *In vitro* available potassium content of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	55.81 [a]	55.41 [b]	55.40 [c]	55.03 [d]	0.021
	Probiotic Yoghurt	56.28 [a]	55.96 [b]	55.90 [c]	55.73 [d]	0.024
	t value	2.81*	3.12*	3.08*	3.87*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	55.45 [a]	54.32 [b]	54.32 [b]	54.07 [c]	0.027
	Probiotic Yoghurt	56.98 [a]	55.46 [b]	55.19 [c]	55.19 [c]	0.094
	t value	3.87*	5.67*	4.61*	5.46*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.4.3.1.3. Potassium

Table 34. shows the *in vitro* availability of potassium content of millet based yoghurts. Initial *in vitro* availability of potassium was 55.81 per cent in non-probiotic yoghurt and 56.28 per cent in probiotic yoghurt for barnyard millet based yoghurt and 55.45 per cent in non-probiotic yoghurt and 56.98 per cent in probiotic yoghurt for finger millet based yoghurt initially. According to t test, there was significant difference

in the case of *in vitro* availability of potassium content of probiotic and non-probiotic yoghurts.

In vitro availability of potassium content decreased after storage, to 55.03 per cent for non-probiotic and 55.73 per cent for probiotic yoghurt in barnyard millet based yoghurt and 54.07 per cent for non-probiotic and 55.19 per cent for probiotic yoghurt in finger millet based yoghurt. The *in vitro* availability of potassium content of probiotic yoghurts differed significantly according to statistical analysis (DMRT).

Table 35. *In vitro* available phosphorus content of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	70.54 [a]	70.50 [b]	70.50 [b]	70.41 [c]	0.023
	Probiotic Yoghurt	71.92 [a]	71.87 [b]	71.43 [c]	71.03 [d]	0.025
	t value	6.48*	6.50*	4.71*	3.48*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	69.35 [a]	69.00 [a]	68.98 [b]	68.82 [b]	0.029
	Probiotic Yoghurt	69.87 [a]	69.74 [b]	69.72 [b]	69.43 [c]	0.020
	t value	2.94*	3.85*	2.09*	3.13*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.4.3.1.4. Phosphorus

Table 35. depicts the *in vitro* availability of phosphorus content of millet based yoghurts. Set 1 lists the *in vitro* availability of phosphorus content of yoghurts made from barnyard millet. The initial *in vitro* availability of phosphorus content of barnyard millet based non-probiotic yoghurt was 70.54 per cent and for probiotic yoghurt was

71.92 per cent and for finger millet based non-probiotic yoghurt the *in vitro* availability of phosphorus content was 69.35 per cent and for probiotic yoghurt was 69.87 per cent. According to t test, there was significant difference in the case of *in vitro* availability of phosphorus content of probiotic and non-probiotic yoghurts.

The *in vitro* availability of phosphorus decreased during storage and reached 70.41 per cent for non-probiotic yoghurt and 71.03 per cent for probiotic yoghurt in barnyard millet based yoghurt and 68.82 per cent for non-probiotic yoghurt and 69.43 per cent for probiotic yoghurt in finger millet based yoghurt. The *in vitro* availability of phosphorus content of probiotic yoghurts differed significantly according to statistical analysis (DMRT).

4.4.3.1.5. Zinc

The *in vitro* availability of zinc content of millet based yoghurts is listed in Table 36. The initial *in vitro* availability of zinc content of barnyard millet based non-probiotic yoghurt was 77.25 per cent and for probiotic yoghurt was 77.29 per cent and for finger millet based non-probiotic yoghurt the *in vitro* availability of zinc content was 61.11 per cent and for probiotic yoghurt was 63.16 per cent. According to t test, there was significant difference in the case of *in vitro* availability of magnesium content of probiotic and non-probiotic yoghurts.

The *in vitro* availability of zinc decreased during storage and reached 72.73 per cent for non-probiotic yoghurt and 73.91 per cent for probiotic yoghurt in barnyard millet based yoghurt and 52.94 per cent for non-probiotic yoghurt and 55.25 per cent for probiotic yoghurt in finger millet based yoghurt. The *in vitro* availability of zinc content of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 36. ***In vitro*** **available zinc content of millet based yoghurts during storage (%)**

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	77.25 [a]	75.03 [b]	73.91 [c]	72.73 [d]	0.022
	Probiotic Yoghurt	77.29 [a]	76.01 [b]	75.02 [c]	73.91 [d]	0.027
	t value	5.50*	5.16*	5.36*	5.80*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	61.11 [a]	58.82 [b]	56.25 [c]	52.25 [d]	0.020
	Probiotic Yoghurt	63.16 [a]	61.11 [b]	58.82 [c]	55.25 [d]	0.022
	t value	9.38*	10.23*	11.28*	13.16*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.4.3.1.6. Magnesium

Table 37. depicts the *in vitro* availability of magnesium of selected millet based probiotic and non-probiotic yoghurt. Non-probiotic yoghurt had an initial *in vitro* availability of magnesium of 65.31 per cent and probiotic yoghurt had an initial *in vitro* availability of magnesium of 66.32 per cent in barnyard based yoghurt and 74.82 per cent for non-probiotic yoghurt and 79.95 per cent for probiotic yoghurt in finger millet yoghurt. According to t test, there was significant difference in the case of *in vitro* availability of magnesium content of probiotic and non-probiotic yoghurts.

All yoghurts showed a decreasing trend in *in vitro* availability of magnesium with increasing storage days. In the case of barnyard millet based yoghurt, it decreased to 64.16 per cent for non-probiotic yoghurt and 64.22 per cent for probiotic yoghurt and to 67.90 per cent for non-probiotic yoghurt and 78.27 per cent for probiotic yoghurt in finger millet based yoghurt at the end of storage. The *in vitro* availability of magnesium of barnyard and finger millet yoghurts differed significantly, according to statistical analysis (DMRT).

Table 37. *In vitro* available magnesium content of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	65.31 [a]	64.95 [b]	64.75 [c]	64.16 [d]	0.022
	Probiotic Yoghurt	66.32 [a]	65.35 [b]	64.31 [c]	64.22 [d]	0.028
	t value	5.04*	2.46*	1.39*	7.00*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	74.82 [a]	74.31 [b]	74.22 [c]	67.90 [d]	0.025
	Probiotic Yoghurt	79.95 [a]	79.48 [b]	78.76 [c]	78.27 [d]	0.022
	t value	15.05*	15.91*	14.04*	20.68*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.4.3.2. Antioxidant activity

The total antioxidant activity of millet based yoghurts is represented in Table 38. Set 1 includes probiotic and non-probiotic yoghurt made with barnyard millet. The probiotic yoghurt (12.99 %) had higher total antioxidant activity, whereas the non-probiotic yoghurt (11.83 %) had the lowest. In the second set, non-probiotic and probiotic yoghurt made with finger millet is discussed. Probiotic yoghurt (11.75 %) had higher total antioxidant activity, whereas non-probiotic yoghurt (10.81 %) had the lowest. According to the t test, there was significant difference in the case of antioxidant activity of probiotic and non-probiotic yoghurt.

The total antioxidant activity undergoes a decrease during storage in both millet (barnyard and finger millet based yoghurt). The antioxidant activity was decreased to 9.12 per cent for non-probiotic yoghurt and 9.31 per cent for probiotic yoghurt in barnyard millet based yoghurt and for finger millet yoghurt the antioxidant activity was decreased to 7.08 per cent in non-probiotic yoghurt and 8.16 per cent in probiotic yoghurt after storage. The statistical analysis (DMRT) of the data showed a significant difference in antioxidant activity of both millet based yoghurts throughout the storage period.

Table 38. Antioxidant activity of millet based yoghurts during storage (%)

Treatments		Initial	5 days	10 days	15 days	C D Value
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	11.83 [a]	10.32 [b]	9.81 [c]	9.12 [d]	0.029
	Probiotic Yoghurt	12.99 [a]	11.59 [ab]	10.45 [b]	9.31 [c]	0.034
	t value	5.53*	6.12*	7.31*	7.35*	
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	10.81 [a]	9.42 [b]	8.96 [c]	7.08 [d]	0.031
	Probiotic Yoghurt	11.75 [a]	10.37 [b]	9.58 [c]	8.16 [d]	0.023
	t value	4.75*	5.03*	3.45*	5.50*	

DMRT row wise comparison (significant at 5 % level)
* Significant at 5 % level

4.4.4. Organoleptic evaluation

Table 39. shows the organoleptic scores for millet based yoghurts. The panel of judges preferred barnyard millet based probiotic yoghurts over non-probiotic yoghurts, as evidenced by their total mean scores on each criterion, with an initial total score of 8.69. The overall acceptability tends to drop after the 5th, 10th and 15th days of storage, with total mean score of 8.62, 8.58 and 8.54, respectively. The barnyard millet based probiotic yoghurt had a higher initial total score than the non-probiotic yoghurt. Initially, the total mean score of non-probiotic barnyard millet based yoghurt was 8.65, whereas the 5th, 10th and 15th day's total scores were 8.55, 8.39 and 8.33.

As shown by their total mean scores in each category, the panellists chose finger millet based probiotic yoghurts over non-probiotic yoghurts, with an initial total score of 8.56. After the 5th, 10th and 15th days of storage, the overall acceptability decreased, with total scores of 8.49, 8.43 and 8.37, respectively. The overall score of non-probiotic finger millet based yoghurt was initially 8.61, however, the total scores on the 5th, 10th and 15th days were 8.50, 8.45 and 8.36, respectively.

4.4.5. Population of *L. acidophilus*

The viability of *L. acidophilus* was accessed initially and on the 5th, 10th and 15th day of storage. For this, 10^9 dilutions of millet based yoghurts were serially dilutedand plated on MRS agar. Table 40. summarises the findings, where the *L. acidophilus* count is expressed in log cfu/ml.

The initial count of *L. acidophilus* was 11.15 log cfu/ml for barnyard millet based probiotic yoghurt and 11.12 log cfu/ml for finger millet based yoghurt. The viable count decreased on storage to 11.11 log cfu/ml for barnyard millet based yoghurt and 11.07 log cfu/ml for finger millet based yoghurt.

Table 39. Mean scores for organoleptic evaluation scores of millet based yoghurts during storage

Treatments			Initial	5 days	10 days	15 days
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	Appearance	8.67	8.53	7.75	7.61
		Colour	8.76	8.65	8.58	8.53
		Flavour	8.60	8.48	8.45	8.38
		Taste	8.60	8.51	8.48	8.43
		Texture	8.62	8.58	8.53	8.49
		Overall acceptability	8.69	8.58	8.55	8.52
		Total score	8.65	8.55	8.39	8.33
	Probiotic yoghurt	Appearance	8.70	8.65	8.63	8.58
		Colour	8.79	8.73	8.69	8.65
		Flavour	8.65	8.53	8.51	8.49
		Taste	8.64	8.51	8.49	8.45
		Texture	8.66	8.61	8.53	8.48
		Overall Acceptability	8.72	8.68	8.65	8.61
		Total score	8.69	8.62	8.58	8.54

Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	Appearance	8.42	8.35	8.22	8.11
		Colour	8.47	8.40	8.36	8.31
		Flavour	8.82	8.73	8.69	8.61
		Taste	8.51	8.41	8.38	8.36
		Texture	8.64	8.53	8.49	8.40
		Overall acceptability	8.53	8.50	8.49	8.43
		Total score	8.56	8.49	8.43	8.37
	Probiotic yoghurt	Appearance	8.48	8.38	8.35	8.30
		Colour	8.52	8.45	8.38	8.31
		Flavour	8.83	8.61	8.53	8.41
		Taste	8.56	8.43	8.35	8.21
		Texture	8.69	8.62	8.59	8.53
		Overall acceptability	8.58	8.51	8.48	8.43
		Total score	8.61	8.50	8.45	8.36

Table 40. Viability of *L acidophilus* count in the millet based yoghurt during storage (×10^9 cfu/ml)

Treatments		Initial	5 days	10 days	15 days
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	ND	ND	ND	ND
	Probiotic Yoghurt	142 (11.15)	140 (11.15)	132 (11.12)	130 (11.11)
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic Yoghurt	ND	ND	ND	ND
	Probiotic Yoghurt	131 (11.12)	128 (11.11)	122 (11.09)	118 (11.07)

ND: Not detected
All values are means of three independent enumerations
Figures in parenthesis indicates log cfu/ml

4.4.6. Enumeration of total micro flora

4.4.6.1. Enumeration of bacteria

In the nutrient agar (NA) medium, the total bacterial count of the developed probiotic and non-probiotic yoghurt was counted and the findings are shown in Table 41. The bacterial count in millet based yoghurts was found to be higher than in the non-probiotic yoghurt. The bacterial count for barnyard millet based yoghurt was 6.54 log cfu/ml for non-probiotic and 7.18 log cfu/ml for probiotic

Table 41. Total bacterial count of millet based yoghurt during storage ($\times 10^5$ cfu/ml)

Treatments		Initial	5 days	10 days	15 days
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic Yoghurt	35 (6.54)	38 (6.58)	40 (6.60)	41 (6.61)
	Probiotic yoghurt	150 (7.18)	148 (7.17)	140 (7.15)	137 (7.14)
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	30 (6.48)	34 (6.53)	36 (6.56)	40 (6.60)
	Probiotic Yoghurt	145 (7.16)	137 (7.13)	128 (7.11)	125 (7.10)

All values are means of three independent enumerations
Figures in parenthesis indicates log cfu/ml

yoghurt. The growth was increased on storage up to 6.61 log cfu /ml for non-probiotic yoghurt and decreased to 7.14 log cfu/ml for probiotic yoghurt.

In the case of finger millet based yoghurt similar fashion was seen. The initial count was 6.48 log cfu/ml for non-probiotic and 7.16 log cfu/ml for probiotic yoghurt. It was again increased to 6.60 log cfu/ml in non-probiotic and decreased to 7.10 log cfu/ml in probiotic yoghurt.

Table 42. Total fungal count of millet based yoghurt during storage (×10^2 cfu/ml)

Treatments		Initial	5 days	10 days	15 days
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	ND	ND	ND	1
	Probiotic yoghurt	ND	ND	ND	1
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	ND	ND	ND	1
	Probiotic yoghurt	ND	ND	ND	1

ND not detected

4.4.6.2. Enumeration of fungi

Throughout the storage period, no fungal colonies were found in the millet based yoghurts except on the 15th day of storage it was 1 cfu/ml. This is depicted in Table 42.

4.4.6.3. Enumeration of yeast

During the storage period, the millet based yoghurts were tested for yeast at 5 day intervals and the findings are listed in Table 43. Throughout the storage period, no yeast counts were found in any of the yoghurts.

Table 43. Total yeast count of millet based yoghurt during storage ($\times 10^2$ cfu/ml)

Treatments		Initial	5 days	10 days	15 days
Set 1 Barnyard millet based yoghurt (T_4)	Non-probiotic yoghurt	ND	ND	ND	ND
	Probiotic yoghurt	ND	ND	ND	ND
Set 2 Finger millet based yoghurt (T_9)	Non-probiotic yoghurt	ND	ND	ND	ND
	Probiotic yoghurt	ND	ND	ND	ND

ND: not detected

4.4.1. Preparation of synbiotic yoghurt

The selected probiotic yoghurt from each set, both barnyard millet and finger millet were modified to synbiotic yoghurt. The prebiotics used were inulin and polydextrose. T_0, the selected yoghurts (both barnyard and finger millet yoghurt) inulin and polydextrose was added at different levels (1%, 2% and 3%). The best one from each set was selected for further studies.

4.4.1.1. Preparation of synbiotic barnyard millet based yoghurt with inulin

The mean scores and mean rank scores obtained for several qualitative parameters of synbiotic yoghurt made from barnyard millet when compared to probiotic yoghurt are detailed in Table 44.

The mean scores for the appearance of barnyard millet based synbiotic yoghurt ranged from 8.49 to 8.75 and 8.44 to 8.83 for colour. For appearance, the mean rank score ranged from 3.20 to 3.63 and for colour, it ranged from 3.30 to 3.67. The treatment T_3 (3 % inulin added synbiotic yoghurt) yielded the highest mean score among the several combinations assessed for the preparation of inulin added synbiotic yoghurt. The mean score for appearance and colour was found to be 8.70 and 8.79 respectively for control yoghurt (probiotic yoghurt without inulin).

Treatment T3 had the highest mean score for flavour (8.81) and taste (8.84) among the three treatments used to make barnyard millet based inulin added yoghurt, followed by T_2. For the flavour and taste of inulin added barnyard millet based yoghurt, the mean rank score ranged from 3.40 to 3.87 and 3.40 to 3.86, respectively.

The texture of inulin added barnyard millet based yoghurt (T_3) made with 3 % inulin obtained the highest mean and mean rank scores of 8.82 and 3.97, respectively. The texture of barnyard millet based probiotic yoghurt (T_0) had an average score of 8.66, with a mean rank score of 3.77.

The highest mean and rank score (8.85 and 3.93) for overall acceptability among the three treatments of barnyard millet based yoghurt was for treatment T_3. However, this was shown to be higher than the control's mean and mean scores (8.72 and 3.84). T_1, which was made with 1 per cent inulin added barnyard millet based yoghurt had the lowest score of 8.51.

The highest total mean score among the three treatments was ranked for T_3 with a score of 8.82 followed by T_2 and T_1. The total mean score for the control was 8.69 which was less than T_3 yoghurt.

Significant agreement among the judges was seen in the evaluation of several sensory attributes of barnyard millet based yoghurt as measured by Kendall's (W) value.

4.4.1.2. Preparation of synbiotic finger millet based yoghurt with inulin

In comparison to finger millet based probiotic yoghurt, Table 45. represents the mean scores and mean rank scores for several sensory parameters of inulin added finger millet synbiotic yoghurt.

For finger millet based yoghurt, the mean score for appearance varied from 8.21 to 8.63. In terms of colour, it ranged from 8.38 to 8.62. The mean rank score for appearance varied from 3.07 to 3.56, while the mean rank score for colour was 3.60 to 3.83. Among the several combinations examined for inulin added finger millet based synbiotic yoghurt, the 3 per cent inulin added obtained the highest mean score (T_6).

Among the three treatments used to produce finger millet based synbiotic yoghurt, T_6 got the highest mean scores for flavour (8.86) and taste (8.68), followed by T_5 and T_4. The mean rank score for the flavour and taste of finger millet based synbiotic yoghurt varied from 3.33 to 4.02 and 3.47 to 3.77, respectively. Probiotic yoghurt scored less than finger millet based synbiotic yoghurt in terms of taste (8.56) and flavour (8.83).

With mean and rank scores of 8.72 and 3.85, the texture of finger millet based yoghurt (T_6) made with 3 per cent inulin added synbiotic yoghurt received the highest scores. The mean texture score for probiotic yoghurt (T_0) was 8.69, with a mean rank score of 3.79.

In the three treatments of finger millet based synbiotic yoghurt, T_6 had the highest mean and rank score (8.60 and 3.83) for overall acceptability. However, this was shown to be lower than the mean and mean scores of the probiotic yoghurt (8.58 and 3.60).

The highest total mean score among the three treatments was T_6 with a score of 8.69 followed by T_5 and T_4. The total mean score for the probiotic yoghurt was 8.61 which was less than T_6 yoghurt.

Table 44. Mean scores for organoleptic evaluation of inulin added barnyard millet based yoghurts

Treatments	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability	Total mean score
Control (Probiotic barnyard millet yoghurt)	8.70 (3.37)	8.79 (3.37)	8.65 (3.57)	8.64 (3.67)	8.66 (3.77)	8.72 (3.84)	8.69
T_1	8.49 (3.20)	8.44 (3.30)	8.44 (3.40)	8.53 (3.40)	8.35 (3.01)	8.51 (3.27)	8.46
T_2	8.51 (3.27)	8.80 (3.42)	8.53 (3.47)	8.68 (3.70)	8.80 (3.81)	8.65 (3.33)	8.66
T_3	8.75 (3.63)	8.83 (3.67)	8.81 (3.87)	8.84 (3.86)	8.82 (3.97)	8.85 (3.93)	8.82
Kendall's W Value	0.924**	0.728**	0.774**	0.982**	0.955**	0.923**	

Figures in parenthesis indicate mean rank scores
*Significant at 1 % level
**Significant at 5 % level

T_0 – 50 % M + 50 % BMS; T_1 – 50 % M + 50 % BMS + 1 % I; T_2 –50 % M + 50 % BMS + 2 % I; T_3 – 50 % M + 50 % BMS + 3 % I

Table 45. Mean scores for organoleptic evaluation of inulin added finger millet based yoghurts

Treatments	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability	Total score
Control (Probiotic finger millet yoghurt)	8.48 (3.23)	8.52 (3.77)	8.83 (3.97)	8.56 (3.60)	8.69 (3.79)	8.58 (3.60)	8.61
T_4	8.21 (3.07)	8.38 (3.60)	8.63 (3.33)	8.34 (3.47)	8.57 (3.6)	8.53 (3.53)	8.44
T_5	8.33 (3.10)	8.42 (3.63)	8.78 (3.86)	8.44 (3.57)	8.61 (3.77)	8.56 (3.57)	8.52
T_6	8.63 (3.56)	8.62 (3.83)	8.86 (4.02)	8.68 (3.77)	8.72 (3.85)	8.60 (3.83)	8.69
Kendall's W Value	0.651**	0.733**	0.909**	0.852**	0.836**	0.728**	

Figures in parenthesis indicate mean rank scores
*Significant at 1 % level
**Significant at 5 % level

T_0 – 50 % M + 50 % FMS; T_1 – 50 % M + 50 % FMS + 1 % I; T_2 –50 % M + 50 % FMS + 2 % I; T_3 – 50 % M + 50 % FMS + 3 % I

The several attributes of millet based fermented dairy products made from finger millet flour, as evaluated by Kendall's (W) value, revealed significant agreement among the judges.

4.4.1.3. Preparation of synbiotic barnyard millet based yoghurt with polydextrose

The mean scores and mean rank scores obtained for several sensory parameters of synbiotic yoghurt made from barnyard millet when compared to its probiotic yoghurt are detailed in Table 46.

The mean scores for the appearance of barnyard millet based synbiotic yoghurt ranged from 8.55 to 8.75 and 8.61 to 8.83 for colour. For appearance, the mean rank score ranged from 3.23 to 3.50 and for colour, it ranged from 3.53 to 3.83. The treatment T_9 (3 % polydextrose added synbiotic yoghurt) yielded the highest mean score among the several combinations assessed for the preparation of polydextrose added synbiotic yoghurt. The mean score for appearance and colour was found to be 8.70 and 8.79 respectively for its probiotic yoghurt (T_0).

Treatment T_9 had the highest mean score for flavour (8.73) and taste (8.68) among the three treatments used to make barnyard millet based polydextrose added yoghurt, followed by T_8 and T_7. For the flavour and taste of polydextrose added barnyard millet based yoghurt, the mean rank score ranged from 3.43 to 3.60 and 2.87 to 3.74, respectively.

The texture of polydextrose added barnyard millet based yoghurt (T_9) made with 3 % polydextrose obtained the highest mean and mean rank scores of 8.71 and 3.53, respectively. The texture of barnyard millet based probiotic yoghurt (T_0) had an average score of 8.66, with a mean rank score of 3.13.

The highest mean and rank score (8.75 and 3.84) for overall acceptability across the three treatments of barnyard millet based yoghurt was for treatment T_9. However, this was shown to be higher than the probiotic yoghurt's mean and mean scores (8.72 and 3.47). T_7, which was made with 1 % polydextrose added barnyard millet based yoghurt had the lowest score of 8.31.

Table 46. Mean scores for organoleptic evaluation of polydextrose added barnyard millet based yoghurts

Treatments	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability	Total mean score
Control (Probiotic barnyard millet yoghurt)	8.70 (3.37)	8.79 (3.61)	8.65 (3.57)	8.64 (3.67)	8.66 (3.13)	8.72 (3.47)	8.69
T_7	8.55 (3.23)	8.61 (3.53)	8.42 (3.43)	8.44 (2.87)	8.56 (2.67)	8.31 (2.87)	8.48
T_8	8.62 (3.27)	8.73 (3.57)	8.64 (3.55)	8.51 (3.30)	8.63 (2.97)	8.58 (3.53)	8.62
T_9	8.75 (3.50)	8.83 (3.83)	8.73 (3.60)	8.68 (3.74)	8.71 (3.53)	8.75 (3.84)	8.74
Kendall's W value	0.564**	0.188**	0.552**	0.437**	0.622**	0.671**	

Figures in parenthesis indicate mean rank scores
*Significant at 1 % level
**Significant at 5 % level

T_0 – 50 % M + 50 % BMS; T_1 – 50 % M + 50 % BMS + 1 % P; T_2 –50 % M + 50 % BMS + 2 % P; T_3 – 50 % M + 50 % BMS + 3 % P

The highest total mean score among the three treatments was ranked T_9 with a score of 8.74 followed by T_8 and T_7. The total mean score for the control was 8.69 which was less than T_9 yoghurt.

Significant agreement among the judges was seen in the evaluation of several sensory attributes of barnyard millet based yoghurt as measured by Kendall's (W) value.

4.4.1.4. Preparation of synbiotic finger millet based yoghurt with polydextrose

In comparison to finger millet based probiotic yoghurt, Table 47. represents the mean scores and mean rank scores for several qualitative parameters of polydextrose added finger millet synbiotic yoghurt.

For finger millet based yoghurt, the mean score for appearance varied from 8.45 to 8.56. In terms of colour, it ranged from 8.38 to 8.58. The mean rank score for appearance varied from 3.57 to 3.93, while the mean rank score for colour was 3.56 to 4.07. Among the several combinations examined for polydextrose added finger millet based synbiotic yoghurt, the 3 per cent polydextrose added obtained the highest mean score (T_{12}). When compared to the probiotic yoghurt, the mean score for appearance and colour was determined to be high (8.48 and 8.52).

Among the three treatments used to produce finger millet based synbiotic yoghurt, T_{12} got the highest mean scores for flavour (8.86) and taste (8.59), followed by T_{11} and T_{10}. The mean rank score for the flavour and taste of finger millet based synbiotic yoghurt varied from 3.63 to 4.23 and 3.63 to 4.05, respectively. Probiotic yoghurt scored less than finger millet based synbiotic yoghurt in terms of taste (8.56) and lower in terms of flavour (8.83).

With mean and rank scores of 8.76 and 4.03, the texture of finger millet based yoghurt (T_{12}) made with 3 per cent polydextrose added synbiotic yoghurt received the highest mean and rank scores. The mean texture score for probiotic yoghurt (T_0) was 8.69, with a mean rank score of 3.79.

Among the three treatments of finger millet based synbiotic yoghurt, T_{12} had the highest mean and rank score (8.63 and 4.07) for overall acceptability. However, this was shown to be higher than mean and mean scores of the control (8.58 and 3.83). The lowest score was 8.48 for T_{10}, which was 1% polydextrose added synbiotic yoghurt.

Table 47. Mean scores for organoleptic evaluation of polydextrose added finger millet based yoghurts

Treatments	Appearance	Colour	Flavour	Taste	Texture	Overall acceptability	Total score
Control (Probiotic finger millet yoghurt)	8.48 (3.70)	8.52 (3.77)	8.83 (3.97)	8.56 (3.69)	8.69 (3.79)	8.58 (3.83)	8.61
T_{10}	8.45 (3.57)	8.38 (3.56)	8.40 (3.63)	8.45 (3.63)	8.56 (3.56)	8.48 (3.63)	8.45
T_{11}	8.52 (3.83)	8.48 (3.64)	8.73 (3.83)	8.58 (3.70)	8.72 (3.85)	8.55 (3.74)	8.64
T_{12}	8.56 (3.93)	8.58 (4.07)	8.86 (4.23)	8.59 (4.05)	8.76 (4.03)	8.63 (4.07)	8.66
Kendall's W Value	0.227**	0.118**	0.098**	0.225**	0.091**	0.09**	

Figures in parenthesis indicate mean rank scores
*Significant at 1 % level
**Significant at 5 % level

T_0 – 50 % M + 50 % FMS; T_1 – 50 % M + 50 % FMS + 1 % P; T_2 –50 % M + 50 % FMS + 2 % P; T_3 – 50 % M + 50 % FMS + 3 % P

The highest total mean score among the three treatments was T_{12} with a score of 8.66 followed by T_{11} and T_{10}. The total mean score for the probiotic yoghurt was 8.61 which was smaller than T_{12} yoghurt.

The examination of several attributes of millet based fermented dairy products made from millet flour, as evaluated by Kendall's (W) value, revealed significant agreement among the judges.

4.3.1. Selection of the most acceptable treatment of synbiotic yoghurts

The selected millet (both barnyard and finger millet) based probiotic yoghurts were enriched with prebiotics, inulin and polydextrose in various proportions as explained in section 4.4.1 to make synbiotic yoghurt. Probiotic yoghurt of each millet was served as control. The selected synbiotic yoghurts are detailed in Table 25. Treatment T_3, T_6, T_9 and T_{12} which had maximum mean score and mean rank score for appearance, colour, flavour, taste, texture and overall acceptability were chosen for further studies.

Table 48. Selected combinations of synbiotic yoghurts

Set	Combination	Treatment
1	50 % M + 50 % BM+ 3 % I	T_3
2	50 % M + 50 % FM+ 3 % I	T_6
3	50 % M + 50 % BM + 3 % P	T_9
4	50 % M + 50 % FM + 3 % P	T_{12}

M - Milk, BM - Barnyard millet slurry, FM - Finger millet slurry, I - Inulin, P - Polydextrose

Inulin added barnyard millet yoghurt

Polydextrose added barnyard millet yoghurt

Inulin added finger millet yoghurt

Polydextrose added finger millet yoghurt

Plate 8. Millet based synbiotic yoghurts

4.5.1. Physico-chemical composition of millet based yoghurts

4.5.1.1. Moisture

The moisture content of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 49 and 50. The moisture content of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The moisture content of barnyard millet based probiotic yoghurt was 87.03 per cent, inulin added barnyard millet based synbiotic yoghurt had moisture content of 87.67 per cent and polydextrose added barnyard millet based synbiotic yoghurt had moisture content of 87. 27 per cent. A significant difference was observed in the moisture content of the yoghurts.

The moisture content of finger millet based probiotic yoghurt was 87.42 per cent, inulin added finger millet based synbiotic yoghurt had moisture content of 88.54 per cent and polydextrose added finger millet based synbiotic yoghurt had moisture content of 88.53 per cent. A significant difference was observed in the moisture content of the yoghurts.

4.5.1.2. Acidity

Tables 49 and 50 list the acidity of the synbiotic yoghurts with additional inulin (barnyard millet and finger millet) and polydextrose (barnyard and finger millet). Inulin and polydextrose based synbiotic yoghurt both had higher acidity than probiotic yoghurt.

Barnyard millet based probiotic yoghurt had an acidity of 0.81 per cent, inulin added synbiotic yoghurt had an acidity of 0.89 per cent and polydextrose added synbiotic yoghurt had an acidity of 0.86 per cent. A significant difference was observed in the acidity of the yoghurts.

Finger millet based probiotic yoghurt had an acidity of 0.78 per cent, finger millet based synbiotic yoghurt with inulin had an acidity of 0.83 per cent and finger millet based synbiotic yoghurt with polydextrose had an acidity of 0.84 per cent. A significant difference was observed in the acidity of the yoghurts.

4.5.1.3. pH

The pH of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 49 and 50 (barnyard and finger millet). Probiotic yoghurt showed lower pH than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had a pH of 3.88, synbiotic yoghurt with inulin added had pH of 3.76 and synbiotic yoghurt with polydextrose added had a pH of 3.74. The results were observed on par according to DMRT study.

The pH of finger millet based probiotic yoghurt was 3.82, that of finger millet based synbiotic yoghurt with inulin was 3.76 and that of finger millet based synbiotic yoghurt with polydextrose was 3.75. A significant difference was observed in the pH of the yoghurts.

4.5.1.4. Water holding capacity

The water holding capacity of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 49 and 50. The water holding capacity of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The water holding capacity of barnyard millet based probiotic yoghurt was 79.75 per cent, inulin added barnyard millet based synbiotic yoghurt had water holding capacity of 80.73 per cent and polydextrose added barnyard millet based synbiotic yoghurt had water holding capacity of 80.64 per cent. A significant difference was observed in the water holding capacity of the yoghurts.

The water holding capacity of finger millet based probiotic yoghurt was 78.30 per cent, inulin added finger millet based synbiotic yoghurt had water holding capacity of 79.41 per cent and polydextrose added finger millet based synbiotic yoghurt had water holding capacity of 79.32 per cent. A significant difference was observed in the water holding capacity of the yoghurts.

4.5.1.5. Syneresis

Tables 49 and 50 list the syneresis of the synbiotic yoghurts with additional inulin (barnyard millet and finger millet) and polydextrose (barnyard and finger millet). Inulin and polydextrose based synbiotic yoghurt both had lower syneresis than probiotic yoghurt.

Barnyard millet based probiotic yoghurt had syneresis of 5.20 per cent, inulin added synbiotic yoghurt had syneresis of 5.15 per cent and polydextrose added synbiotic yoghurt had syneresis of 5.12 per cent. The results were observed on par according to DMRT study.

Finger millet based probiotic yoghurt had syneresis of 5.10 per cent, finger millet based synbiotic yoghurt with inulin had syneresis of 5.08 per cent and finger millet based synbiotic yoghurt with polydextrose had syneresis of 5.04 per cent. The results were observed on par according to DMRT study.

4.5.1.6. Viscosity

The viscosity of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 49 and 50 (barnyard and finger millet). Probiotic yoghurt showed lower viscosity than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had a viscosity of 23204 cP, synbiotic yoghurt with inulin added had viscosity of 24201 cP and synbiotic yoghurt with polydextrose added had a viscosity of 25203 cP. A significant difference was observed in the viscosity of the yoghurts.

The viscosity of finger millet based probiotic yoghurt was 22800 cP, that of finger millet based synbiotic yoghurt with inulin was 23381 cP and that of finger millet based synbiotic yoghurt with polydextrose was 23310 cP. A significant difference was observed in the viscosity of the yoghurts.

4.5.1.7. Cohesiveness

Tables 49 and 50 illustrate the cohesiveness of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower cohesiveness.

Cohesiveness for probiotic yoghurt prepared from barnyard millet was 0.64 N, for synbiotic yoghurt with inulin added, it was 0.67 N and for synbiotic yoghurt with polydextrose added, it was 0.66 N. A significant difference was observed in the cohesiveness of the yoghurts.

Finger millet based probiotic yoghurt had a cohesiveness of 0.62 N, 0.63 N for finger millet based synbiotic yoghurt with inulin and 0.64 N for finger millet based synbiotic yoghurt with polydextrose. The results were observed on par according to DMRT study.

4.5.1.8. Gumminess

The gumminess of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 49 and 50. The gumminess of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The gumminess of barnyard millet based probiotic yoghurt was 56.65 N, inulin added barnyard millet based synbiotic yoghurt had gumminess of 56.87 N and polydextrose added barnyard millet based synbiotic yoghurt had gumminess of 58.32 N. A significant difference was observed in the gumminess of the yoghurts.

The gumminess of finger millet based probiotic yoghurt was 63.86 N, inulin added finger millet based synbiotic yoghurt had gumminess of 66.89 N and polydextrose added finger millet based synbiotic yoghurt had gumminess of 64.33 N. A significant difference was observed in the gumminess of the yoghurts.

4.5.1.9. Resilience

Tables 49 and 50 list the resilience of the synbiotic yoghurts with additional inulin (barnyard millet and finger millet) and polydextrose (barnyard and finger millet). Inulin and polydextrose based synbiotic yoghurt both had greater resilience than probiotic yoghurt.

Barnyard millet based probiotic yoghurt had resilience of 41.74 N, inulin added synbiotic yoghurt had resilience of 42.64 N and polydextrose added synbiotic yoghurt had resilience of 42.38 N. A significant difference was observed in the resilience of the yoghurts.

Finger millet based probiotic yoghurt had resilience of 39.66 N, finger millet based synbiotic yoghurt with inulin had resilience of 40.98 N and finger millet based synbiotic yoghurt with polydextrose had resilience of 40.03 N. A significant difference was observed in the resilience of the yoghurts.

4.5.1.10. Carbohydrate

Tables 49 and 50 illustrate the carbohydrate of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower carbohydrate.

Carbohydrate for probiotic yoghurt prepared from barnyard millet was 8.58 g/100 g, for synbiotic yoghurt with inulin added, it was 8.47 g/100 g and for synbiotic yoghurt with polydextrose added, it was 8.41 g/100 g. A significant difference was observed in the carbohydrate of the yoghurts.

Finger millet based probiotic yoghurt had a carbohydrate of 8.32 g/100 g, 8.18 g/100 g for finger millet based synbiotic yoghurt with inulin and 8.14 g/100 g for finger millet based synbiotic yoghurt with polydextrose. The results were observed on par according to DMRT study.

4.5.1.11. Protein

Tables 49 and 50 list the protein content of the synbiotic yoghurts with additional inulin (barnyard millet and finger millet) and polydextrose (barnyard and finger millet). Inulin and polydextrose based synbiotic yoghurt both had greater protein content than probiotic yoghurt.

Barnyard millet based probiotic yoghurt had protein content of 3.52 g/100 g, inulin added synbiotic yoghurt had protein content of 3.63 g/100 g and polydextrose added synbiotic yoghurt had protein content of 3.61 g/100 g. The results were observed on par according to DMRT study.

Finger millet based probiotic yoghurt had protein content of 3.91 g/100 g, finger millet based synbiotic yoghurt with inulin had protein content of 3.99 g/100 g and finger millet based synbiotic yoghurt with polydextrose had protein content of 3.98 g/100 g. The results were observed on par according to DMRT study.

Table 49. Physico-chemical composition of barnyard millet based synbiotic yoghurt

Treatments	Probiotic yoghurt without prebiotic	BM based probiotic yoghurt + 3 % inulin	BM based probiotic yoghurt + 3 % polydextrose	CD Value
Moisture (%)	87.03 [a]	87.67 [b]	87.27 [c]	0.030
Acidity (%)	0.81[a]	0.89 [b]	0.86 [c]	0.023
pH	3.88 [a]	3.76 [b]	3.74 [b]	0.021
Water holding capacity (%)	79.75 [a]	80.73 [b]	80.64 [c]	0.363
Syneresis (%)	5.20 [a]	5.15 [b]	5.12 [b]	0.025
Viscosity (cP)	23204 [a]	24201 [b]	25203 [c]	67.431
Cohesiveness (N)	0.64 [a]	0.67 [b]	0.66 [c]	0.028

Table 49. Contd.

Gumminess (N)	56.65 [a]	56.87 [b]	58.32 [c]	0.065
Resilience (N)	41.74 [a]	42.64 [b]	42.38 [c]	0.030
Carbohydrate (g/100 g)	8.58 [a]	8.47 [b]	8.41 [c]	0.030
Protein (g/100 g)	3.52 [a]	3.63 [b]	3.61 [bc]	0.025
Fat (g/100 g)	0.63 [a]	0.69 [b]	0.66 [c]	0.028
TSS (^{o} brix)	11 [a]	10 [b]	9 [c]	0.998
Reducing Sugar (g/100 g)	7.55 [a]	6.46 [b]	6.67 [c]	0.024
Total Sugar (g/100 g)	10.99 [a]	9.56 [b]	9.45 [c]	0.027

Table 49. Contd.

Crude Fibre (g/100 g)	0.50 [a]	0.45 [b]	0.43 [b]	0.025
Total ash (%)	0.69 [a]	0.76 [b]	0.71 [b]	0.030

DMRT row wise comparison (significant at 5 % level)

Table 50. Physico-chemical properties of finger millet based synbiotic yoghurt

Treatments	Probiotic yoghurt without prebiotic	FM based probiotic yoghurt + 3 % inulin	FM based probiotic yoghurt + 3 % polydextrose	CD Value
Moisture (%)	87.42 [a]	88.54 [b]	88.53 [b]	0.088
Acidity (%)	0.78 [a]	0.83 [b]	0.84 [c]	0.02
pH	3.82 [a]	3.76 [b]	3.75 [b]	0.003
Water holding capacity (%)	78.30 [a]	79.41 [b]	79.32 [c]	0.028
Syneresis (%)	5.10 [a]	5.08 [b]	5.04 [b]	0.025

Table 50. Contd.

Viscosity (cP)	22800 [a]	23381 [b]	23310 [c]	445.649
Cohesiveness (N)	0.62 [a]	0.63 [b]	0.64 [b]	0.002
Gumminess (N)	63.86 [a]	66.89 [b]	64.33 [c]	0.032
Resilience (N)	39.66 [a]	40.98 [b]	40.03 [c]	0.030
Carbohydrate (g/100 g)	8.32 [a]	8.18 [b]	8.14 [b]	0.020
Protein (g/100 g)	3.91 [a]	3.99 [b]	3.98 [b]	0.023
Fat (g/100 g)	0.39 [a]	0.42 [b]	0.43 [c]	0.024
TSS (° brix)	11 [a]	10 [b]	9 [c]	0.003
Reducing Sugar (g/100 g)	7.38 [a]	6.53 [b]	6.78 [c]	0.020

Table 50. Contd.

Total Sugar (g/100 g)	10.42 [a]	9.38 [b]	9.43 [c]	0.030
Crude Fibre (g/100 g)	0.90 [a]	0.87 [b]	0.85 [c]	0.022
Total ash (%)	0.78 [a]	0.82 [b]	0.84 [c]	0.022

DMRT row wise comparison (significant at 5 % level)

4.5.1.12. Fat

Tables 49 and 50 illustrate the fat contents of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower fat content.

Fat content for probiotic yoghurt prepared from barnyard millet was 0.63 g/100 g, for synbiotic yoghurt with inulin added, it was 0.69 g/100 g and for synbiotic yoghurt with polydextrose added, it was 0.66 g/100 g. A significant difference was observed in the fat content of the yoghurts.

Finger millet based probiotic yoghurt had a fat content of 0.39 g/100 g, 0.42 g/100 g for finger millet based synbiotic yoghurt with inulin and 0.43 g/100 g for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the fat content of the yoghurts.

4.5.1.13. TSS

The TSS of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 49 and 50 (barnyard and finger millet). Probiotic yoghurt showed higher TSS than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had TSS of 11º brix, synbiotic yoghurt with inulin added had TSS of 10º brix and synbiotic yoghurt with polydextrose added had TSS of 9º brix. A significant difference was observed in the TSS of the yoghurts.

The TSS of finger millet based probiotic yoghurt was 11º brix, that of finger millet based synbiotic yoghurt with inulin was 10º brix and that of finger millet based synbiotic yoghurt with polydextrose was 9º brix. A significant difference was observed in the TSS of the yoghurts.

4.5.1.14. Reducing sugar

Tables 49 and 50 illustrate the reducing sugar of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a higher reducing sugar.

Reducing sugar for probiotic yoghurt prepared from barnyard millet was 7.55 g/100 g, for synbiotic yoghurt with inulin added, it was 6.46 g/100 g and for synbiotic yoghurt with polydextrose added, it was 6.67 g/100 g. A significant difference was observed in the reducing sugar of the yoghurts.

Finger millet based probiotic yoghurt had a reducing sugar of 7.38 g/100 g, 6.53 g/100 g for finger millet based synbiotic yoghurt with inulin and 6.78 g/100 g for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the reducing sugar of the yoghurts.

4.5.1.15. Total sugar

The total sugar of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 49 and 50. The total sugar of both synbiotic yoghurt (both inulin and polydextrose) was lower than probiotic yoghurt.

The total sugar of barnyard millet based probiotic yoghurt was 10.99 g/100 g, inulin added barnyard millet based synbiotic yoghurt had total sugar of 9.56 g/100 g and polydextrose added barnyard millet based synbiotic yoghurt had total sugar of 9.45 g/100 g. A significant difference was observed in the total sugar of the yoghurts.

The total sugar of finger millet based probiotic yoghurt was 10.42 g/100 g, inulin added finger millet based synbiotic yoghurt had total sugar of 9.38 g/100 g and polydextrose added finger millet based synbiotic yoghurt had total sugar of 9.43 g/100 g. A significant difference was observed in the total sugar of the yoghurts.

4.5.1.16. Crude fibre

The crude fibre of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 49 and 50 (barnyard and finger millet). Probiotic yoghurt showed higher crude fibre than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had a crude fibre of 0.50 g/100 g, synbiotic yoghurt with inulin added had crude fibre of 0.45 g/100 g and synbiotic yoghurt with polydextrose added had a crude fibre of 0.43 g/100 g. The results were observed on par according to DMRT study.

The crude fibre of finger millet based probiotic yoghurt was 0.90 g/100 g, that of finger millet based synbiotic yoghurt with inulin was 0.87 g/100 g and that of finger millet based synbiotic yoghurt with polydextrose was 0.85 g/100 g. A significant difference was observed in the crude fibre of the yoghurts.

4.5.1.17. Total ash

Tables 49 and 50 illustrate the total ash of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower total ash.

Total ash for probiotic yoghurt prepared from barnyard millet was 0.69 per cent, for synbiotic yoghurt with inulin added, it was 0.76 per cent and for synbiotic yoghurt with polydextrose added, it was 0.71 per cent. The results were observed on par according to DMRT study.

Finger millet based probiotic yoghurt had a total ash of 0.78 per cent, 0.82 per cent for finger millet based synbiotic yoghurt with inulin and 0.84 per cent for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the total ash of the yoghurts.

4.5.2. Mineral availability of millet based yoghurts

4.5.2.1. Calcium

The calcium content of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 51 and 52. The calcium content of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The calcium content of barnyard millet based probiotic yoghurt was 59.36 mg/100 g, inulin added barnyard millet based synbiotic yoghurt had calcium content of 60.02 mg/100 g and polydextrose added barnyard millet based synbiotic yoghurt had calcium content of 59.97 mg/100 g. The results were observed on par according to DMRT study.

The calcium content of finger millet based probiotic yoghurt was 73.18 mg/100 g, inulin added finger millet based synbiotic yoghurt had calcium content of 74.26 mg/100 g and polydextrose added finger millet based synbiotic yoghurt had calcium content of 73.38 mg/100 g. A significant difference was observed in the calcium content of the yoghurts.

4.5.2.2. Iron

Tables 51 and 52 list the iron content of the synbiotic yoghurts with additional inulin (barnyard millet and finger millet) and polydextrose (barnyard and finger millet). Inulin and polydextrose based synbiotic yoghurt both had higher iron content than probiotic yoghurt.

Barnyard millet based probiotic yoghurt had an iron content of 0.25 mg/100 g, inulin added synbiotic yoghurt had an iron content of 0.27 mg/100 g and polydextrose added synbiotic yoghurt had an iron content of 0.26 mg/100 g. The results were observed on par according to DMRT study.

Finger millet based probiotic yoghurt had an iron content of 0.24 mg/100 g, finger millet based synbiotic yoghurt with inulin had an iron content of 0.25 mg/100 g and finger millet based synbiotic yoghurt with polydextrose had an iron content of 0.26 mg/100 g. A significant difference was observed in the iron content of the yoghurts.

4.5.2.3. Potassium

The potassium of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 51 and 52 (barnyard and finger millet). Probiotic yoghurt showed lower potassium than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had a potassium of 57.85 mg/100 g, synbiotic yoghurt with inulin added had potassium of 58.25 mg/100 g and synbiotic yoghurt with polydextrose added had a potassium of 57.99 mg/100 g. A significant difference was observed in the potassium of the yoghurts.

The potassium of finger millet based probiotic yoghurt was 54.67 mg/100 g, that of finger millet based synbiotic yoghurt with inulin was 55.21 mg/100 g and that of finger millet based synbiotic yoghurt with polydextrose was 55.01 mg/100 g. A significant difference was observed in the potassium of the yoghurts.

4.5.2.4. Phosphorus

Tables 51 and 52 illustrate the phosphorus of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower phosphorus.

Phosphorus for probiotic yoghurt prepared from barnyard millet was 52.68 mg/100 g, for synbiotic yoghurt with inulin added, it was 53.76 mg/100 g and for synbiotic yoghurt with polydextrose added, it was 52.99 mg/100 g. A significant difference was observed in the phosphorus of the yoghurts.

Finger millet based probiotic yoghurt had a phosphorus of 49.65 mg/100 g, 50.02 mg/100 g for finger millet based synbiotic yoghurt with inulin and 49.96 mg/100 g for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the phosphorus of the yoghurts.

4.5.2.5. Zinc

The zinc of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 51 and 52. The zinc of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The zinc of barnyard millet based probiotic yoghurt was 0.25 mg/100 g, inulin added barnyard millet based synbiotic yoghurt had zinc of 0.26 mg/100 g and polydextrose added barnyard millet based synbiotic yoghurt had zinc of 0.27 mg/100 g. A significant difference was observed in the zinc of the yoghurts.

The zinc of finger millet based probiotic yoghurt was 0.19 mg/100 g, inulin added finger millet based synbiotic yoghurt had zinc of 0.20 mg/100 g and polydextrose added finger millet based synbiotic yoghurt had zinc of 0.21 mg/100 g. A significant difference was observed in the zinc of the yoghurts.

Table 51. Minerals in barnyard millet based synbiotic yoghurt

Treatments	Probiotic yoghurt without prebiotic	BM based probiotic yoghurt + 3 % inulin	BM based probiotic yoghurt + 3 % polydextrose	CD Value
Calcium (mg/100 g)	59.36 [a]	60.02 [b]	59.97 [b]	0.058
Iron (mg/100 g)	0.25 [a]	0.27 [b]	0.26 [bc]	0.003
Potassium (mg/100 g)	57.85 [a]	58.25 [b]	57.99 [c]	0.033
Phosphorus (mg/100 g)	52.68 [a]	53.76 [b]	52.99 [c]	0.040
Zinc (mg/100 g)	0.25 [a]	0.26 [b]	0.27 [c]	0.004
Magnesium (mg/100 g)	6.23 [a]	6.87 [b]	6.73 [c]	0.049

DMRT row wise comparison (significant at 5 % level)

Table 52. Minerals in finger millet based synbiotic yoghurt

Treatments	Probiotic yoghurt without prebiotic	FM based probiotic yoghurt + 3 % inulin	FM based probiotic yoghurt + 3 % polydextrose	CD Value
Calcium (mg/100 g)	73.18 [a]	74.26 [b]	73.38 [c]	0.058
Iron (mg/100 g)	0.24 [a]	0.25 [b]	0.26 [c]	0.003
Potassium (mg/100 g)	54.67 [a]	55.21 [b]	55.01 [c]	0.033
Phosphorus (mg/100 g)	49.65 [a]	50.02 [b]	49.96 [c]	0.040
Zinc (mg/100 g)	0.19 [a]	0.20 [b]	0.21 [c]	0.004
Magnesium (mg/100 g)	9.98 [a]	10.04 [b]	11.98 [c]	0.049

DMRT row wise comparison (significant at 5 % level)

4.5.2.6. Magnesium

Tables 51 and 52 illustrate the magnesium content of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower magnesium content.

Magnesium content for probiotic yoghurt prepared from barnyard millet was 6.23 mg/100 g, for synbiotic yoghurt with inulin added, it was 6.87 mg/100 g and for synbiotic yoghurt with polydextrose added, it was 6.73 mg/100 g. A significant difference was observed in the magnesium content of the yoghurts.

Finger millet based probiotic yoghurt had a magnesium content of 9.98 mg/100 g, 10.04 mg/100 g for finger millet based synbiotic yoghurt with inulin and 11.98 mg/100 g for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the magnesium content of the yoghurts.

4.5.3. Health studies

4.5.3.1. *In vitro* mineral availability of millet based yoghurts

4.5.3.1.1. Calcium

The *in vitro* availability of calcium content of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 53 and 54. The *in vitro* availability of calcium content of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The *in vitro* availability of calcium content of barnyard millet based probiotic yoghurt was 78.59 per cent, inulin added barnyard millet based synbiotic yoghurt had *in vitro* availability of calcium content of 78.91 per cent and polydextrose added barnyard millet based synbiotic yoghurt had *in vitro* availability of calcium content of 78.84 per cent. A significant difference was observed in the *in vitro* availability of calcium content of the yoghurts.

The *in vitro* availability of calcium content of finger millet based probiotic yoghurt was 72.67 per cent, inulin added finger millet based synbiotic yoghurt had *in vitro* availability of calcium content of 73.15 per cent and polydextrose added finger millet based synbiotic yoghurt had *in vitro* availability of calcium content of 73.64 per cent. A significant difference was observed in the *in vitro* availability of calcium content of the yoghurts.

4.5.3.1.2. Iron

Tables 53 and 54 list the *in vitro* availability of iron content of the synbiotic yoghurts with additional inulin (barnyard millet and finger millet) and polydextrose (barnyard and finger millet). Inulin and polydextrose based synbiotic yoghurt both had higher *in vitro* availability of iron content than probiotic yoghurt.

Barnyard millet based probiotic yoghurt had *in vitro* availability of iron content of 70.02 per cent, inulin added synbiotic yoghurt had *in vitro* availability of iron content of 71.10 per cent and polydextrose added synbiotic yoghurt had *in vitro* availability of iron content of 72.31 per cent. A significant difference was observed in the *in vitro* availability of iron content of the yoghurts.

Finger millet based probiotic yoghurt had *in vitro* availability of iron content of 76.98 per cent, finger millet based synbiotic yoghurt with inulin had *in vitro* availability of iron content of 78.01 per cent and finger millet based synbiotic yoghurt with polydextrose had *in vitro* availability of iron content of 78.61 per cent. The results were observed on par according to DMRT study.

4.5.3.1.3. Potassium

The *in vitro* availability of potassium of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 53 and 54 (barnyard and finger millet). Probiotic yoghurt showed lower *in vitro* availability of potassium than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had *in vitro* availability of potassium of 56.28 per cent, synbiotic yoghurt with inulin added had *in vitro* availability of potassium of 57.77 per cent and synbiotic yoghurt with polydextrose added had *in vitro* availability of potassium of 57.65 per cent. A significant difference was observed in the *in vitro* availability of potassium of the yoghurts.

The *in vitro* availability of potassium of finger millet based probiotic yoghurt was 56.98 per cent, that of finger millet based synbiotic yoghurt with inulin was 57.12 per cent and that of finger millet based synbiotic yoghurt with polydextrose was 57.09 per cent. A significant difference was observed in the *in vitro* availability of potassium of the yoghurts.

4.5.3.1.4. Phosphorus

Tables 53 and 54 illustrate the *in vitro* availability of phosphorus of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower *in vitro* availability of phosphorus.

In vitro availability of phosphorus for probiotic yoghurt prepared from barnyard millet was 71.92 per cent, for synbiotic yoghurt with inulin added, it was 73.55 per cent and for synbiotic yoghurt with polydextrose added, it was 73.39 per cent. A significant difference was observed in the *in vitro* availability of phosphorus of the yoghurts.

Finger millet based probiotic yoghurt had *in vitro* availability of phosphorus of 69.87 per cent, 72.65 per cent for finger millet based synbiotic yoghurt with inulin and 72.02 per cent for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the *in vitro* availability of phosphorus of the yoghurts.

4.5.3.1.5. Zinc

The *in vitro* availability of zinc of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 53 and 54. The *in vitro* availability of zinc of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The *in vitro* availability of zinc of barnyard millet based probiotic yoghurt was 77.29 per cent, inulin added barnyard millet based synbiotic yoghurt had *in vitro* availability of zinc of 80.02 per cent and polydextrose added barnyard millet based synbiotic yoghurt had *in vitro* availability of zinc of 80.92 per cent. A significant difference was observed in the *in vitro* availability of zinc of the yoghurts.

The *in vitro* availability of zinc of finger millet based probiotic yoghurt was 63.16 per cent, inulin added finger millet based synbiotic yoghurt had *in vitro* availability of zinc of 68.42 per cent and polydextrose added finger millet based synbiotic yoghurt had *in vitro* availability of zinc of 70.01 per cent. A significant difference was observed in the *in vitro* availability of zinc of the yoghurts.

4.5.3.1.6. Magnesium

Tables 53 and 54 illustrate the *in vitro* availability of magnesium content of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose (barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower *in vitro* availability of magnesium content.

In vitro availability of magnesium content for probiotic yoghurt prepared from barnyard millet was 66.32 per cent, for synbiotic yoghurt with inulin added, it was 69.58 per cent and for synbiotic yoghurt with polydextrose added, it was 68.80 per cent. A significant difference was observed in the *in vitro* availability of magnesium content of the yoghurts.

Finger millet based probiotic yoghurt had *in vitro* availability of magnesium content of 79.95 per cent, 80.16 per cent for finger millet based synbiotic yoghurt with inulin and 80.11 per cent for finger millet based synbiotic yoghurt with polydextrose. A significant difference was observed in the *in vitro* availability of magnesium content of the yoghurts.

Table 53. *In vitro* mineral availability and antioxidant activity of barnyard millet based synbiotic yoghurts

Treatments	Probiotic yoghurt without prebiotic	BM based probiotic yoghurt + 3 % inulin	BM based probiotic yoghurt + 3 % polydextrose	CD Value
Calcium (%)	78.59 [a]	78.91 [b]	78.84 [c]	0.026
Iron (%)	70.02 [a]	71.10 [b]	72.31 [c]	0.02
Potassium (%)	56.28 [a]	57.77 [b]	57.65 [c]	0.020
Phosphorus (%)	71.92 [a]	73.55 [b]	73.39 [c]	0.064
Zinc (%)	77.29 [a]	80.02 [b]	80.92 [c]	0.024
Magnesium (%)	66.32 [a]	69.58 [b]	68.80 [c]	0.043
Antioxidant activity (%)	12.99 [a]	14.38 [b]	14.39 [bc]	0.045

DMRT row wise comparison (significant at 5 % level)

Table 54. *In vitro* mineral availability and antioxidant activity of finger millet based synbiotic yoghurts

Treatments	Probiotic yoghurt without prebiotic	FM based probiotic yoghurt + 3 % inulin	FM based probiotic yoghurt + 3 % polydextrose	CD Value
Calcium (%)	72.67 [a]	73.15 [b]	73.64 [c]	0.025
Iron (%)	76.98 [a]	78.01 [b]	78.61 [b]	0.453
Potassium (%)	56.98 [a]	57.12 [b]	57.09 [c]	0.030
Phosphorus (%)	69.87 [a]	72.65 [b]	72.02 [c]	0.023
Zinc (%)	63.16 [a]	68.42 [b]	70.01 [c]	0.029
Magnesium (%)	79.95 [a]	80.16 [b]	80.11 [c]	0.021
Antioxidant activity (%)	11.75 [a]	12.48 [b]	12.42 [bc]	0.045

DMRT row wise comparison (significant at 5 % level)

4.5.3.2. Antioxidant activity

The antioxidant activity of inulin added synbiotic yoghurt (both barnyard millet and finger millet) and polydextrose added synbiotic yoghurt (both barnyard and finger millet) are mentioned in Table 53 and 54. The antioxidant activity of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt.

The antioxidant activity of barnyard millet based probiotic yoghurt was 12.99 per cent, inulin added barnyard millet based synbiotic yoghurt had antioxidant activity of 14.38 per cent and polydextrose added barnyard millet based synbiotic yoghurt had antioxidant activity of 14.39 per cent. The results were observed on par according to DMRT study.

The antioxidant activity of finger millet based probiotic yoghurt was 11.75 per cent, inulin added finger millet based synbiotic yoghurt had antioxidant activity of 12.48 per cent and polydextrose added finger millet based synbiotic yoghurt had antioxidant activity of 12.42 per cent. The results were observed on par according to DMRT study.

4.5.4. Population of *L. acidophilus*

The viability of *L. acidophilus* of the synbiotic yoghurts with added inulin (from finger millet and barnyard millet) and polydextrose are shown in Tables 55 (barnyard and finger millet). Probiotic yoghurt showed lower viability of *L. acidophilus* than inulin and polydextrose based synbiotic yoghurt.

Probiotic yoghurt made from barnyard millet had viability of 11.15 log cfu/ml synbiotic yoghurt with inulin added had viability of 11.16 log cfu/ml and synbiotic yoghurt with polydextrose added had viability of 11.17 log cfu/ml.

The viability of finger millet based probiotic yoghurt was 11.11 log cfu/ml, that of finger millet based synbiotic yoghurt with inulin was 11.15 log cfu/ml and that of finger millet based synbiotic yoghurt with polydextrose was 11.18 log cfu/ml.

4.5.5. Enumeration of total micro flora

4.5.5.1. Enumeration of bacteria

Tables 56 and 57 illustrate the viability of bacteria of the synbiotic yoghurts with additional inulin (from finger millet and barnyard millet) and polydextrose

Table 55. Population of *L. acidophilus* of probiotic and synbiotic millet based yoghurts (cfu/ml)

Treatments	Probiotic yoghurt without prebiotic	M based probiotic yoghurt + 3 % inulin	M based probiotic yoghurt + 3 % polydextrose
Set 1 (Barnyard millet)	142 (11.15)	146 (11.16)	149 (11.17)
Set 2 (Finger millet)	131 (11.11)	143 (11.15)	152 (11.18)

(barnyard and finger millet). Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a higher viable count than probiotic yoghurt.

The viability of bacteria in probiotic yoghurt prepared from barnyard millet was 7.18 log cfu/ml for synbiotic yoghurt with inulin added, it was 7.20 log cfu/ml and for synbiotic yoghurt with polydextrose added, it was 7.21 log cfu/ml.

Finger millet based probiotic yoghurt had viability of 7.16 log cfu/ml, 7.21 log cfu/ml for finger millet based synbiotic yoghurt with inulin and 7.23 log cfu/ml for finger millet based synbiotic yoghurt with polydextrose.

4.5.4.2. Enumeration of fungi

The viability of fungi of each set of synbiotic yoghurt was analysed and it was found that there were no fungal colonies which is tabulated in Table 56 and 57.

4.5.4.3. Enumeration of yeast

The viability of yeast of each set of synbiotic yoghurt was analysed and it was found that there was no yeast counts which is tabulated in Table 56 and 57.

Table 56. Microbial enumeration of barnyard millet based synbiotic yoghurt

Treatments	Probiotic yoghurt without prebiotic	BM based probiotic yoghurt + 3 % inulin	BM based probiotic yoghurt + 3 % polydextrose
Bacteria (cfu/ml)	150 (7.18)	160 (7.20)	164 (7.21)
Fungi	ND	ND	ND
Yeast	ND	ND	ND

All values are means of three independent enumerations
Figures in parenthesis indicates log cfu/ml
ND: Not detected

4.6. Cost of production of millet based yoghurts

The cost of production for the selected millet based normal, probiotic and synbiotic yoghurt were calculated by considering the material cost, labour charges, fuel and electricity costs. The cost was calculated per 100 g and presented in Table 58.

The production cost of yoghurt with barnyard was Rs. 18.56/100 g and for finger millet based yoghurt it was Rs. 17.54/100 g. The cost of probiotic barnyard millet based yoghurt was found to be Rs.21.65 Rs/100g and that of probiotic finger millet based yoghurt was 23.74 Rs/100 g. In the case of synbiotic yoghurt, cost of the yoghurt with inulin was 25.76 Rs/100 g for barnyard millet based synbiotic yoghurt and 26.66 Rs/100 g for finger millet based synbiotic yoghurt. Another prebiotic which was used to prepare synbiotic yoghurt was polydextrose. The cost for barnyard millet based synbiotic yoghurt was 26.88 Rs/100g and for finger millet based synbiotic yoghurt was 27.88 Rs/100g.

Table 57. Microbial enumeration of finger millet based synbiotic yoghurt

Treatments	Probiotic yoghurt without prebiotic	FM based probiotic yoghurt + 3 % inulin	FM based probiotic yoghurt + 3 % polydextrose
Bacteria (cfu/ml)	145 (7.16)	162 (7.21)	170 (7.23)
Fungi	0	0	0
Yeast	0	0	0

All values are means of three independent enumerations
Figures in parenthesis indicates log cfu/ml
ND: Not detected

Table 58. Cost of millet based yoghurts

Millet based yoghurt	**Cost (Rs./100 g)**
Barnyard millet based yoghurt	18.56
Finger millet based yoghurt	17.54
Barnyard millet based probiotic yoghurt	21.65
Finger millet based probiotic yoghurt	23.74
Barnyard millet based synbiotic yoghurt (inulin)	25.76
Finger millet based synbiotic yoghurt (inulin)	26.66
Barnyard millet based synbiotic yoghurt (polydextrose)	26.88
Finger millet based synbiotic yoghurt (polydextrose)	27.88

Discussion

DISCUSSION

5.1. Standardisation of proportion of ingredients in the yoghurt

Yoghurt is a traditional dairy product made from lactic acid fermentation by *Lactobacillus bulgaricus* and *Streptococcus thermophiles.* The present study aimed to increase the quality of yoghurt, with the addition of probiotic bacteria into millet based yoghurt which can improve the nutritional profile as well as the therapeutic potential of the food.

Millet slurry was mixed with milk in different quantities to make millet based yoghurt. The most acceptable yoghurt (one each from barnyard millet and finger millet) (Fig. 2 and 3) was chosen from the different treatments and that were compared with plain yoghurt (control). The appearance, colour, flavour, taste, texture and overall acceptability of the yoghurt were studied for the comparative evaluation.

Based on the organoleptic evaluation of millet based yoghurt with 50 per cent milk and 50 per cent millet slurry from both barnyard and finger millet, was chosen for further studies. The organoleptic acceptability of millet based yoghurts was shown to be most acceptable, when the amount of millet slurry was increased up to 50 per cent. The total score for selected barnyard millet based yoghurt was 51.94 and finger millet based yoghurt was 51.39. Figures 2 and 3 show the mean scores for the overall acceptability of millet based yoghurt from the two millets.

Rice based yoghurts were standardised by Sarabhai (2012) and the best selected treatment was 50 per cent of milk with 50 per cent of rice slurry made from raw, germinated and parboiled rice flour. The range of overall acceptability of selected rice based yoghurt was 8.10 for raw rice based yoghurt, 8.60 for parboiled rice based yoghurt and 8.80 for germinated rice based yoghurt.

Ramawickrama (2012) prepared yoghurt with rice flour and finger millet flour. A mixture of 60 per cent rice flour and 40 per cent finger millet flour contributed to a yoghurt with good sensory rating. The finger millet based drinkable yoghurt had a mean score of 8.23 for appearance, 8.56 for colour, 8.36 for mouth feel, 8.64 for taste, 8.48 for texture and 8.57 for overall acceptability.

Finger millet based drinkable yoghurt was developed by Awanthika *et al*. (2015) using germinated finger millet flour, roasted finger millet flour and raw finger millet flour. The germinated finger millet based yoghurt was selected as the best which had an acceptable score of 8.52 for appearance, 8.36 for colour, 8.48 for flavour, 8.39 for texture, 8.78 for taste and 8.64 for overall acceptability.

According to Remya (2020) the probiotic yoghurts containing jackfruit pulp with 30 per cent jackfruit pulp incorporation was found to be the most acceptable. Two varieties of jackfruits were used to prepare probiotic yoghurt, which were *koozha* and *varikka*. The overall acceptability of *koozha* based probiotic yoghurt was 8.66 and for *varikka* the mean score was 8.67.

By making a slurry of the millet (4 : 1 (400 ml water + 100 ml kodo millet)) and 3 : 1 (400 ml water + 100 ml kodo millet) and milk, Kumari and Nazni (2021) made kodo millet based yoghurt. The best treatment among them was a 4 : 1 treatment which had a score of 8.70 and 8.0 for 3 : 1 concentration.

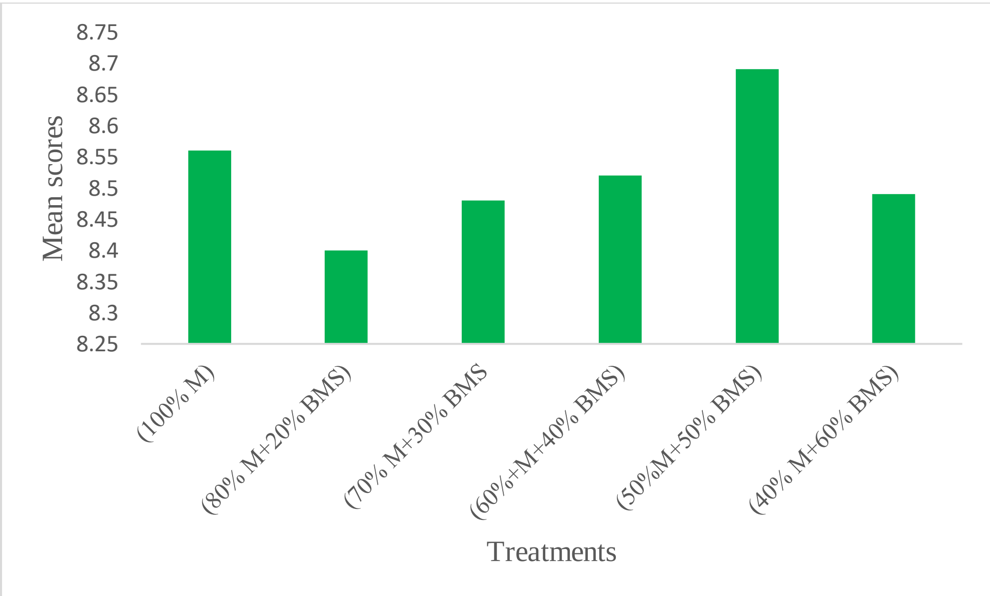


Fig. 2. Mean scores for overall acceptability of barnyard millet based yoghurts

M: Milk, BMS: Barnyard millet slurry

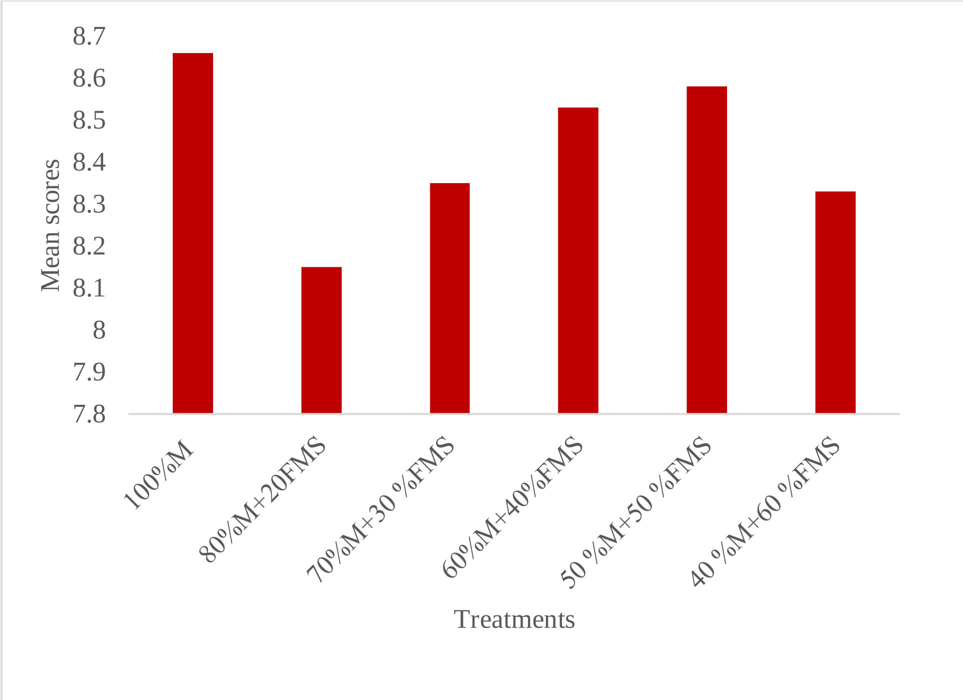


Fig. 3. Mean scores for overall acceptability of finger millet based yoghurts

M: Milk, FMS: Finger millet slurry

5.2. Optimisation of conditions for the growth of *L. acidophilus*

The best selected yoghurt from each set (both barnyard and finger millet) was optimised and the maximum growth of *L. acidophilus* was observed for 25 g (Fig. 4) of yoghurt, inoculated with 100 µl of probiotic culture (Fig. 7) and 200 µl of yoghurt culture, fermented at 38º C (Fig. 6) for 6 h (Fig. 5). The viable count of selected barnyard millet based yoghurt and finger millet based yoghurt was 106 × 10^9 cfu/ml (5.15 log cfu/ml) and 90 × 10^9 cfu/ml (4.87 log cfu/ml) respectively. The probiotic yoghurts must have more than 9 log cfu/ml of live probiotic microorganisms per serving portion (Hill *et al*., 2017). Furthermore, the viability of *L. acidophilus* at a concentration of 1 ml meets the FSSAI (2016) probiotic product standards.

Vijayalakshmi (2005) developed yoghurt containing 75 per cent corn flour, 10 per cent mango pulp and 1 per cent *L. acidophilus* culture and studied the viability of *L. acidophilus* and it was found to be 8.41 log cfu/ml.

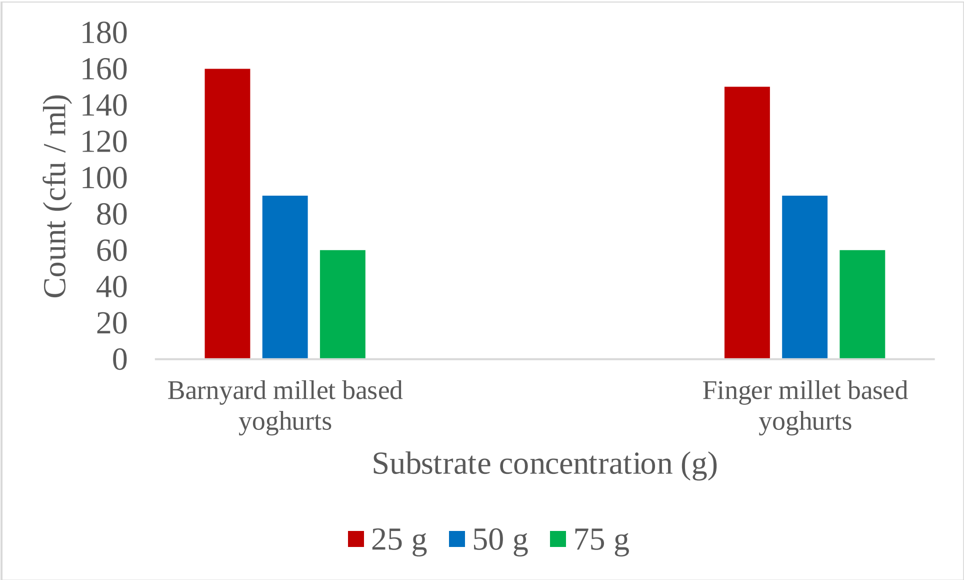


Fig. 4. Viable count of *L. acidophilus* in millet based yoghurts with different substrate concentration

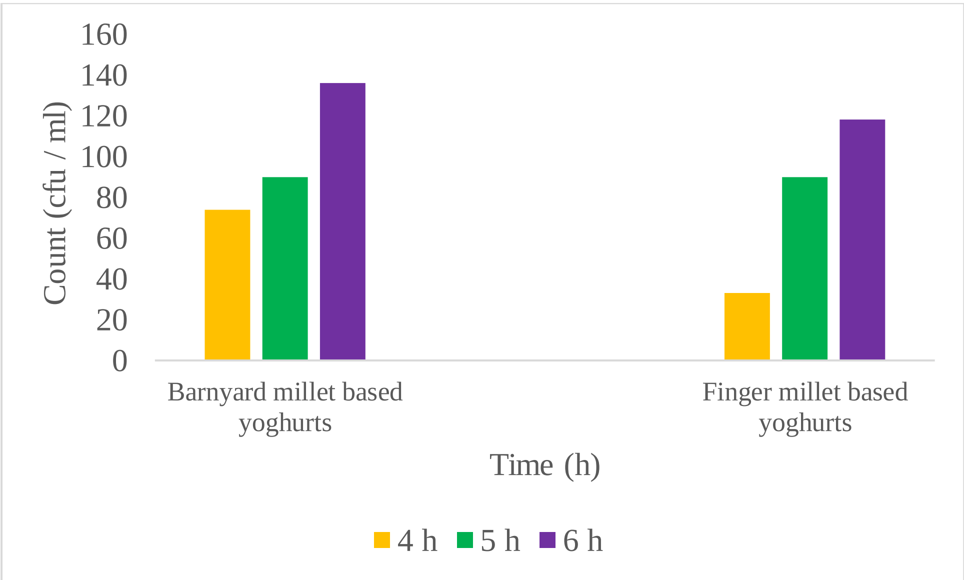


Fig. 5. Viable count of *L. acidophilus* in millet based yoghurts with different time of incubation

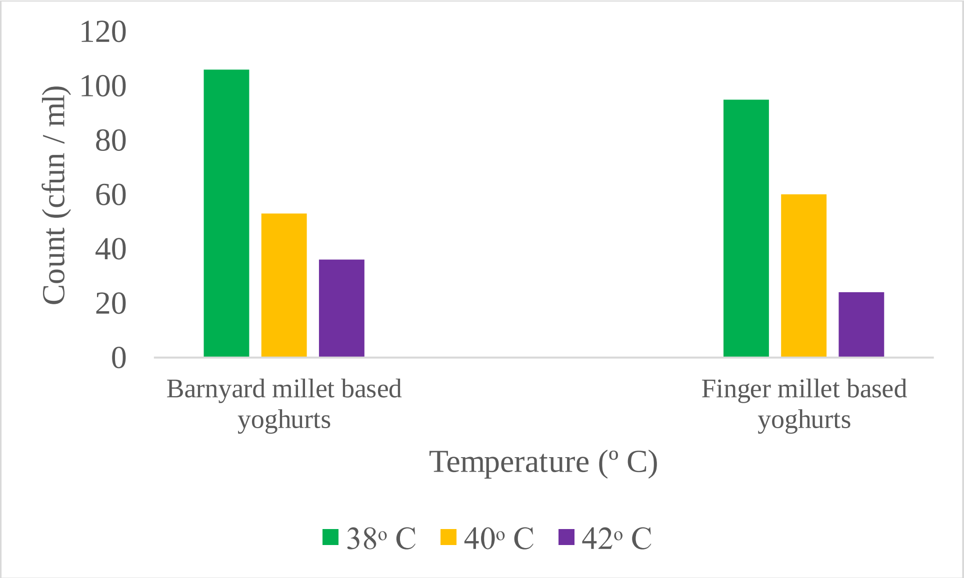


Fig. 6. Viable count of *L. acidophilus* in millet based yoghurts with different temperature

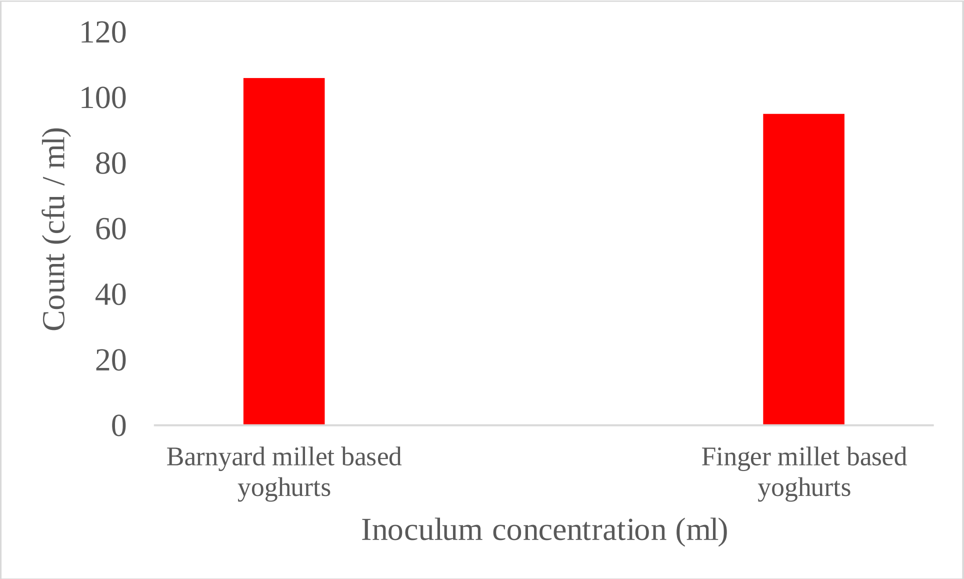


Fig. 7. Viable count of *L. acidophilus* in millet based yoghurts with different inoculum concentration

The survival rates of probiotics during the manufacturing of yoghurt were examined by Mortazavian *et al.* (2006) using 3 incubation temperatures (37° C, 40° C and 44° C). They found that fermenting *L. acidophilus* at 37° C had the highest success rate.

Kumar (2009) developed probiotic yoghurt with mango pulp and the growth of *L. acidophilus* was recorded. With the addition of mango pulp in the yoghurt, growth of *L. acidophilus* increased. The growth of *L. acidophilus* was 7.63 log cfu/ml for 0.5 per cent of mango pulp added probiotic yoghurt and 7.86 log cfu/ml for 1.5 per cent of mango pulp added probiotic yoghurt.

Sujatha (2013) made probiotic *dahi* with whey protein concentrate and fruits (mango, pineapple and apple). The count for *L. acidophilus* was enumerated as 8.92 log cfu/ml for yoghurt with mango, 8.83 log cfu/ml for yoghurt with pineapple and 8.79 log cfu/ml for yoghurt with apple.

The probiotic growth of 10 per cent stirred papaya added with probiotic yoghurt incubated at 42° C inoculated with *L. bulgaricus* and *S. thermophiles* for 4 to 5 h had a growth of 7.15 log cfu/ml for *S. thermophiles* and 7.11 log cfu/ml for *L. bulgaricus* (Punnagaiarasi *et al.*, 2016).

A stimulating impact on probiotic yoghurt was demonstrated by the inclusion of Spirulina, a cyanobacterium and phototrophic microbe. *B. bifidum* was used to inoculate the probiotic yoghurt as a probiotic culture with yoghurt culture. A ratio of 1 g of Spirulina per litre of the mixture was used to make the probiotic yoghurt with Spirulina enhancement. *B. bifidum* growth was measured at 4 log cfu/ml for probiotic yoghurt and 6.66 log cfu/ml for probioticyoghurt with added Spirulina (Narayana and Kale, 2019).

According to Remya (2020), in jackfruit based yoghurt, the maximum growth of *L. acidophilus* was obtained when 25 g (75 and 67 × 10^9 cfu/ml for *koozha* and *varikka* variety jackfruit respectively) of the yoghurt sample fermented at 38º C (84 and 72 × 10^9 cfu/ml in *koozha* and *varikka* variety jackfruit respectively) for 6 hours (99 and 88 × 10^9 cfu/ml in *koozha* and *varikka* variety jackfruit respectively), inoculated with 100 µl of probiotic culture and 200 µl of yoghurt culture.

Manoharan *et al*. (2020) developed mango (10 %) based probiotic yoghurt incubated at 42° C, inoculated with 1 ml of both *L. brevis* and fermented for 3 to 5 h, recorded the growth of *L. brevis* as 10.57 log cfu/ml (Prasad *et al.,* 1998).

5.3. Quality evaluation of selected millet based yoghurts

5.3.1. Physicochemical composition

5.3.1.1. Moisture

The moisture content of millet based yoghurt (both barnyard and finger millet) was studied (Fig. 8). After analysing the data, it was found that the non-probiotic yoghurt of each millet based yoghurt had lowest moisture content than the probiotic yoghurt. The moisture content of each millet based yoghurts was shown to increase during storage.

The higher moisture content in probiotic yoghurt may be because of the presence of *L. acidophilus* in probiotic yoghurt. The metabolism (by fermentation, complex macronutrients is converted into simple forms) which has taken place by *L. acidophilus* produce CO_2 and water. The increase in moisture content is because of the increase in microbial population, which hastened hydrolysis and the conversion of the carbohydrate to liquid (Georgala *et al*., 1995). According to Yang *et al*. (2017), moisture is produced when the structural elements of the carbohydrate are released by microbial and enzymatic hydrolysis.

A similar result was found by Soni *et al*. (2020) who developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The moisture content of non-probiotic yoghurt was 87.32 per cent and for probiotic yoghurt, moisture content was 87.46 per cent and was found to be significantly different. This difference may be because of the formation of water due to fermentation.

In an another study by Remya (2020), who developed jackfruit (*koozha*) based probiotic yoghurt with *L. acidophilus*, the moisture contents of the control - homogenised milk based yoghurt (non-probiotic yoghurt) was 75.29 and for probiotic yoghurt, it was 78.52 per cent. During storage, the moisture content of bio yoghurts increased considerably. After 15 days of storage, the moisture content was increased to 77.28 per cent for control yoghurt and 81.63 per cent for the homogenised milk based *koozha* added yoghurt added yoghurt and a significant difference in the moisture content was found. The high moisture content was seen in probiotic yoghurt than in the non-probiotic yoghurt and it was found that when storage days increases the moisture content also increases.

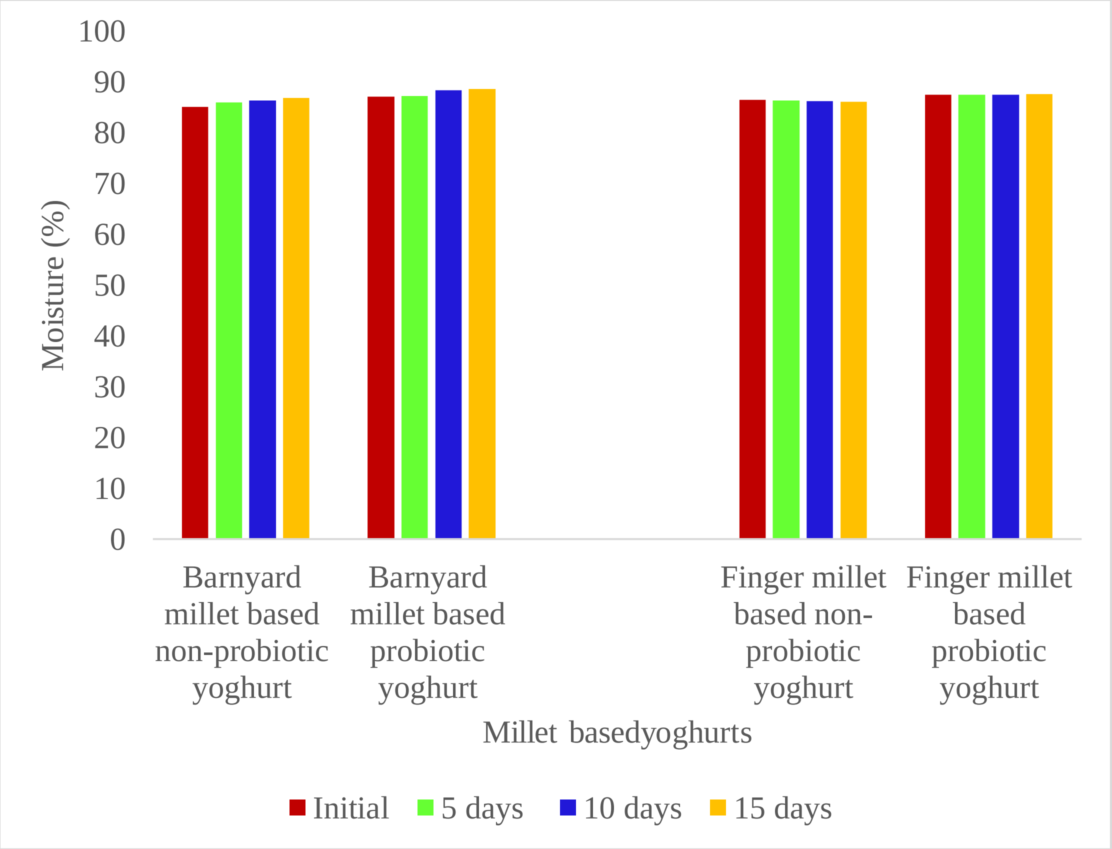


Fig. 8. Moisture content of millet based yoghurts during storage (%)

5.3.1.2. Acidity

The acidity of millet based yoghurts was studied and it was observed that the acidity of both millet based probiotic yoghurts is higher than the non-probiotic yoghurt. The acidity of the developed millet based yoghurts increased during storage (Fig.9).

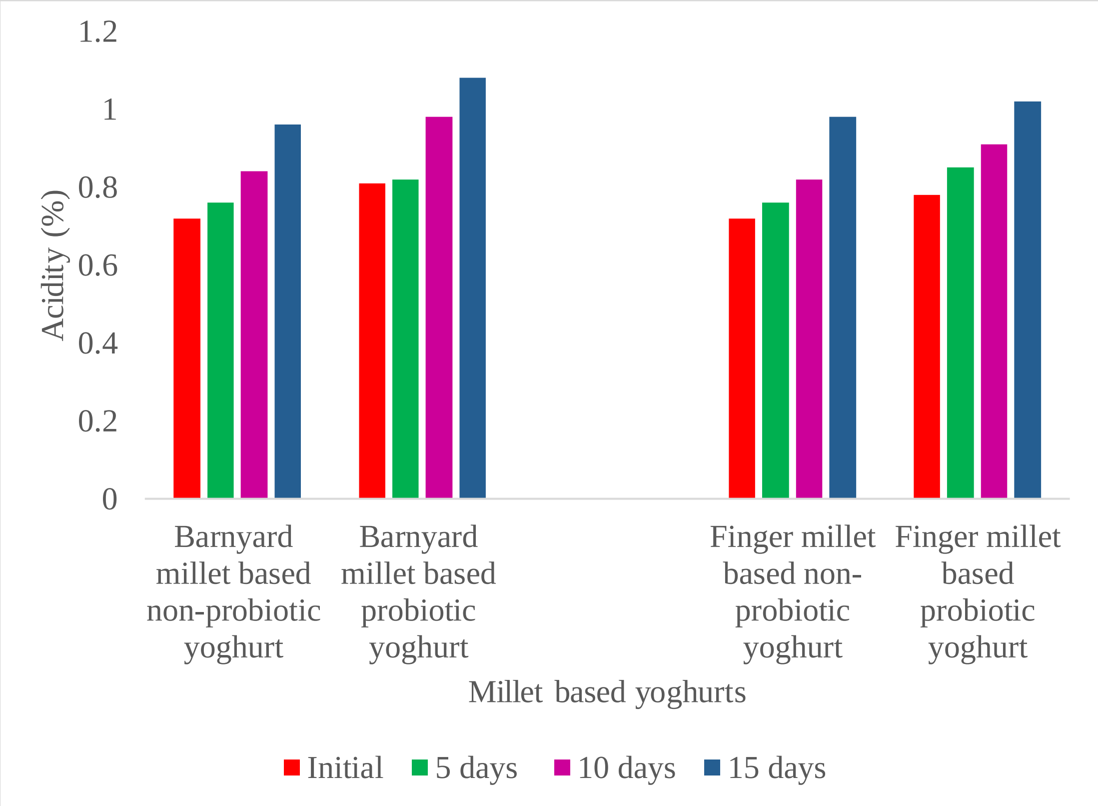


Fig. 9. Acidity of millet based yoghurts during storage (%)

The higher acidity of probiotic yoghurt may be due to the presence of *L. acidophilus* as a probiotic organism which helps to increase the production of lactic acid and also improve its sensory characteristics (Laroia and Martin, 1990; Georgala *et al*., 1995**)**.

According to Sarabhai (2012) when the storage days increases the acidity of the yoghurt also increases. Acidity increased in rice based yoghurts and reached a maximum on the 14th day of storage. The initial acidity of control yoghurt was 1.02 per cent and for rice based yoghurt it was 0.73 per cent. Later on storage, it increased and reached 1.03 per cent for control and 0.91 for rice based yoghurt respectively.

The increase of acidity during storage was seen in yoghurt prepared by Lovely (2019). Here the acidity of control yoghurt was 0.70 per cent initially and it increased every five days, reaching 0.78 after 15 days of storage.

The increase in acidity of probiotic yoghurt was also seen by Soni *et al*. (2020) who developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The acidity of non-probiotic yoghurt was 0.12 per cent and for probiotic yoghurt, the acidity was 0.14 per cent. This increase was due the high production of lactic acid by *L. acidophilus* in the probiotic yoghurt. On fermentation with the addition of *L. acidophilus* as a probiotic organism, the acidity of the yoghurt increased because it helps to increase the production of lactic acid by the conversion of lactose into lactic acid and a significant difference was observed between probiotic non-probiotic yoghurt.

The acidity of fermented yoghurt was standardised by FSSAI (2022) that the titrable acidity should be the minimum of 0.6 per cent which agrees the present study.

5.3.1.3. pH

The pH of selected millet based yoghurts is presented in Fig. 10. All yoghurts showed a declining trend in pH with increasing storage days. After the conclusion of the 15th day of storage, the pH of the millet based yoghurts had significantly decreased.

Vahedi *et al*. (2008) claimed that the pH lowering was caused by the activity of the microorganisms. According to some researchers, the residual enzymes created by starters during fermentation are to blame for the pH decline that occurs throughout the storage period (Christopher *et al*., 2009). The transformation of ammonia and lactate into lactic acid causes the pH to change. In this formation, ammonia produced by the fermentation of amino acids and glycerol by bacteria is combined with carbohydrates. The type of bacteria and how they use oxygen during the metabolic process, as well as other factors, impact how many carbohydrates are fermented and how much lactose is produced (Juturu and Wu, 2016). The change in pH during cold storage is because of post-acidification (Donkor *et al*., 2007). The pH and acidity are inversely proportional to each other. Finally, we can conclude that the pH of probiotic yoghurt was lesser than non-probiotic yoghurt (Georgala *et al*., 1995; Khandelwal *et al*., 2016**)**

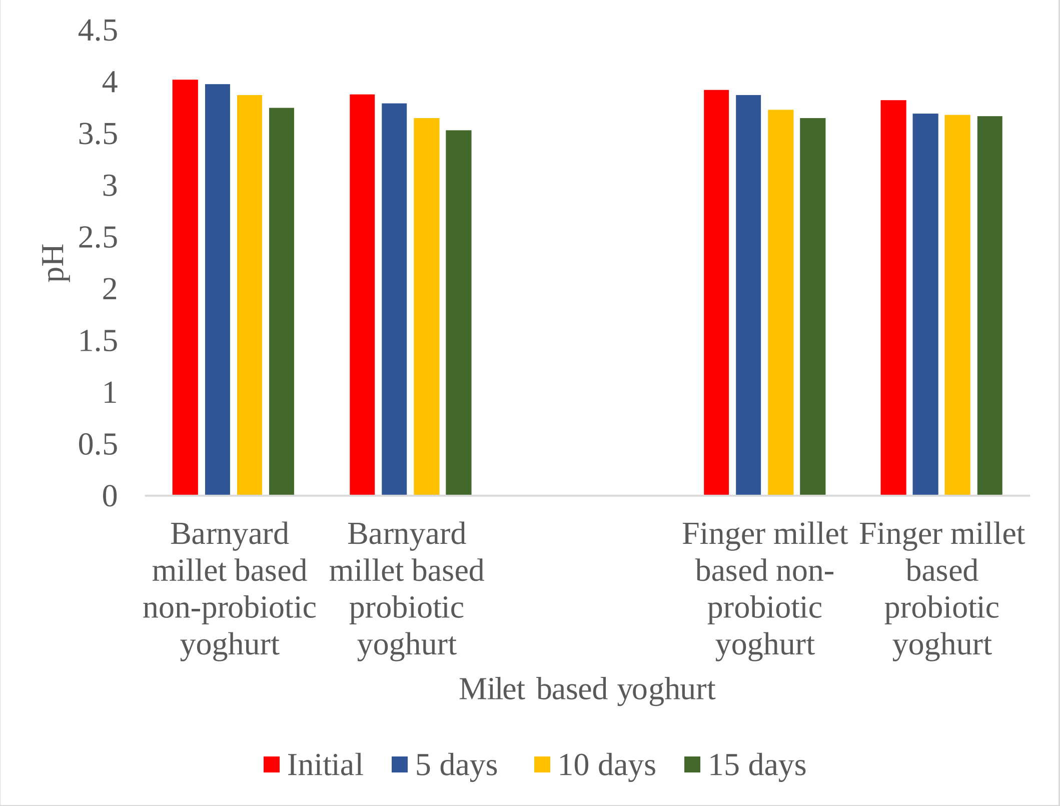


Fig. 10. pH of millet based yoghurts during storage

A similar result was seen in the study by Pagthinathan *et al*. (2018) who developed probiotic milk yoghurt with *Bifidobacterium* and studied its physicochemical attributes. The pH of non-probiotic yoghurt was 4.70 per cent and for probiotic yoghurt, it was 4.68 per cent. Here the pH was comparatively less in probiotic yoghurt when compared to non-probiotic yoghurt.

Soni *et al.* (2020) developed probiotic milk yoghurt and compared it with non-probiotic yoghurt. The probiotic organism used was *L. acidophilus*. The pH of non-probiotic yoghurt was 4.43 and for probiotic yoghurt, the pH was 4.39. The lower pH in probiotic yoghurt was because of the presence of *L. acidophilus* and a significant difference was found between probiotic and non-probiotic yoghurt.

5.3.1.4. Water holding capacity of millet based yoghurt

The structural organisation and microstructure of the protein network determine the rheological and textural features of fermented dairy products (Delikanli and Ozcan, 2017). Throughout the fifteen day storage period, the rheological parameters of millet based yoghurts were evaluated at five day intervals. Water holding capacity (WHC), syneresis, viscosity and texture analysis were investigated. LAB can also significantly alter the textural properties of the end products through acidification, proteolytic activity or the production of extracellular polysaccharides (Smid and Kleerebezem, 2014). Fig. 11. represents the water holding capacity of each millet based yoghurts.

The WHC was higher in non-probiotic yoghurt than probiotic yoghurt. On storage, the WHC decreased in both probiotic and non-probiotic yoghurts.

The microstructure of the protein network is indicated by the water holding capacity of yoghurt. Whey will be expelled on the product's surface during storage if there is insufficient water binding. WHC is inversely proportional to syneresis.

The research was in line with the findings of Soni *et al*. (2020) who developed probiotic milk yoghurt using *L. acidophilus* and compared it with non-probiotic milk yoghurt. The water holding capacity of non-probiotic yoghurt was 56.50 per cent and for probiotic yoghurt it was 54.74 per cent and there was a significant difference was found between probiotic and non-probiotic yoghurt.

When the storage days increases the water holding capacity decreases. According to Lovely (2019), plain yoghurt had an initial water holding capacity of 53.66 per cent, but after the 15th day of storage, it decreased to 47.00 per cent. The WHC of papaya pulp based yoghurt was initially 56.34 per cent which decreased on storage to 53.00 per cent. Lower WHC or whey separation refers to a gel network weakening (Singh and Muthukumarappan, 2008).

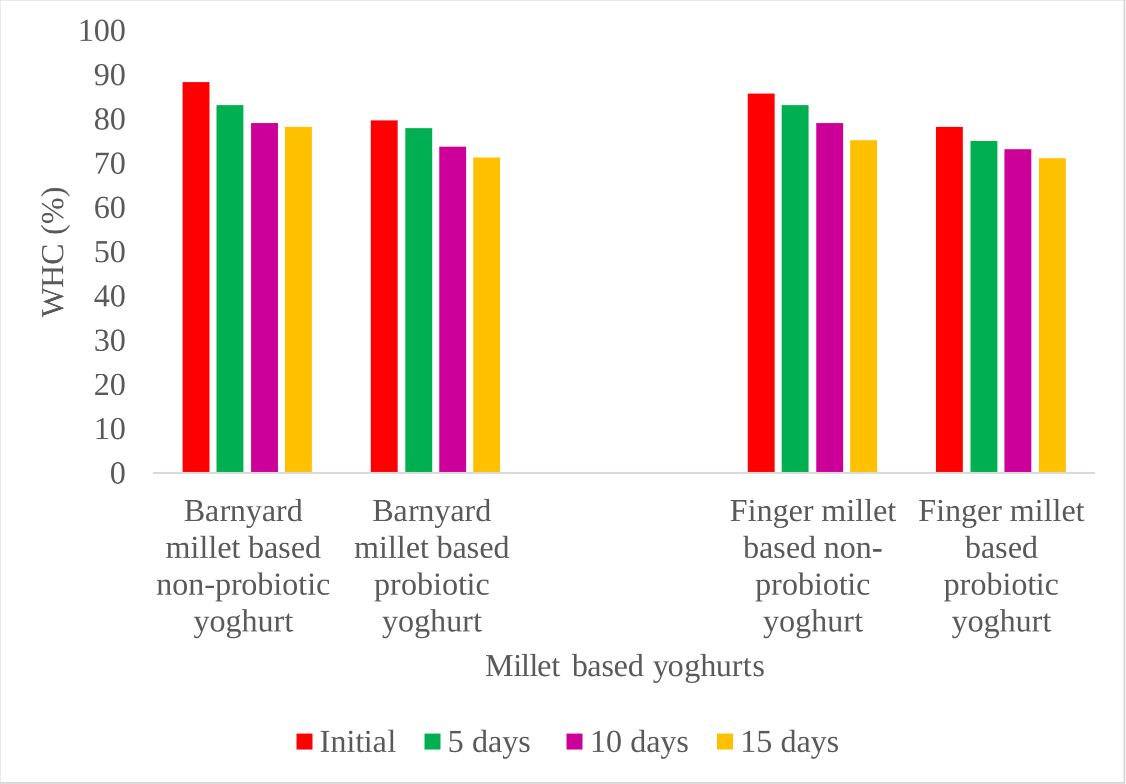


Fig. 11. Water holding capacity of millet based yoghurts (%)

5.3.1.5. Syneresis of millet based yoghurts

Yoghurt's surface oozing with water is known as syneresis. One of the yoghurt quality criteria is syneresis. Yoghurt of poor quality had a higher syneresis value, which is evident. The syneresis of the millet based yoghurts was recorded and according to this data, the probiotic yoghurt had maximum syneresis than non-probiotic yoghurt. The syneresis increased during storage (Fig. 12).

Syneresis is the most noticeable flaw in yoghurt preservation and it might have an impact on the end product's acceptability (Fishman *et al*., 2004). Syneresis occurs when the capacity of the yoghurt gel to entrap the serum phase is lost owing to the weakening of the gel network, resulting in whey separation (Lucey, 2004). Yoghurt with probiotic may have the highest level of syneresis, which may be due to differentiation in metabolic activities of starter cultures which cause poor consistency of the coagulum of milk and its inability to retain serum (Yilmaz-Ersan and Kurdal, 2014). The increase in syneresis on storage is due to a decrease in pH (Nguyen *et al*., 2016). Yoghurt syneresis with storage was shown to be increasing.

The results are similar to the study by Pagthinathan and Nafees (2018) who developed probiotic yoghurt and studied its rheological attributes. The syneresis of non-probiotic yoghurt was 36.77 per cent and for probiotic it was 36.93 per cent.

Soni *et al.* (2020) developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The syneresis of non-probiotic yoghurt was 12.40 per cent and for probiotic yoghurt, syneresis was 13.91 per cent and a significant difference was found between non-probiotic and probiotic yoghurt.

When the storage days increase the syneresis of the yoghurt also increases. Similar result was observed in the study by Lovely (2019) who prepared yoghurt with fruits and studied its rheological properties. The syneresis of control yoghurt was 1 per cent and for sapota added yoghurt it was 0.7 per cent. After storage of 15 days, it was increased to 2.6 per cent for control yoghurt and 1.8 for sapota added yoghurt.

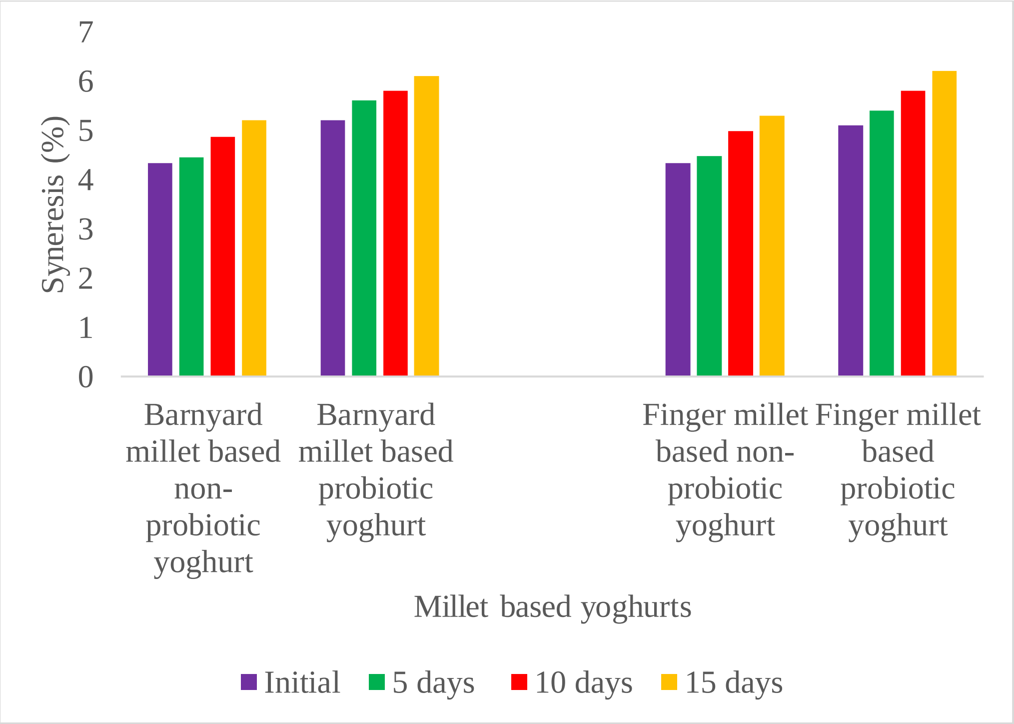


Fig. 12. Syneresis of millet based yoghurts during storage (%)

5.3.1.6. Viscosity of millet based yoghurt

In this study, the viscosity of millet based non-probiotic and probiotic yoghurt was recorded. The probiotic yoghurt of both millets has the maximum viscosity than non-probiotic yoghurt and finally, on storage, the viscosity was decreased in each set of yoghurt (Fig. 13).

The viscosity and the structure of the gel are influenced by several factors, including the incubation temperature, casein concentration, heat treatment of the milk, acidity and type of starter culture; as well as the temperature at which the measurements are made. The viscosity is higher in probiotic yoghurt than non-probiotic yoghurt (Tamime, 2006). The decrease in viscosity on storage depends on the concentration of organism used (Donkor *et al*., 2007)**.**

Remya (2020) proved that the viscosity of jack fruit based yoghurt decreased on storage. For control yoghurt (non-probiotic yoghurt), the viscosity was 27200 cP and for jackfruit (*koozha*) based probiotic yoghurt the viscosity was 28800 cP. On storage, it was reduced to 21500 cP and 23400 cP for control yoghurt and jackfruit probiotic yoghurt respectively. So, we can conclude that viscosity was higher in probiotic yoghurt than in non-probiotic yoghurt and during storage it has decreased.

Soni *et al.* (2020) developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The viscosity of non-probiotic yoghurt was 816 mPa and for probiotic yoghurt, viscosity was 876 mPa. Similar findings were observed in this study, high viscosity was seen in probiotic yoghurt and on storage the viscosity has decreased and was found to be significant difference between them.

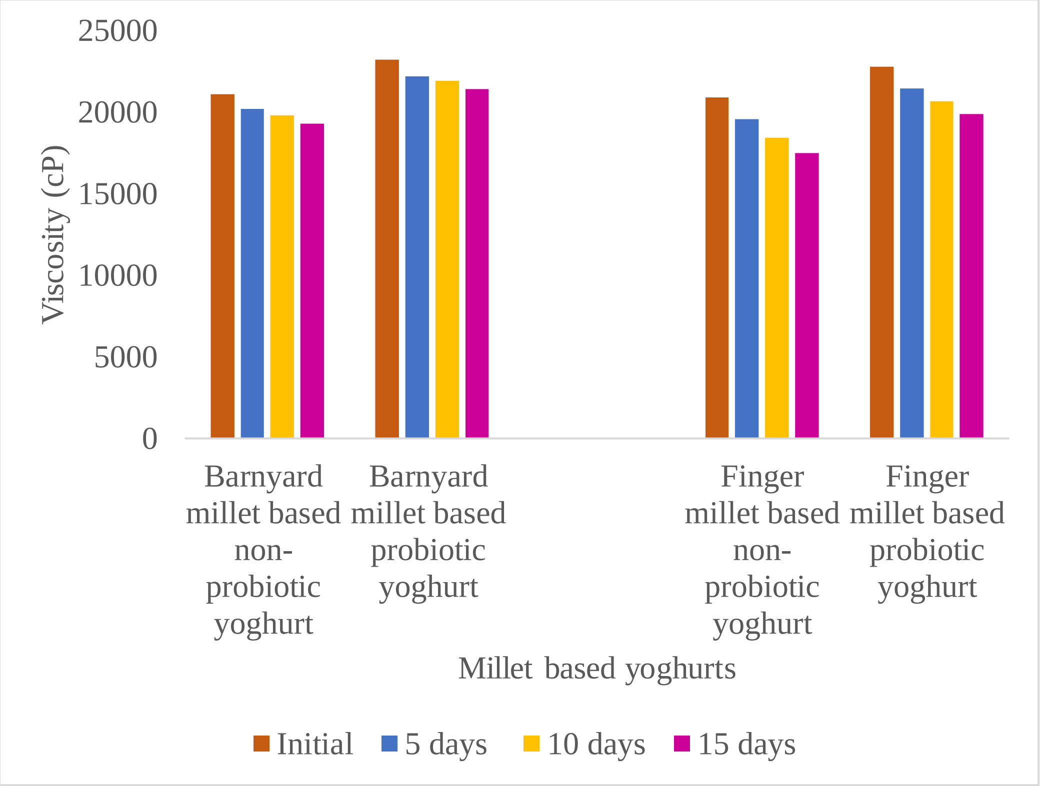


Fig. 13. Viscosity of millet based yoghurts during storage (cP)

5.3.1.7. Texture analysis of millet based yoghurt

Texture analysis of each set of yoghurts was done in the present study. The parameters assessed were cohesiveness, gumminess and resilience. Each parameter decreased after 15 days of storage and each parameter was high in probiotic than in non-probiotic yoghurt.

Cohesiveness refers to the strength of the internal linkages that make up the body and the degree to which it may be bent before breaking. Since cohesiveness is related to the strength of the internal bonds in the yoghurt structure, the lower the cohesiveness the smoother the yoghurt texture. The ratio of the positive force area during the second penetration to that of the initial penetration is known as cohesiveness. It may be calculated as the rate at which a material disintegrates when subjected to mechanical activity. Cohesiveness is shown in tensile strength. The cohesion of a product refers to its capacity to stay (Chandra and Shamasundar, 2015).

In the present study cohesiveness of both barnyard and finger millet was analysed (Fig. 14). The cohesiveness was higher in probiotic yoghurt than non-probiotic yoghurt in both sets and the cohesiveness of each set of millet based yoghurt was decreased on storage. This was similar to the findings of Yang *et al*. (2016), where the cohesiveness of fermented corn flour was higher compared to non-fermented corn flour. The cohesiveness of non-fermented food was 0.18 N and for fermented corn flour, the cohesiveness was 0.40 N. Rosni *et al*. (2020) prepared coconut dregs using *Rhizopus oligosporus* and studied the comparison of both fermented and non-fermented coconut dregs. She noticed cohesiveness of fermented coconut dregs was 0.38 N and for non-fermented coconut dregs was 0.33 N.

The product of hardness and cohesiveness is referred to as gumminess. A high gumminess rating is also found in yoghurt with a high hardness value. Gumminess is a property of semisolid foods that have a low degree of hardness but a high level of cohesion (Yildiz-Akgul *et al*., 2018).

The gumminess of barnyard and finger millet was studied and it was graphically represented in Fig. 15. The gumminess was higher in probiotic yoghurt than non-probiotic yoghurt in both sets and the gumminess of each set of millet based yoghurt was decreased on storage. According to Yang *et al*. (2016) the gumminess of fermented corn flour was higher compared to non-fermented corn flour. The gumminess of non-fermented food was 272 per cent and for fermented corn flour, the gumminess was 843 per cent.

In the present study the resilience of both barnyard and finger millet based yoghurt was analysed and it was graphically represented in Fig.16. The higher resilience was seen in probiotic yoghurt of both millet based yoghurt and by storage it was decreases. Resilience is another textural feature of yoghurt samples measured by TPA analysis. It has to do with the product's capacity to return to its original position following deformation (Yildiz-Ersan and Kurdal, 2014).

Rosni *et al*. (2020) prepared coconut dregs using *Rhizopus oligosporus* and studied the comparison of both fermented and non-fermented coconut dregs. She noticed cohesiveness of fermented coconut dregs was 0.14 N and for non-fermented coconut dregs was 0.13 N.

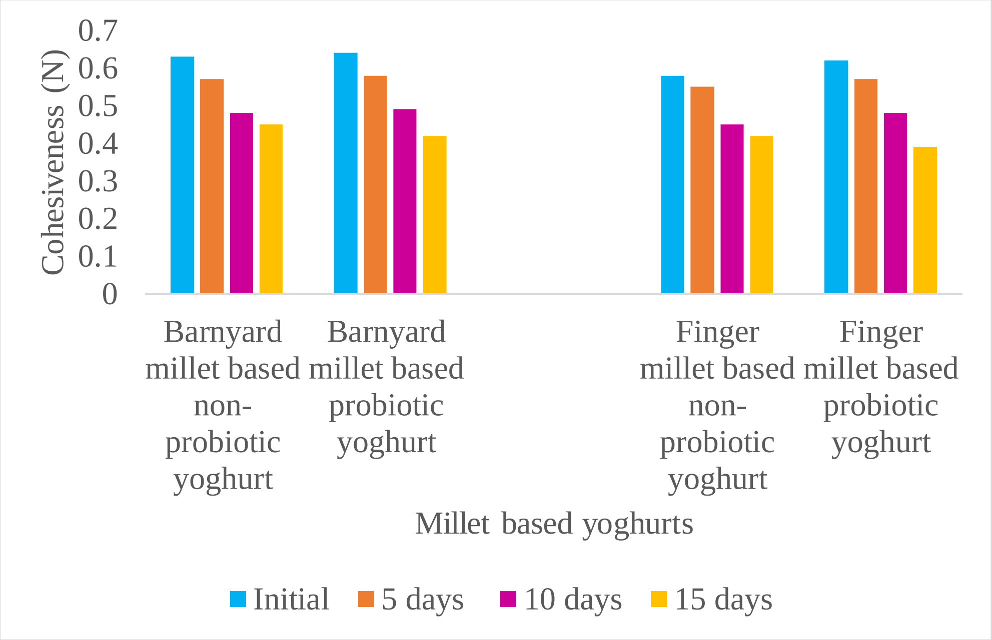


Fig. 14. Cohesiveness of millet based yoghurts during storage (N)

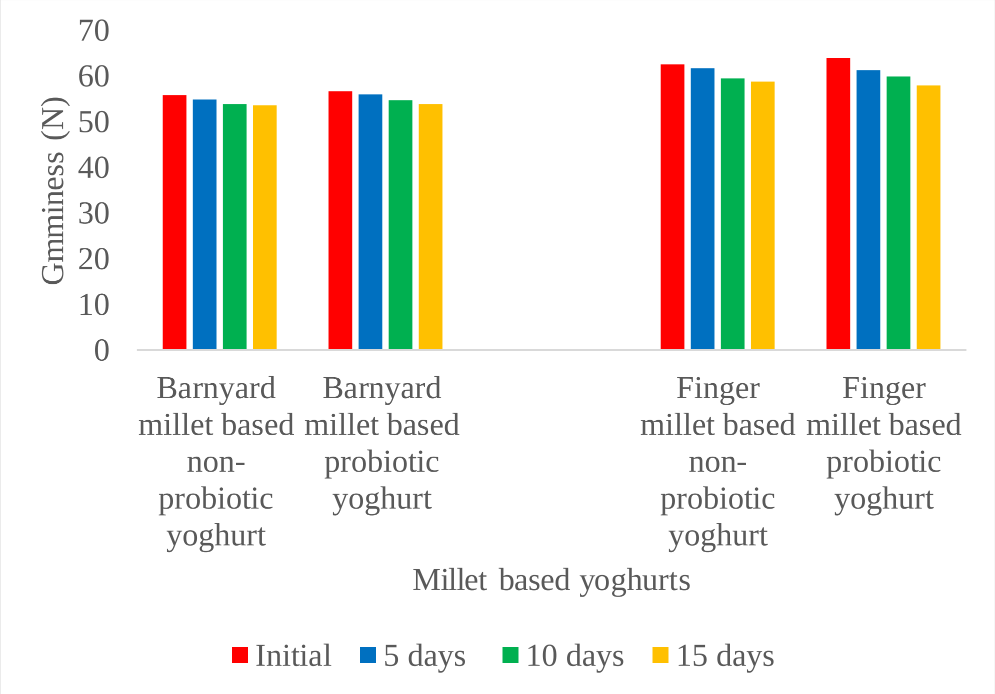


Fig. 15. Gumminess of millet based yoghurts during storage (N)

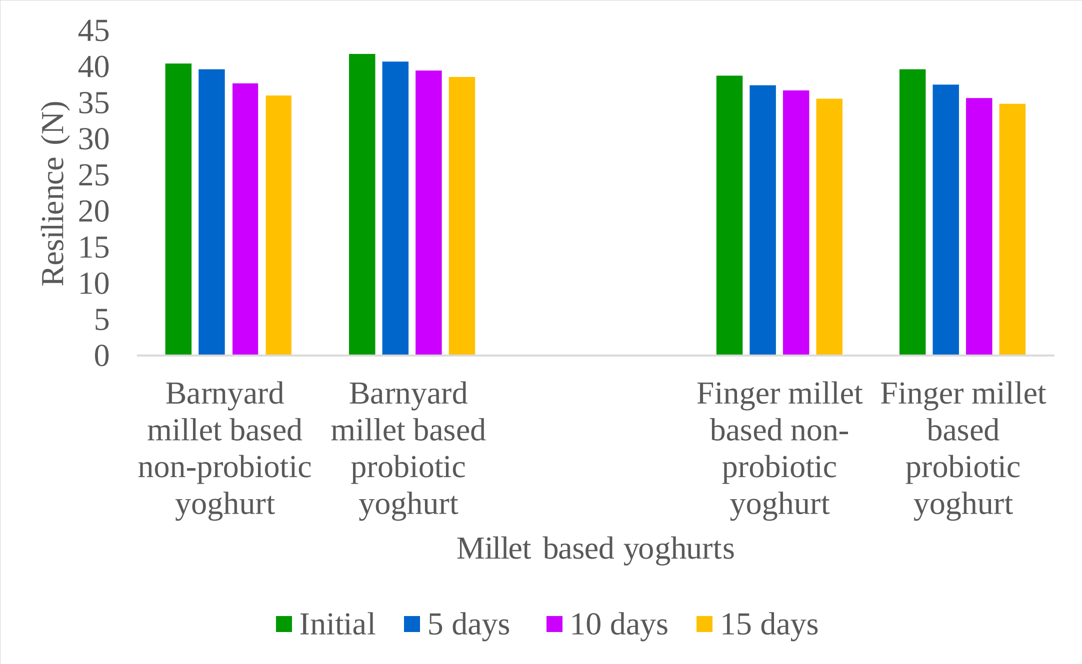


Fig. 16. Resilience of millet based yoghurts during storage (N)

5.3.1.8. Carbohydrate

The carbohydrate of millet based yoghurts was calculated and is shown in Fig.17. According to this study, probiotic (both barnyard and finger millet) yoghurts had more carbohydrates compared to non-probiotic yoghurt. The carbohydrate of yoghurts in both sets was reduced.

Increased carbohydrate breakdown and moisture conversion may be related to the decrease in the carbohydrate Yang *et al*. (2017). Nnam and Obiakor (2003), studied the availability of carbohydrate in fermented food products and concluded that the availability of carbohydrate decreased during fermentation. The simple carbohydrates are used by the organisms present in the fermented food products for their growth. So that the availability of carbohydrate is less compared to non-fermented food products.

This was seen by Soni *et al*. (2020), who developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The carbohydrate content of non-probiotic yoghurt was 6.65 g/100 g and for probiotic yoghurt carbohydrate content was 6.60 g/100 g. Here the carbohydrate was high in non-probiotic yoghurt. A significant difference was seen in both non-probiotic and probiotic yoghurt.

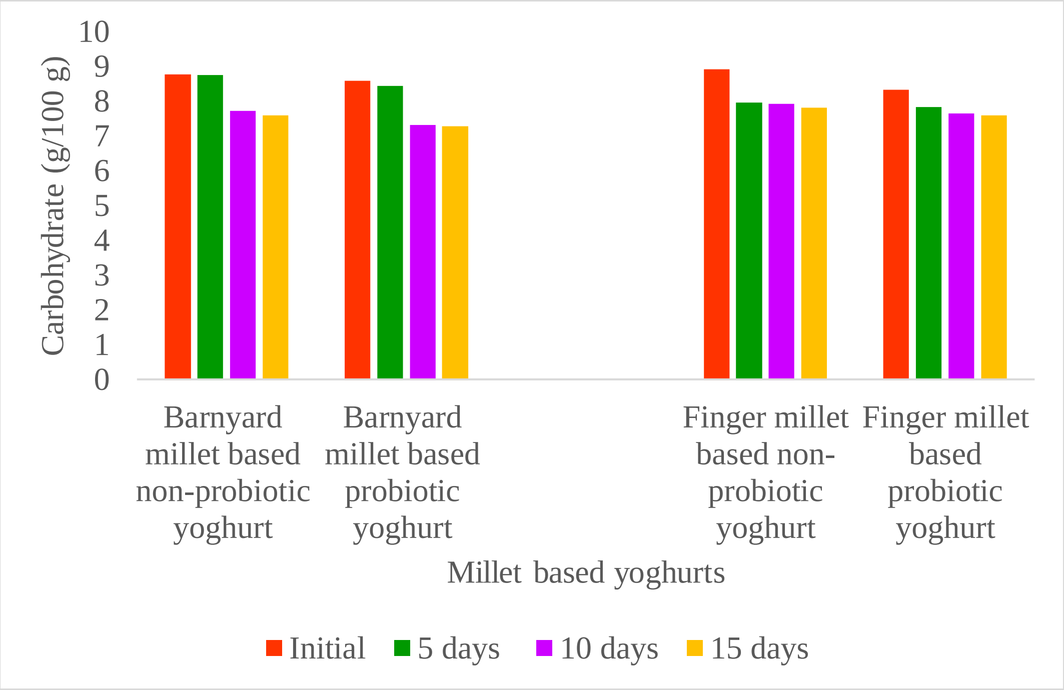


Fig. 17. Carbohydrate of millet based yoghurts during storage (g/100 g)

When the storage increases the carbohydrate content will decrease. This can be seen in the study by Lovely (2019) that prepared fruit based yoghurt with a carbohydrate of 11.5 per cent in control yoghurt and 10.60 per cent for sapota added yoghurt. This was reduced to 10 per cent in control and 9.4 per cent in sapota based yoghurt after storage.

5.3.1.9. Protein

The protein content of millet based yoghurt was determined and the results are shown in Fig.18. Non-probiotic (barnyard and finger millet) yoghurt had less protein than probiotic yoghurt, according to this study. The protein of yoghurts in each set decreased on storage.

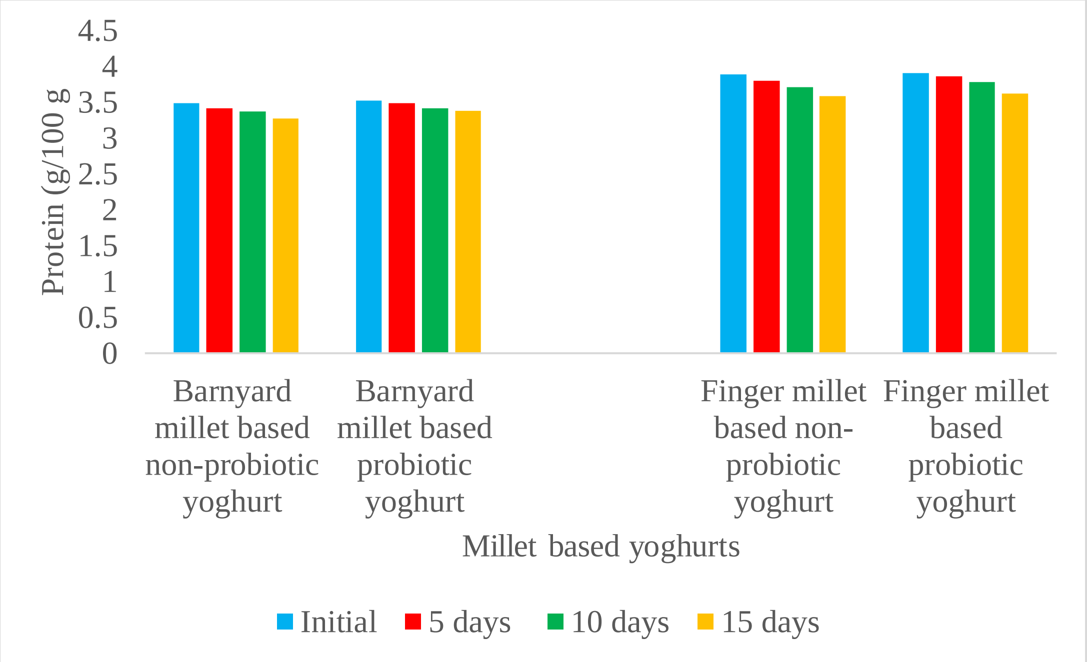


Fig. 18. Protein of millet based yoghurts during storage (g/100 g)

As the fermentation process continues, there is an increase in microbial population and a degradative reaction, which might explain the increase in protein (Gupta *et al*., 2007). This makes it easier for the bacteria in fermented foods to release more protein. Due to the viability of probiotic organisms, the proteolytic activity of yoghurt increases, so the availability of protein in yoghurt increases (Adhikari *et al*., 2002). Milk proteins are acidified by lactic acid and hydrolysed by proteases and peptidases from bacteria during the fermentation process (Tzvetkova *et al*., 2007).

This was seen in the study by Hussain *et al*. (2016) who studied the difference in the physicochemical properties of non-probiotic and probiotic freeze dried dahi with *Lactococcus lactis* and probiotic culture *L. paracasei ssp. paracasei*. The protein content of probiotic yoghurt was 5.30 per cent and for non-probiotic yoghurt, the protein content was 5.40 per cent.

In another study by Soni *et al*. (2020) probiotic milk yoghurt was compared with non-probiotic milk yoghurt. The probiotic organism used was *L. plantarum*. The protein content of non-probiotic yoghurt was 3.21 g and for probiotic yoghurt, the protein content was 3.93 g. the protein content was high in the case of probiotic yoghurt. The non-probiotic and non-probiotic yoghurts were found to be significantly different.

When the storage days increases the protein content decreases, this was similar to the findings of Lovely (2019) who prepared fruit based yoghurt with a protein content of 4.59 per cent in control yoghurt and 3.77 per cent for sapota added yoghurt. This was reduced to 3.35 per cent in control and 2.71 per cent in sapota based yoghurt after storage.

According to FSSAI (2022) the yoghurt should have the minimum protein of 2.9 per cent which agrees the present study.

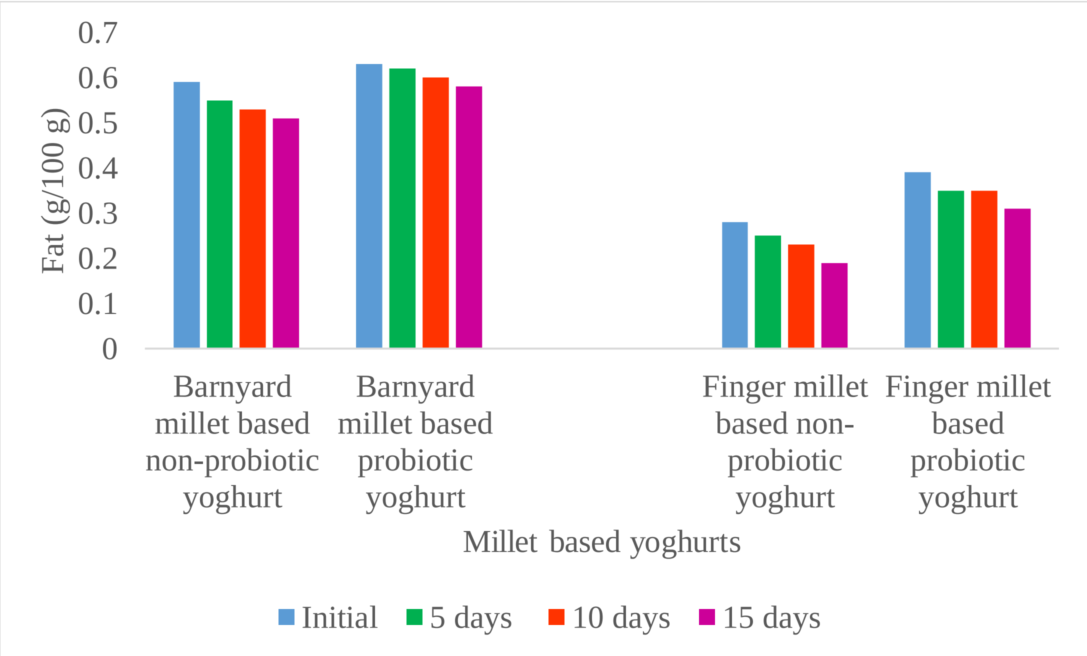


Fig. 19. Fat content of millet based yoghurts during storage (g/100 g)

5.3.1.10. Fat

The fat content of selected millet based yoghurts was studied (Fig. 19). The fat content of both millet (barnyard and finger millet) based yoghurt was higher in probiotic yoghurt than in non-probiotic yoghurt. With increasing storage days, all yoghurts exhibited a decreasing trend in fat. The fat content of the yoghurts had drastically decreased at the end of the 15^{th} day of storage.

The availability of high fat content of probiotic yoghurt is because of the increased level of acidity due to the increase of lactic acid which can hydrolyse fat molecules into smaller molecules, so the bioavailability of fat increases in probiotic yoghurt (Tzvetkova *et al*., 2007).

Hussain *et al*. (2016) studied the difference in the physicochemical properties of non-probiotic and probiotic freeze dried dahi with *Lactococcus lactis* and probiotic culture *L. paracasei ssp. paracasei*. The fat content of probiotic yoghurt was 0.76 per cent and for non-probiotic yoghurt, the fat content was 0.29 per cent and a significant difference was observed between fermented and non-fermented coconut dregs

Pagthinathan and Nafees (2018) also developed probiotic yoghurt and studied its physicochemical attributes. The fat of non-probiotic yoghurt was 2.91 per cent and for probiotics, it was 2.92 per cent.

The fat content of yoghurt was standardised by FSSAI (2022) that the fat should be more than 0.5 and Less than 3.0 for skimmed milk based yoghurt and this agrees to the present study.

5.3.1.11. TSS

The TSS of selected millet based yoghurts was tabulated and is presented in Fig. 20. According to this data, the TSS of probiotic (both barnyard and finger millet) yoghurt was lower than non-probiotic yoghurt. The TSS of yoghurts in each millet based yoghurts, decreased with storage.

By fermentation process, the complex carbohydrate hydrolyses to form simple carbohydrates. In the case of yoghurt, the lactose is formed by fermentation and this lactose is used by the *L. acidophilus*. So the bioavailability of soluble solids decreased in probiotic yoghurt than in non-probiotic yoghurt (Blandino *et al*., 2003).

During storage, the TSS of yoghurt decreased from 7.33º brix to 6.83º brix in corn milk yoghurts and from 15.33º brix to 14.9 º brix in cow milk yoghurts (Vasiljevic and Jelen, 2002). The decrease may be because of the use of sugar by the probiotic organism *L. delbrueckii*.

The TSS difference in non-probiotic and probiotic milk yoghurt was studied by Soni *et al.* (2020) who said that the TSS of non-probiotic milk yoghurt was greater than probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The TSS of non-probiotic yoghurt was 12.11° brix and for probiotic yoghurt, TSS was 11.91 ° brix which was in line with the findings of the present study and it was found to be a significant difference between them.

According to FSSAI (2020) standards specification the TSS of yoghurts should have the minimum of 8° brix and this agrees to the findings of the present study.

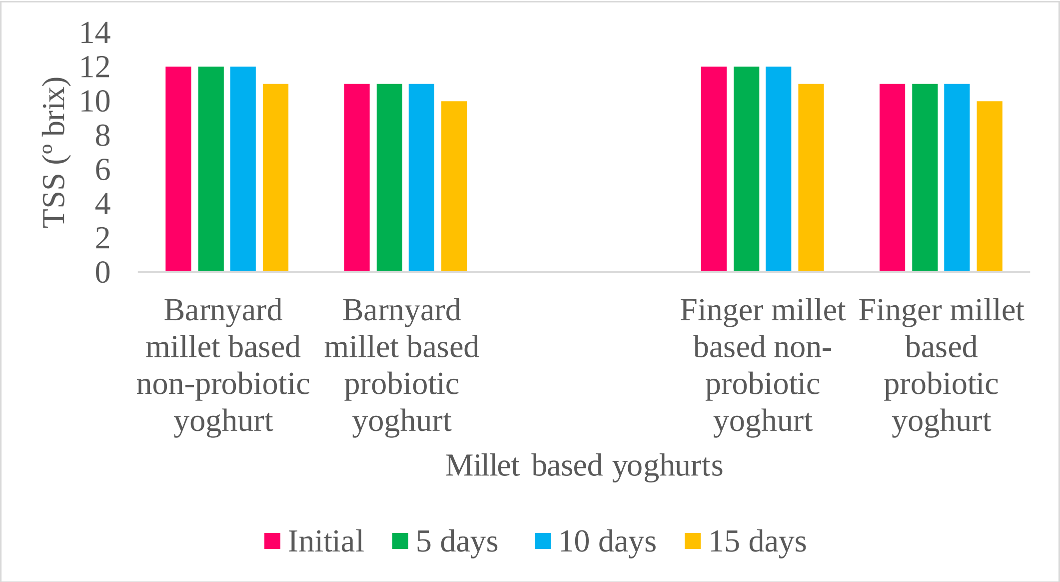


Fig. 20. TSS of millet based yoghurts during storage (° brix)

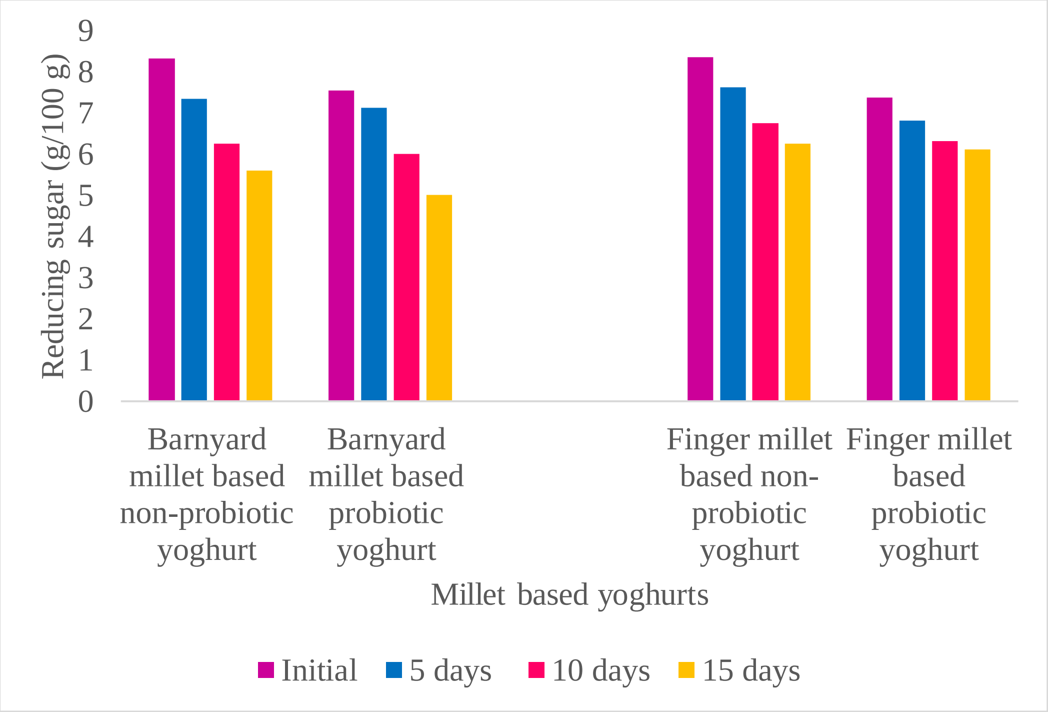


Fig. 21. Reducing sugar of millet based yoghurts during storage (g/100 g)

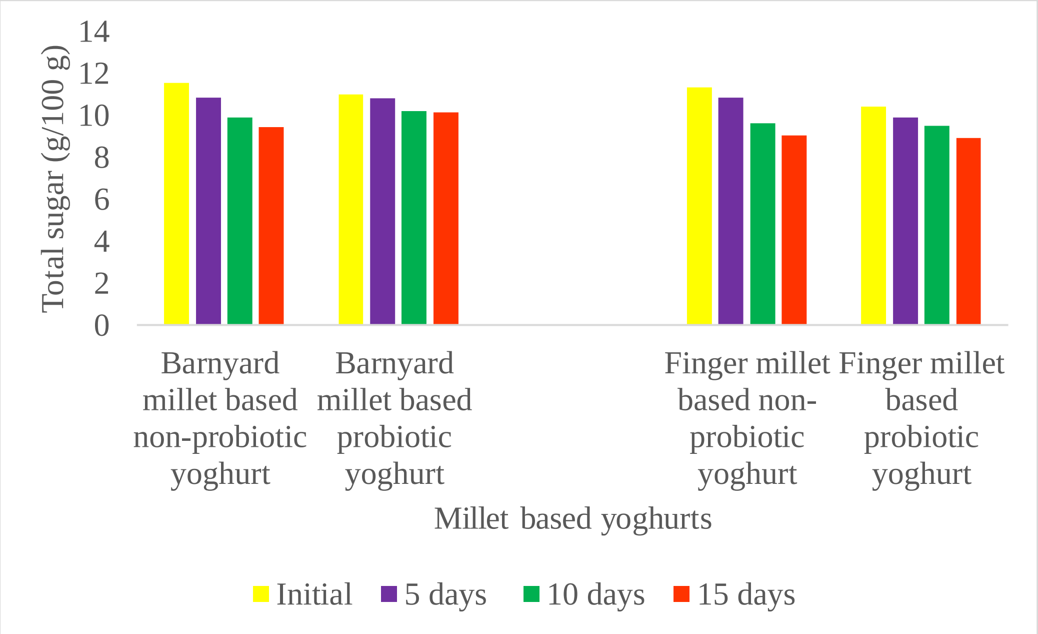


Fig. 22. Total sugar of millet based yoghurts during storage (g/100 g)

5.3.1.12. Reducing sugar and total sugar

The reducing and total sugar of selected millet based yoghurts were tabulated and are presented in Fig. 21 and 22. The reducing sugar and total sugar of both millet based probiotic yoghurt were less compared to non-probiotic yoghurt. On storage, there was a reduction in reducing and total sugar of both barnyard and finger millet yoghurt.

The conversion of lactose into lactic acid by lactic acid bacteria is utilised for the growth of the probiotic organism. This causes the reduction of sugar in fermented food products (Metry and Owayss, 2009).

Pagthinathan and Nafees (2018) developed probiotic yoghurt with *Bifidobacterium* and studied its physicochemical attributes. The reducing sugar of non-probiotic yoghurt was 2.40 per cent and for probiotic it was 2.37 per cent. The total sugar of non-probiotic yoghurt was 13.53 per cent and for probiotic it was 13.17 per cent.

According to Lovely (2019), the total sugar content was decreased on storage of selected fruit pulp based yoghurt and its control yoghurt. For control yoghurt the total sugar was 11.58 per cent and 15.14 for sapota added yoghurt. It was decreased to 11.71 for control yoghurt and 14.94 for sapota added yoghurt after 15 days of storage. In the case of reducing sugar, in control yoghurt the reducing sugar was reduced from 5.15 per cent to 5.08 per cent and for sapota added yoghurt it was 7.14 per cent to 6.63 per cent. When the storage days increase the reducing and total sugar of each yoghurt decreases. A significant difference was found between them in both reducing and total sugar.

5.3.1.13. Crude fibre

The crude fibre of a variety of millet based yoghurts was calculated and is shown in Fig.23. According to this study, probiotic (both barnyard and finger millet) yoghurt has lower crude fibre compared to non-probiotic yoghurt. The crude fibre of yoghurts in both sets reduced on storage.

The probiotic organisms present in the fermented food products utilised fibre as the source of carbon for their growth, so the availability of fibre in probiotic is less compared to non-probiotic food products (Ogodo *et al*., 2017).

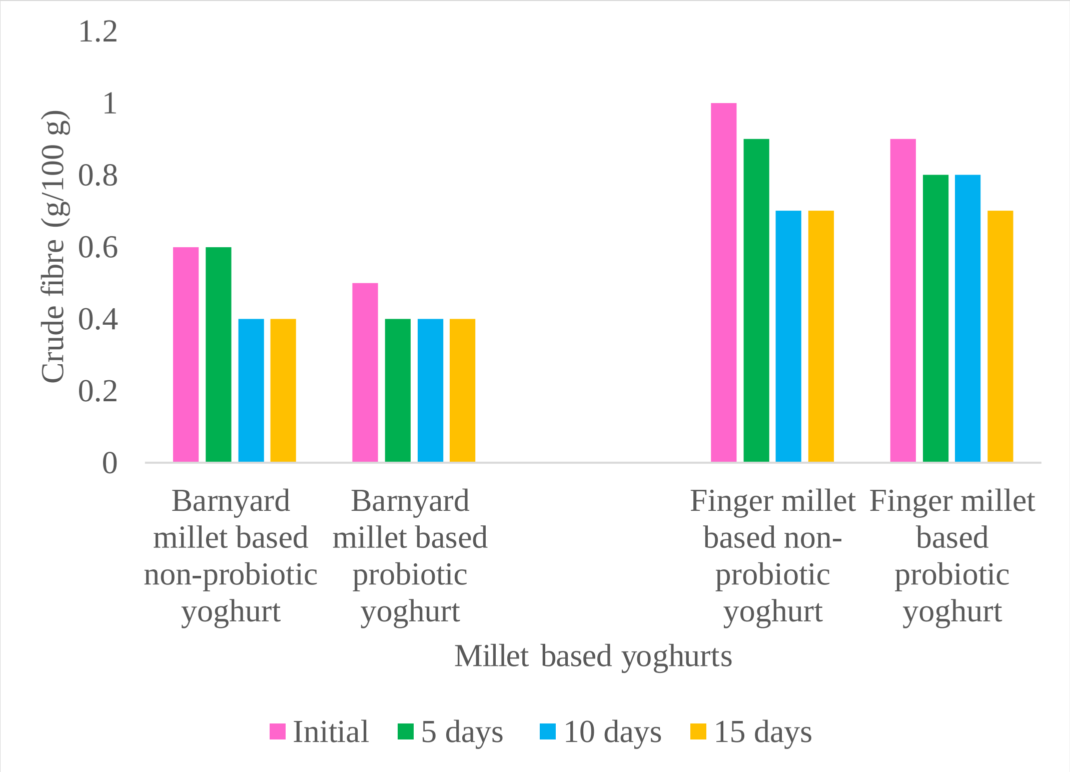


Fig. 23. Crude fibre of millet based yoghurts during storage (g/100 g)

Rosni *et al*. (2020) prepared coconut dregs using *Rhizopus oligosporus* and studied the comparison of both fermented and non-fermented coconut dregs. She noticed crude fibre of fermented coconut dregs was 5.54 per cent and for non-fermented coconut dregs was 6.32 per cent.

According to Ogundipe *et al*, (2021) crude fibre of tiger nut based yoghurt was found to be 0.81-0.11 per cent. A reduction in fibre content was observed throughout the storage period. This may be because of the action of fermenting bacteria present in the yoghurt. Lactic acid produced during fermentation will cause hydrolysis of fibre and the presence of moisture will enhance this process.

5.3.1.14. Total ash

The total ash content of millet based yoghurts was determined and the results are detailed in Fig.24. According to this study, probiotic yoghurt (both barnyard and finger millet) has higher total ash than non-probiotic yoghurt and total ash decreased with storage in each set of yoghurts.

Ilowefah *et al*. (2015) studied the ash content of fermented food products and concluded that by fermentation, the ash content is increased, due to the increase in bioavailability of minerals.

This result was in line with the findings of Soni *et al*. (2020) who developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The ash content of non-probiotic yoghurt was 0.6 the 7 g and for probiotic yoghurt, ash content was 0.71 gram.

When the storage days increase the ash content also decreases. Similar observation can be seen in Lovely (2019) who prepared fruit-based yoghurt with ash content of 1.69 per cent in control yoghurt and 1.63 per cent for sapota added yoghurt. This was reduced to 0.96 per cent in control and 0.70 per cent in sapota based yoghurt after storage.

5.3.1.15. Mineral availability of millet based yoghurt

The mineral content of millet based yoghurts is discussed in this section. The minerals include calcium, iron, potassium, phosphorus, zinc and magnesium. Plant based diets include a significant quantity of phytate, which decreases the absorption of dietary minerals including zinc, iron, calcium and magnesium (Irving and Mc Mullen, 1980). Fermentation results in a reduction in phytate levels, which may increase the availability of minerals (Mohite *et al*., 2013).

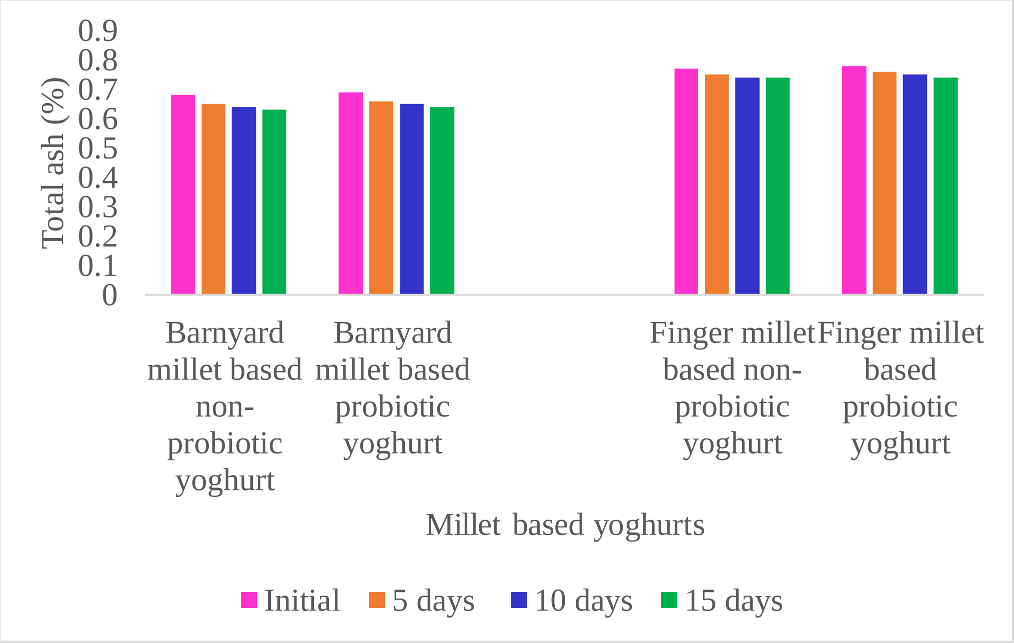


Fig. 24. Total ash of millet based yoghurts during storage (%)

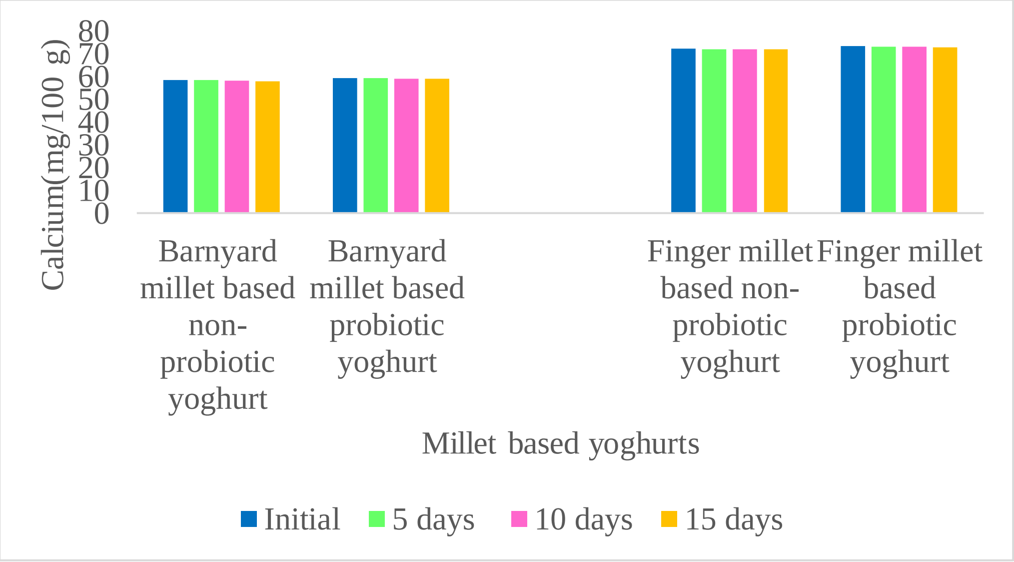


Fig. 25. Calcium content of millet based yoghurts during storage (mg / 100 g)

5.3.1.15.1. Calcium

The prepared millet based yoghurts showed higher calcium in probiotic yoghurt in both millets (barnyard and finger millet) than in non-probiotic yoghurt and during storage, the calcium was decreased (Fig. 25).

Rekha and Vijayalakshmi (2010) studied the difference between non-fermented soy milk and fermented soy milk and found that the calcium content of soy milk fermented was 18.50 mg/100 g and for non-fermented soy milk the calcium content was 5.40 mg/100 g.

When the storage days increase the calcium content of yoghurt decreased. This was in line to the findings of Sarabhai (2012) who developed rice based yoghurt and recorded the calcium content as 97.9 mg/100 g for milk yoghurt which decreased on storage to 97 mg/100 g and for unroasted raw rice based yoghurt it was 35.7 mg/100 g and on storage it was decreased to 34.6 mg/100 g.

When compared to fermented and non-fermented food the calcium content was high in probiotic or fermented food. This was similar to the findings by Soni *et al*. (2020) who developed probiotic milk yoghurt and compared it with non-probiotic yoghurt. The probiotic organism used was *L. plantarum*. The calcium content of non-probiotic yoghurt was 110.07 mg and for probiotic yoghurt, calcium content was 125.61 mg and a significant difference was observed between non-probiotic and probiotic yoghurt.

Rahim *et al*. (2020) studied the fermentation of soya beans with *Bacillus amyloliquefaciens* and non-fermented soya beans. The calcium content of fermented soya beans was recorded as 1834.64 mg/kg and for non-fermented soy beans the calcium content was 1754.41 mg/kg. Here it is clear that fermentation can enhance minerals in food.

5.3.1.15.2. Iron

The prepared millet based yoghurts showed higher iron content in probiotic yoghurt than non-probiotic yoghurt in both millets (barnyard and finger millet) with no significant difference between probiotic and non-probiotic yoghurt. In both sets, the iron content decreased with increased storage days (Fig. 26).

Goswami *et al*. (2016) investigated the mineral availability of both fermented and non-fermented foods (*Poita bhat* is a traditional fermented food made from rice). The cooked rice had an iron concentration of 0.45 mg / g and after 12 hours of fermentation, it had increased to 1.35 mg / g. The decrease in phytic acid level brought on by fermentation and the subsequent release of iron may be connected to the greater iron content after fermentation. According to Mohite *et al*. (2013), fermented meals made from cereals such *Kurdai, Bidbe* and *Gulgula, Idli, Dosa, etc*. have an increased iron content after fermentation.

According to Soni *et al*. (2020) the iron content was high in probiotic milk yoghurt than non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The iron content of non-probiotic yoghurt was 0.21 mg/100 g and for probiotic yoghurt iron content was 0.24 mg/100 g.

Rahim *et al*. (2020) conducted research on both fermented and unfermented soy beans using *Bacillus amyloliquefaciens*. Fermented soya beans had an iron content of 61.93 mg/kg, whereas non-fermented soy beans had an iron content of 44.23 mg/kg. Here, it is evident that food may have its nutrients enhanced through fermentation.

5.3.1.15.3. Potassium

The potassium content of probiotic yoghurt was comparatively higher than non-probiotic yoghurt but there was no significant difference. The prepared millet based yoghurts showed a decreasing trend in potassium content with increasing storage days. After the 15th day of storage, the potassium of both millet based yoghurts had significantly decreased (Fig. 27).

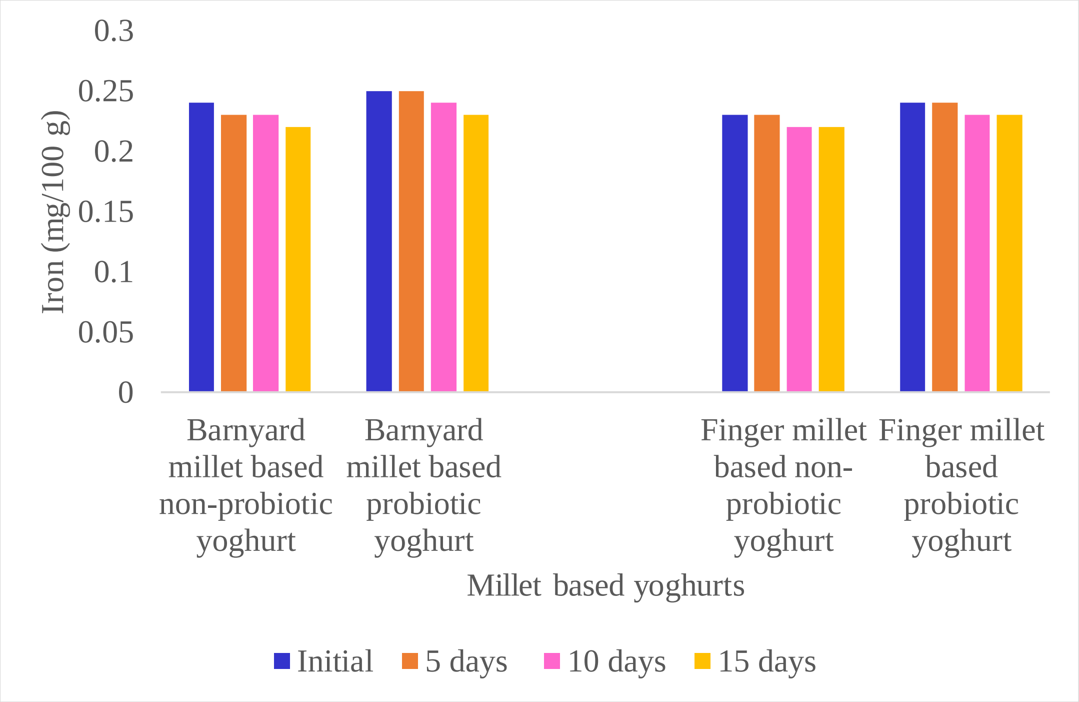


Fig. 26. Iron content of millet based yoghurts during storage (mg / 100 g)

When the storage increases the potassium content decreases. This was studied by Sarabhai (2012) who developed rice based yoghurt and recorded the potassium content as 88.30 mg/100 g for milk yoghurt which decreased on storage to 86.20 mg/100 g and for unroasted raw rice based yoghurt it was 39.30 mg/100 g and on storage it was decreased to 38.10 mg/100 g.

The mineral content of *Poita bhat*, a traditional fermented dish made from rice, was studied by Goswami *et al*. (2016) (both fermented and non-fermented food). Unfermented rice had a potassium level of 0.51 mg / g, which increased to 1.85 mg / g after 12 hours of fermentation. Wheat flour's potassium level increased to 186 mg/100 g after fermentation, from 133 mg/100 g before fermentation (Ijarotimi, 2012). After fermentation with various LAB and yeast cultures, it has been observed that the potassium content of *ogwo*, a fermented sorghum-Irish potato gruel increased (Adegbehingbe, 2015).

Using *Bacillus amyloliquefaciens*, Rahim *et al*. (2020) studied both fermented and unfermented soy beans. Compared to non-fermented soy beans, which had a potassium of 9945 mg/kg, fermented soy beans had a potassium of 10321 mg/kg. It is clear from this that food that undergo fermentation has increased nutrient content.

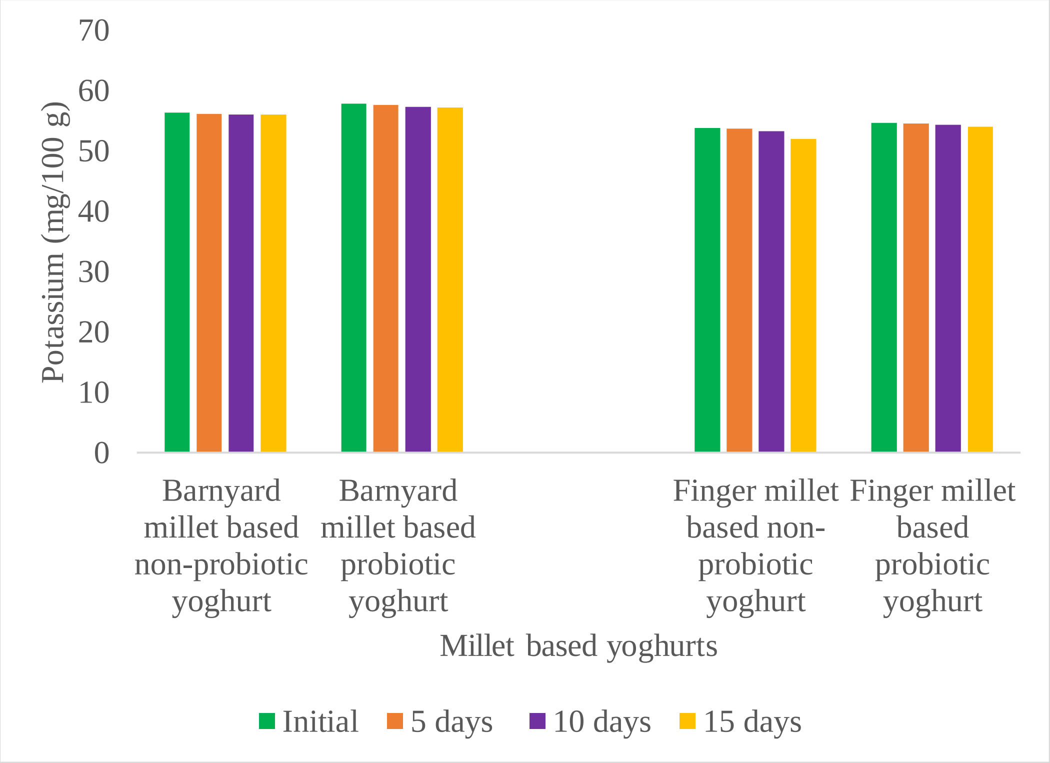


Fig. 27. Potassium content of millet based yoghurts during storage (mg / 100 g)

5.3.1.15.4. Phosphorus

The prepared millet based yoghurts showed a decreasing trend in phosphorus with increasing storage days and the phosphorus availability of probiotic yoghurt was higher than non-probiotic yoghurt (Fig. 28).

The mineral availability of *Poita bhat* is a traditional fermented food made from rice (both fermented and non-fermented foods) was studied by Goswami *et al*. (2016). Before fermentation, the phosphorus level of rice was 0.41 mg/g, rising to 0.80 mg/g after 12 hours of fermentation. The breakdown of phytic acid and subsequent release of phosphorus may be the reason for the increase in phosphorus concentration following fermentation. According to Bhatia and Khetarpaul (2012), following fermentation at 35 and 40° C, respectively, the phosphorus content of whole wheat bread altered with sprouted chickpea increased to 8.80 per cent and 10.10 per cent.

The sample's increased phosphorus concentration was attributed to microbial activity that breaks down phytic acid and release the bound phosphorus as a result.

This was similar to the findings of Soni *et al*. (2020) who developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. plantarum*. The phosphorus content of non-probiotic yoghurt was 78.55 mg/100 g and for probiotic yoghurt phosphorus content was 85.31 mg/100 g. A significant difference was observed between probiotic and non-probiotic yoghurt.

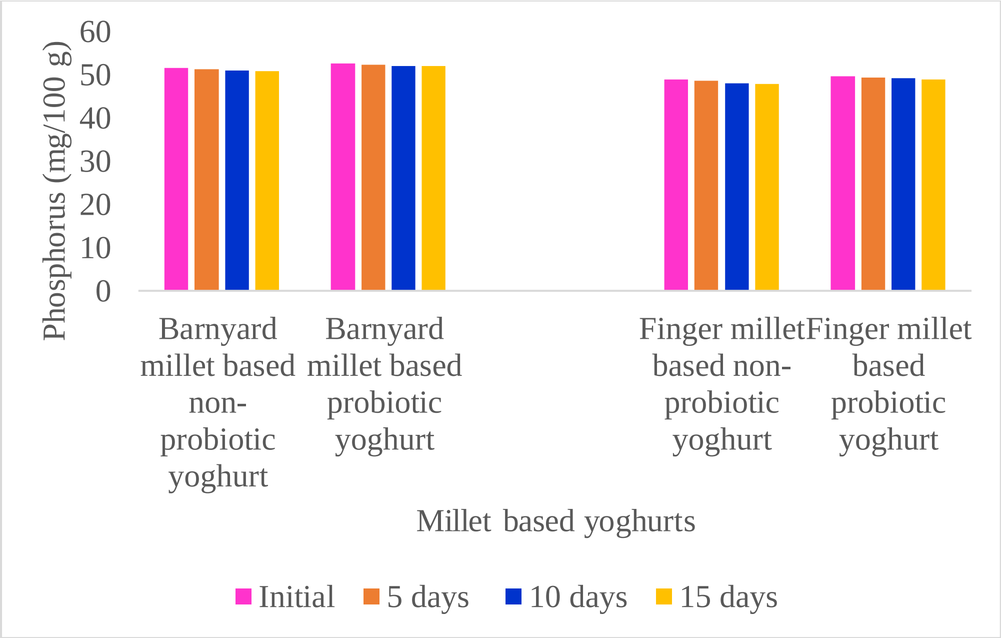


Fig. 28. Phosphorus of millet based yoghurts during storage (mg / 100 g)

5.3.1.15.5. Zinc

The zinc content of probiotic was higher than in non-probiotic yoghurt (Fig. 29). The prepared millet based yoghurts showed a declining trend in zinc content with increasing storage days.

Goswami *et al*. (2016) examined the mineral composition of *Poita bhat*, a traditional fermented rice dish (both fermented and non-fermented food). The zinc content of the fermented sample increased from 0.02 mg / g to 0.03 mg / g. Ijarotimi (2012) found that the zinc content of fermented wheat flour increased with fermentation. However, Onwurafor *et al*. (2014) showed that the zinc content of Mung Bean flour decreased after fermentation and Dwivedi *et al.* (2015) noted a comparable decrease in zinc concentration in *Nilamadana*, a fermented dish made from grain which hypothesised that the bacteria active in the fermentation process would have utilized the zinc for its development.

Similar results was seen in the study by Soni *et al*. (2020), who developed probiotic milk yoghurt and compared it with non-probiotic milk yoghurt. The probiotic organism used was *L. acidophilus*. The zinc content of non-probiotic yoghurt was 0.31 mg/100 g and for probiotic yoghurt, zinc content was 0.35 mg/100 g.

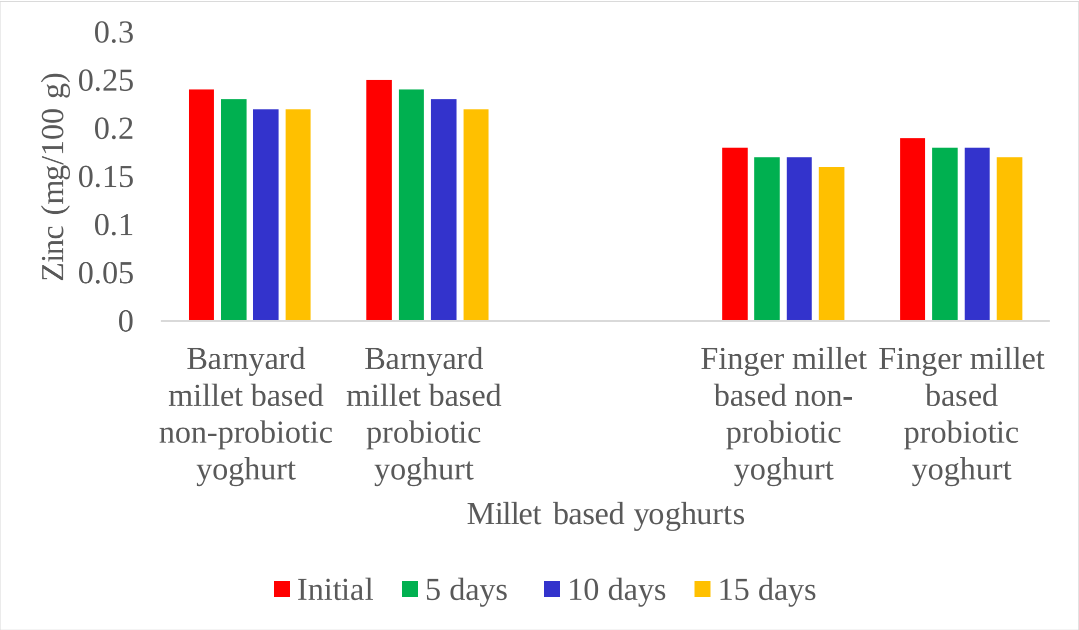


Fig. 29. Zinc of millet based yoghurts during storage (mg / 100 g)

Using *Bacillus amyloliquefaciens*, Rahim *et al*. (2020) studied both fermented and unfermented soy beans. Comparing the zinc level of fermented and non-fermented soy beans, the zinc content of fermented soy beans is 33.98 mg/kg and for non-fermented soy bean is 29.32 mg/kg. According to this, food can undergo fermentation to provide extra nutrients.

5.3.1.15.6. Magnesium

The magnesium content were higher in probiotic than in non-probiotic yoghurt (Fig. 30). The prepared millet based yoghurts showed a decreasing trend in magnesium with increasing storage days.

Goswami *et al*. (2016) investigated the mineral availability of *Poita bhat*, a traditional fermented food prepared from rice (both fermented and non-fermented food). Magnesium level before fermentation was 2.60 mg/g and increased to approximately 5.20 mg/g after fermentation. It was found that following fermentation, the magnesium content of several fermented cereals and meals based on pulses, such as *Idli, Dosa, Chikni papad, etc*., increased (Mohite *et al*., 2013). After fermentation, the samples higher magnesium level may also have resulted from microbial activity that reduced the samples phytate content. After fermentation, a reduction in pH may have also had an impact on the availability of magnesium. According to Grynspan and Cheryan (1983), phytate: magnesium complex, which has a molar ratio of 6: 1, totally breaks at pH 5, which also remains true for phosphorus.

Rahim *et al*. (2020) investigated both fermented and unfermented soy beans using *Bacillus amyloliquefaciens*. Fermented soy beans have magnesium content of 882.32 mg/kg compared to non-fermented soy beans 787.54 mg/kg. This indicates that food that go through fermentation provide more nutrients.

5.3.2. Health studies

5.3.2.1. *In vitro* mineral availability of millet based yoghurts

Bioavailability (biological availability, bio-absorption) is the degree to which a nutrient is changed by the body into a form appropriate for absorption and utilisation in metabolic processes and/or for storage (Jackson, 1997).

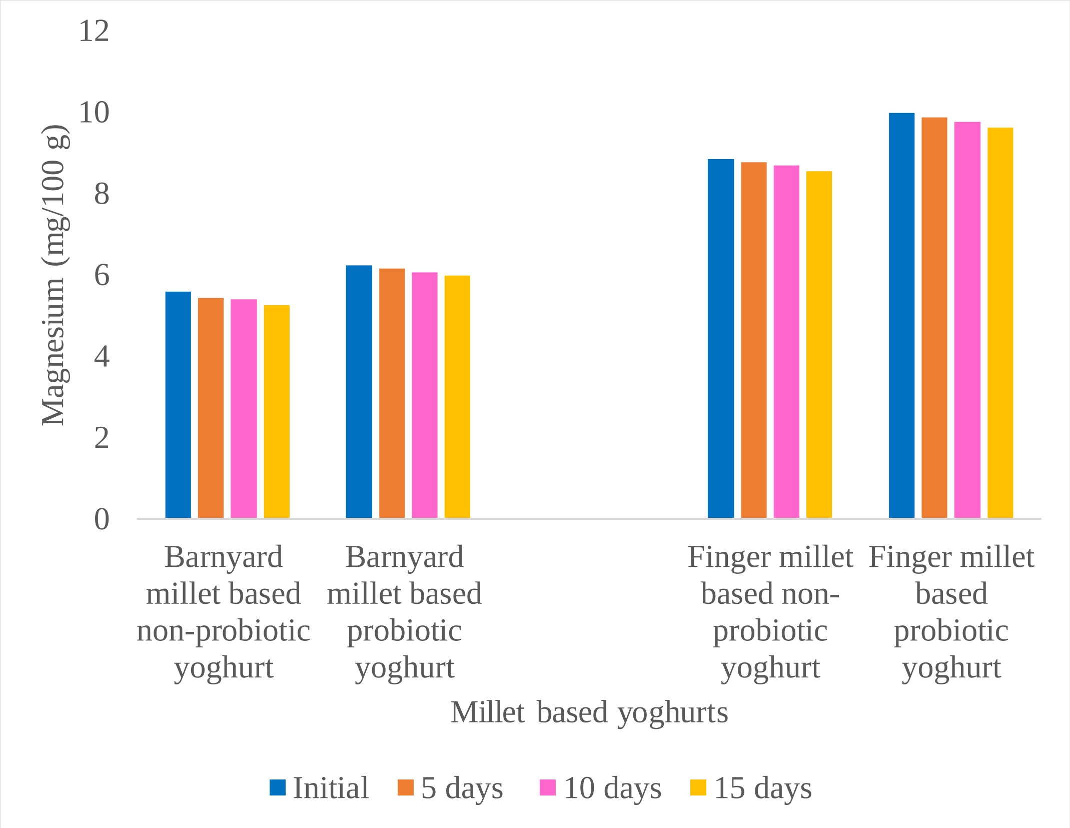


Fig. 30. Magnesium of millet based yoghurts during storage (mg / 100 g)

The three basic transition metals, iron, zinc and calcium are necessary for all life and for cellular viability (Lane *et al*., 2015). Phytate, phytic acid, oxalic acid and complex polysaccharides are examples of anti-nutritional substances that have a direct impact on the bioavailability of certain minerals (Gupta *et al*., 2015). Fermentation using filamentous fungus and bacteria, especially Aspergillus oryzae and L. acidophilus, helps to reduce the anti-nutritional and toxic components in the raw materials by making the proteins and minerals complex with phytochemicals more available (Guan *et al*., 2015; Tokuoka *et al*., 2010; Chancharoonpong *et al*., 2012; Adegbehingbe, 2015).

Evidence suggests that various fermentation processing techniques enhanced the mineral bioavailability in meals derived from plants. Five LAB strains have been shown to have the potential to increase mineral bioavailability.

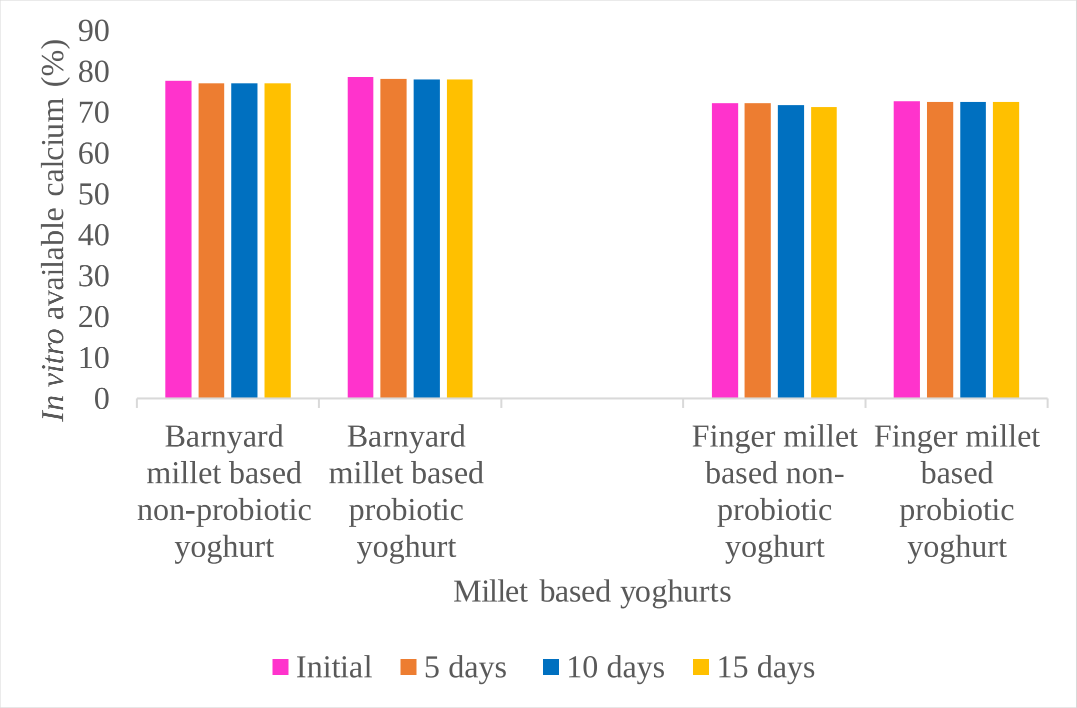


Fig. 31. *In vitro* available calcium of millet based yoghurts during storage (%)

5.3.2.1.1. Calcium

The prepared millet based yoghurts showed higher *in vitro* availability of calcium in probiotic yoghurt in both millets (barnyard and finger millet) than in non-probiotic yoghurt and during storage, the *in vitro* calcium availability was decreased (Fig. 31).

The impact of *Aspergillus oryzae*'s fermentation of peanut oil cakes on the bioavailability of micronutrients (*in vitro*) was analysed and it was found that the *In vitro* mineral availability of calcium in non-fermented peanut oil cake was 887 mg/kg and for fermented peanut oil cake it was 890 mg/kg. Here the calcium availability was high in fermented food than in non-fermented food (Sadh *et al*., 2017).

Rahim *et al*. (2020) made fermented soybean with *Bacillus amyloliquefaciens* and studied its mineral availability. The calcium availability of fermented soybean was 1834.64 g/kg and for non-fermented soybean, it was 1754 g/kg.

Lopez *et al*. (2000) found that in whole-wheat flour, where phytic acid was degraded by LAB, led to the increase in calcium and magnesium availability.

Fig. 32. *In vitro available* iron of millet based yoghurts during storage (%)

5.3.2.1.2. Iron

The prepared millet based yoghurts showed higher *in vitro* availability of iron content in probiotic yoghurt than non-probiotic yoghurt in both millets (barnyard and finger millet). In both sets, *in vitro* availability of iron content was decreased with increased storage days (Fig. 32).

Sadh *et al*. (2017) aimed to assess how *Aspergillus oryzae*'s fermentation of peanut oil cakes affected the micronutrients' bioavailability. The *in vitro* iron availability in non-fermented peanut oil cake was 34 mg/kg and 36 mg/kg in fermented peanut oil cake. In this case, fermented sample had a higher iron availability than non-fermented sample.

Rahim *et al*. (2020) made fermented soybean with *Bacillus amyloliquefaciens* and studied its mineral availability. The iron availability of fermented soybean was 61.93 g/kg and for non-fermented soybean, it was 44.23 g/kg.

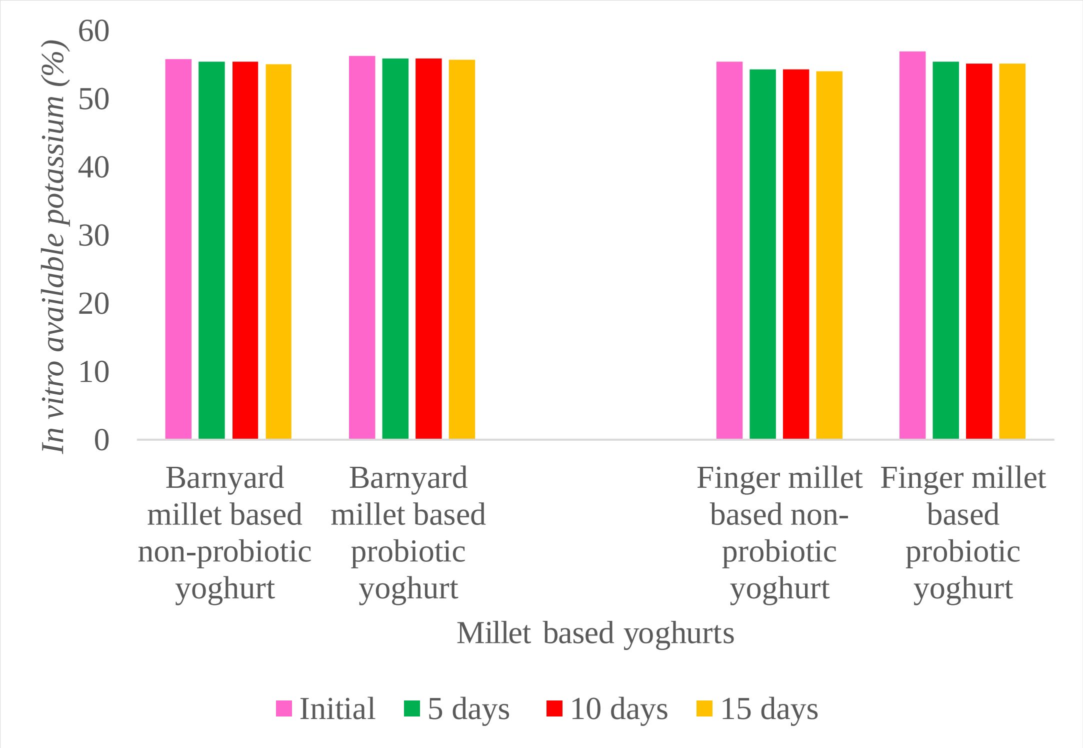


Fig. 33. *In vitro available* potassium of millet based yoghurts during storage (%)

5.3.2.1.3. Potassium

The *in vitro* availability of potassium availability of probiotic yoghurt was higher than non-probiotic yoghurt. The prepared millet based yoghurts showed a decreasing trend in *in vitro* availability of potassium availability with increasing storage days. After the 15^{th} day of storage, the *in vitro* potassium availability of both millet based yoghurts had significantly decreased (Fig. 33).

Rekha and Vijayalakshmi (2010) studied the difference between non-fermented soy milk and fermented soy milk and found that the bioavailability of potassium in soy milk fermented was 34.15 mg/100 g and for non-fermented soy milk the potassium content was 32.33 mg/100 g.

5.3.2.1.4. Phosphorus

The prepared millet based yoghurts showed a decreasing trend in *in vitro* phosphorus availability with increasing storage days and the *in vitro* availability of phosphorus and of probiotic yoghurt was higher than non-probiotic yoghurt (Fig. 34).

Rekha and Vijayalakshmi (2010) studied the difference between non-fermented soy milk and fermented soy milk and found that the bioavailability of phosphorus in soy milk fermented is 342.55 mg /100 g and for non-fermented soy milk the zinc content was 334.33 mg/100 g.

Rahim *et al*. (2020) made fermented soybean with *Bacillus amyloliquefaciens* and studied its mineral availability. The potassium availability of fermented soybean was 10321 g/kg and for non-fermented soybean, it was 9945 g/kg. The potassium content of fermented food is higher than non-fermented food.

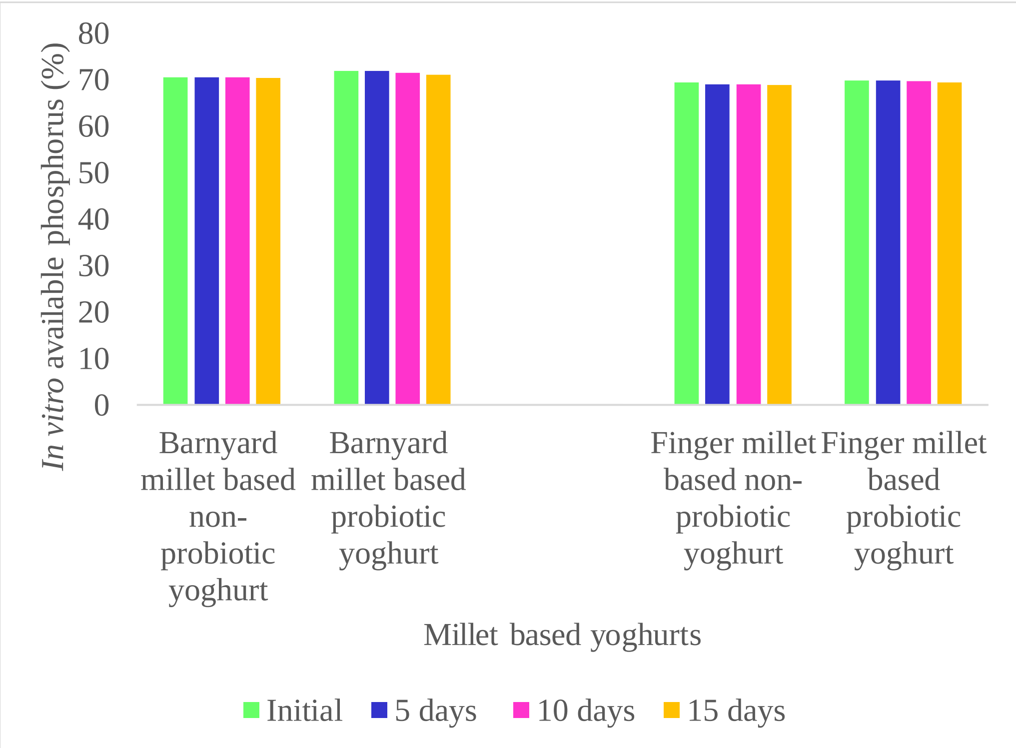


Fig. 34. *In vitro available* phosphorus of millet based yoghurts during storage (%)

5.3.2.1.5. Zinc

The *in vitro* zinc availability of probiotic was higher than in non-probiotic yoghurt (Fig. 35). The prepared millet based yoghurts showed a declining trend *in vitro* zinc availability with increasing storage days.

Sadh *et al*. (2017) aimed to determine how the bioavailability of micronutrients was impacted by *Aspergillus oryzae*'s fermentation of peanut oil cakes. *In vitro* mineral availability values of zinc in non-fermented and fermented peanut oil cake were 42.18 mg/kg and 42.39 mg/kg, respectively. In this instance, the zinc availability of fermented sample was greater than that of unfermented sample.

Rekha and Vijayalakshmi (2010) studied the difference between non-fermented soy milk and fermented soy milk and found that the bioavailability of zinc in soy milk fermented was 24.15 mg/100 g and for non-fermented soy milk the zinc content was 22.33 mg/100 g.

Another study by Rahim *et al*. (2020) who made fermented soybean with *Bacillus amyloliquefaciens* and studied its mineral availability. The zinc availability of fermented soybean was 33.98 g/kg and for non-fermented soybean, it was 29.32 g/kg.

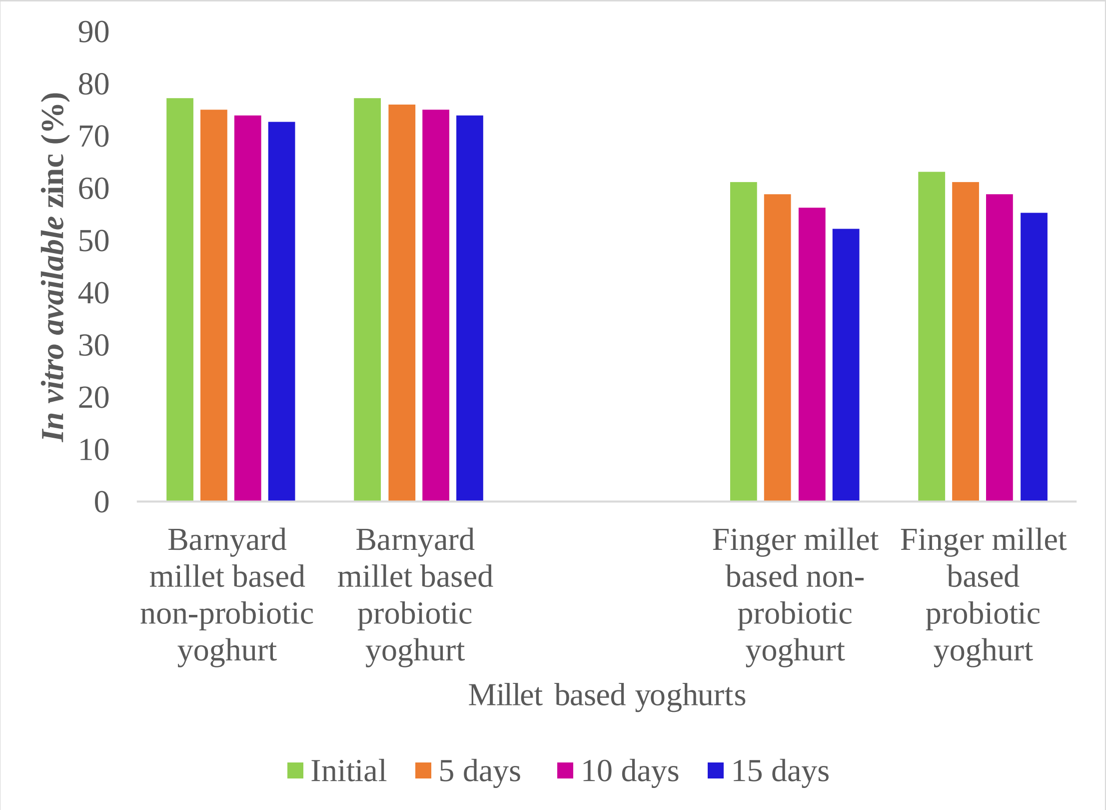


Fig. 35. *In vitro available* zinc of millet based yoghurts during storage (%)

5.3.2.1.6. Magnesium

The magnesium content and *in vitro* availability of magnesium were high in probiotic than in non-probiotic yoghurt (Fig. 36).The prepared millet based yoghurts showed a decreasing trend in magnesium and *in vitro* magnesium availability with increasing storage days.

Rekha and Vijayalakshmi (2010) studied the difference between non-fermented soy milk and fermented soy milk and found that the *in vitro* availability of magnesium content of soy milk fermented was 359.52 mg 100 g and for non-fermented soy milk the magnesium content was 346.22 mg 100 g.

Rahim *et al*. (2020) made fermented soybean with *Bacillus amyloliquefaciens* and studies its mineral availability. The magnesium availability of fermented soybean was 882 g/kg and for non-fermented soybean, it was 787 g/kg.

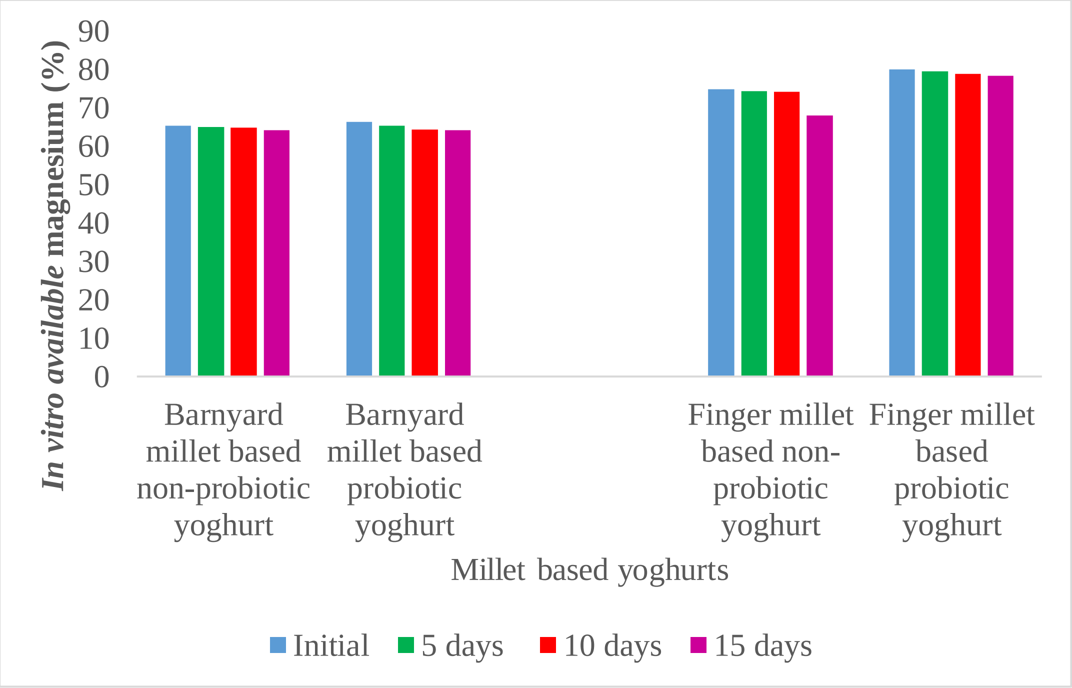


Fig. 36. *In vitro available* magnesium of millet based yoghurts during storage (%)

5.3.2.2. Antioxidant activity

The antioxidant activity of millet based yoghurts was calculated and is shown in Fig. 37. According to the data obtained in the present study both barnyard and finger millet based probiotic yoghurt had higher antioxidant activity than non-probiotic yoghurt and in each set of yoghurts, antioxidant activity reduced on storage.

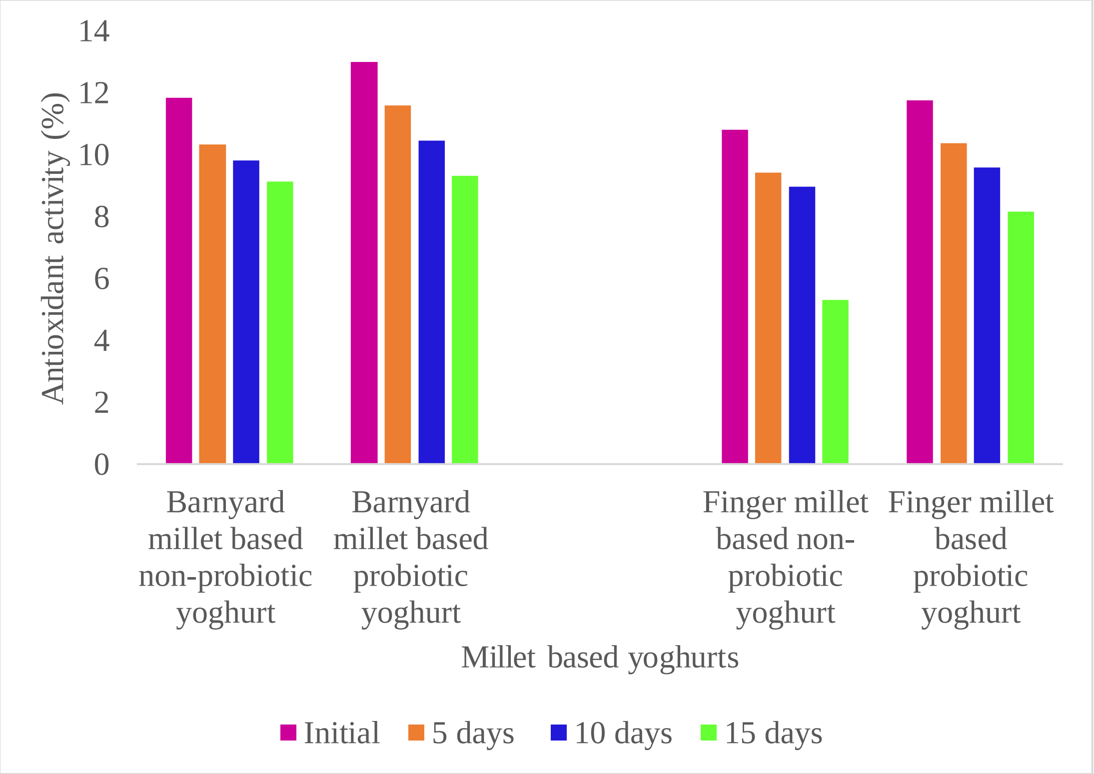


Fig. 37. Antioxidant activity of millet based yoghurts during storage (%)

The antioxidant activity of yoghurt is mainly because of the hydrolysis of milk components by LAB (Virtanen et al., 2007; Sah *et al*., 2016). This increase in antioxidant activity might be due to phenolic component breakdown and enhanced interactions between milk proteins and polyphenols (Amirdivani and Baba, 2011). Fermentation of the milk by lactic acid bacteria releases a large number of peptides and amino acids which causes highest antioxidant and antibacterial activities (Taha *et al.*, 2017).

Soya milk fermented with a single probiotic strain or multiple probiotic strains consistently had much greater antioxidative benefits than soy milk that had not been fermented. *S. thermophilus* CCRC 14085, *L. acidophilus* CCRC 14079, *B. longum* B6 and *B. infantis* CCRC 14633 all exhibit antioxidant activity. The antioxidative activity of soy milk rises with fermentation duration and that fermentation with all strains combined produced superior antioxidant results than fermentation with each strain separately. Finally, although being less antioxidative than unfermented soy milk, fermented soy milk nevertheless had a greater level of antioxidative activity (Wang *et al*., 2006).

Bacillus subtilis is the most widely used strain for fermenting foods made from soybeans. According to Han *et al*. (2015), sword beans that have undergone *B. subtilis* fermentation contain anti-inflammatory and antioxidant compounds. The fermented sword beans have more antioxidant activity and DPPH radical scavenging activity than unfermented beans and it was significantly different. Similar research found that the *B. subtilis* strain BCRC 14714 had substantial antioxidative activity, strong reducing power and chelating activity for ferrous ions (Lin *et al*., 2012).

5.3.3. Organoleptic evaluation

To define and quantify the sensory qualities of products, sensory analysis is done. Sensory analysis describes and evaluates the characteristics of a product as they are experienced by the five senses ; sight, hearing, smell, taste and touch. As previously reported (Salvador and Fiszman, 2004; Sowonola *et al*., 2005), customer preference for food items may depend on a perfect integration of sensory qualities such as flavour, smell, texture and appearance.

Achi (1999) prepared fermented soybean naturally and studied its physicochemical properties. The fermentation showed to improve the acceptability to the consumers. Ratings for appearance and colour were higher for flour items made from fermented than unfermented flour. The processing procedure had no impact on the flavour, texture, or overall acceptance.

Aparna (2015) developed probiotic honey based beverage with aloevera. The initial overall acceptability of probiotic beverage was 4.50 and for non-probiotic it was 4.00.On storage the overall acceptability decreased in both the cases.

The present research was in line with the finding of Hussain *et al*. (2016) who studied the acceptability of non-probiotic and probiotic freeze dried dahi with *Lactococcus lactis* and probiotic culture *L. paracasei ssp. Paracasei*. The overall acceptability of probiotic yoghurt was 8.20 and for non-probiotic yoghurt it was 7.75 (Fig. 37).

By adding 1 per cent inoculum of the probiotic *Bifidobacterium bifidum* to yoghurt cultures, Narayana and Kale (2019) produced probiotic yoghurt and compared it to normal yoghurt. When compared to non-probiotic yoghurt, probiotic yoghurt had a higher overall acceptance. The mean score for probiotic yoghurt was 7.78, whereas the mean score for non-probiotic yoghurt was 7.69.

Soni *et al*. (2020) also revealed that the overall acceptability of probiotic milk yoghurt was higher (8.51) compared to non-probiotic milk yoghurt (8.14).

In the present study, the total score was more for probiotic yoghurts in each set of millet based yoghurts compared to non-probiotic yoghurts and it was decreased on storage. Sarabahi (2012) who prepared yoghurt with rice flour and found that of the overall acceptability of control yoghurt (8.60) and unroasted germinated rice flour yoghurt (8.70) decreased to 7.90 in both cases on storage.

Meera (2020) prepared fruit based probiotic drink and said that the probiotic drink was better than non-probiotic yoghurt according to organoleptic evaluation. The total score for non-probiotic drink was 50.17 for passion fruit based mango drinks and for probiotic yoghurt the total score was 50.37 and it was decreased to 49.95 for non-probiotic drink and 50.14 for probiotic yoghurt based drink after 15 days of storage.

5.3.4. Population of *L. acidophilus*

The viability of *L. acidophilus* is graphically represented in Fig. 39. The viability of *L. acidophilus* was seen in probiotic yoghurt throughout the storage.

Cell viability mainly depends on the strains used, interaction between species present, culture condition, oxygen content, final acidity of the product and presence of acetic acid in the food. The presence of probiotic organism has so much of beneficial effects, immune modulation and carcinogen binding in the host (Ouwehand and Salminen, 1998; Salminen *et al*., 1998).

Angelov *et al*. (2006) studied the viability of oat based probiotic drink fermented with *L. acidophilus* and found that the viability was high in probiotic drink than non-probiotic drink.

The findings of the present study collaborate with the observations made by Cakmakci *et al*. (2012) prepared probiotic (*L. acidophilus*) yoghurt with banana marmalade. The viability of *L. acidophilus* was recorded as 6.21 log cfu/ml initially and it was decreased to 3.40 log cfu/ml after 14 days of storage.

Narayana and Kale (2019) developed probiotic yoghurt by adding 1 per cent inoculum of probiotic *B. bifidum* to yoghurt cultures and compared it with normal yoghurt. The viability of Bifidobacterium bifidum for probiotic yoghurt was recorded as 4.00 log cfu/ml and it was decrease to 3 log cfu/ml after 7 days of storage.

Remya (2020) analysed the viability of *L. acidophilus* of jackfruit based probiotic yoghurt. The viability of *L. acidophilus* of jackfruit based yoghurt was 3.57 log cfu/ml. After 15 days the viability was decreased to 2.29 log cfu/ml.

Meera (2020) developed fruit based probiotic drink and compared it with non-probiotic drink. The viability of *L. acidophilus* in probiotic drink was 9.67 log cfu/ml and it was decreased to 9.43 log cfu/ml after 15 days of storage.

Bernat (2014) prepared fermented almond milk and non-fermented almond milk. *L. reuteri* and *S. thermophiles* were used as probiotic organism. The initial viability of each organism was recorded as 7.59 log / cfu/ml for *L. reuteri* and 7.54 log cfu/ml for *S. thermophiles.* After 28 days of storage this was decreased to 7.06 log / cfu/ml for *L. reuteri* and 6.57 log cfu/ml for *S. thermophiles.*

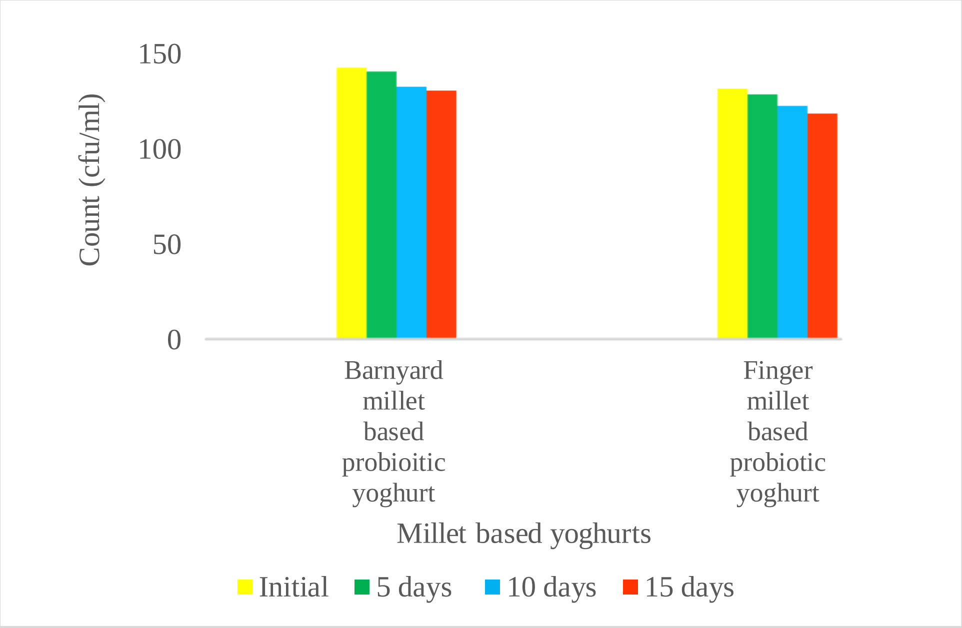


Fig. 38. Viability of *L. acidophilus* count in the millet based yoghurts during storage (cfu / ml)

5.3.5. Enumeration of total micro flora

The microbiological analyses revealed that the millet based probiotic yoghurts had higher bacterial count than its non-probiotic yoghurt and it was increased on storage. The other microbes such as yeast was absent throughout the storage period and fungi was absent initially and was found on the 15th day of storage in each set of millet based yoghurt. This conforms to the FSSAI (2016) criteria for fermented milk products.

During 21 days of storage of carrot yoghurt, Salwa *et al*. (2004) found a rise in yeast, mould and coliform levels.

Mould and yeast were not discovered in rice based yoghurt or control during the storage period, according to Sarabhai (2012), while mould and yeast development were observed in fruit-enriched yoghurt on the 14th day of storage.

Narayana and Kale (2019) developed probiotic yoghurt by adding 1 per cent inoculum of probiotic *Bifidobacterium bifidum* to yoghurt cultures and compared it with normal yoghurt. There was no growth for yeast and mould throughout the storage period.

Meera (2020) compared probiotic and non-probiotic drink and said that the bacterial viability of non-probiotic drink was 9.80 log cfu/ml and decreased to 9.59 log cfu/ml, for probiotic drink the bacterial count was 2.80 log cfu/ml and it decreased to 3.40 log cfu/ml after storage of 15 days. There was no fungal growth in both probiotic and non-probiotic passion fruit based drink. Fungi growth was seen in probiotic and non-probiotic drinks after 10 days of storage.

5.4. Preparation of synbiotic yoghurt

Preparation of millet based (both barnyard and finger millet) synbiotic yoghurt with inulin and polydextrose was standardised and the best one from each set was selected. The treatments are T_3 (3 % of inulin added barnyard millet based synbiotic yoghurt), T_6 (3 % inulin added finger millet based synbiotic yoghurt), T_9 (3 % polydextrose added barnyard millet based synbiotic yoghurt) and T_{12} (3 % polydextrose added finger millet based synbiotic yoghurt) was found to be the best. The total score was 46.3 for T_3 (Fig. 40) and 51.16, 47.03 and 50.08 for T_6 (Fig. 41), T_9 (Fig. 42) and T_{12} (Fig. 43) respectively.

A prebiotic is defined as “a non-digestible dietary item that has a positive impact on the host by selectively promoting the development and/or activity of one or a small number of bacteria in the colon, which enhances human health” (Gibson and Roberfroid, 1995). Dietary prebiotics is "selectively fermented ingredients that result in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefits upon host health," definition given at the 6^{th} meeting of the International Scientific Association of Probiotics and Prebiotics (ISAPP) in 2008 (Gibson *et al.*, 2010). The common prebiotics used is inulin, its derivatives fructooligosaccharides and galactooligosaccharides, polydextrose, soluble corn fibre, pyrodextrin, lactosucrose, lactulose etc.

Commercially, prebiotic inulin is used as a food ingredient. The health benefits of inulin include mineral absorption, stimulation of immune function, reduce the risk of irritable bowel disease, constipation and colorectal cancer and improvement in gut microbiota (Bielecka *et al.*, 2002; Scholz-Ahrens *et al.*, 2002; Gibson *et al.*, 2004). Prebiotics also help to improve the functioning of gastrointestinal micro flora by increasing the number of micro flora i.e. Lactobacilli and Bifidobacteria (Mulabagal *et al*., 2009). The combination of probiotic and prebiotic is said to be synbiotic (Roberfroid, 2000).

Polydextrose is prepared by thermal polymerization of glucose, sorbitol and citric acid (Craig *et al*., 1998). Polydextrose is neutral in taste. In baking foods, confectionery, dairy products and functional beverages polydextrose is used as a bulking agent. It can be used as a curing agent for itchy skin, diabetes, prediabetes and infant development

Gonzalez and Riboli (2010) prepared plain yoghurt, prebiotic yoghurt and synbiotic yoghurt with peach puree syrup and yoghurt base. The probiotic organism was *L. acidophilus* (1 %) and the prebiotic was raftilose (1.4 %). The overall acceptability was 5.8 for plain yoghurt, 6.2 for prebiotic yoghurt and 4.1 for synbiotic yoghurt.

Shirisha *et al*. (2021) developed yoghurt by incorporating probiotics (*L. bulgaricus* and *Streptococcus thermophiles*) and the prebiotic fructooligosaccharide. The best yoghurt had 1.5 per cent of fructooligosaccharide and the overall acceptability of the selected yoghurt was 4.87.

A low fat synbiotic yoghurt was developed by Delavari *et al*. (2014) with inulin, inoculated with *L. plantarum.* The overall acceptability was 4.30 for synbiotic yoghurt prepared with 1 per cent inulin, 4.25 for 1.5 per cent inulin and 3.65 for yoghurt without inulin.

Synbiotic yoghurts were prepared with different combinations of prebiotics like inulin, hi-maize, lactitol, lactulose, β-glucan and maltodextrin by Heidari *et al*. (2022). The probiotic organism used was *L. acidophilus.* The results revealed that the maximum total score was obtained for yoghurt with 3 per cent inulin (28.10) followed by β-glucan (39.5), hi maize (38.2), lactulose (36.7), lactitol (33.5) and maltodextrin (21.1).

Huang *et al.* (2020) prepared prebiotic yoghurt with polydextrose. The concentration used for the study was 1.5, 3 and 5 per cent. The best treatment selected was 3 per cent of polydextrose added prebiotic yoghurt with a total score of 78. The total score for 1.5 and 3 per cent of polydextrose added yoghurt was 71.

The overall acceptability of synbiotic yoghurt (low fat synbiotic yoghurt with 1 % of inulin) inoculated with *L. acidophilus* (probiotic organism) and mint extract was recorded by All-Shawi (2020) as 4.60, 4.50 for mint alcoholic extract added synbiotic yoghurt and 4.80 for mint aqueous extract added synbiotic yoghurt.

Ranjitham and Poornakala (2020) developed synbiotic yoghurt with inulin (0.5 to 1.5 %) using probiotic organisms *L. acidophilus, L. casei*, *L. plantarum* and *L. rhamnosus*. The maximum mean score was found to be 8.20 with 1 per cent of inulin of each probiotic organism.

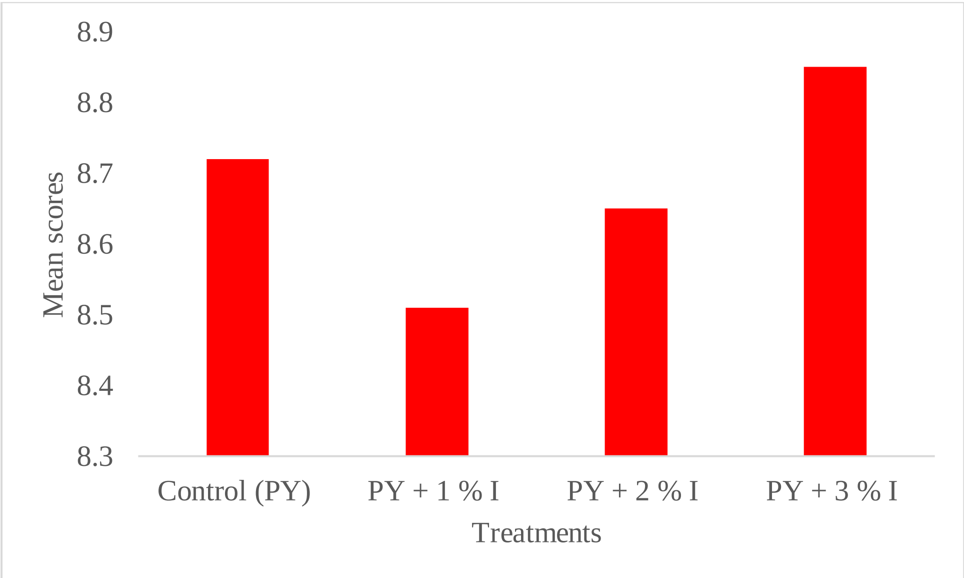


Fig. 40. Mean scores for overall acceptability of inulin added barnyard millet based synbiotic yoghurts

PY: Probiotic yoghurt, I: Inulin

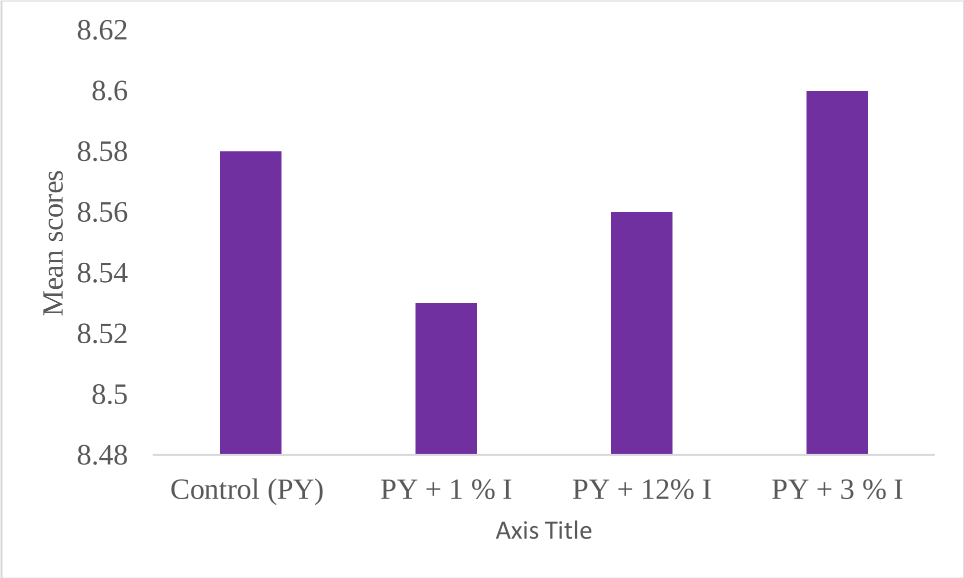


Fig. 40. Mean scores for overall acceptability of inulin added finger millet based synbiotic yoghurts

PY: Probiotic yoghurt, I: Inulin

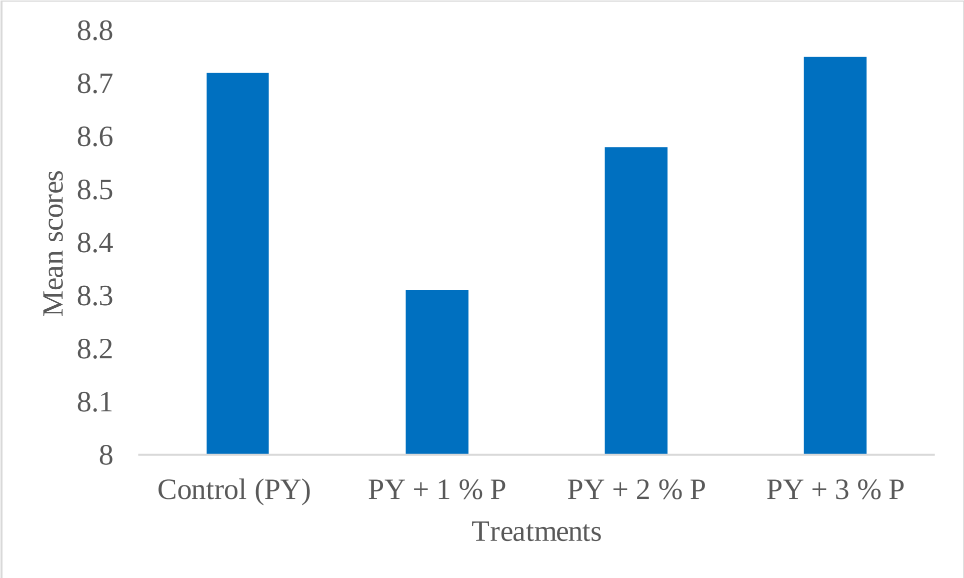


Fig. 41. Mean scores for overall acceptability of polydextrose added barnyard millet based synbiotic yoghurts

PY: Probiotic yoghurt, P: Polydextrose

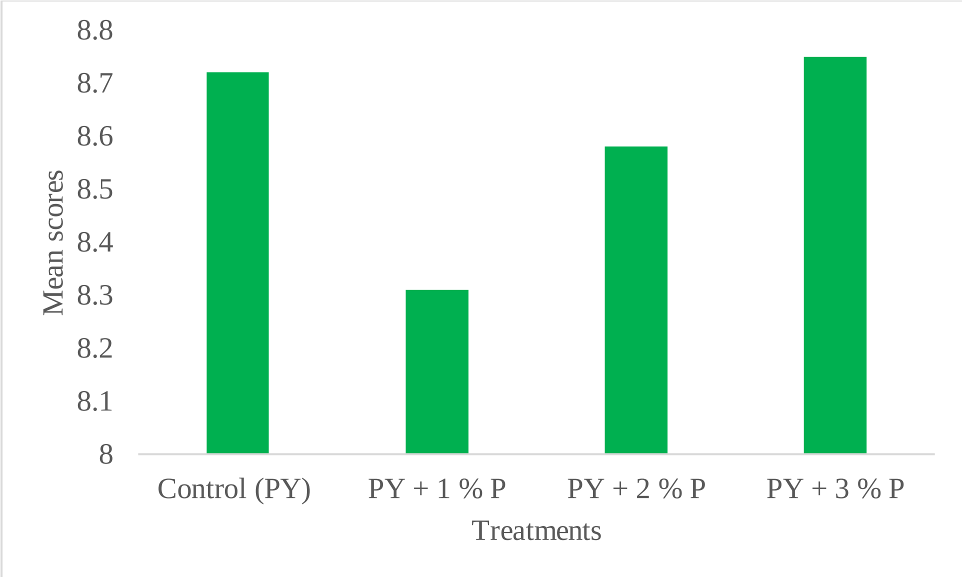


Fig. 42. Mean scores for overall acceptability of polydextrose added finger millet based synbiotic yoghurts

PY: Probiotic yoghurt, P: Polydextrose

Falah *et al*. (2021) prepared cereal based synbiotic yoghurt with 1, 2.5 and 5 per cent of inulin and *L. brevis*. When the concentration of inulin increased the mean score for the synbiotic yoghurt increased by 2.5 per cent (6.8) and then it decreased to 5 per cent (6.4) for inulin added yoghurt. The maximum mean score was seen in 2.5 per cent of inulin added synbiotic yoghurt.

5.4. Quality evaluation of selected millet based synbiotic yoghurts

5.4.1. Physico-chemical properties of millet based synbiotic yoghurt

5.4.1.1. Moisture

The moisture content of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of moisture content of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 44.

There will be no significant difference in moisture by the addition of prebiotic. But the addition of prebiotic in probiotic yoghurt may increase the growth of probiotic organism (Oliveira *et al*., 2011). So the chance of increase in moisture is high in synbiotic yoghurt compared to probiotic yoghurt.

Abd-Rabou *et al*. (2020) developed probiotic and synbiotic cheese and studied its nutritional qualities. Here, the probiotic microorganisms used were *L. rhamnosus and Bifidobacterium* and the prebiotic was inulin. The moisture content of probiotic with *L. rhamnosus* was 71.73 per cent and for synbiotic yoghurt the moisture content was 73.05 per cent. The *Bifidobacterium* used probiotic cheese contain 72.70 per cent of moisture and for synbiotic cheese the moisture content was 74.84 per cent.

The similar result was seen in synbiotic yoghurt which was recorded by All-Shawi (2020) as 87.95 per cent for plain yoghurt, 90.35 per cent for mint alcoholic extract added synbiotic yoghurt.

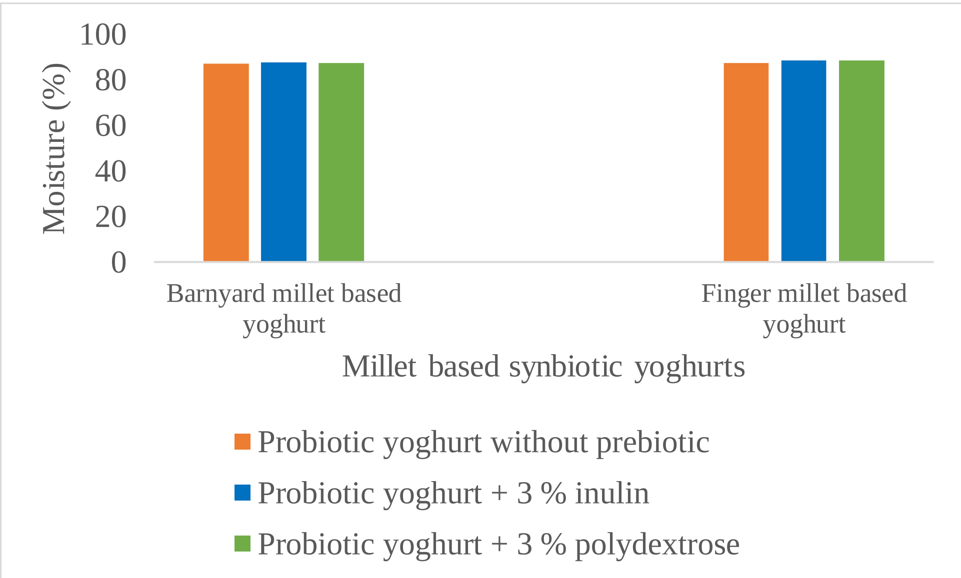


Fig. 44. Moisture content of millet based synbiotic yoghurt (%)

5.4.1.2. Acidity

Compared to probiotic yoghurt, each millet based synbiotic yoghurt had higher acidity. Figure 45 shows a graphical comparison of the acidity of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

The presence of prebiotic, influence the acidity of yoghurt. The addition of prebiotics in yoghurt enhances the growth of the probiotic organism, so the acidity of yoghurt increases (Oliveira *et al*., 2011).

The presence of prebiotics increases the biomass of probiotic organisms (Pedreschi *et al*., 2003). The difference in acidity was recorded in fermented cashew juice when compared with fermented cashew juice with fructooligosaccharides. The probiotic organism used here was *L. brevis*. The acidity was increased for synbiotic juice compared to its control (Pereira *et al*., 2012).

The titrable acidity of synbiotic butter milk was higher than its probiotic butter milk (control). The acidity of control yoghurt was 0.73 per cent and for synbiotic yoghurt with honey and oligosaccharide the acidity was 0.74 per cent. The above results revealed that the addition of prebiotics and probiotics (*L. acidophilus*) had influence on the acidity of the buttermilk (Malarkannan, 2019).

Falah *et al*. (2021) produced synbiotic yoghurt that contains 2.5 per cent inulin. The yoghurt was fermented using a strain of *L. brevis* from dairy and cereal products. The acidity of synbiotic yoghurt was 0.18 per cent, compared to 0.16 per cent for control probiotic yoghurt. In this case, adding prebiotic (inulin) to probiotic yoghurt made synbiotic yoghurt more acidic.

Reshma *et al*. (2022) developed synbiotic yoghurt with oat flour and the acidity of normal yoghurt was 0.81 per cent, for probiotic yoghurt the acidity was 0.80 per cent, 1 per cent oat flour added synbiotic yoghurts acidity was 0.82 per cent. The probiotic organism which was used in this study was *Bifidobacterium bifidum*.

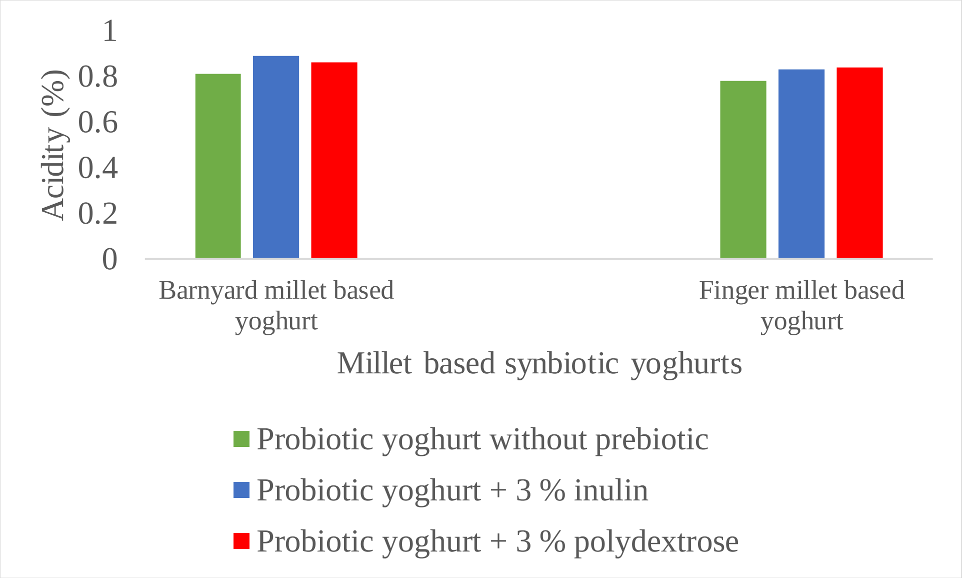


Fig. 45. Acidity of millet based synbiotic yoghurts (%)

5.4.1.3. pH

Each millet based synbiotic yoghurt had a lower pH than its probiotic yoghurt. Probiotic yoghurt prepared from millet (barnyard and finger millet) and synbiotic yoghurt is graphically compared in Figure 46 for pH levels.

The pH of synbiotic yoghurt was represented by All-Shawi (2020) as 4.50, for plain yoghurt the pH was 4.51, for mint alcoholic extract added synbiotic yoghurt the pH was 4.51 and for mint aqueous extract added synbiotic yoghurt the pH was 4.50.

Falah *et al*. (2021) produced synbiotic yoghurt with 2.5 per cent of inulin with a strain of *L. brevis* from fermented dairy and cereal products. The pH of control probiotic yoghurt was recorded as 4.41 and for synbiotic yoghurt it was 3.82. Here the addition of prebiotic (inulin) in probiotic yoghurt decreased the pH of synbiotic yoghurt.

Reshma *et al*. (2022) developed synbiotic yoghurt with oat flour and the pH was 4.39, for control probiotic yoghurt the pH was 4.40. The probiotic organism which used in this study was *B. bifidum*.

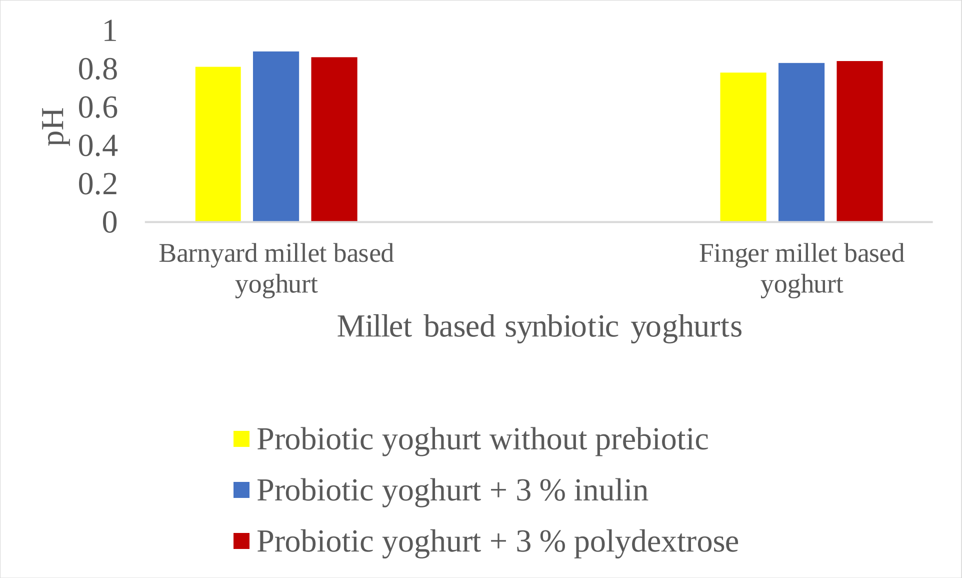


Fig. 46. pH of millet based synbiotic yoghurt

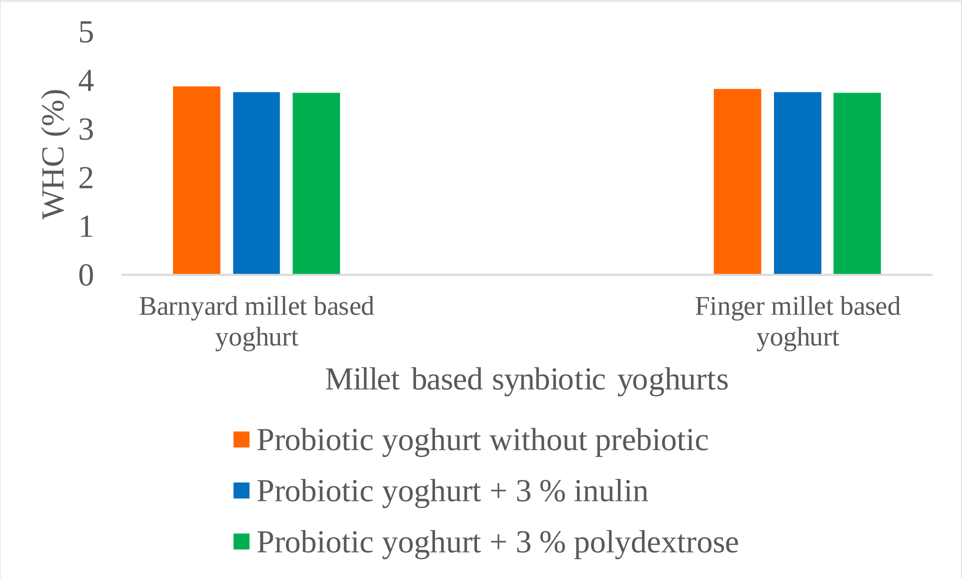


Fig. 47. Water holding capacity of millet based synbiotic yoghurt (%)

5.4.1.4. Water holding capacity

The water holding capacity of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of water holding capacity of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 47.

The prebiotic in fermented food products have the capacity to increase water holding capacity of synbiotic food due to the increase in probiotic microorganism. According to Ranok *et al*. (2021), increasing higher fat and total solids to yoghurt products is the reason behind the increase of water holding capacity.

The similar study by Falah *et al*. (2021) aimed to produce a synbiotic yoghurt with a 2.5 per cent inulin content. A strain of *L. brevis* from dairy and cereal products was used to ferment the yoghurt. Synbiotic yoghurt had a 12.25 per cent water holding capacity, compared to a 10.25 per cent water holding capacity for control probiotic yoghurt. In this instance it is clear that prebiotic (inulin) added to probiotic yoghurt, increase the water holding capacity of synbiotic yoghurt.

Reshma *et al.* (2022) developed synbiotic yoghurt with oat flour and the water holding capacity (WHC) of control yoghurt was 499.58 g/kg, for control probiotic yoghurt the WHC was 517.33 g/kg, 1 per cent oat flour added synbiotic yoghurts WHC was 539.91 g/kg and 2 per cent oat flour added synbiotic yoghurts WHC was 547.00 g/kg. The increased WHC of synbiotic yoghurt was because of increased fat and total soluble salts (Ranok *et al*., 2021). The probiotic organism which was used in this study was *Bifidobacterium bifidum*.

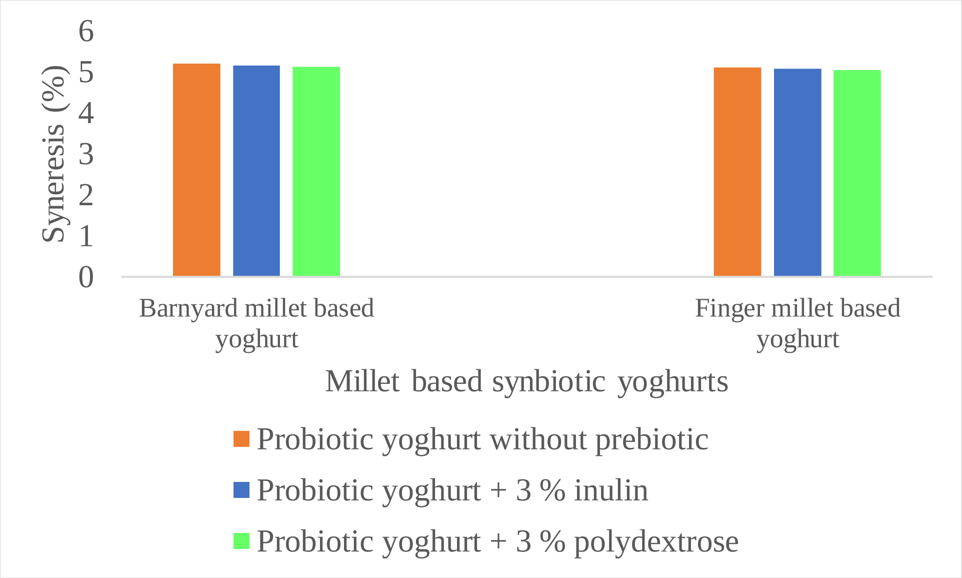


Fig. 48. Syneresis of millet based synbiotic yoghurt (%)

5.4.1.5. Syneresis

Each millet based synbiotic yoghurt had a lower syneresis than its probiotic yoghurt. The syneresis of probiotic yoghurt prepared from millet (barnyard and finger millet) and synbiotic yoghurt is graphically compared in Figure 48.

The level of syneresis decreased with the addition of inulin and it was inversely associated with the inulin concentration, due to the inverse relation with water holding capacity (Shalaby and Amin, 2019). The water holding capacity and syneresis was inversionally proportional to each other.

Delavari *et al.* (2014) developed inulin added synbiotic yoghurt and studied syneresis of each yoghurt and summarised that 13.20 per cent of syneresis for 1 per cent of inulin added low fat synbiotic yoghurt and for control, the syneresis was 19.38 per cent.

Reshma *et al.* (2022) developed synbiotic yoghurt with oat flour and the syneresis of control yoghurt was 3.41 per cent, probiotic yoghurt was 3.15 per cent; and for 1 per cent oat flour added and 2 per cent oat flour added synbiotic yoghurts the syneresis was 2.86 and 2.80 per cent respectively. The probiotic organism used in this study was *B. bifidum*.

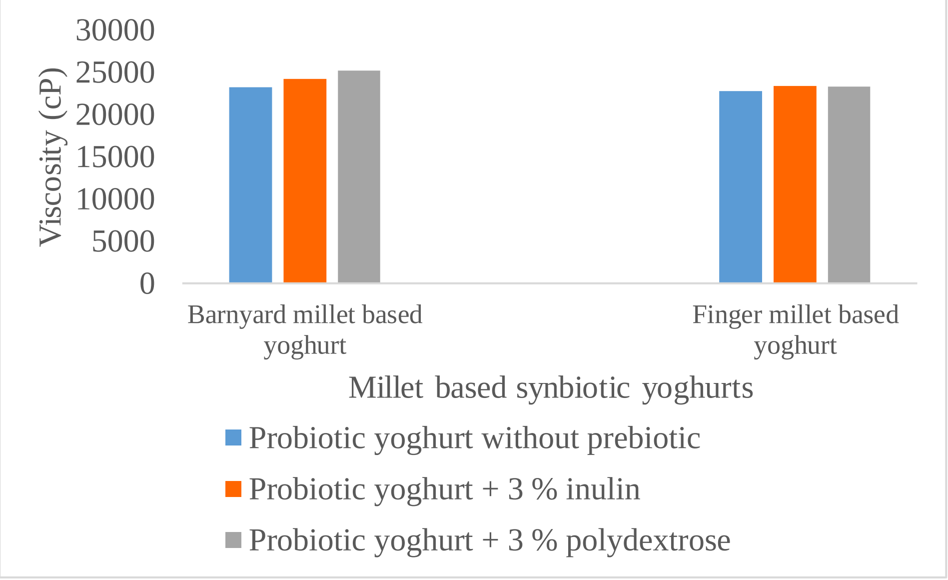


Fig. 49. Viscosity of millet based synbiotic yoghurt (cP)

5.4.1.6. Viscosity

Compared to its probiotic yoghurt, each millet based synbiotic yoghurt had a higher viscosity. Figure 49 shows a graphical comparison of the viscosity of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

The addition of inulin enhanced the viscosity and hardness of the yoghurt samples by causing water to connect with the network of nonintegrated proteins (Madhu *et al*., 2012). In the synbiotic yoghurt, inulin served as a stable protein polysaccharide network that may increase viscosity and provide a creamier texture. The factors influencing viscosity were the method of processing, type of starter culture, heat treatment and formulation (Jaster *et al*., 2018).

(Sukarminah *et al*., 2019) developed sorghum based synbiotic yoghurt with *L. acidophilus* and recorded viscosity range from 3296.67 to 8380.00 cPs. The normal viscosity of yoghurt was >1500 cPs (Tamime and Robinson, 2007).

Reshma *et al.* (2022) developed synbiotic yoghurt with oat flour and the viscosity of control yoghurt was 706.07 cPs, for control probiotic yoghurt the viscosity was 873.33 cPs, 1 per cent oat flour added synbiotic yoghurts viscosity was 2253.33 cPs and 2 per cent oat flour added synbiotic yoghurts viscosity was 3120.00 cPs. The probiotic organism which used in this study was *B. bifidum*.

5.4.1.7. Textural properties of millet based yoghurt

Each synbiotic yoghurt made from millet contained greater cohesiveness than the probiotic yoghurt. Figure 50 compares the cohesiveness content of probiotic yoghurt made from millet (barnyard and finger millet) to synbiotic yoghurt.

Each synbiotic yoghurt made from millet has more gumminess than probiotic yoghurt. Figure 51 depicts the gumminess composition of synbiotic yoghurt, which was made from millet (barnyard and finger millet).

Each synbiotic yoghurt made from millet has more resilience than probiotic yoghurt. Figure 52 depicts the resilience composition of synbiotic yoghurt, which was made from millet (barnyard and finger millet).

In comparison to the control and probiotic yoghurts, the synbiotic yoghurt with 1 per cent inulin positive impact on textural attributes in terms of cohesiveness, gumminess and resilience without adversely affecting the palatability of natural yoghurt, according to the texture profile analysis outlined in this study. Thus, the textural features of yoghurt may have been affected by the addition of probiotic (*S. boulardii*) both alone and in combination with prebiotic (inulin) at various concentrations (Sarwar *et al*., 2019).

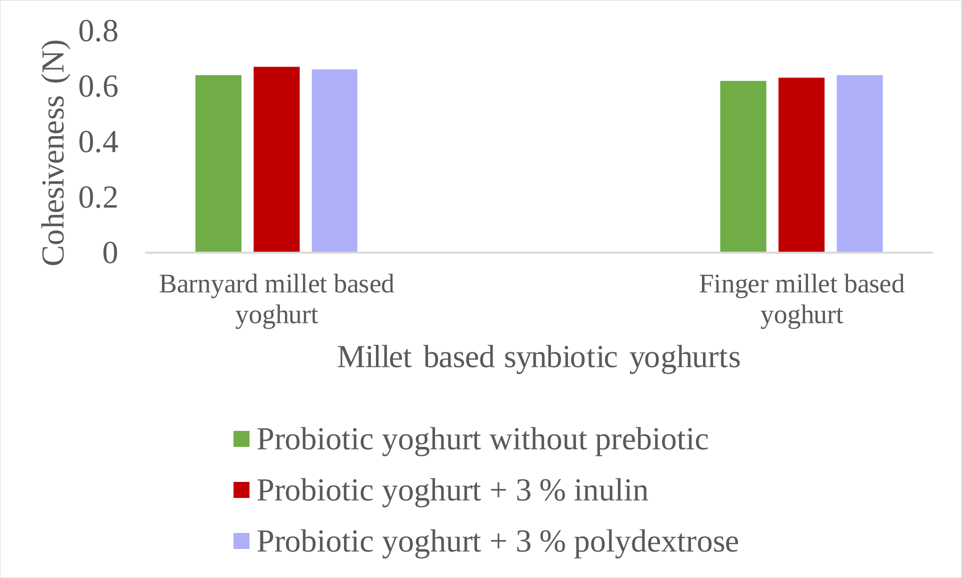


Fig. 50. Cohesiveness of millet based synbiotic yoghurt (N)

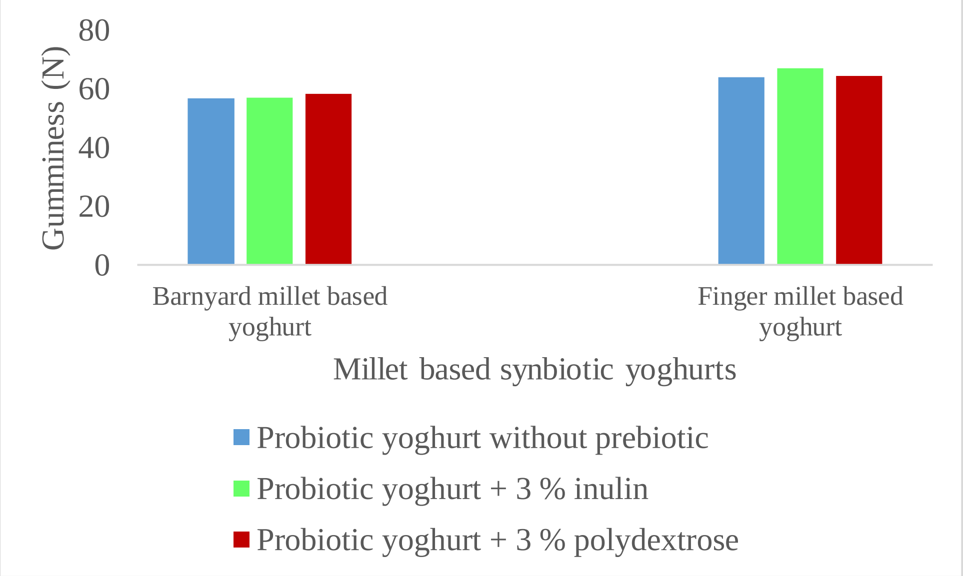


Fig. 51. Gumminess of millet based synbiotic yoghurt (N)

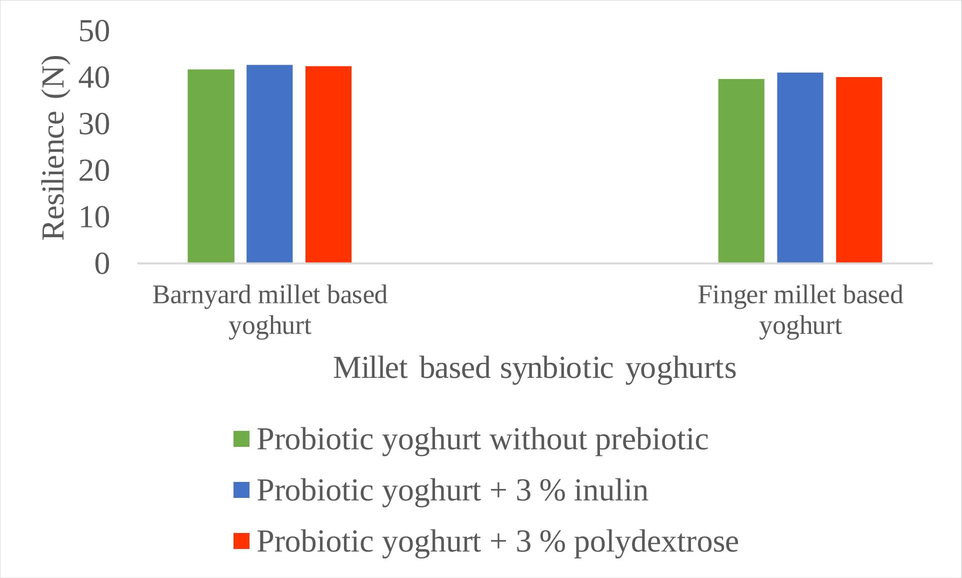


Fig. 52. Resilience of millet based synbiotic yoghurt (N)

5.4.1.8. Carbohydrate

Each millet based synbiotic yoghurt had a lower carbohydrate than its probiotic yoghurt. Probiotic yoghurt prepared from millet (barnyard and finger millet) and synbiotic yoghurt is graphically compared in Figure 53 for carbohydrate content.

Hauly *et al*. (2005) prepared soy yoghurt without prebiotic addition and soy yogurt containing inulin (14.43 %) and oligofructose (14.24 %). The addition of prebiotic influenced the carbohydrate content of the yoghurt. In this study the lower carbohydrate was seen in yoghurt containing prebiotic. This is because of the high viability of microbes which reduces the availability of carbohydrate because it was used by them for their growth.

5.4.1.9. Protein

Each synbiotic yoghurt made from millet has more protein than probiotic yoghurt. Figure 54 depicts the protein composition of synbiotic yoghurt, which was made from millet (barnyard and finger millet).

The presence of prebiotics in probiotic yoghurt increased the viability of probiotic organisms so that the acidity of the yoghurt increases and it helps in proteolysis so the presence of protein increases in synbiotic yoghurt than probiotic yoghurt. An increase in microbial population and a degradative reaction occurs as the fermentation process progresses, which might account for the increase in protein (Gupta *et al*., 2007). This facilitates the release of additional protein by the microorganisms in fermented meals. Yoghurt's proteolytic activity rises as a result of the probiotic organisms' vitality, increasing the availability of protein in the yoghurt (Adhikari *et al*., 2002). During the fermentation process, lactic acid acidifies milk proteins and bacterial proteases and peptidases hydrolyze them (Tzvetkova *et al*., 2007).

The protein content in the control (probiotic milk) samples was 3.96 per cent. The protein content in samples that contain inulin was 4.24 per cent. The honey incorporated sample had a protein content of 4.15 per cent and the FOS-incorporated sample had a protein level of 4.05 per cent. This led to the conclusion that the addition of prebiotics were the best growth stimulants for culture organisms (*L. acidophilus* + *B. bifidum*) (Mariammal, 2016).

Compared to probiotic buttermilk, synbiotic buttermilk has higher protein (control). The protein content of the probiotic yoghurt used as a control was 1.89 per cent, the synbiotic yoghurt with honey was 1.92 per cent and the synbiotic buttermilk with the addition of oligosaccharides was 1.91 per cent. The outcomes mentioned earlier showed that adding prebiotics like oligo-fructose, honey and probiotics such as *L. acidophilus* has an impact on the protein level of buttermilk (Malarkannan, 2019).

All-Shawi (2020) studied synbiotic yoghurt and said that Mint alcoholic extract added synbiotic yoghurt treatment had a higher protein content (4.90 %), which differed significantly from plain yoghurt, followed by mint aqueous extract added synbiotic yoghurt, synbiotic yoghurt and plain yoghurt, which had 4.88, 4.86 and 3.98, respectively.

5.4.1.10. Fat

Each synbiotic yoghurt made from millet contained higher fat than the probiotic yoghurt. Figure 55 compares the fat content of probiotic yoghurt made from millet (barnyard and finger millet) to synbiotic yoghurt.

The presence of prebiotics in probiotic yoghurt increased the viability of probiotic organisms so that the acidity of the yoghurt increases and it helps in lipolysis so the presence of fat increases in synbiotic yoghurt than probiotic yoghurt.

Synbiotic buttermilk has more fat than probiotic buttermilk (control). The fat content of the control yoghurt was 0.23 per cent, that of the synbiotic yoghurt with honey was 0.28 per cent and that of the synbiotic buttermilk with oligosaccharide addition was 0.28 per cent (Malarkannan, 2019).

Plain yoghurt, synbiotic yoghurt, Mint alcoholic extract added synbiotic yoghurt and mint aqueous extract added synbiotic yoghurt have a fat content of 0.17 percent, 0.29 per cent, 0.32 per cent and 0.30 per cent, respectively, according to All-Shawi (2020).

Falah *et al*. (2021) aimed to create a synbiotic yoghurt with 2.5 per cent inulin content with a strain of *L. brevis* from dairy and cereal products. In comparison to control probiotic yoghurt, which had 3.41 per cent fat, synbiotic yoghurt had 3.45 per cent fat. Here, prebiotic (inulin) and probiotic is combined to higher the fat content of synbiotic yoghurt.

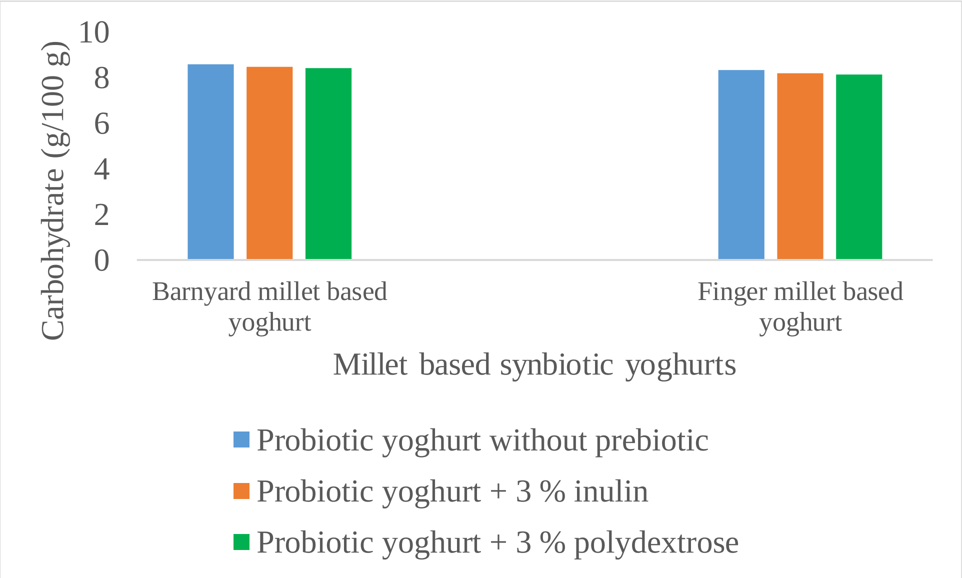


Fig. 53. Carbohydrate of millet based synbiotic yoghurt (g/100 g)

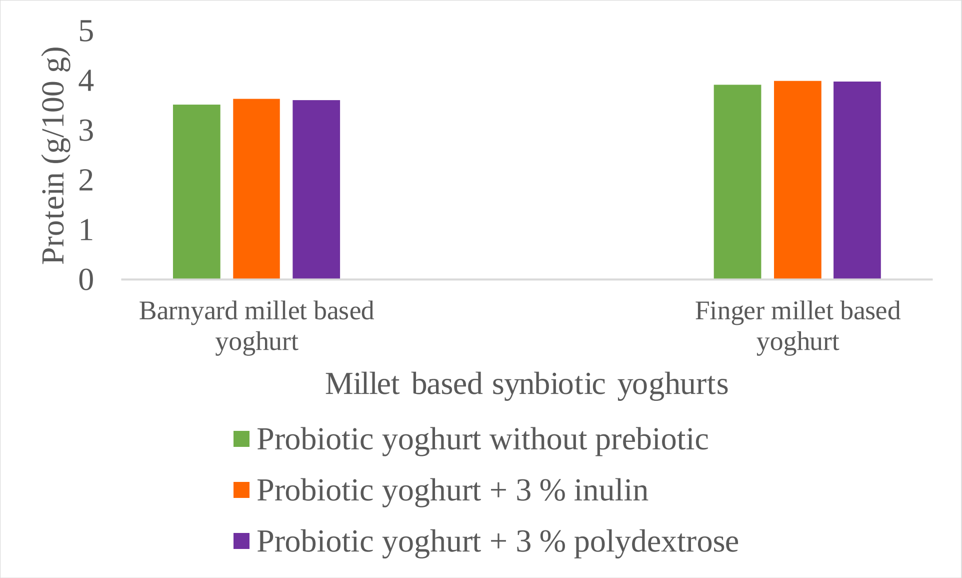


Fig. 54. Protein of millet based synbiotic yoghurt (g/100 g)

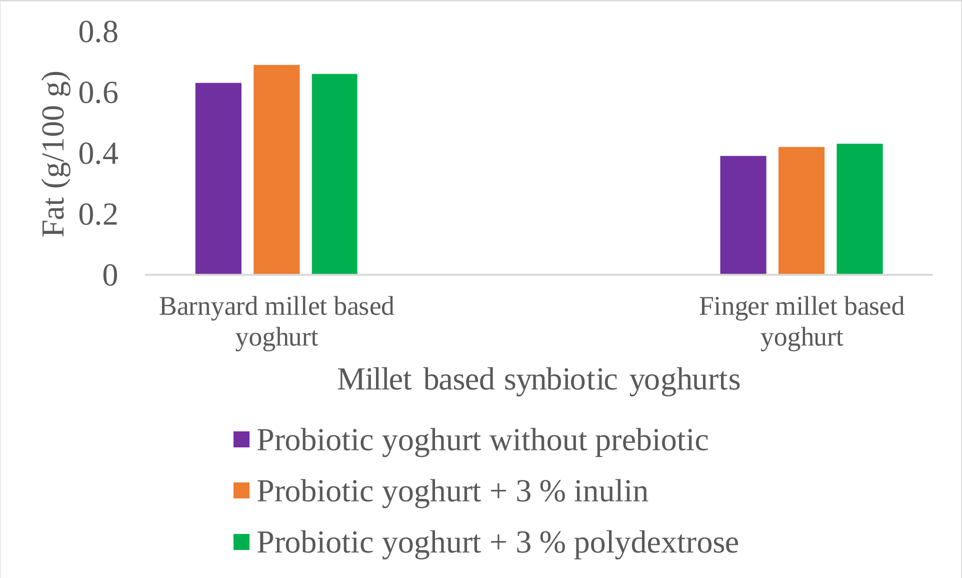


Fig. 55. Fat content of millet based synbiotic yoghurts (g/100 g)

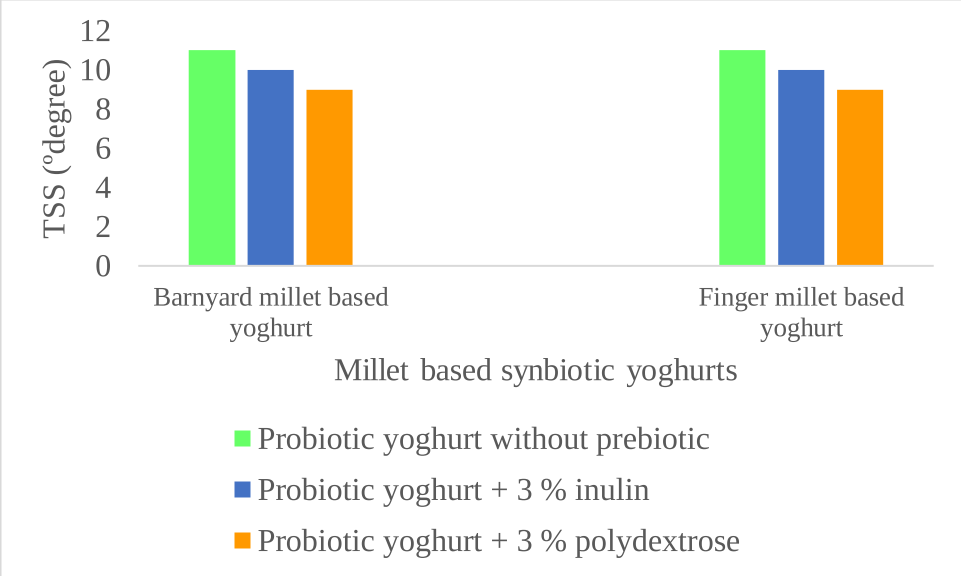


Fig. 56. TSS of millet based synbiotic yoghurts (º brix)

5.4.1.11. TSS

Each millet based synbiotic yoghurt had lower TSS than the probiotic yoghurt. The TSS of probiotic yoghurt derived from millet (barnyard and finger millet) and synbiotic yoghurt are shown in Figure 56.

The significant reduction in TSS of fermented food products was due to fermentation. During fermentation, the homofermentative Lactobacillus converts the fermentable sugar into lactic acid. So the sugar content of fermented food products is decreased. With the addition of prebiotics in fermented food products, the viability of microbes increases (Wong *et al*., 2003; Bonet *et al*., 2006).

According to Yoon *et al*. (2004), the number of soluble solids reduced with time as the microbes used them to develop in tomato juice. After 48 hours of fermentation, the total soluble solids in the cucumber juice containing 3 per cent *L. acidophilus* and 3 per cent prebiotic (inulin) decreased from 5.9 to 3.1º brix (Priya, 2018). Over time, total soluble solids in orange juice decreased as the microbes in the juice sample used the sugars to boost their growth (Humayun *et al*., 2014).

Carrot based synbiotic beverage was prepared by Alwis *et al*. (2015) and studied its nutritional content. The TSS of control beverage was 12º brix and for synbiotic beverage the TSS was 11.50º brix. The probiotic organism used here was *L. casei* and prebiotic was sucrose.

Another study which is similar to this study. Falah *et al*. (2021) produced synbiotic yoghurt that contains 2.5 per cent inulin. The yoghurt was fermented using a strain of *L. brevis* from dairy and cereal product. Synbiotic yoghurt had a 16.98º brix of TSS whereas control probiotic yoghurt had a 17.48º brix of TSS. Here, probiotic yoghurt is combined with prebiotic (inulin) to reduce the TSS of synbiotic yoghurt.

5.4.1.12. Reducing sugar

Each synbiotic yoghurt made from millet had more reducing sugar than probiotic yoghurt. Figure 57 depicts the reducing sugar content of probiotic yoghurt made from millet (barnyard and finger millet) and synbiotic yoghurt.

Carrot based synbiotic beverage was prepared by Alwis *et al*. (2015) and studied its nutritional content. The reducing sugar content of control beverage was 0.47 per cent and for synbiotic beverage the reducing sugar was 0.41 per cent. The probiotic organism used here was *L. casei* and prebiotic was sucrose.

The probiotic cucumber juice had a reducing sugar content of 498 g / ml at the 0^{th} hour. The decreasing sugar for the 3 per cent prebiotic was determined to be 328 g / ml after 48 hours of fermentation. The probiotic microbe *L. acidophilus* was thought to need the reducing sugars for growth, which is why there has been a reduction (Priya, 2018). According to Yoon *et al*. (2006) the concentration of reducing sugar dropped as the cabbage juice fermented. Buruleanu *et al*. (2009) showed similar outcomes in the case of the addition of prebiotic (inulin) in carrot juice.

5.4.1.13. Total sugar

Each millet based synbiotic yoghurt contained lower total sugar than probiotic yoghurt. Probiotic yoghurt produced from millet (barnyard and finger millet) and synbiotic yoghurt's total sugar content is shown in Figure 58.

Carrot based synbiotic beverage was prepared by Alwis *et al*. (2015) and studied its nutritional content. The total sugar content of control beverage was 6.42 per cent and for synbiotic beverage the total sugar was 5.88 per cent. The probiotic organism used here was *L. casei* and prebiotic was sucrose.

After 72 hours of fermentation, the total sugar content of the fermented juice (a mixture of cucumber and tomato juice with 3 per cent inulin, was reduced to 179 g / ml), because they served as substrates for microbial growth (*L. acidophilus*) and increased acid production, which is what caused the juice's pH to drop, total sugars in the juice were decreased during fermentation (Priya, 2018).

In contradictory to this Rani and Srividya (2016) developed low fat yoghurt with inulin and fructooligosacharide and studied total sugar of each set of yoghurt. The total sugar of control yoghurt was recorded as 6.1 g /100 g, for inulin yoghurt the total sugar was 9.7 g /100 g and for fructooligosacharide yoghurt the total sugar was recorded as 10 g /100 g.

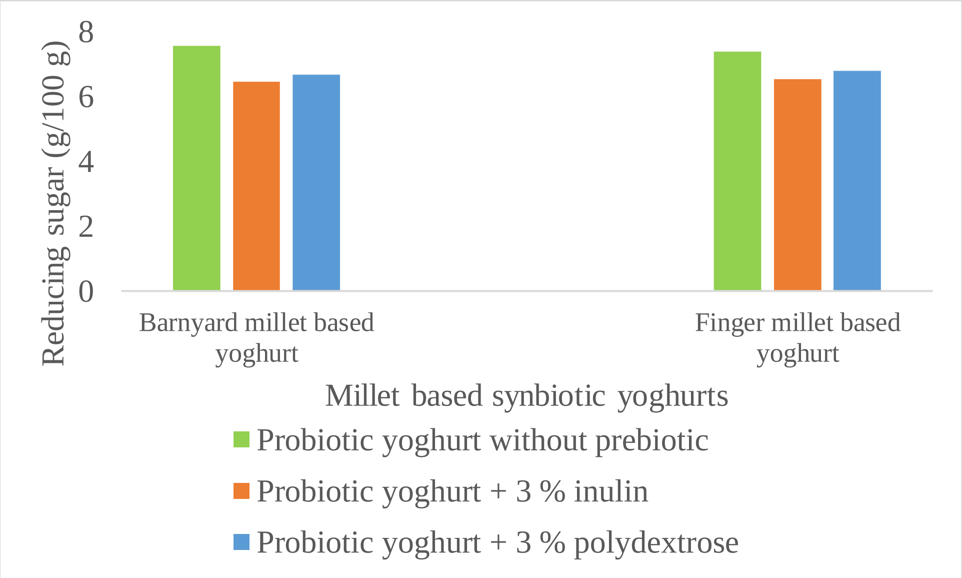


Fig. 57. Reducing sugar of millet based synbiotic yoghurts (g/100 g)

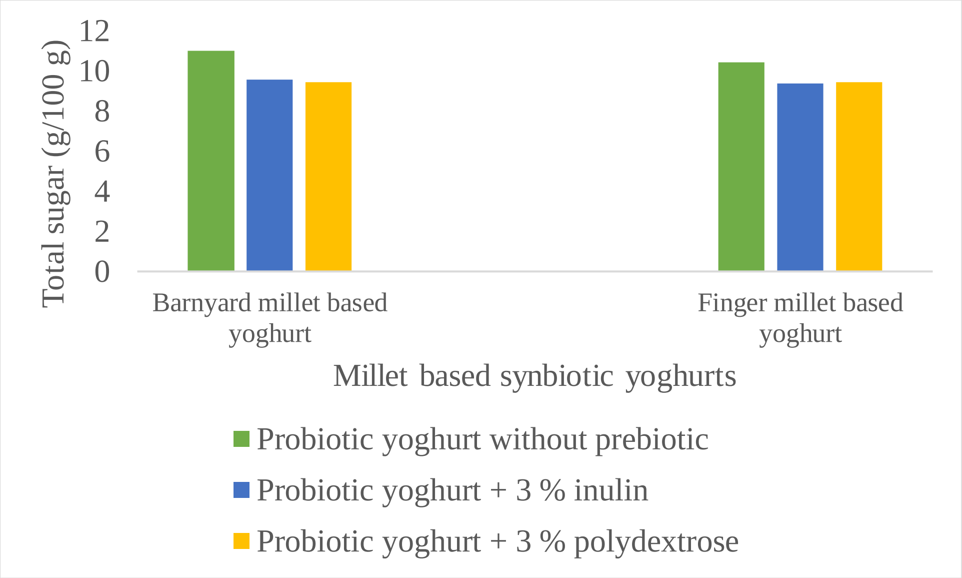


Fig. 58. Total sugar of millet based synbiotic yoghurts (g/100 g)

5.4.1.14. Crude fibre

Each millet based synbiotic yoghurt has less crude fibre than probiotic yoghurt. Figure 59 shows the crude fibre of millet based synbiotic yoghurt (barnyard and finger millet).

The presence of prebiotic decreases the crude fibre of fermented food. This is because of the increased viability of probiotics present in the fermented food (Yoon *et al*. 2004).

Carrot based synbiotic beverage was prepared by Alwis *et al*. (2015) and studied its nutritional content. The crude fibre of control beverage was 1.02 per cent and for synbiotic beverage the fibre was 1.01 per cent. The probiotic organism used here was *L. casei* and prebiotic was sucrose.

5.4.1.15. Total ash

The ash content of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of ash content of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 60.

The addition of prebiotic in fermented food increases the presence of ash. So that the ash content was high in synbiotic food than probiotic food (Yoon *et al*. 2004).

Synbiotic buttermilk has more ash content than probiotic buttermilk (control). The ash content of the probiotic buttermilk was 0.37 per cent, synbiotic buttermilk with honey was 0.40 per cent. The addition of prebiotics such as honey with probiotic organisms increases the ash content of butter milk (Malarkannan, 2019).

All-Shawi (2020) studied synbiotic yoghurt and said that mint alcoholic extract added synbiotic yoghurt treatment had a higher ash content (0.93 %), which differed significantly from plain yoghurt (0.55 %) followed by mint aqueous extract added synbiotic yoghurt (0.92 %).

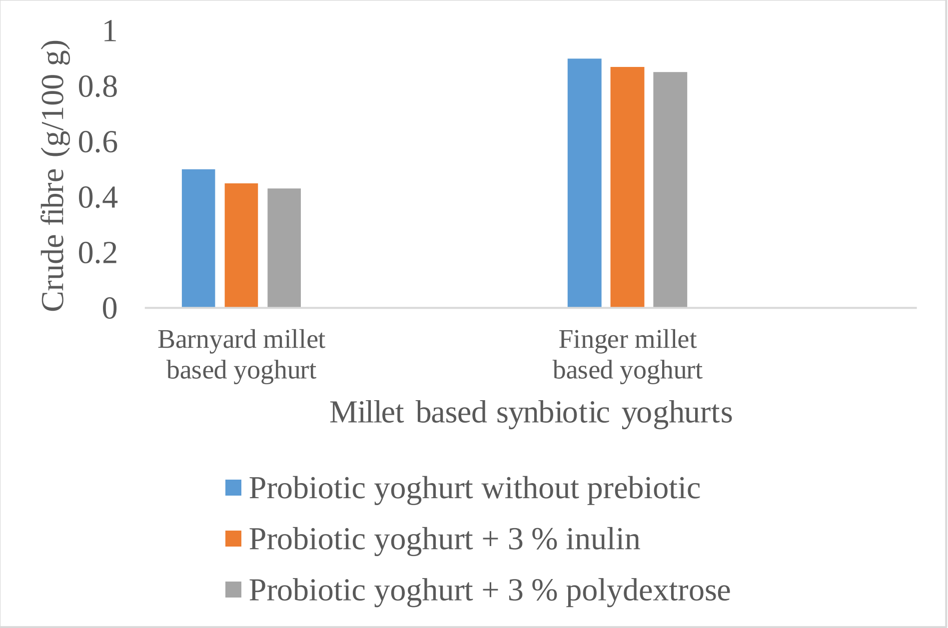


Fig. 59. Crude fibre of millet based synbiotic yoghurts (g/100 g)

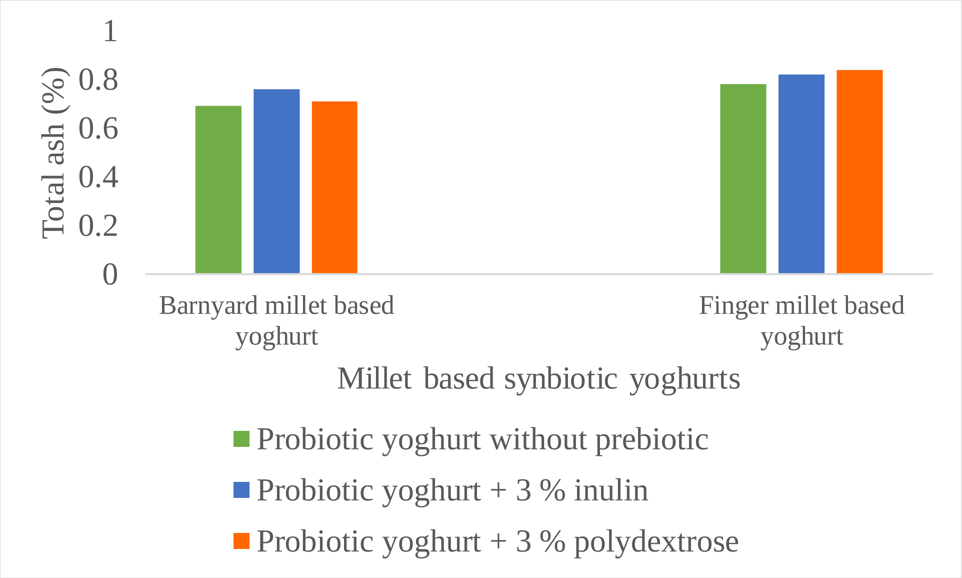


Fig. 60. Total ash of millet based synbiotic yoghurts (%)

5.4.1.16. Minerals

The addition of prebiotics in fermented food can enhance the presence of minerals because of the higher viability of probiotic microorganisms than fermented food products. Probiotic organisms have the capacity to remove phytates from the food, so that the presence of minerals in synbiotic food increases (Scholz-Ahrens *et al*., 2001).

5.4.1.16.1. Calcium

The calcium content of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of calcium content of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 61.

Mahdavi *et al*. (2015) examined the mineral content of probiotic and synbiotic foods. *L. acidophilus* served as the probiotic organism while fructooligosaccharides served as the prebiotic. Synbiotic food had a calcium concentration of 659.40 mg per 100 g, while probiotic food had a calcium content of 613.60 mg per 100 g.

Rani and Srividya (2016) developed low fat yoghurt with inulin and fructooligosaccharide and studied the calcium of each set of yoghurt. The calcium of control yoghurt was recorded as 123 g /100 g, for inulin yoghurt it was 276 g /100 g and for fructooligosaccharide yoghurt it was recorded as 308 g /100 g.

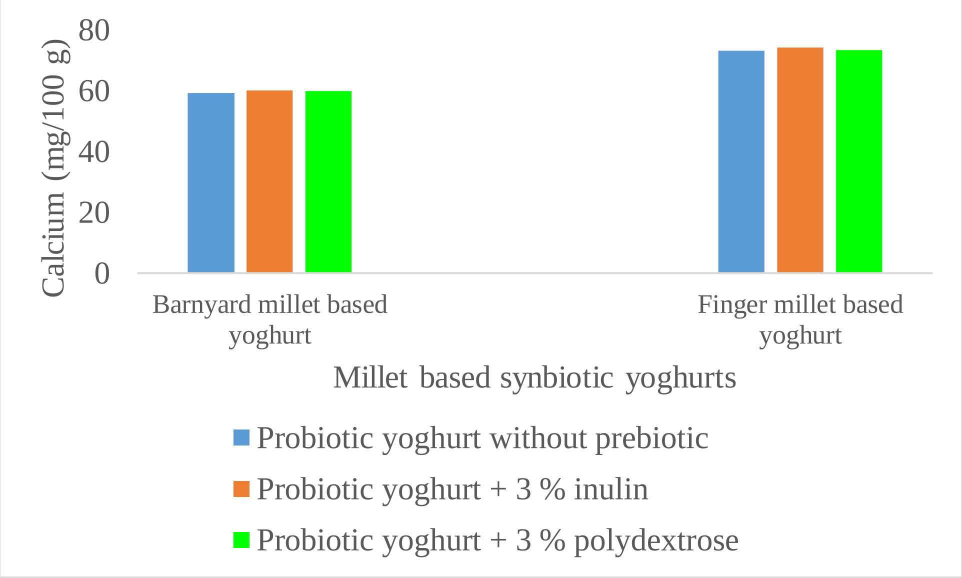


Fig. 61. Calcium content of millet based synbiotic yoghurts (mg/100 g)

5.4.1.16.2. Iron

Compared to probiotic yoghurt, each millet based synbiotic yoghurt had higher iron. Figure 62 shows a graphical comparison of the iron of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

Karthiga and Nilofer (2018) developed synbiotic juices as alternative to dairy probiotic products containing probiotic culture *Bacillus coagulans* and sabja seeds as prebiotic in fruit juices like papaya, pineapple and pomegranate. The iron content of papaya based synbiotic juice was 0.75 mg /100 ml and for control it was 0.30 mg / 100 ml. For pineapple added synbiotic juice the iron content was 1.75 mg /100 ml and for control it was 1.50 mg / 100 ml. The pomegranate added synbiotic juice contained 1.32 mg / 100 ml of iron content and 0.75 mg / 100 ml for control juice.

5.4.1.16.3. Potassium

The potassium of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of potassium of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 63.

Karthiga and Nilofer (2018) developed synbiotic juices as alternative to dairy probiotic products containing probiotic culture *Bacillus coagulans* and sabja seeds as prebiotic in fruit juices like papaya, pineapple and pomegranate. The potassium of papaya based synbiotic juice was 9.98 mg /100 ml and for control it was 8.23 mg / 100 ml. For pineapple added synbiotic juice the potassium was 10.76 mg /100 ml and for control it was 8.98 mg / 100 ml. the pomegranate added synbiotic juice contained 8.60 mg / 100 ml of potassium and 6.25 mg / 100 ml for control juice.

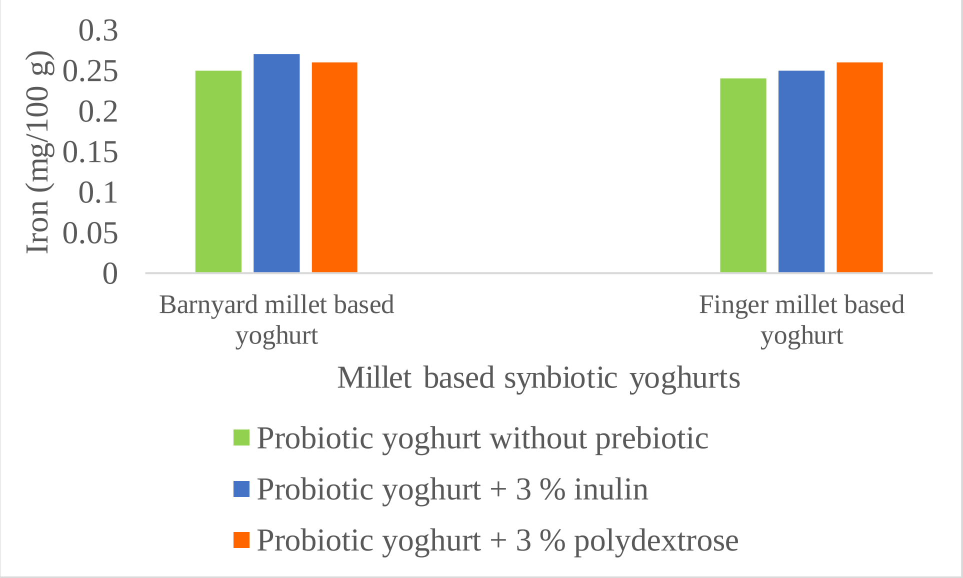


Fig. 62. Iron content of millet based synbiotic yoghurts (mg/100 g)

5.4.1.16.4. Phosphorus

Compared to its probiotic yoghurt, each millet based synbiotic yoghurt had a higher phosphorus. Figure 64 shows a graphical comparison of the phosphorus of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

Rani and Srividya (2016) developed low fat yoghurt with inulin and fructooligosacharide and studied the phosphorus of each set of yoghurt. The phosphorus of control yoghurt was recorded as 86.9 g /100 g, for inulin yoghurt, the phosphorus was 154.5 g /100 g and for fructooligosacharide yoghurt the phosphorus was recorded as 156.4 g /100 g.

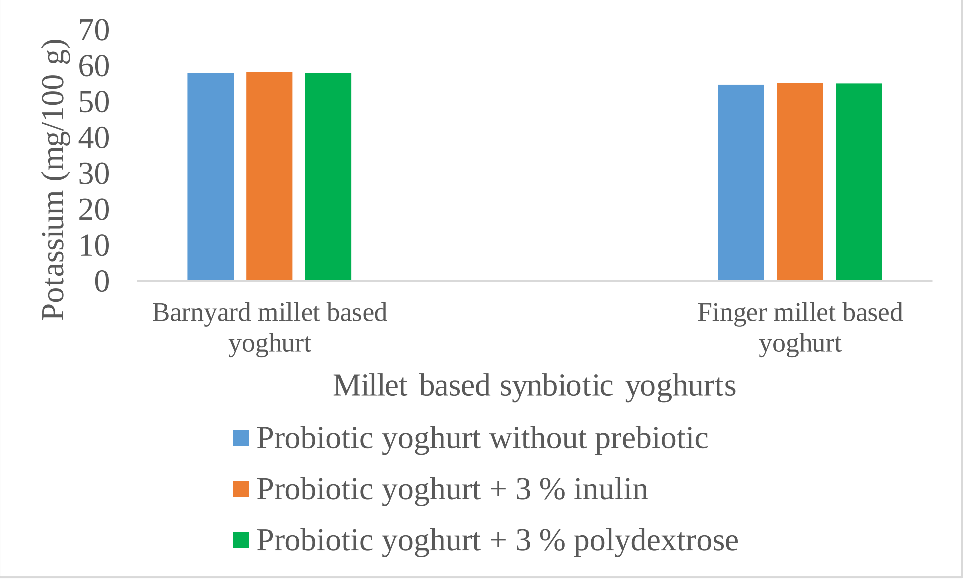


Fig. 63. Potassium content of millet based synbiotic yoghurts (mg/100 g)

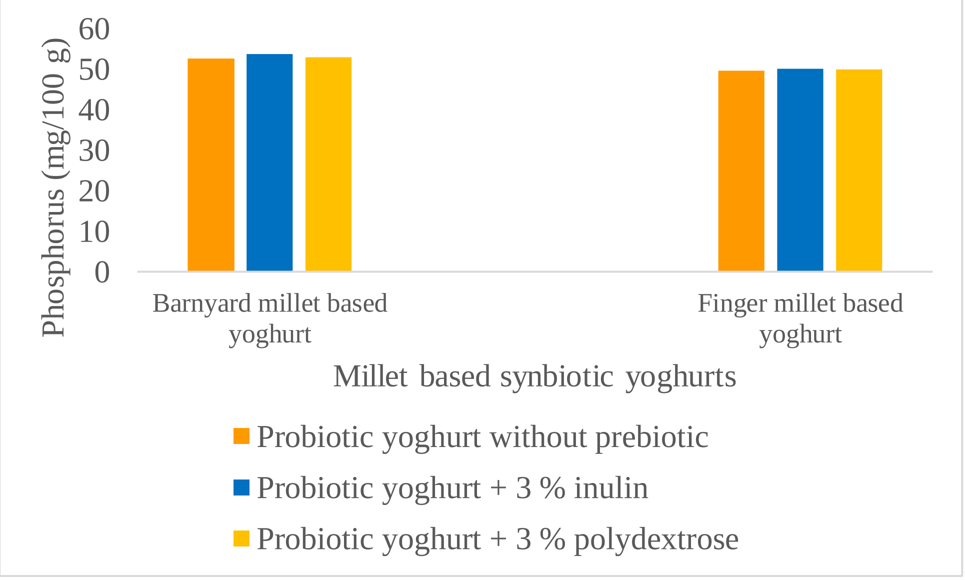


Fig. 64. Phosphorus content of millet based synbiotic yoghurts (mg/100 g)

5.4.1.16.5. Zinc

Each millet based synbiotic yoghurt had a higher zinc than its probiotic yoghurt. Probiotic yoghurt prepared from millet (barnyard and finger millet) and synbiotic yoghurt is graphically compared in Figure 65 for zinc.

Mahdavi *et al*. (2015) studied and compared the presence of minerals in probiotic and synbiotic food. The probiotic organism was *L. acidophilus* and the prebiotic was fructooligosaccharides. The zinc content of synbiotic food was 8.80 mg/100 g recorded and for probiotic food, it was 8.20 mg/100 g.

Karthiga and Nilofer (2018) developed synbiotic juices as alternative to dairy probiotic products containing probiotic culture *Bacillus coagulans* and sabja seeds as prebiotic in fruit juice of pomegranate. The zinc content of synbiotic juice was 0.41 mg / 100 ml and for control the zinc content was 0.32 mg / 100 ml.

5.4.1.16.6. Magnesium

Each synbiotic yoghurt made from millet has more magnesium than probiotic yoghurt. Figure 66 depicts the magnesium of synbiotic yoghurt, which was made from millet (barnyard and finger millet).

Rani and Srividya (2016) developed low fat yoghurt with inulin and fructooligosacharide and studied the magnesium of each set of yoghurt. The magnesium of control yoghurt was recorded as 16.40 g/100 g and for inulin yoghurt, the magnesium was 16.80 g/100 g.

Karthiga and Nilofer (2018) developed synbiotic juices as alternative to dairy probiotic products containing probiotic culture *Bacillus coagulans* and sabja seeds as prebiotic in fruit juices like papaya, pineapple and pomegranate. The magnesium content of papaya based synbiotic juice was 9 mg/100 ml and for control it was 6 mg/ 100 ml. For pineapple added synbiotic juice the magnesium content was 19 mg/100 ml and for control it was 14 mg/100 ml. the pomegranate added synbiotic juice contained 26.6 mg/100 ml of magnesium content and 20.25 mg/100 ml for control juice.

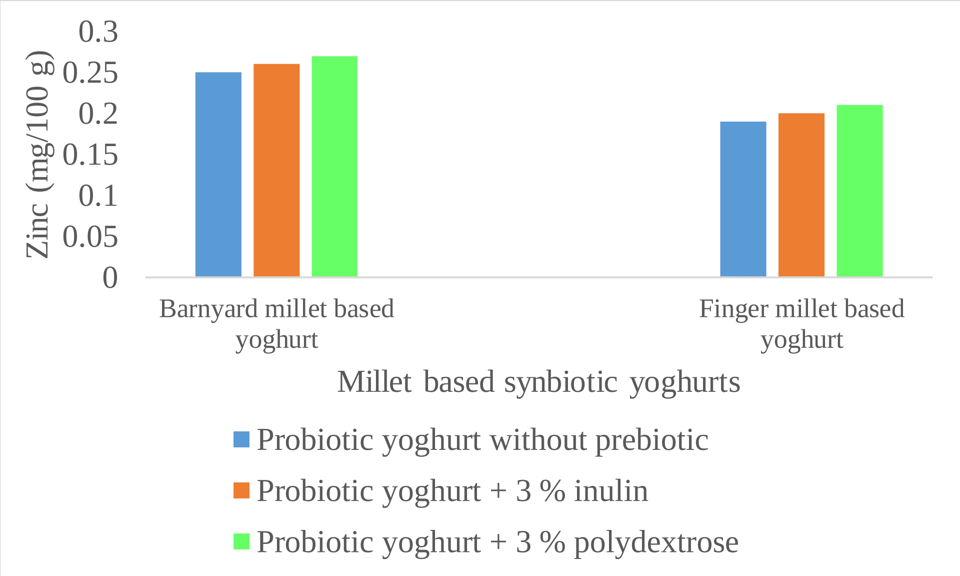


Fig. 65. Zinc content of millet based synbiotic yoghurts (mg/100 g)

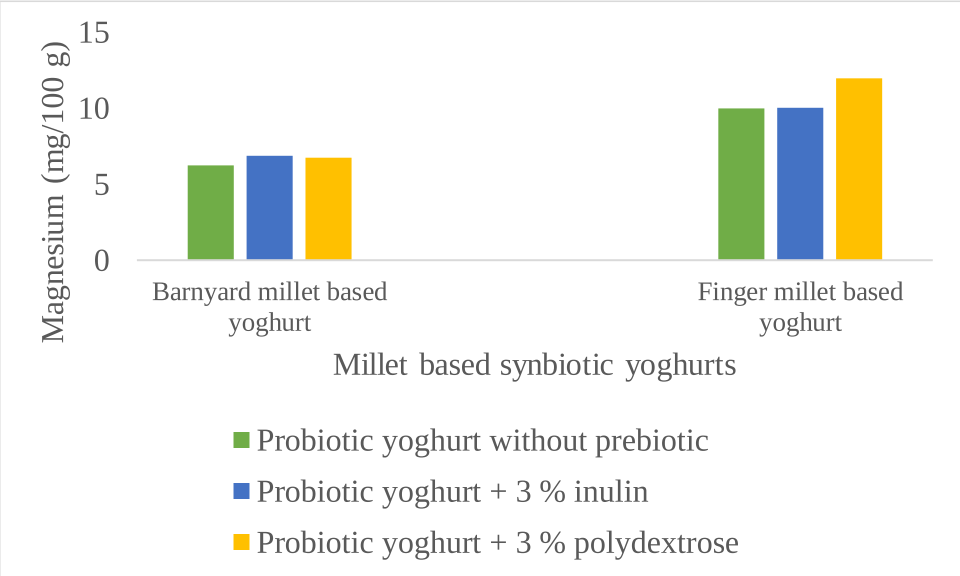


Fig. 66. Magnesium content of millet based synbiotic yoghurts (mg/100 g)

5.4.2. Health studies

5.4.2.1. *In vitro* mineral availability of selected millet yoghurt

The addition of prebiotics in fermented food can enhance the presence of mineral availability, because of the higher viability of probiotic microorganisms than fermented food products. Probiotic organisms have the capacity to remove phytates from the food, so that the presence of mineral availability in synbiotic food increased (Scholz-Ahrens *et al*., 2001).

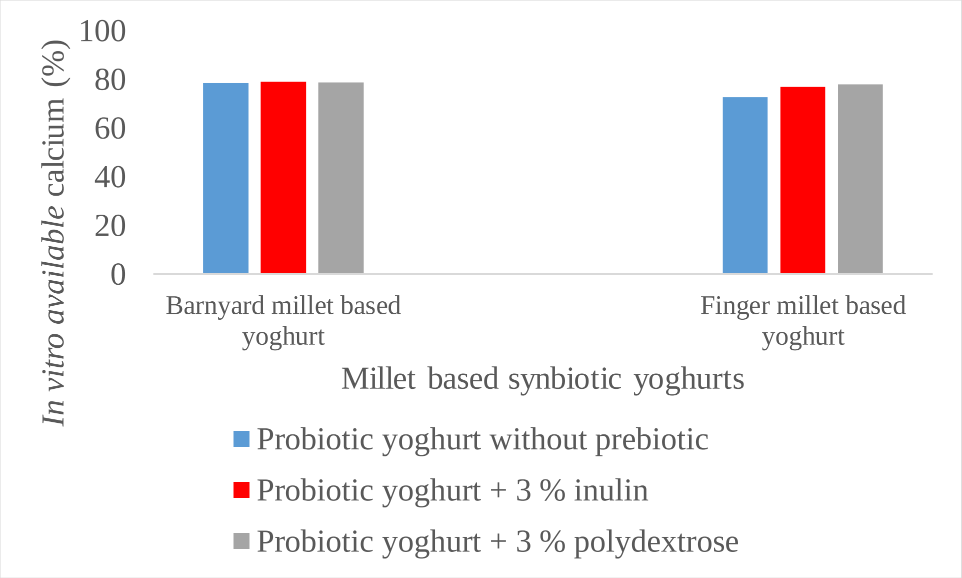


Fig. 67. *In vitro available* calcium content of millet based synbiotic yoghurts (%)

5.4.2.1.1. Calcium

The calcium availability of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of calcium availability of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 67.

Rani and Srividya (2016) developed low fat yoghurt with inulin and fructooligosacharide and studied *in vitro* availability of calcium of each set of yoghurt. The *in vitro* availability of calcium of control yoghurt was recorded as 26.9 mg /100 g, for inulin yoghurt the *in vitro* availability of calcium was 28.6 mg /100 g and for fructooligosacharide yoghurt the *in vitro* availability of calcium was recorded as 27.1 mg /100 g. The addition of inulin and oligofructose into yoghurt enhance the absorption of calcium (Griffin *et al*., 2002).

The bioavailability of calcium is also impacted by a few food based compounds. While non-digestible dietary oligosaccharides including inulin, fructooligosaccharides, lactulose and resistant starches can boost calcium absorption, some of them including phytate, long-chain saturated fatty acids, uronic acid and cellulose which decrease calcium absorption (Zafar *et al*., 2004).

A study was conducted to find out how Western strain weaned rats' absorption of different minerals was affected by baby cereal diets enhanced with synbiotic. When the study's findings were analysed, it was found that adding synbiotic to infant cereal diets, improved the absorption of calcium (Masoud *et al*., 2014).

Asemi *et al*. (2017) studied the mineral availability of synbiotic food with *L. sporogenes* and inulin as prebiotic, and it was compared with control. The calcium availability of synbiotic food was 1016 mg/day and for control it was 933 mg/day.

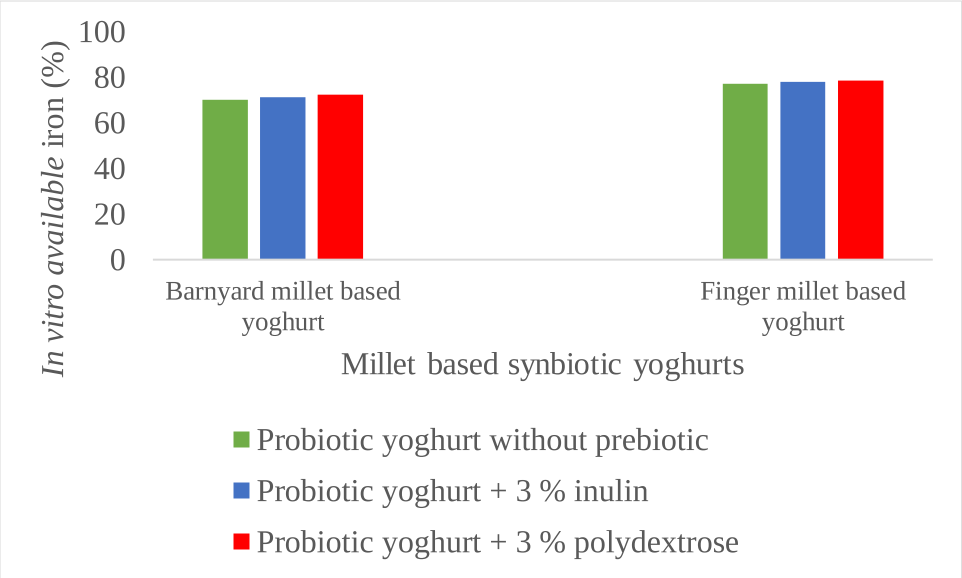


Fig. 68. *In vitro available* iron content of millet based synbiotic yoghurts (%)

5.4.2.1.2. Iron

Compared to probiotic yoghurt, each millet based synbiotic yoghurt had higher iron availability. Figure 68 shows a graphical comparison of the iron availability of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

A research was done to see how baby cereal meals supplemented with synbiotic influenced the absorption of several minerals in Western strain weaned rats. The results were analysed and it was discovered that inclusion of synbiotic in newborn cereal diets enhanced the iron absorption (Masoud *et al*., 2014).

According to a study, prebiotics and probiotics combined into synbiotics helped Wistar rats better absorb iron, which raised their haemoglobin levels. The authors proposed that iron fortified tempeh and synbiotics might be a successful approach to deal with the issue of iron deficiency anaemia (Helmyati *et al*., 2016).

In another instance, it was found that giving Sprague Dawley rats a unique galactooligosaccharides combination, improve their ability to absorb iron. Researchers gave non-purified galactooligosaccharides to Sprague Dawley rats to test this theory. A control group of rats received no galactooligosaccharides, whereas a treatment group received 5 g of these sugars per 100 g. In the study, the treatment group's rate of iron absorption (39.21 %) increased considerably compared to the control group (31.58 %). The study (Maawia *et al*., 2016) revealed that galactooligosaccharides might increase iron absorption in rat models.

5.4.2.1.3. Potassium

The potassium availability of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of potassium availability of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 69.

Asemi *et al*. (2017) studied the mineral availability of synbiotic food with *L. sporogenes* and inulin as prebiotic and it was compared with control. In case of potassium the bioavailability was 104 mg/day for control and 107 mg/day for synbiotic food.

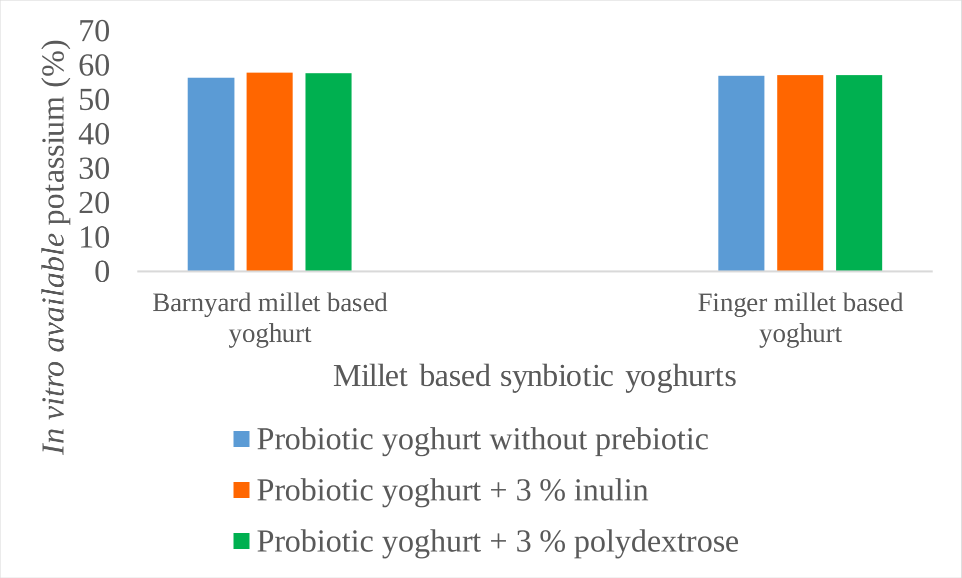


Fig. 69. ***In vitro available*** **potassium content of millet based synbiotic yoghurts (%)**

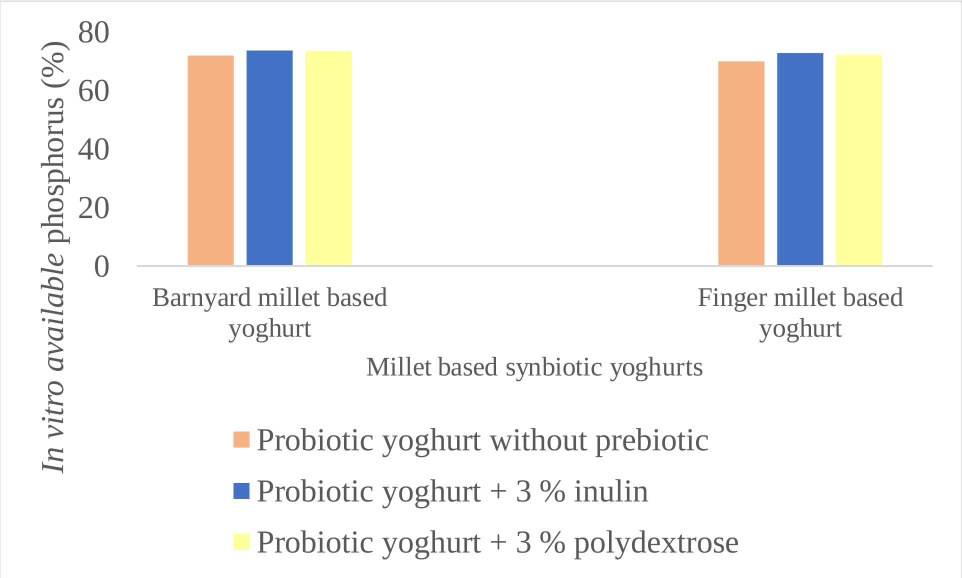


Fig. 70. ***In vitro available*** **phosphorus content of millet based synbiotic yoghurts (%)**

5.4.2.1.4. Phosphorus

Compared to its probiotic yoghurt, each millet based synbiotic yoghurt had a higher phosphorus availability. Figure 70 shows a graphical comparison of the phosphorus availability of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

Asemi *et al*. (2017) studied the mineral availability of synbiotic food with *L. sporogenes* and inulin as prebiotic and it was compared with control. In case of phosphorus the bioavailability was 1043 mg/day for control and 1079 mg/day for synbiotic food.

5.4.2.1.5. Zinc

Each millet based synbiotic yoghurt had a higher zinc availability than its probiotic yoghurt. Probiotic yoghurt prepared from millet (barnyard and finger millet) and synbiotic yoghurt is graphically compared in Figure 71 for zinc availability.

A study was conducted to examine the absorption of zinc of synbiotic baby cereal meals formula by using Western strain weaned rats. When the study's findings were analysed, it was found that adding prebiotic to infant cereal meals improved the absorption of zinc (Masoud *et al*., 2014).

Asemi *et al*. (2017) studied the mineral availability of synbiotic food consisting of *L. sporogenes* and inulin as prebiotic and it was compared with control. For the availability of zinc the synbiotic food contained 9.1 mg/day and for control food contained 8.9 mg/day.

5.4.2.1.6. Magnesium

Each synbiotic yoghurt made from millet has more magnesium availability than probiotic yoghurt. Figure 72 depicts the magnesium availability of synbiotic yoghurt, which was made from millet (barnyard and finger millet).

Klobukowski *et al*. (2008) studied and compared the rate of magnesium absorption in rats given probiotic and synbiotic soft cheeses. Maltodextrins was used as a prebiotic and the strain *L. plantarum* as a probiotic. The animals were fed soft cheese with probiotics and probiotic cheese with 2.5 % maltodextrins added for ten days. For probiotic cheese and for synbiotic cheese, the rat absorbed 96.4 and 70.5 mg of magnesium, respectively.

Asemi *et al*. (2017) studied the mineral availability of synbiotic food consisting of *L. sporogenes* and inulin as prebiotic and it was compared with control. The magnesium availability was measured as 277.80 mg/day for synbiotic food and 262.60 for control food.

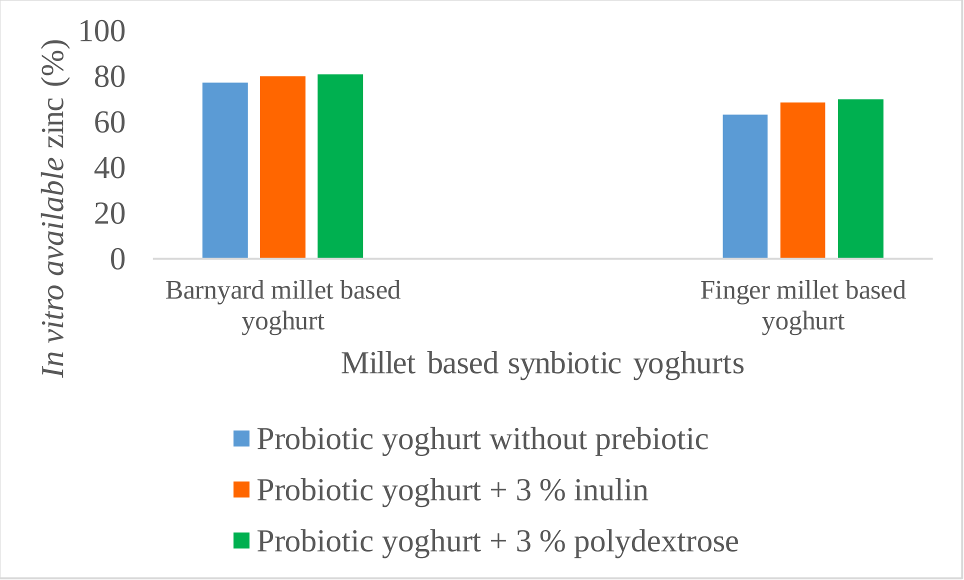


Fig. 71. *In vitro available* zinc content of millet based synbiotic yoghurts (%)

5.4.2.2. Antioxidant activity

The antioxidant activity of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. The comparison of antioxidant activity of both millet based probiotic yoghurt and synbiotic yoghurt are graphically represented in Figure 73.

Madhu *et al*. (2012) developed a probiotic milk yoghurt and compared it with a synbiotic milk yoghurt. The two different probiotic organisms used were *L. plantarum* and *L. fermentum*. The prebiotic used was fructooligosaccharides. The antioxidant activity was higher in synbiotic yoghurt compared to probiotic yoghurt with both probiotic organisms used in synbiotic yoghurt. The antioxidant activity of *L. plantarum* and *L. fermentum* used probiotic yoghurt was 82.40 per cent and 81.40 per cent respectively. For synbiotic yoghurt with *L. fermentum* and *L. plantarum* the antioxidant activity was 82.10 per cent and 84.70 per cent respectively.

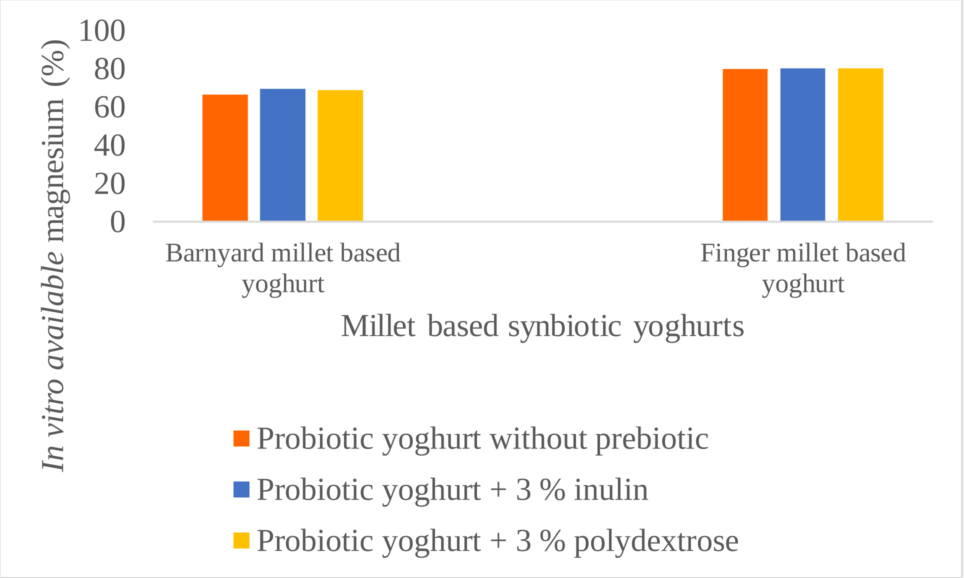


Fig. 72. *In vitro available* magnesium content of millet based synbiotic yoghurts (%)

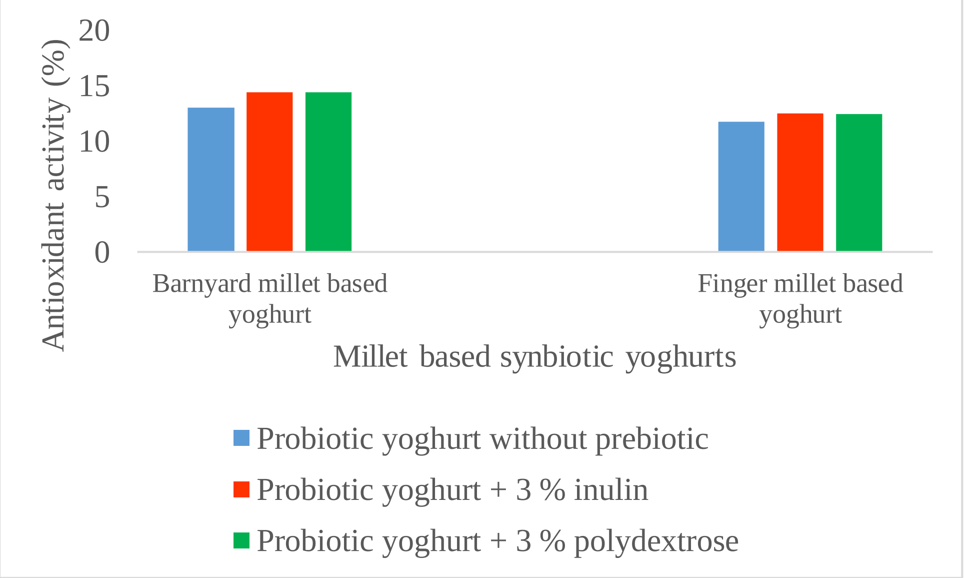


Fig. 73. Antioxidant activity of millet based synbiotic yoghurts (%)

5.4.3. Population of *L. acidophilus*

Compared to probiotic yoghurt, each millet based synbiotic yoghurt had higher viability of *L. acidophilus* than probiotic yoghurt. Figure 74 shows a graphical comparison of the viability of *L. acidophilus* of probiotic yoghurt made from both millet (barnyard and finger millet) and synbiotic yoghurt.

Sukarminah *et al*. (2019) developed sorghum based synbiotic yoghurt with *L. acidophilus*. The maximum viability of *L. acidophilus* (7.89 log cfu/ml) was in 5 per cent of sorghum flour added synbiotic yoghurt where as in control yoghurt it was 7.40 log cfu/ml.

The maximal colony forming unit concentration of 3.14×10^{10} cfu/ml in cucumber juice with 3 per cent prebiotic was shown to have a higher viability of *L. acidophilus* compared to its control (3.02×10^{10} cfu/ml). This is because the probiotic *L. acidophilus*, prebiotic (inulin) and carbohydrate sources found in the cucumber juice work together to produce this effect. The findings concur with those of Thomas (2009) who stated that prebiotics promote the development of beneficial microorganisms. A food product must include at least 6×10^{6} cfu/ml of microorganisms (Shah, 2001). According to observations, the growth of *L. acidophilus* and *B. lactis* was promoted by the addition of inulin, improving their viability in ice cream. The viable count of L. acidophilus in control yoghurt was 8.11 log cfu/ml and for synbiotic ice cream it was 8.45 log cfu/ml (Akin *et al*. 2007).

Delavari *et al*. (2014) developed inulin added synbiotic yoghurt and studied viability of *L. plantarum* of each yoghurt and summarised that 9.54 log cfu/ml of viability of *L. plantarum* for 1 per cent of inulin added low fat synbiotic yoghurt, 9.77 cfu/ml for 1.5 per cent inulin added synbiotic yoghurt and for control the *L. plantarum* was 9.43 cfu/ml.

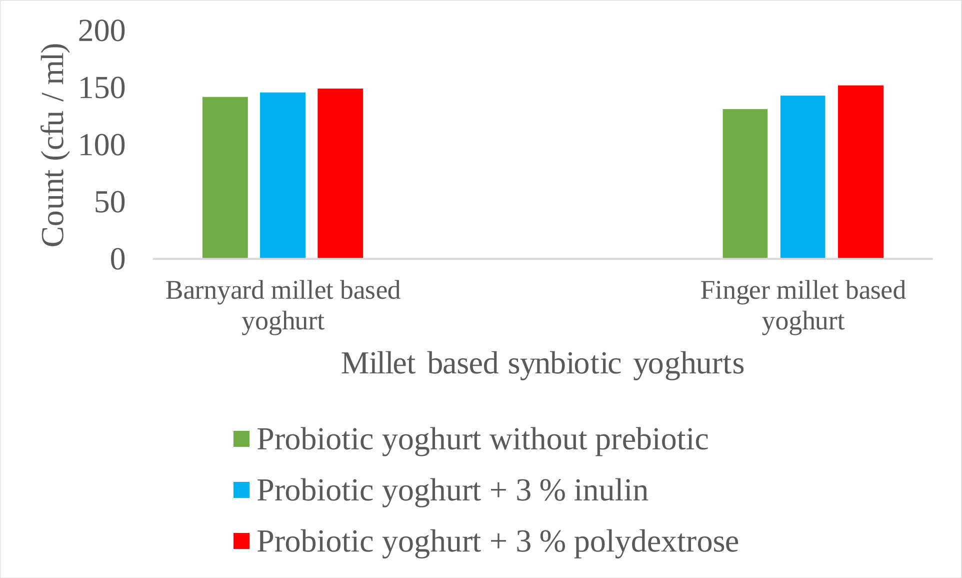


Fig. 74. Population of *L. acidophilus* of millet based synbiotic yoghurts (cfu/ml)

5.4.4. Enumeration of total micro flora

The bacterial count of each millet based synbiotic yoghurt was higher compared to its probiotic yoghurt. There were no fungal and algae colonies in each set of millet based synbiotic yoghurts.

Alegro *et al*. (2007) prepared synbiotic chocolate mousse with *L. paracasei* and inulin and it was compared with its probiotic chocolate mousse. The growth of yeast and fungi in each chocolate mousse was absent.

Bisar *et al*., (2015) developed synbiotic fermented dairy product (yoghurt) with different probiotic organism and prebiotics. The *B. longum* and *S. thermophiles* added food contained 7.42 log cfu/ml, for inulin added 8.74 log cfu/ml and for polydextrose added 8.51 log cfu/ml of bacterial count. The *B. longum* and *L. placts* added product contained 8.18 log cfu/ml, for inulin added 9.87 log cfu/ml and for polydextrose added 8.77 log cfu/ml of bacterial count. There was no fungal and yeast colonies in any of the products.

5.5. Cost of production

The cost for each millet based yoghurts were recorded. The variations in cost of each millet based yoghurts is because of the addition of probiotic organism in probiotic yoghurt and prebiotics (inulin and polydextrose) in synbiotic yoghurt. The cost of commercially available fruit contained yoghurt is in the range of Rs. 30-40/100 g.

The cost of production of plain yoghurt, rice flour added yoghurt and fruit enriched yoghurt was Rs.14, Rs. 13 and Rs. 15 /100 ml respectively (Sarabhai, 2012).

Manoharan *et al*. (2020) developed fruit pulp (mango and banana) based synbiotic yoghurt with fructooligosaccharide and honey as prebiotic and *L. brevis* as probiotic organism and the cost of these synbiotic yoghurt was Rs. 24.55/100 g for fortified fructooligosaccharide used mango based yoghurt, Rs.19.45/100 g for fortified honey used mango based yoghurt Rs.23.93/100 g for fortified fructooligosaccharide used banana based yoghurt and Rs. 18.85/100 g for fortified honey used banana.

Remya (2020) developed jackfruit based probiotic yoghurt with *L. acidophilus* and calculated the cost. This was ranged from Rs. 18.56-19.56/100 gram of yoghurt sample.

Jagdale and Ghodke (2020) developed synbiotic lassi and studied its cost and compared it with probiotic lassi. The probiotic used here was *L. acidophilus*. The cost of maltodextrins added synbiotic lassi was Rs. 57.39/100 g and the cost of lassi without maltodextrins was Rs. 51.68/100 g.

Summary

SUMMARY

The study entitled "Standardisation and quality evaluation of millet based probiotic yoghurts" was carried out with the objectives of developing millet based probiotic and synbiotic yoghurts using barnyard millet, finger millet and *Lactobacillus acidophilus* and evaluation of its acceptability, nutritional, health and shelf life qualities of the selected products.

The millet based yoghurts were standardised and yoghurt with 50 per cent milk and 50 per cent millet slurry from both millet (barnyard and finger millet) were found to be the best. The addition of *L. acidophilus* made this yoghurt a probiotic and the conditions for the growth of *L. acidophilus* were analysed. The maximum growth was seen with 25 g of yoghurt sample fermented for 6 hours with 1 ml of probiotic culture (*L. acidophilus*) and 2 ml of starter culture at 38º C. The viability of *L. acidophilus* in barnyard millet based probiotic yoghurt was 9.02 log cfu/ml and in finger millet based probiotic yoghurt was 8.98 log cfu/ml. From optimisation, the parameters for the maximum viability of *L. acidophilus* were used to prepare millet based probiotic yoghurt and it was stored for 15 days under refrigerated conditions (4º C). The quality aspects (physico-chemical composition, health studies, organoleptic evaluation and microbial analysis) of each millet based yoghurts (both non-probiotic and probiotic) were studied at 5 day intervals.

The moisture content of both barnyard and finger millet based non-probiotic yoghurt was lower than probiotic yoghurt. The moisture content of barnyard millet based non-probiotic yoghurt and probiotic yoghurt was 85.05 per cent and 87.03 per cent respectively. In case of finger millet based yoghurts it was 86.38 per cent for non-probiotic and 87.42 per cent for probiotic yoghurt. During storage, the moisture content increased in all types of yoghurts.

The acidity was maximum for probiotic yoghurt than non-probiotic yoghurt of both barnyard and finger millet based yoghurt. The acidity of non-probiotic yoghurt was 0.72 per cent for both barnyard millet and finger millet based yoghurt. Whereas, the acidity of probiotic yoghurt with finger millet was 0.81 per cent and that with finger millet was 0.78 per cent. The increased fashion was seen in storage in both barnyard and finger millet based yoghurts.

The yoghurt with probiotic had lower pH than non-probiotic yoghurt, because of the higher acidity of probiotic yoghurt than non-probiotic yoghurt. The pH of barnyard millet based probiotic yoghurt was 3.88 and for finger millet based probiotic yoghurt it was 3.82. Non-probiotic yoghurt with barnyard millet had a pH of 4.02 and finger millet had 3.92. After 15 days of storage the pH was decreased because of the increase in acidity on storage.

The rheological properties like water holding capacity, syneresis, viscosity, cohesiveness, gumminess and resilience were assessed. The study revealed that the maximum syneresis, viscosity, cohesiveness, gumminess and resilience and a minimum of water holding capacity were seen in probiotic yoghurt of both barnyard and finger millet than in non-probiotic yoghurt. On storage, all the rheological parameters decreased except syneresis.

The water holding capacity of probiotic yoghurt of barnyard and finger millet based yoghurt and non-probiotic yoghurt of barnyard and finger millet based yoghurt was 79.75 per cent, 78.30 per cent, 88.30 per cent and 85.80 respectively. The syneresis was 5.20 per cent, 5.10 per cent and 4.33 per cent for barnyard millet based probiotic yoghurt, finger millet based probiotic yoghurt and non-probiotic yoghurt of both millet respectively. In the case of viscosity, the probiotic yoghurt of barnyard and finger millet based yoghurt had 23204 cP and 22800 cP respectively. For non-probiotic yoghurt, it was 21104 cp and 20900 cP respectively for barnyard and finger millet.

The parameters analysed by the texture analyser include cohesiveness, gumminess and resilience. The cohesiveness of probiotic yoghurt of barnyard millet and finger millet was 0.64 N and 0.62 N, whereas for non-probiotic yoghurt, it was 0.63 N and 0.58 N respectively. The gumminess of non-probiotic yoghurt was 55.73 N for barnyard millet and 62.45 N for finger millet, while the gumminess of millet based probiotic yoghurt was 56.65 N for barnyard millet and 63.86 N for finger millet. The resilience of probiotic yoghurt with barnyard millet and finger millet was 41.74 N and

39.66 N respectively. Non probiotic yoghurt with finger millet had a resilience of 38.77 N and for barnyard millet it was 40.45 N.

Nutrient analysis of both probiotic and non-probiotic millet based yoghurts were carried out. The carbohydrate content of millet based non probiotic yogurts was higher than probiotic yoghurts. It was 8.58 per cent and 8.76 per cent respectively for barnyard millet based probiotic and non-probiotic yoghurt whereas for finger millet based yoghurt, the content was 8.32 per cent for probiotic and 8.91 per cent for non-probiotic yoghurt. The protein and fat content of probiotic yoghurts were found to be maximum when compared to non-probiotic yoghurt. The protein and fat content of barnyard millet based probiotic yoghurt was 3.52 per cent and 0.63 per cent respectively. Finger millet based probiotic yoghurt had 3.91 per cent protein and 0.39 per cent fat. For non-probiotic yoghurt of both barnyard millet based and finger millet based yoghurt, the protein content was 3.49 and 3.89, and fat was 0.59 per cent and 0.28 per cent respectively. All the macro nutrients had a decreasing trend during the storage.

The TSS of millet based yoghurt was analysed and maximum TSS was seen in non-probiotic yoghurt than probiotic yoghurt. The TSS of non-probiotic yoghurt of both barnyard and finger millet was 12º brix and for probiotic yoghurt it was 11º brix. On storage TSS of both non-probiotic and probiotic yoghurt were decreased.

The reducing as well as total sugar content of both millet based yoghurts were analysed and it was observed that both was highest in non-probiotic yoghurt than probiotic yoghurt. The reducing sugar content of barnyard millet based probiotic and non-probiotic yoghurt was 7.55 per cent and 8.33 per cent respectively. The finger millet based probiotic yoghurt had 7.38 per cent reducing sugar and for non-probiotic yoghurt the reducing sugar was 8.38 per cent. The total sugar content of probiotic yoghurt of barnyard millet based yoghurt was 10.99 per cent and for finger millet based non-probiotic yoghurt it was 11.55 per cent. In the case of probiotic finger millet yoghurt, the total sugar content was 10.42 per cent and for non-probiotic yoghurt it was 11.32 per cent. On storage both reducing and total sugar were decreased.

The crude fibre content of probiotic yoghurt was 0.50 per cent for barnyard millet based yoghurt and 0.90 per cent for finger millet based yoghurt. For non-probiotic yoghurt, the crude fibre content of barnyard millet was 0.60 per cent and for finger, millet was 1 per cent. On storage, the crude fibre content of each set of yoghurt were decreased.

The total ash content of probiotic yoghurt was 0.69 per cent for barnyard millet based yoghurt and 0.78 per cent for finger millet based yoghurt. For non-probiotic yoghurt, the total ash content of barnyard millet was 0.68 per cent and for finger, millet was 0.77 per cent. On storage, the total ash content of each set of yoghurt decreased.

Minerals content and *in vitro* availability of calcium, iron, potassium, phosphorus, zinc and magnesium was estimated in the selected millet based yogurts. Mineral content and the availability of minerals was found to be higher in probiotic yoghurts than non-probiotic yoghurts.

The calcium content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 58.43 mg/100 g, 59.36 mg/100 g, 72.06 mg/100 g and 73.18 mg/100 g respectively. The iron content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 0.50 mg/100 g, 0.61 mg/100 g, 0.23 mg/100 g and 0.24 mg/100 g respectively. The potassium of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 56.33 mg/100 g, 57.85 mg/100 g, 53.84 mg/100 g and 54.67 mg/100 g respectively. The phosphorus of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 51.58 mg/100 g, 52.68 mg/100 g, 48.84 mg/100 g and 49.65 mg/100 g respectively. The zinc content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 0.24 mg/100 g, 0.25 mg/100 g, 0.18 mg/100 g and 0.19 mg/100 g respectively. The magnesium of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 5.58 mg/100 g, 6.23 mg/100 g, 8.85 mg/100 g and 9.98 mg/100 g respectively. The *in vitro* calcium availability of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 77.73 per cent, 78.59 per cent, 72.19 per cent and 72.67 per cent respectively. The *in vitro* availability of iron content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 69.82 per cent, 70.02 per cent, 75.96 per cent and 76.98 per cent respectively. In the case of *in vitro* availability of potassium of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was per cent, 55.81 per cent, 56.28 per cent 55.45 per cent and 56.98 per cent respectively. The *in vitro* mineral availability of phosphorus of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 70.54 per cent, 71.92 per cent, 69.35 per cent and 69.87 per cent respectively. The *in vitro* availability of zinc content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 77.25 per cent, 77.29 per cent, 61.11 per cent and 63.16 per cent respectively. The *in vitro* availability of magnesium content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 65.31 per cent, 66.32 per cent, 74.82 per cent and 79.95 per cent respectively.

The antioxidant activity of the yoghurts were estimated and was found that barnyard millet based probiotic had highest antioxidant activity (12.99 %) followed barnyard millet based non-probiotic yoghurt (11.83 %), finger millet based probiotic yoghurt (11.75 %) and finger millet based non-probiotic yoghurt (10.81 %).

Each set of millet yoghurts were organoleptically evaluated for 15 days at 5 days interval. Overall acceptability of probiotic yoghurts was higher than non-probiotic yoghurts and the scores decreased during storage.

Population of *L. acidophilus* was enumerated. The viability of each probiotic yoghurt met the standard viability of probiotic organism. On storage it was decreased.

Microbial enumeration was carried out during the storage period and found that the bacterial count increased during storage. There was no growth of fungal and yeast during storage except 15th day which had fungal growth.

Standardisation of synbiotic yoghurt was carried by adding inulin and polydextrose and found that addition of 3 per cent of these prebiotics to the yoghurt with 50 per cent milk, 50 per cent millet slurry were the best.

The moisture content of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt. The moisture content of barnyard millet based probiotic yoghurt, inulin added synbiotic yoghurt and polydextrose added synbiotic yoghurt was 87.03 per cent, 87.67 per cent and 87. 27 per cent respectively. The moisture content of finger millet based probiotic yoghurt, inulin added synbiotic yoghurt polydextrose added synbiotic yoghurt was 87.42 per cent, 88.54 per cent and 88.53 per cent respectively.

Inulin and polydextrose based synbiotic yoghurt both had higher acidity than probiotic yoghurt. Barnyard millet based probiotic yoghurt, inulin added synbiotic yoghurt and polydextrose added synbiotic yoghurt had an acidity of 0.81 per cent, 0.89 per cent and 0.86 per cent respectively. Finger millet based probiotic yoghurt had an acidity of 0.78 per cent, finger millet based synbiotic yoghurt with inulin had an acidity of 0.83 per cent and finger millet based synbiotic yoghurt with polydextrose had an acidity of 0.84 per cent.

Probiotic yoghurt showed lower pH than inulin and polydextrose based synbiotic yoghurt. Probiotic yoghurt made from barnyard millet had a pH of 3.88, synbiotic yoghurt with inulin added had pH of 3.76 and synbiotic yoghurt with polydextrose added had a pH of 3.74. The pH of finger millet based probiotic yoghurt was 3.82, that of finger millet based synbiotic yoghurt with inulin was 3.76 and that of finger millet based synbiotic yoghurt with polydextrose was 3.75.

The water holding capacity and viscosity of both synbiotic yoghurt (both inulin and polydextrose) was higher than probiotic yoghurt and lower in the case of syneresis. The water holding capacity of barnyard millet and finger millet based probiotic yoghurt was 79.75 per cent and 78.30 per cent respectively. In case of synbiotic yoghurt it varies from 78.30 - 80.73 per cent. The syneresis of barnyard millet and finger millet based probiotic yoghurt was 5.20 per cent and 5.10 per cent respectively. In case of synbiotic yoghurt it varies from 5.04 - 5.12 per cent. The viscosity of barnyard millet and finger millet based probiotic yoghurt was 23204 cP and 5.10 22800 cP, respectively. In case of synbiotic yoghurt it varies from 23310 - 25203 cP.

Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower cohesiveness, gumminess and resilience. The cohesiveness of barnyard millet and finger millet based probiotic yoghurt was 0.64 N and 0.62 N respectively. In case of synbiotic yoghurt it varies from 0.63 - 0.67 N. The gumminess of barnyard millet and finger millet based probiotic yoghurt was 56.65 N and 63.86 N respectively. In case of synbiotic yoghurt it varies from 56.87 - 66.89 N. The resilience of barnyard millet and finger millet based probiotic yoghurt was 41.74 N and 39.66 N respectively. In case of synbiotic yoghurt it varies from 40.03 - 42.64 N.

Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower carbohydrate, higher protein and fat. The carbohydrate of barnyard millet and finger millet based probiotic yoghurt was 8.58 per cent and 8.32 per cent respectively. In case of synbiotic yoghurt it varies from 8.14 - 8.47 per cent. The protein of barnyard millet and finger millet based probiotic yoghurt was 3.52 per cent and per cent respectively. In case of synbiotic yoghurt it varies from 3.61 - 3.99 per cent. The fat of barnyard millet and finger millet based probiotic yoghurt was 0.63 per cent and 0.39 per cent respectively. In case of synbiotic yoghurt it varies from 0.42 -0.69 per cent.

Probiotic yoghurt showed higher TSS than inulin and polydextrose based synbiotic yoghurt. Probiotic yoghurt made from barnyard millet had TSS of 11° brix, synbiotic yoghurt with inulin added had TSS of 10° brix and synbiotic yoghurt with polydextrose added had TSS of 9° brix. The TSS of finger millet based probiotic yoghurt was 11° brix, that of finger millet based synbiotic yoghurt with inulin was 10° brix and that of finger millet based synbiotic yoghurt with polydextrose was 9° brix.

Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a higher reducing sugar and total sugar. The reducing sugar of barnyard millet and finger millet based probiotic yoghurt was 7.55 per cent and 7.38 per cent respectively. In case of synbiotic yoghurt it varies from 6.46 – 6.78 per cent. The total sugar of barnyard millet and finger millet based probiotic yoghurt was 10.99 per cent and 10.42 per cent respectively. In case of synbiotic yoghurt it varies from 9.38 - 9.56 per cent.

Probiotic yoghurt showed higher crude fibre than inulin and polydextrose based synbiotic yoghurt. Probiotic yoghurt made from barnyard millet had a crude fibre of 0.50 per cent, synbiotic yoghurt with inulin added had crude fibre of 0.45 per cent and synbiotic yoghurt with polydextrose added had a crude fibre of 0.43 per cent. The crude fibre of finger millet based probiotic yoghurt was 0.90 per cent, that of finger millet based synbiotic yoghurt with inulin was 0.87 per cent and that of finger millet based synbiotic yoghurt with polydextrose was 0.85 per cent.

Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower total ash. Total ash for probiotic yoghurt prepared from barnyard millet was 0.69 per cent, for synbiotic yoghurt with inulin added, it was 0.76 per cent and for synbiotic yoghurt with polydextrose added, it was 0.71 per cent. Finger millet based probiotic yoghurt had a total ash of 0.78 per cent, 0.82 per cent for finger millet based synbiotic yoghurt with inulin and 0.84 per cent for finger millet based synbiotic yoghurt with polydextrose.

The mineral content and bioavailability (calcium, iron, potassium, phosphorus, zinc and magnesium) of each yoghurt was analysed. Each mineral was high in synbiotic yoghurt than probiotic yoghurt.

The calcium content of barnyard millet and finger millet based probiotic yoghurt was 59.36 mg/100 g and 73.18 mg/100 g, respectively. In case of synbiotic yoghurt it varies from 60.02 - 74.26 mg/100 g. The iron content of barnyard millet and finger millet based probiotic yoghurt was 0.61 mg/100 g and 0.24 mg/100 g respectively. In case of synbiotic yoghurt it varies from 0.25 - 0.67 mg/100 g. The potassium of barnyard millet and finger millet based probiotic yoghurt was 57.85 mg/100 g and 54.67mg/100 g, respectively. In case of synbiotic yoghurt it varies from 55.01 -58.25 mg/100 g. The phosphorus of barnyard millet and finger millet based probiotic yoghurt was 52.68mg/100 g and 49.65 mg/100 g respectively. In case of synbiotic yoghurt it varies from 49.96 - 53.76 mg/100 g. The zinc of barnyard millet and finger millet based probiotic yoghurt was 0.25 mg/100 g and 0.19 mg/100 g respectively. In case of synbiotic yoghurt it varies from 0.20 - 0.27 mg/100 g. The magnesium of barnyard millet and finger millet based probiotic yoghurt was 6.23 mg/100 g and 9.98 mg/100 g respectively. In case of synbiotic yoghurt it varies from 6.73 - 11.98 mg/100 g. The *in* *vitro* availability of calcium content of barnyard millet and finger millet based probiotic yoghurt was 78.59 per cent and 72.40 per cent, respectively. In case of synbiotic yoghurt it varies from 73.15 - 78.91 per cent. The *in vitro* availability of iron content of barnyard millet and finger millet based probiotic yoghurt was 70.02 per cent and 76.98 per cent respectively. In case of synbiotic yoghurt it varies from 71.10 - 78.61 per cent. The *in vitro* availability of potassium of barnyard millet and finger millet based probiotic yoghurt was 56.28 per cent and 56.98 per cent, respectively. In case of synbiotic yoghurt it varies from 57.09 -57.77 per cent. The *in vitro* availability of phosphorus of barnyard millet and finger millet based probiotic yoghurt was 71.92 per cent and 69.87 per cent respectively. In case of synbiotic yoghurt it varies from 72.02 - 73.55 per cent. The *in vitro* zinc of barnyard millet and finger millet based probiotic yoghurt was 77.29 per cent and 63.16 per cent respectively. In case of synbiotic yoghurt it varies from 68.42 - 80.92 per cent. The *in vitro* magnesium of barnyard millet and finger millet based probiotic yoghurt was 66.32 per cent and 79.95 per cent respectively. In case of synbiotic yoghurt it varies from 68.80 - 80.16 per cent.

The antioxidant activity of barnyard millet based synbiotic yoghurt was 14.38 per cent and 14.39 per cent respectively for inulin and polydextrose; which was much higher than its probiotic yoghurt having 12.99 per cent. Antioxidant activity of synbiotic finger millet yoghurt added with inulin was higher (12.48 %) followed by thatadded with polydextrose (12.42 percent) and probiotic yoghurt (11.75 %).

The viability of *L. acidophilus*, bacteria, fungi and yeast were analysed. The maximum viability of *L. acidophilus* and bacteria was seen in synbiotic yoghurt than probiotic yoghurt. There was no fungal and yeast growth in each set of millet based yoghurts.

The cost of production of the selected millet based probiotic and synbiotic yoghurts were calculated. Probiotic yoghurt with 50 per cent each of milk and millet slurry costs Rs.21.65 - 23.74 / 100g. Barnyard millet and finger millet based synbiotic yoghurt had the cost of Rs. 25.76 - 27.88 / 100g.

The study revealed that the development of probiotic and synbiotic yoghurt with millet had higher nutritive and therapeutic value. Fermentation with *L. acidophilus* can enhance the nutrients of yoghurt.

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Appendices

APPENDIX I

Score card for the organoleptic evaluation of barnyard millet based yoghurts

Date:

Name:

Signature:

	T_0	T_1	T_2	T_3	T_4	T_5
Appearance						
Colour						
Flavour						
Taste						
Texture						
Overall Acceptability						

Nine point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

APPENDIX II

Score card for the organoleptic evaluation of finger millet based yoghurts

Date:

Name:

Signature:

	T_0	T_6	T_7	T_8	T_9	T_{10}
Appearance						
Colour						
Flavour						
Taste						
Texture						
Overall Acceptability						

Nine point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

APPENDIX III

Score card for the organoleptic evaluation of inulin added barnyard millet based synbiotic yoghurts

Date:

Name:

Signature:

	T_0	T_1	T_2	T_3
Appearance				
Colour				
Flavour				
Taste				
Texture				
Overall Acceptability				

Nine point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

APPENDIX IV

Score card for the organoleptic evaluation of inulin added finger millet based synbiotic yoghurts

Date:

Name:

Signature:

	T_0	T_4	T_5	T_6
Appearance				
Colour				
Flavour				
Taste				
Texture				
Overall Acceptability				

Nine point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

APPENDIX V

Score card for the organoleptic evaluation of polydextrose added barnyard millet based synbiotic yoghurts

Date:

Name:

Signature:

	T_0	T_7	T_8	T_9
Appearance				
Colour				
Flavour				
Taste				
Texture				
Overall Acceptability				

Nine point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

APPENDIX VI

Score card for the organoleptic evaluation of polydextrose added finger millet based synbiotic yoghurts

Date:

Name:

Signature:

	T_0	T_{10}	T_{11}	T_{12}
Appearance				
Colour				
Flavour				
Taste				
Texture				
Overall Acceptability				

Nine point hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like or dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

STANDARDISATION AND QUALITY EVALUATION OF MILLET BASED PROBIOTIC YOGHURTS

By
AMRUTHA U. A.
(2019-16-003)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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(FOOD SCIENCE AND NUTRITION)

Faculty of Agriculture

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ABSTRACT

Fermented millet products serve as a natural probiotic. Millets act as super foods because as it is the reservoir of nutrients for better health and are rich in B vitamins, calcium, iron, potassium, magnesium, zinc, dietary fibre and phytochemicals. Probiotics are live microorganisms that when administered in adequate amounts confer a health benefit on the host. Prebiotics are non-digestible ingredients that enhance the activity of colon bacteria and the viability of probiotics. Synbiotics involve the combination of probiotics and prebiotics. Hence, the present study entitled "Standardisation and quality evaluation of millet based probiotic yoghurts" was undertaken to develop probiotic and synbiotic yoghurts incorporating barnyard millet and finger millet and to evaluate its acceptability, nutritional, health and shelf life qualities.

Millet based yoghurts were prepared with different combinations of millet slurry and milk using both barnyard and finger millet. Among these yoghurts prepared, 50 per cent milk and 50 per cent millet slurry (from both barnyard and finger millet) were found to be the best with the total score of 51.94 for barnyard millet based yoghurt and 51.39 for finger millet based yoghurt. The addition of *L. acidophilus* made this yoghurt a probiotic after optimising the growth conditions for *L. acidophilus,* with regard to substrate concentration, temperature, time and inoculum concentration. The maximum growth was seen with 25 g of yoghurt sample fermented for 6 h with 1 ml of probiotic culture (*L. acidophilus*) with 2 ml of yoghurt culture at 38^{o} C. The viability of *L. acidophilus* in barnyard millet based probiotic yoghurt was 9.02 log cfu / ml and in finger millet based probiotic yoghurt was 8.98 log cfu / ml. The prepared probiotic yoghurt of both millet based were stored for 15 days and its qualities were analysed and compared with non-probiotic yoghurt of each millet, at 5 days interval.

The physico-chemical composition, health studies, organoleptic evaluation, population of *L. acidophilus* and enumeration of total micro flora were analysed and found that moisture, acidity, water holding capacity, viscosity, cohesiveness, gumminess, resilience, protein, fat, total ash, minerals, *in vitro* mineral availability of minerals (calcium, iron, potassium, phosphorus, zinc and magnesium) and antioxidant

activity were higher in probiotic yoghurt of both millets than in non-probiotic control. The other parameters such as pH, syneresis, carbohydrate, TSS, reducing sugar, total sugar and crude fibre were higher in non-probiotic yoghurt than probiotic yoghurt in both millets. On storage each parameters decreased except moisture, acidity and syneresis which was shown to increase.

The acidity of probiotic and non-probiotic yoghurt of barnyard millet based yoghurt was found to be 0.81 and 0.72 per cent respectively and for finger millet based it was 0.72 and 0.78 per cent for non-probiotic and probiotic yoghurt respectively. For probiotic and non-probiotic yoghurt of barnyard millet was found to be 8.58 g/100 g and 8.76 g/100 g for carbohydrate and 3.52 and 3.49 g/100 g for protein. In the case of finger millet based non-probiotic and probiotic yoghurt, carbohydrate found to be 8.91 and 8.32 g/100 g. The protein content of finger millet based probiotic and non-probiotic yoghurt 3.89, 3.91 g/100 g respectively. Fat was high in probiotic yoghurt of both millets (0.63 g/100 g for barnyard millet and 0.39 g/100 g for finger millet based yoghurt). In the case of non-probiotic yoghurt the fat content of barnyard millet based yoghurt was 0.59 g/100 g and 0.28 g/100 g for finger millet based yoghurt. The crude fibre of barnyard millet based probiotic and non-probiotic yoghurt and finger millet based probiotic and non-probiotic was 0.50, 0.60, 0.90, 1 g/100 g respectively.

The water holding capacity was less in probiotic yoghurt (79.75 per cent for barnyard and 78.30 for finger millet based yoghurt) than non-probiotic yoghurt (88.30 per cent for barnyard millet based yoghurt and 85.80 per cent for finger millet based yoghurt). The syneresis of barnyard millet based probiotic and non-probiotic yoghurt was 5.20 and 4.33 per cent respectively. For finger millet based yoghurt the syneresis of non-probiotic yoghurt was 4.33 per cent and 5.10 per cent for probiotic yoghurt. The viscosity was high in probiotic than non-probiotic yoghurt, for barnyard millet yoghurt the viscosity was 21104 cP for non-probiotic and 23204 cP for probiotic yoghurt. In the case of finger millet based yoghurt the viscosity was 20900 cP for non-probiotic and 22800 cP for probiotic yoghurt.

The calcium content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 58.43 mg/100 g, 59.36 mg/100 g, 72.06 mg/100 g and 73.18 mg/100 g respectively. The iron content of barnyard millet based non-probiotic and probiotic yoghurt and finger millet based non-probiotic and probiotic yoghurt was 0.24 mg/100 g, 0.25 mg/100 g, 0.23 mg/100 g and 0.24 mg/100 g respectively.

The bioavailability of minerals in probiotic yoghurt of both millet based yoghurts was higher than non-probiotic yoghurt. On Storage bioavailable calcium was decreased to 77.13 per cent for non-probiotic and 78.07 per cent for probiotic yoghurt of barnyard millet based yoghurts and in the case of finger millet based yoghurt it was 77.13 per cent for non-probiotic yoghurt and 72.54 per cent for probiotic yoghurt. The bioavailability of iron for barnyard millet based probiotic yoghurt was 70.02 per cent and non-probiotic yoghurt was 69.82 per cent initially. For non-probiotic yoghurt and probiotic yoghurt of finger millet based was 775.96 per cent and 76.98 per cent of *in vitro* iron respectively.

On storage, the viability of *L. acidophilus* decreased and on the 15th day it was 11.11 and 11.07 log cfu/ml for barnyard and finger millet based yoghurts respectively.

On microbial enumeration, the bacterial count was 6.54 and 7.18 log cfu/ml for barnyard millet based non-probiotic and probiotic yoghurts. The bacterial count for finger millet based probiotic and non-probiotic yoghurts was found to be 6.48 and 7.16 log cfu/ml. There was no fungal and yeast growth initially and on the 15th day, fungi growth was found to be 1 cfu/ml for both barnyard and finger millet based yoghurts, but it was within the permissible limit.

Synbiotic yoghurts were standardised with the addition of inulin and polydextrose with varying percentages. The addition of 3 per cent of these prebiotics to the yoghurt with 50 per cent milk, 50 per cent millet slurry were found to be the best.

Compared to synbiotic yoghurt made with inulin and polydextrose, probiotic yoghurt had a lower carbohydrate, higher protein and fat. In case of synbiotic yoghurt carbohydrate content varied from the range of 8.14 - 8.47 g/100 g, protein between 3.61 - 3.99 g/100 g and fat ranged from 0.42 - 0.69 g/100 g. The textural properties such as water holding capacity, syneresis and viscosity of synbiotic yoghurt was in the range of

79.32 - 80.73 per cent, 5.04 - 5.15 per cent and 23310 - 25203 cP respectively.

The calcium content of barnyard millet and finger millet based probiotic yoghurt was 59.36 mg/100 g and 73.18 mg/100 g, respectively. In case of synbiotic yoghurt it varies from 60.02 - 74.26 mg/100 g.

The bioavailability of calcium was found to be 78.91 and 78.84 per cent for inulin added polydextrose added barnyard millet based synbiotic yoghurts and 73.15 and 73.64 per cent for polydextrose added of finger millet based yoghurt respectively. The *in vitro* iron content was 71.10 and 72.31 per cent for inulin added barnyard and finger millet based yoghurts and 78.01 and 78.61 per cent for polydextrose added barnyard and finger millet based yoghurts respectively.

The viability of *L. acidophilus* of inulin added barnyard and finger millet based yoghurts was 11.16 and 11.15 log cfu / ml and for polydextrose added barnyard and finger millet based yoghurts was 11.17 and 11.18 log cfu / ml.

The cost of production of the selected barnyard millet based probiotic yoghurt was Rs. 21.65 / 100 g and for finger millet based probiotic yoghurt it was Rs. 23.74 / 100 g. The cost for inulin and polydextrose added barnyard millet based synbiotic yoghurt was Rs. 25.76 / 100 g and Rs. 26.66 / 100 g and for inulin and polydextrose added finger millet based yoghurt was Rs. 26.88 / 100 g and Rs. 27.88 / 100 g.

Probiotic yoghurt is a popular functional food product around the world. Delivering an appropriate number of viable probiotic bacteria is critical in determining the health improving properties of yoghurt. Prebiotics and probiotics both support the body in building and maintaining a healthy colony of bacteria and other microorganisms, which supports the gut and aids digestion. So the fermentation of millet with probiotics can enhance the availability of nutrients and aid better health.