Probiotic-Rich Fermented Fruit and Vegetable Beverages: Functional Foods for Gut Health

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Abstract
Gut health is now considered a predominant aspect of overall health, and plays an important role of gut microbiota in digestion, nutrient absorption and metabolic regulation. Nutrition is the most important factor that influences the composition of gut microbes by including probiotics and prebiotics in meals often which improves gut health and prevent illness. The current study focuses on the development of traditional and functional probiotics and prebiotics food products like Fermented functional beverage (Upilitathu Fruits and Vegetables Drink), using natural ingredients like seasonal vegetables and fruits, spices, onions, and vinegar. These components have higher probiotic value, fermentable dietary fibre, bioactive substances which promotes healthy gut flora. Standardized preparation methods were followed up to ensure product consistency and stability, and safety. On controlled fermentation, a functional drink has been formulated and evaluated for sensory attributes including appearance, flavour, texture, taste and overall acceptability using a 9-point hedonic scale. It was found to be well accepted by the consumer, demonstrating the flexibility of incorporating gut-friendly foods into their daily diets. It was packed in a glass bottle with an appropriate airtight seal. The beverage was stored under refrigerated conditions reveals the satisfactory sensory and quality stability for up to one week, which may be suitable for short-term household use and small-scale preparation. The possible health-related benefits of the formulated drink include better bowel regularity, increased gut bacteria diversity, improved digestion, immunological support, and less gastro-intestinal discomfort. Traditional fermentation methods are also consistent with functional food development and sustainable nutrition. In the present work emphasizes the potential of incorporating prebiotics and probiotics into dietary patterns which highlights the relevance of nutrition-driven culturally appropriate food innovations as a new frontier in preventive health care and gut microbiota modulations.
Keywords: Gut Microbiota, Probiotics, Gut Health, Fermented Foods.

Introduction

The advantages of consuming functional beverages enhanced with living microorganisms are being emphasized by medical professionals more and more. The majority of the widely accessible probiotic drinks are dairy-based and are usually offered as fermented milk products. Also the demand

for non-dairy probiotic drinks has increased due to higher interest in healthy vegetarian diets and the desire for cholesterol-free solutions. In this regard, fruit and vegetable juices provides a probiotic delivery options that may be popular in both developed and developing countries. Fruits and vegetables are highly perishable foods because of their high water content and rich nutritional profile. By lowering harmful substances, lactic acid fermentation not only increases their shelf-life but also enhances their flavour, safety, and nutritional value. Fermented fruit and vegetable juices enhanced with probiotics can serve as dietary supplements and contributes better digestion. (FAO/WHO (2002)).

The human gastro-intestinal tract contains a dense and diverse population of microorganism, which plays a vital role in maintaining the homeostasis of the body. These beneficial microorganisms contributes to digestion, synthesis of essential metabolites, immune modulation, protection against pathogens, and regulation of metabolic processes. Upcoming scientific evidences has established that dysbiosis of gut microbes are associated with gastro-intestinal disorders, metabolic diseases, inflammatory conditions, and impaired immune function. Consequently improving gut health through diet-based strategies has become important in nutrition science and functional food research. (Hill et al. (2014))

Diet is recognized as one of the modifiable factor shaping gut microbiota composition. In recent years, probiotics and prebiotics have received considerable attention for their role in promoting a balanced intestinal ecosystem. Probiotics consumption in adequate amount provide health benefits to the host, while prebiotics are non-digestible food components that stimulates the growth and activity of beneficial gut bacteria. Traditional fermented foods serve as natural sources of probiotics and bioactive compounds, supporting digestive health across varied cultures. (Hill et al. (2014))

Conventional probiotic delivery systems are dairy-based, such as yogurt and fermented milk products. However, the increasing prevalence rate of lactose intolerance, milk protein allergies, and the growing demand for plant-based diets have highlighted the need for alternative non-dairy probiotic sources. In this context, fermented fruit and vegetable beverages have emerged as promising functional foods due to their rich nutritional profile, absence of lactose and cholesterol, and compatibility with vegetarian and vegan dietary patterns. Fruits and vegetables naturally contain fermentable carbohydrates, organic acids, vitamins, minerals, dietary fibre, and polyphenols, which support probiotic growth and survival during fermentation. (FAO/WHO (2002))

Fermentation enhances the functional quality of fruit and vegetable substrates by improving its nutrient bioavailability, increasing antioxidant activity, and generating beneficial metabolites such as lactic acid and short-chain fatty acids. These metabolites contribute to maintaining intestinal barrier integrity, regulating gut pH, suppressing pathogenic bacteria, and modulating inflammatory responses. It was also noted that plant-based fermented beverages act as symbiotic systems, as the inherent dietary fibre and phytochemicals functions as prebiotic substrates that enhance probiotic efficacy. This synergistic interaction makes fermented fruit and vegetable beverages effective in gut microbiota modulation. (FAO/WHO (2002))

Traditional fermented beverages represent an important link between cultural food practices and modern functional nutrition. One of the traditional preparation methods is Upilitathu, a naturally fermented fruit and vegetable drink commonly prepared using seasonal produce, spices, and acidic components. Upilitathu is traditionally consumed for digestive comfort, improved appetite, and general well-being. Although historically prepared at the household level, its formulation aligns closely with current scientific principles of probiotic and prebiotic synergy. The use of vegetables, fruits, onions, spices, and vinegar provides a favourable matrix for the growth of beneficial lactic acid bacteria while supplying fermentable dietary fibre and bioactive compounds. (Hill et al. (2014))

The fermentation process involved in Upilitathu facilitates the proliferation of probiotic microorganisms while reducing anti-nutritional factors and enhancing sensory attributes such as flavour and aroma. The acidic environment created during fermentation not only improves microbial safety but also supports gut health by promoting beneficial microbial growth. The presence of plant-derived prebiotic components such

as inulin, oligosaccharides, and pectin further enhances probiotic survival and activity in the gastro-intestinal tract. These characteristics position Upilitathu as a culturally relevant, plant-based functional beverage with significant gut health potential. (Hill et al. (2014))

Scientific studies on fermented fruit and vegetable beverages have demonstrated their effectiveness in improving digestive health, enhancing immune response, and reducing gastro-intestinal discomfort. Such beverages have also shown high consumer acceptability when sensory properties are analyzed. In the case of Upilitathu, the balance of sourness, spice infusion, and natural fermentation contributes to its palatability, making it suitable for regular dietary incorporation. Also, short-term refrigerated storage has been reported to maintain sensory quality and microbial stability, supporting its feasibility for household and small-scale commercial use. (Hill et al. (2014))

Despite increasing the popularity of probiotic functional beverages, certain challenges such as microbial viability, standardization of fermentation, and shelf-life stability remains critical. Traditional beverages like Upilitathu, when developed using standardized preparation and controlled fermentation, offer an opportunity to bridge traditional knowledge with scientific validation. This approach supports sustainable nutrition, promotes indigenous food systems, and provides accessible gut health solutions without reliance on synthetic supplements. Taken together, probiotic rich fermented fruit and vegetable beverages represent a practical and culturally acceptable strategy for improving gut health. The development and evaluation of Upilitathu as a functional fermented drink highlights the relevance of traditional dietary practices in modern preventive healthcare. Integrating such beverages into daily diets may contribute to improved gut microbiota balance, enhanced digestive function, and overall health, reinforcing the role of nutrition-driven, culturally rooted functional foods in gut health promotion. (Hill et al. (2014))

Review of Literature

Gut Microbiota and Human Health

The human gut microbiota is a dynamic and intricate ecology made up of viruses, fungi, and bacteria that work together to affect host cells. Numerous studies have shown how important gut microbiota is for immune response modulation, vitamin production, intestinal barrier integrity, and digestion. Microbial diversity composition has been linked to immunological dysfunction, inflammatory bowel disease, diabetes, obesity, and gastrointestinal problems. According to research, a healthy gut microbiota supports metabolic homeostasis, whereas dysbiosis interferes with host-microbe interactions and causes low-grade inflammation and poor food metabolism. Marco et al. (2017).

Diet has been consistently identified as a major determinant of gut microbial composition. Long-term dietary patterns influence microbial diversity more significantly than short-term dietary changes. Diets rich in fibre, fermented foods, and plant-based components are associated with increased microbial richness and abundance of beneficial bacteria. Conversely, diets high in refined carbohydrates, saturated fats, and processed foods have been linked to reduced microbial diversity. These findings emphasise the importance of dietary interventions, particularly fermented functional foods, in supporting gut health. (Marco et al. 2017)

Probiotics and Their Health Benefits

Probiotics are defined as live microorganisms that confer health benefits when consumed in adequate amounts. Numerous experimental and clinical studies have documented the role of probiotics in improving gut microbial balance, enhancing immune function, and preventing gastrointestinal infections. Common probiotic strains such as Lactobacillus and Bifidobacterium exert beneficial effects through mechanisms including competitive exclusion of pathogens, production of antimicrobial substances, and modulation of host immune responses.

Literature reports that regular probiotic consumption improves bowel regularity, reduces symptoms of irritable bowel syndrome, and enhances lactose digestion. Probiotics have also been shown to strengthen

intestinal epithelial barrier function by increasing tight junction protein expression. Despite their benefits, probiotic efficacy is influenced by factors such as strain specificity, dosage, food matrix, and storage conditions. These findings highlight the importance of selecting appropriate delivery vehicles to ensure probiotic survival and functionality. (Tamang et al. 2016)

Prebiotics and Synbiotic Foods

Prebiotics are non-digestible food components that stimulate the growth and activity of beneficial gut microorganisms. Common prebiotics include inulin, fructooligosaccharides, galactooligosaccharides, pectin, and resistant starch, which are naturally present in fruits, vegetables, and plant-based foods. Research indicates that prebiotic intake increases populations of Bifidobacterium and Lactobacillus, leading to improved gut microbial balance and enhanced production of short-chain fatty acids.

Synbiotic foods, which combine probiotics and prebiotics, have gained increasing attention due to their synergistic effects. Studies suggest that prebiotics enhance probiotic survival during storage and gastrointestinal transit, thereby improving colonisation efficiency in the gut. Synbiotic formulations have been associated with improved digestive health, reduced inflammation, and enhanced immune responses. Literature emphasises that plant-based fermented foods naturally function as synbiotic systems, providing both live microbes and fermentable substrates. (Marco et al. 2017)

Non-Dairy Probiotic Beverages

While dairy products remain the most common probiotic carriers, non-dairy probiotic beverages have emerged as effective alternatives due to changing dietary preferences and health considerations. Lactose intolerance, milk protein allergies, and increased adoption of plant-based diets have driven research toward non-dairy probiotic matrices. Fruits and vegetables provide suitable substrates for probiotic growth because of their sugar content, micronutrients, and bioactive compounds.

Studies have shown that non-dairy probiotic beverages support comparable probiotic viability to dairy-based products when fermentation conditions are optimised. It was also noted that plant-based beverages are cholesterol-free and often rich in antioxidants and dietary fibre. Research indicates that the food matrix plays a crucial role in protecting probiotics from environmental stress, highlighting the suitability of fruit and vegetable substrates for probiotic delivery. (Marco et al. 2017)

Fermented Fruit and Vegetable Beverages

Fermented fruit and vegetable beverages have been extensively studied for their functional and nutritional properties. Fermentation enhances the bioavailability of phenolic compounds, increases antioxidant capacity, and improves sensory attributes such as flavour and aroma. Literature reports that lactic acid fermentation lowers pH, improves microbial safety, and extends the shelf life of beverages.

Several studies have demonstrated that fermented vegetable and fruit drinks exhibit high probiotic viability during refrigerated storage. These beverages contribute beneficial metabolites such as organic acids and short-chain fatty acids, which support gut health by maintaining intestinal pH and inhibiting pathogenic bacteria. Sensory evaluation studies indicate that fermentation improves overall acceptability, particularly when traditional ingredients and spices are incorporated. (Tamang et al. 2016)

Traditional Fermented Foods and Indigenous Knowledge

Traditional fermented foods represent an important component of indigenous dietary systems and have been consumed for centuries for their digestive and therapeutic benefits. Indigenous fermentation practices rely on naturally occurring microorganisms and locally available ingredients, resulting in diverse microbial populations. Recent scientific investigations have validated the functional properties of traditional fermented foods, linking them to improved gut health and immune function.

In the Indian context, traditional fermented preparations such as Upilitathu are particularly significant. Upilitathu is prepared using seasonal fruits and vegetables, onions, spices, and acidic agents such as vinegar. Literature suggests that onions act as natural prebiotic sources, while spices contribute antimicrobial and antioxidant properties. These ingredients collectively support probiotic fermentation and enhance gut microbiota modulation. The integration of indigenous knowledge with scientific validation offers a sustainable approach to functional food development. (Tamang et al. 2016)

Research Gap Identified

Many studies have been conducted on probiotics and fermented foods, the majority of studies focus on dairy-based products. Limited scientific literature is available on traditional non-dairy fermented fruit and vegetable beverages prepared using indigenous methods. There is also a lack of studies evaluating the sensory acceptability, short-term shelf-life, and probiotic potential of traditional formulations such as Upilitathu. Also, standardised preparation methods and controlled fermentation studies on such beverages remain insufficient. Hence, the present study aims to address these gaps by developing and evaluating a probiotic-rich fermented fruit and vegetable beverage based on the traditional Upilitathu formulation. (Marco et al. (2017))

Methodology

Study Design

In the present work followed an experimental product development and evaluation aimed at formulating probiotic rich fermented functional beverage using fruits and vegetables by using traditional Upilitathu method. In the present work involved formulation, fermentation, sensory evaluation and storage analysis. The overall study emphasises on gut health, acceptability and storage.

Selection of Raw Materials

Fresh and seasonally available fruits and vegetables were procured from markets, ensuring good quality. The selection of fruits and vegetables includes criteria like freshness, maturity, absence of cuts or any other physical damage and also free from microbial spoilages. Plant based product like green chilli has been chosen. Vinegar was also included. Spices were also included for the flavour enhancement and bioactive properties.

Table 1 List of Ingredients

Ingredients	Quantity
Amla/Pineapple/Carrot/Raw mango	75g
Green chilli	20g
Salt	25g
Water	250ml
Vinegar	5ml

Pre-Processing of Ingredients

Raw materials were thoroughly washed with water to remove the contaminants and dirt on the surface. The fruits and vegetables were peeled off and chopped into even size pieces. Green chillies were slit into half. The ingredients were also air-dried using the cloth blotting method to remove the excess moisture on the surface. Proper hygiene conditions were maintained throughout the pre-processing to minimise the contamination.

Formulation of Fermented Functional Beverage

- Chopped fruits, vegetables, green chillies, salt and vinegar were added in the sterilised glass container.
- Warm water was added to the container to achieve the beverage consistency.
- The ingredients were mixed properly to ensure the even distribution of the substrates and bioactive components.
- The fermentation was allowed to occur naturally without any addition of an external starter.
- Total fermentation time takes about 24–72 hours (1–3 days) under ambient conditions.

Fermentation Process

The formulated mixture was covered loosely and allowed to ferment in room temperature for predetermined duration (24–72 hours). During the fermentation process, the container was left undisturbed to promote lactic acid bacterial growth. Initiation of the fermentation was observed by changes such as mild acidic aroma, gas bubble formation, and gradual reduction in pH. Fermentable sugars present in the fruits and vegetables acts as natural substrate that supports the lactic acid bacterial growth. Stabilisation of pH, absence of further gas production indicates the completion of the fermentation process. Refrigerated storage will help to arrest further fermentation. Visual changes and flavour development are the indicators for active fermentation. The probiotic enrichment and microbial safety are contributed by the acidic environment due to fermentation.

Packing and Storage

After the completion of the fermentation, the beverage was filtered and transferred to an airtight glass container. To maintain the microbial stability the product was stored in refrigerator. And it also involves maintaining the sensory quality. Storage was limited to a week and evaluated for short-term shelf-life suitability in household and small-scale applications.

Sensory Evaluation

Sensory evaluation was conducted using a 9-point hedonic scale to assess the appearance, flavour, texture, and overall acceptability. A semi-trained panel evaluated the product. Individual scores were recorded, and the values were calculated to determine the consumer preferences and acceptability of the fermented beverage.

Shelf-Life and Quality Assessment

Periodic observations of the beverage were made during the refrigeration for changes in the sensory quality, colour, odour, texture, and spoilage. The indicators of product quality include sensory stability and pH changes. The shelf stability is indicated by the absence of off flavours, microbial spoilage and excessive gas formation.

Assessment of Functional and Therapeutic Potential

The assessment of the functional fermented beverage was based on ingredient composition, outcome of the fermentation, and the documented health benefits of the product. The overall importance was placed on the benefits of the gut health that includes improved digestion, increase in beneficial gut microbes, enhanced bowel regularity and lowers gastrointestinal discomfort.

Ethical Interventions

The study involved no clinical interventions. And the sensory panel was voluntary and consented and consent was obtained before the evaluation.

Result and Discussion

The fermented fruit and vegetable beverages developed in this present study was evaluated primarily for sensory attributes and short-term storage stability, as these parameters are essential for consumer acceptance and practical applicability of functional foods. The results obtained are discussed in relation to the traditional fermentation practices and existing literature on probiotic-rich beverages.

A. Sensory Evaluation

Sensory evaluation revealed that the fermented beverage was well accepted by the panel members across all evaluated attributes, including appearance, aroma, texture, taste, and overall acceptability. Among these parameters, taste and overall acceptability recorded comparatively higher mean scores, indicating favourable consumer perception of the product.

The pleasant taste profile can be attributed to the balanced combination of fruits and vegetables, mild acidity developed during fermentation, and the use of natural spices (green chillies). Fermentation is known to reduce raw vegetable flavour while enhancing the development of organic acids and flavour-active compounds, which likely contributed to improved palatability. The acceptable consistency of the beverage suggests that fermentation did not negatively affect mouthfeel, which is often a concern in vegetable-based functional drinks. Appearance and aroma were also rated positively, reflecting the stability of colour and the absence of undesirable fermented odours. This indicates that the fermentation process was well controlled and did not lead to spoilage-related sensory defects. Taken together, the sensory results suggest that the traditional fermentation approach adopted in this study is suitable for developing a consumer-acceptable functional beverage.

B. Overall Acceptability

The highly acceptability score observed in the present study highlights the feasibility of incorporating probiotic and prebiotic components into a beverage format without compromising sensory quality. Consumer compliance is a major challenge in functional food utilisation, and products with poor sensory appeal often fail despite their health benefits. The result of this study demonstrate that functional efficacy and sensory acceptance can coexist when traditional knowledge is combined with standardised preparation methods. These findings are consistent with previous studies on fermented fruit and vegetable beverages, which report improved acceptability due to the development of mild acidity and flavour complexity during fermentation.

Table 2 Sensory Evaluation Scores of Fermented Functional Beverages Prepared with Different Ingredients and Levels Using a 9-Point Hedonic Scale

Ingredient	Quantity (g)	Appearance	Colour	Aroma	Taste	Texture/ Mouth feel	Overall Acceptability
Carrot	25 g	7.2	7.0	6.8	6.9	7.1	7.0
	50 g	8.0	8.1	7.8	7.9	8.0	8.0
	75 g	6.8	6.7	6.5	6.4	6.6	6.5
Amla	25 g	6.5	6.6	6.2	6.0	6.3	6.2
	50 g	7.4	7.5	7.2	7.1	7.3	7.3
	75 g	5.8	5.9	5.6	5.4	5.7	5.6
Pineapple	25 g	7.8	7.9	7.6	7.7	7.8	7.7
	50 g	8.6	8.7	8.5	8.6	8.5	8.6
	75 g	7.0	7.1	6.9	6.8	7.0	6.9
Raw Mango	25 g	7.0	7.2	6.9	6.8	7.0	6.9
	50 g	8.2	8.3	8.0	8.1	8.2	8.1
	75 g	6.2	6.3	6.0	5.9	6.1	6.0

The sensory evaluation of the fermented functional beverage formulated with different ingredients and concentrations revealed that ingredient type and level significantly influenced overall acceptability. Among the three variations tested (25 g, 50 g, and 75 g), the 50 g concentration consistently received higher sensory scores across all attributes, including appearance, aroma, taste, texture, and overall acceptability. This indicates that moderate incorporation of ingredients resulted in a balanced flavour profile and improved palatability.

Among the ingredients evaluated, the pineapple-based fermented beverage at the 50 g level exhibited the highest overall acceptability score, suggesting superior sensory appeal due to its natural sweetness and favourable acid balance developed during fermentation. Carrot and raw mango formulations at the 50 g level also showed good acceptability, at the same time amla-based beverages demonstrated comparatively lower scores, particularly at higher concentrations, possibly due to increased acidity and astringency. The 25 g variations, although acceptable, showed comparatively lower scores due to mild flavour intensity, whereas the 75 g variations exhibited reduced acceptability, likely resulting from overpowering sourness and strong fermented notes. These findings highlight the excessive ingredient concentration negatively impacts sensory quality. Taken together, the sensory evaluation confirmed that ingredient optimisation is essential for consumer acceptability of fermented functional beverages. The results support the selection of 50 g as the optimal ingredient concentration for formulation, with pineapple emerging as the most preferred ingredient.

C. Shelf-Life Stability under Refrigerated Storage

The shelf-life evaluation conducted under refrigerated conditions indicates that the fermented beverage remained organoleptically acceptable for up to one week. No significant deterioration in sensory attributes such as taste, aroma, or appearance was observed during the storage period. The short-term stability observed to the acidic environment created by fermentation, which inhibits the growth of spoilage microorganisms. Refrigerated storage condition further contributes to maintain product quality by slowing down microbial and enzymatic activity. Although the shelf life was limited to one week, this duration is considered appropriate for fresh, preservative-free functional beverages intended for household consumption or small-scale production. The restrict storage evaluation to one week was intentional, as the product was developed without chemical preservatives. This approach aligns with the growing consumer preference for minimally processed and naturally preserved foods.

D. Nutritional and Functional Implications

From a functional perspective, the fermented beverage contains a combination of naturally occurring probiotics and plant-based prebiotics derived from fruits, vegetables, onion, and vinegar. This symbiotic combination is expected to support gut microbial balance by promoting the growth of beneficial bacteria in the gastro-intestinal tract. Although microbial enumeration was not performed in the present study, the use of traditional fermentation methods and fermentable substrates suggests potential probiotic activity. The presence of dietary fibre and bioactive compounds may further enhance gut health by improving bowel regularity and supporting microbial diversity. The results emphasise that even simple, traditionally fermented foods can be repositioned as functional foods when developed using a scientific framework. Such approaches are particularly relevant in the context of sustainable nutrition and preventive healthcare.

E. Comparison with Existing Studies

The findings of this study are in agreement with earlier research on fermented functional beverages, which report high sensory acceptability and short-term stability when stored under refrigerated conditions. However, unlike many commercial probiotic drinks that rely on added starter cultures, the present study emphasises natural fermentation using locally available seasonal ingredients, making it more accessible and culturally appropriate. This distinction highlights the relevance of indigenous food systems in addressing modern health concerns, particularly in regions where access to commercial functional foods may be limited.

F. Limitations and Scope for Further Research

While the sensory and stability results are promising, the study has certain limitations, microbiological analysis and nutritional profiling were not included and should be addressed in future research. Further studies focusing on probiotic count, identification of microbial strains, and extended shelf-life evaluation would strengthen the functional claims and support commercialisation.

Conclusion

The current experimental work demonstrates the feasibility of developing a traditional fermented fruit and vegetable-based functional beverage enriched with probiotics and prebiotics using simple, natural ingredients. The formulation of the Upilitathu beverage through controlled natural fermentation reflects the effective integration of indigenous food practices with modern functional food concepts. The high sensory acceptability observed for taste, aroma, and overall quality indicates that such fermented beverages can be successfully incorporated into regular dietary patterns without compromising consumer preference. The maintenance of acceptable sensory characteristics under refrigerated storage for up to one week further supports the suitability of the product for short-term household consumption and small-scale applications.

From a nutritional perspective, the combined presence of fermentable dietary fibres, bioactive compounds, and naturally developed probiotic microorganisms suggests a positive role in supporting gut microbial balance, digestive efficiency, and general gastrointestinal well-being. The observations indicate the importance of diet-based strategies in gut health management and reinforce the relevance of traditional fermentation techniques in the development of culturally appropriate functional foods.

Taken together, this study emphasises that traditional fermented beverages can be scientifically standardised and evaluated to serve as practical tools for preventive nutrition. Further investigations involving microbial characterisation, nutritional profiling, and extended storage studies may enhance the scope for commercialisation and broader public health application.

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