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NON-DAIRY YOGHURT ENRICHED WITH FUNCTIONAL PLANT-BASED INGREDIENTS - A REVIEW

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Abstract

The paradigm surrounding milk has shifted as consumer preferences evolve due to lactose intolerance awareness and the prevalence of cow's milk allergies. Consequently, plant-based milk substitutes have gained popularity. This study offers a comprehensive examination of the physicochemical, rheological and sensory attributes of various functional plant-based yoghurts, coconut yoghurt with tapioca, fruits and soy yoghurt with red fruits, mango, lemon grass, etc. The study reveals the potential of these products to fulfil consumer demands for both sensory satisfaction and nutritional benefits. Furthermore, it identifies avenues for further refinement and innovation in product development and formulation, thereby providing valuable insights for both industry stakeholders and consumers seeking viable dairy alternatives. This study underscores the growing importance of plant-based options in meeting diverse dietary needs and preferences in today's evolving food scene. Moreover, it emphasizes the necessity of transitioning to a more plant-based diet to address climate change, reduce environmental impacts, and improve health.

***Key words**: functional, non-dairy yoghurt, plant-based.*

INTRODUCTION

Yoghurt is widely acknowledged as a delicious and nutritious food, rich in essential vitamins and minerals. For individuals prioritizing sustainability in their diets, those with lactose intolerance, or those opting for non-dairy alternatives like vegans, lactose-free plant-based yoghurt becomes a preferred choice.

Typically, these individuals, as well as those eager to explore new food options, find the most satisfaction when the plant-based yoghurt alternative closely resembles the appearance and texture of traditional dairy yoghurt.

The increasing demand for non-dairy yoghurts, along with the growing interest in plant-based milk and meat alternatives, has spurred the development of a plant-based food industry valued at USD 5 billion, reshaping the culinary landscape in America.

Over the past 15 years, there has been a remarkable 300% surge in the number of Americans embracing plant-based diets (International, 2024).

The surge in interest for alternative foods is on the rise, spurred by the imperative to sustainably nourish the expanding global population. Companies and consumers alike are increasingly focused on sourcing foods that are both eco-friendly and nutritious. While plant-based dairy substitutes have been consumed for generations in various cultures, there's a renewed curiosity driving their market expansion. Time-honoured options like Spanish Horchata and Asian soya milk stand alongside modern favourites such as soy, almond, and rice-based milk substitutes (Mäkinen et al., 2016).

In recent years, scientific research has emphasized the significant positive impact of shifting towards plant-based diets on ecosystems. This dietary change can reduce environmental impact, preserve biodiversity, and mitigate climate change (Westhoek et al., 2014).

Several studies analysing the health effects of plant-based diets indicate the potential for significant benefits (Zhong et al., 2021). Dairy is facing significant competition from these plant-based alternatives, particularly in Western countries, where the demand for such products is escalating (International, 2020). The development of non-dairy yoghurt holds significant importance in meeting the nutritional needs of both elderly individuals and those seeking energy-dense, protein-enriched food options, addressing a gap in the market. Over recent years, soybean, oat, and coconut have gained recognition as functional foods due to their protein, dietary fibre, mineral, antioxidant, vitamin, and energy content (Inglett et al., 2003). Soybean and oats particularly serve as cost-effective protein sources, catering to vegetarians, vegans, and individuals with limited access to meat and dairy (Oyeniyi et al., 2014). Non-dairy yoghurt, containing unsaturated fatty acids, aids in reducing the risk of cardiovascular diseases and proves beneficial for lactose intolerant individuals. Furthermore, non-dairy yoghurts boast high levels of nutrients and minerals, acting as symbiotic foods crucial for gut health and immunity enhancement (Osundahunsi et al., 2007). Soy milk, oat milk, and coconut milk serve as viable substitutes for animal milk in dairy product manufacturing. Fermentation of milk has been reported to diminish antinutritional factors and enhance mineral bioavailability (Adeyemo et al., 2013). Yoghurt, whether dairy or non-dairy, serves as a carrier for probiotics, rich in protein, magnesium, potassium, fat, and vitamins (Lourens-Hattingh et al., 2001). Non-dairy yoghurts typically utilize low-fat milk, coagulating to a custard-like consistency, and contain cultures like *Lactobacillus bulgaricus* and *Streptococcus thermophilus* (Potter et al., 2012). Soy yoghurt fermentation primarily involves friendly bacteria, notably *L. bulgaricus* and *S. thermophilus*, utilizing sugars such as stachyose and raffinose instead of lactose. Soy protein offers nutrients equivalent to those found in meat and eggs, essential for human health (Oyeniyi et al., 2014). Extensive research has been conducted on probiotics due to their potential health benefits. According to definitions provided by the Food and Agriculture Organization and the World Health Organization, probiotics are live microorganisms that, when consumed in adequate amounts, enhance the health of the individual (Hill et al., 2014).

For probiotics to be effective, they must possess certain essential characteristics. These include robust stability during storage and distribution, non-pathogenic and non-toxic properties, sustainability within the host's body, ability to adhere effectively, resistance to low pH and bile salts in the gastrointestinal tract, and positive activity that promotes beneficial effects on the host, such as enhanced immunity (Shori et al., 2021).

To ensure the health benefits of fermented plant-based milk products, it's essential for probiotics to meet the minimum level requirement of probiotic bacteria ranging between 10^6 and 10^7 colony-forming units (CFU) per millilitre until the expiration date (Shori et al., 2018).

MATERIALS AND METHODS

For this review, we conducted a comprehensive literature search across multiple databases including Web of Science, PubMed, Google Scholar, and ScienceDirect, using the key words "yoghurt", "functional food", "non-dairy food", and "plant-based foods" within the timeframe of 2011 to January 2024. After removing duplicates, we focused exclusively on studies pertaining to non-dairy food products. Following this initial screening, articles meeting the inclusion criteria were selected based on their titles and abstracts, with a broad interpretation applied.

The inclusion criteria for article selection were as follows:

- Peer-reviewed articles and reviews published in English;
- Studies specifically addressing non-dairy functional fermented products (e.g., soy yoghurt with lemon grass);
- Research providing empirical data on the functional properties, as well as other important physicochemical and microbiological properties, of plant-based yoghurt;
- Articles discussing the significance of non-dairy products.

Exclusion criteria were applied to eliminate studies that:

- Did not directly pertain to non-dairy products;
- Lacked empirical data or failed to provide sufficient detail on methodology and results;

- Were published in languages other than English without an available English translation.

Selected articles underwent a thorough evaluation, with relevant information such as publication year, authors, study objectives, methodology, key findings, and conclusions extracted. This data enabled a comprehensive analysis of non-dairy plant-based functional yoghurts from various perspectives, including shelf life, nutritional quality, antioxidant activity, and sensory attribute. Special attention was given to studies showcasing innovative uses of functional ingredients in plant-based yoghurt production, along with those offering insights into future research and commercial potential.

The data gathered was carefully synthesized to highlight emerging trends, areas of agreement, and discrepancies within the literature we reviewed. Our rigorous methodology demonstrates our commitment to thoroughly examining and interpreting current research on non-dairy plant-based functional yoghurt,

RESULTS AND DISCUSSIONS

1. Technology of plant-based yoghurt

Currently, plant-based yoghurt products utilize the conventional yoghurt production method, which involves fermenting plant-based milks (Kizer et al., 2023). To prepare a cow milk yoghurt alternative, the milk samples were pasteurized at an optimum temperature of 72°C for 20 min by a double boiling method to avoid gelatinization. This method uses the steam from the simmering water to warm the milk in the bowl gently, with indirect heat. Then, the milk was cooled to 45°C. The starter cultures (*L. bulgaricus* and *S. thermophilus*) were added as 0.4% of the milk mixture weight. After inoculation, 10% of sucrose was added to the milk mixture to optimize the growth of lactic acid bacteria. To strengthen the gel network of the yoghurt, corn starch was added (5%) at above 60°C, xanthan gum (0.15%) at above 70°C under continuous stirring, and pectin (0.75%) at above 25°C.

The milk was incubated at 41°C for 18 h to maintain the humidity and temperature in favourable conditions for the growth of microorganisms. The formed yoghurt was cooled to a room temperature of 27°C and stored in a refrigerator at 4°C for 1 h (Paul, 2020).

2. Plant-based raw material alternatives

Due to its important nutritional characteristics, such as calcium, high-quality proteins and an adequate level of isoflavones, which prevent bone degradation and have anticancer effects, the inclusion of plant based milk alternatives and its by-products in the diet is raising substantial interest (Pachekrepapol, 2021; Rahmatuzzaman, 2021).

The preparation of yoghurt consists of the lactic acid fermentation of milk by the action of starter bacteria (Salehi et al., 2021). Unfortunately, plant based yoghurt alternatives present texture and stability limitations compared to dairy yoghurts. The various textures of commercial plant based yoghurt alternatives could be caused by their reduced protein concentrations, and because these proteins do not coagulate as well as casein, gelling agents need to be added (Pachekrepapol et al., 2021). On the other hand, novel ingredients such as peas, lupins, oats, quinoa, and different type of fruits (strawberries, raspberry, blueberries) are also being assessed to improve the physicochemical characteristics of vegan yoghurt alternatives and the overall impression of consumers. For example, the physicochemical and sensory characteristics of soy yoghurt alternatives with lactic acid cultures (10^6 CFU/mL) containing 0.3% gelatine, strawberry were improved compared to the control sample (Salehi et al., 2021).

The adoption of plant-based milk, such as those derived from almonds, soy, and corn, as primary ingredients in yoghurt production has garnered significant interest in recent years. The food industry has responded by developing plant-based milk beverages to meet this demand. Almond milk, in particular, has gained popularity due to its protein content and water intake being comparable to that of bovine milk. Soy milk is another widely used plant-based milk, finding its way into various non-dairy products such as soy cheese, tofu, and soy yoghurt (Mäkinen et al., 2016). Almond milk stands out as a nutritious option due to its rich content of various essential nutrients. It contains significant amounts of vitamin E

(25.87 mg/100 g α-tocopherol), B-complex vitamins, proteins (16-23 g/100 g), monounsaturated fats (31-35 g/100 g) primarily consisting of oleic acid, dietary fibres (11-14 g/100 g), total phenolic compounds (260-350 mg/100 g), and various minerals. Despite almonds being relatively more expensive, almond milk has found its place among other plant-based milk substitutes in the market (Mäkinen et al., 2016).

On the other hand, coconut, known for its nutritional value, yields coconut milk which presents the highest fat content and the lowest protein content among non-dairy milk options. Notably, approximately 87% of the fat content in coconut milk is saturated, with lauric acid being the predominant component (44%), followed by caprylic and capric acids (13%). However, this high saturated fat content may potentially elevate harmful cholesterol levels (LDL) (Paul et al., 2020).

Cashew milk is rich in beneficial fats like monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). With its oil content comprising 48%, it provides a significant source of these healthy fats. Oleic acid, a key monounsaturated fat, constitutes approximately 73.73% of the fat content. Additionally, cashew milk contains about 4.7% ash content, 19.8% protein, and 1.2% fibre, contributing to its status as a low-calorie beverage option. The ample presence of MUFAs and PUFAs, along with its relatively low calorie count, positions cashew milk as a nutritious alternative to traditional dairy milk and other plant-based milk varieties (Tamuno et al., 2019). Groundnut, commonly known as peanut, is an economical source of nutrients and is often utilized in the production of nut milk, which is considered akin to a complete food similar to cow's milk. Groundnut milk provides a substantial amount of carbohydrates, ranging from 49% to 63.5%, as well as protein content ranging from 4.5% to 7.4%. Additionally, it offers dietary fibre in the range of 3.2% to 4.4%, and notably contains negligible cholesterol content at 0.01%, in contrast to cow milk. Given its nutritional composition and affordability, groundnut milk serves as a viable and widely accepted alternative for the production of nut milk-based food items (Murevanhema et al., 2013).

Oats have been a staple food for centuries, valued for their nutritional content, particularly their high fibre content. Oat milk, derived from oats, is notable for its elevated levels of protein, carbohydrates, and dietary fibres compared to other plant-based milk alternatives. Research indicates that beta-glucan, a type of fibre found in oat milk, possesses cholesterol-lowering properties, making it beneficial for heart health (Ho et al., 2016).

Quinoa, characterized by its small round yellow seeds, is abundant in protein, starch, fibres, and essential fatty acids. This versatile grain has found applications not only in traditional dishes but also in the production of fermented alcoholic beverages. Additionally, quinoa remains relatively unexplored as a grain for the creation of plant-based foods, presenting opportunities for further culinary innovation and exploration (Srujana et al., 2019).

In the realm of plant-based yogurt production, the utilization of rennet derived from plant sources mirrors an emerging trend within the dairy industry. Innovatively, an array of fresh cheeses can now be obtained through coagulation with lettuce, echoing the trend in the dairy industry towards utilizing plant-based methods. This approach not only caters to the preferences of vegetarians but also offers nutritional benefits, as it allows for the incorporation of bioactive compounds from plant sources into the cheese-making process, similar to advancements seen in plant-based yogurt production (Nitu et al., 2022).

Therefore, among the most commonly encountered are coconut and soy yogurt, with various additives, described in the following section.

3. Functional coconut yoghurt

Coconut (*Cocos nucifera*) holds significant economic importance, particularly in Southeast Asian nations (Sethi et al., 2016). In recent times, considerable focus has been directed towards coconut milk as a viable alternative to dairy milk. With fat content ranging from 31% to 35% and protein content between 3.5% and 4.0%, coconut milk is recognized for its richness in essential amino acids, as well as its abundance in vital nutrients such as calcium, phosphorus, potassium, vitamin C, E, and B6, making it easily digestible (Góral et al., 2018). Coconut milk naturally forms an oil-in-water emulsion. This emulsion is stabilized by coconut proteins (globulin and albumin) and phosphor-lipids, which act as emulsifiers. These components adhere to the surface of coconut oil droplets, preventing phase separation (Lu et al., 2018).

Unlike allergies to tree nuts, coconut allergies are uncommon and are not directly associated with nut allergies (Anagnostou et al., 2017).

There are limited studies focusing on fermented coconut milk products. Many of these studies have included other protein sources, such as chickpea (Mesquita et al., 2020), which can raise the risk of allergenicity including additives which may not be in line with the rising demand for clean label products (Montemurro et al., 2021).

3.1. Coconut yoghurt with tapioca

Replacing cow milk with coconut milk in the production of yoghurt with both high consumer acceptance and optimal characteristics poses a significant and somewhat challenging issue. Often, stabilizers or thickeners are added to attain the desired texture and minimize the syneresis (Pachekrepapol et al., 2021).

The objective of the study conducted by Pachekrepapol (2021) is to create a yoghurt-like product using coconut milk while minimizing the use of additives. Initial investigations revealed that incorporating *tapioca starch* resulted in a smoother texture with reduced syneresis compared to other tested stabilizers such as pectin, xanthan gum, and corn starch. The study involved formulating samples with tapioca starch at concentrations of 0.5%, 1.0%, 1.5%, and 2.0% (w/w). These products were then assessed for pH variations and viability of lactic. The results are presented in Table 1.

3.2. Pineapple coconut yoghurt

In addition to its function as an aroma enhancer, pineapple can enhance the rheological properties of food items, particularly in terms of texture, mouthfeel, and colour. Moreover, pineapple serves as an additional source of dietary fibre, attributed to its high pectin content (García-Cano et al., 2019). The utilization of fortified pineapple puree (*Ananas comosus* (L.) Merr) in this study was chosen not only due to the widespread cultivation of pineapple but also because of its health-promoting properties. Pineapple is rich in beneficial compounds such as antioxidants, bromelain enzymes, phenolic compounds, and organic acids, as highlighted in studies by (Barzegar et al., 2023). The novelty of Parhusip's (2024) study lies in utilizing plant-based ingredients like coconut milk as the primary material for yoghurt production, aimed at decreasing reliance on animal-based food ingredients. Addressing the drawbacks of coconut milk, particularly its susceptibility to lipid oxidation, is achieved through the incorporation of pineapple puree, which serves as an inhibitor. The objective of Parhusip‘s study (2024) is to identify the optimal fermentation duration for coconut milk yoghurt, focusing on both physicochemical parameters (including pH, acidity, water holding capacity, viscosity, and fat content) and microbiological parameters (such as total plate count and total lactic acid bacteria). The rise in soluble solids, attributed to the addition of pineapple puree, enhances the water holding capacity and viscosity of yoghurt. The pectin content present in pineapple serves as a filler material in coconut milk yoghurt. Coconut milk yoghurt fortified with pineapple contains predominantly lauric acid, offering potential health benefits. Thus, employing coconut milk with pineapple fortification as plant-based ingredients for yoghurt presents promising prospects as a functional food alternative (Parhusip et al., 2024). Other results are presented in Table 1.

3.3. Strawberry coconut yoghurt

Enhancing the nutritional profile of plant-based milks involves incorporating beneficial micro-organisms that support the human microbiota, alongside fruit pulps to enhance nutrient content and flavour (Bedani et al., 2014).

The study of Mauro et al. (2022) aimed to create and analyse two coconut milk products fermented by *Lactobacillus reuteri* LR 92, with and without strawberry pulp. Additionally, it sought to determine the optimal concentration of guar and xanthan gum for product stability, assess the fatty acid profile, evaluate microorganism survival post-gastrointestinal simulation, and conduct sensory acceptance tests for the products. During sensory analysis, the overall acceptance scores for coconut milk products were notably high, averaging above 7.5 on a 9-point scale. Lauric acid emerged as the predominant fatty acid in the products. These findings indicate that fermented coconut milk products are well-received and can serve as effective carriers for *L. reuteri*, offering consumers functional fermented non-dairy options (Mauro, 2022). More results are included in Table 1.

Table 1. Coconut yoghurt with functional ingredients

Functional ingredient	Concentration of the functional ingredient	Proprieties	References
Tapioca	0.5%, 1.0%, 1.5%, 2.0% (w/w)	The pH levels of all samples decreased during 14-day storage period at 4 ◦C The syneresis level of all samples decreased with storage time The decrease in viscosity during shearing indicated shear-thinning behaviour of the samples. Yoghurt-like products made from coconut milk with 1.0, 1.5 and 2.0% tapioca starch received significantly higher scores for overall acceptability and flavour ($p < 0.05$)	(Pachekrepapol et al., 2021)
Pineapple puree	0%, 4%, 8%, 12%	pH : • Coconut milk unfortified 6.11±0.03 • Pineapple puree 3.90±0.01 • Pineapple puree fortification (4%) 5.89±0.04 • Pineapple puree fortification (8%) 5.66±0.03 • Pineapple puree fortification (12%) 5.49±0.06 Fat content 10.57-15.12±0.06 % Viscosity 2547- 3360±55.84 cP Total plate count 7.11-7.48±0.34 log cfu/g	(Parhusip et al., 2024)
Strawberry pulp	20% (w/v)	Moisture: 84.27b (± 0.04) % Proteins: 0.32a (± 0.01)% pH: 4.02c (± 0.03)% Ashes: 0.11a (± 0.05)% Lauric acid, C12:0 (SFA, MCFA): 41.78A ± 1.13 The fermented coconut products presented a satisfactory number of viable cells after gastrointestinal simulation.	(Mauro et al., 2022)

4. Functional soy yoghurt

Soybean milk serves as an alternative for those unable to consume cow's milk due to lactose intolerance or milk protein allergies. Derived from the *Glycine max* (L.) Merrill plant, soybean is rich in protein, making it a cost-effective protein source (Myagmardorj et al., 2018).

Among the ingredients used in the preparation of non-dairy functional yogurts, are vegetables such as mung beans, fruits in the form of powder or pulp, and aromatic plants in the form of essential oils.

4.1. Soy yoghurt enriched with legumes

Soy yoghurt enriched with mungbeans

Mungbeans, scientifically known as *Vigna radiata* (L.) R. Wilczek, boast abundant vitamins and minerals. Furthermore, they exhibit a higher carbohydrate content (approximately 62.3%) and lower fat content (approximately 1.9%) compared to soybeans. Soybeans, in contrast, contain around 33.9% carbohydrates and approximately 21% fat (Dahiya et al., 2015). Mungbean demonstrates a notably higher total phenolic content and antioxidant activity compared to soybean. Additionally, mungbean exhibits greater tyrosinase inhibition than other legume crops, potentially contributing to the prevention of type II diabetes (Yao et al., 2011). The elevated carbohydrate content in mungbean milk could lead to a reduction in pH following fermentation (An et al., 2024). This study conducted by An suggests that fermented mungbean milk holds promise as a food ingredient for creating milk substitutes when combined with soy milk. This combination has the potential to enhance the nutritional balance of dairy products. Additionally, it explores the feasibility of utilizing mungbean milk as a substrate for lactic acid bacteria (LAB) fermentation.

4.2. Soy yoghurt enriched with fruits

Soy yoghurt enriched with red dragon fruit

Among the fruits used to enhance non-dairy yogurts are dragon fruit, red fruit extract, mango pulp, and lemon juice. Soy milk, known for its rich content of high-quality plant protein, has been explored as a base for producing probiotic-enriched yoghurt, promoting digestive health (De et al., 2022). Thus, the replacement of red dragon fruit, renowned for its abundance of antioxidants and natural pigments, was aimed at enhancing both the antioxidant properties and aroma of soy yoghurt. The research of Marjan et al. (2023) delved into assessing the antioxidant activity and lactic acid bacteria levels in soy yoghurt infused with red dragon fruit. This analysis encompassed sensory assessment, proximate analysis, determination of antioxidant activity, and estimation of total Lactic Acid Bacteria (LAB). Among the various formulations tested, Formula 3, featuring a 35% substitution of red dragon fruit, emerged as the optimal choice. Proximate analysis revealed a water content of 92.75%, ash content of 0.23%, protein content of 0.48%, fat content of 3.08%, and carbohydrate content of 3.46% (Marjan et al., 2023).

Soy-based yoghurt enriched with red fruit extract

Red fruit extract (*Pandanus conoideus* Lam.) has been found to contain significant amounts of β-carotene and α-carotene, with levels of 130 µg and 1,980 µg per 100 g of sample, respectively. Additionally, it exhibits a high antioxidant content, particularly in terms of α-tocopherol, with a concentration of 21.20 mg per 100 g of sample (Surono et al., 2008). Given the notably high antioxidant content found in red fruit, which is recognized for its potential to combat free radicals, there's a compelling need to innovate processed food items by incorporating red fruit paste ingredients. This strategic utilization aims to yield food products of superior quality, not only in terms of their functional efficacy but also their sensory attributes (Tang'nga et al., 2019). The objective of Tang'nga's research is to develop functional food products, specifically focusing on the predominance of soy milk yoghurt combined with red fruit paste. This innovative combination aims to offer an alternative to animal milk consumption while simultaneously providing antioxidant activity. Results about the pH, ash content, moisture and other are presented in Table 2.

Soy yoghurt with mango pulp

Incorporating protein-enriched yoghurt with fortified fruits presents an advantageous strategy to mitigate the characteristic beany taste associated with soy milk while maximizing nutritional benefits. The addition of flavourings and their respective quantities typically adhere to regulatory standards specific to each country (Jayalalitha et al., 2015).

The study of Jayalalitha (2015) focused on creating innovative, value-enriched yoghurt using a combination of soy milk and mango pulp. Initially, different levels of soy milk (0%, 10%, 20%, and 30%) were tested for inclusion in the yoghurt. Through optimization, it was determined that incorporating up to 30% soy milk enhances the yoghurt's protein content without compromising its physicochemical properties or sensory quality. Significant alterations in the protein and total solids content were observed between the control yoghurt and the value-enriched variant. The highest recorded values for protein and solid non-fat (SNF) content were 7.12% and 14.31%, respectively, in the yoghurt formulated with 30% soy milk and 15% mango pulp. Attempts were made to include dried mango pulp during culture inoculation. However, upon physicochemical and sensory evaluation, it was noted that yoghurt containing dried mango pulp could not be stored beyond 5 days at refrigeration temperature due to increased acidity, syneresis, unfavourable flavour, and reduced overall acceptability (Jayalalitha et al., 2015). The study's additional significant findings are presented in Table 2.

Table 2. Soy yoghurt with functional ingredients

Functional ingredient	Concentration of the functional ingredient	Proprieties	References
Red dragon fruit	25%, 30%, 25%	Antioxidant activity increased, while total LAB, pH decreased with red dragon fruit substitution. Viscosity decreased with the substitution of red dragon fruit because of its high water content Protein: 0.48%; Fat: 3.08% Carbohydrate: 3.46%; Moisture: 92.75%	(Marjan, 2023)
Moringa oleifera	0.1%	pH: 4.11; Ash content: 1.2% Protein content and fibre content increased The carbohydrate content decreased Incorporating Moringa root powder implies the potential for utilizing it as a dietary supplement to enhance the micronutrient content of food, thereby serving as a means for food enrichment.	(Ponka, 2022)
Scent leaf (*Ocimum gratissimum*) essential oil	0.5%	With the introduction of microcapsules containing essential oil derived from Scent leaf there was a notable result: the flavonoid content surged from 0.11 mg/100 g to 0.35 mg/100 g, while the FRAP content increased from 20.01 mg/100 g to 27.51 mg/100 g. Moreover, the iron chelating capacity rose from 7.50% to 11.08%, and the phenolic content escalated from 3.34mgGAE/g to 5.94mgGAE/g. Additionally, the DDPH value soared from 50.90% to 56.88%. Over five days at room temperature, there was a decrease in pH from 4.75 to 4.15, an increase in acidity from 0.71% to 0.99%, and a reduction in syneresis from 26.44% to 23.03%	(Olabiran, 2023)
Lemon grass	25, 50, 75 and 100 µL/L.	Moisture content range from 89.3% to 89.6% Protein content range from 5.5-6.8% Fat content range from 2.7 to 3.6% Total ash: 0.43-0.53%; Crude fibre: 0.06-0.33% pH range from 4.30 to 5.59 Titrable acidity: 0.01-0.07 g/L; Total phenolic compound: 8.59-18.40 mg/g	(Angelique, 2024)
Red fruit (*Pandanus conoideus* Lam.)	5%	pH: 3.91; Moisture: 38,97 % Total solids: 61.02%; Ash: 0.71% The results of the antioxidant activity evaluation for the red fruit combination yoghurt formulation revealed an IC50 value of 21.32 ppm, indicating a very strong antioxidant capacity.	(Tang'nga, 2019)
Mango pulp	5%, 10%, 15%	Fat: 3.11-3.41 %; Protein: 6.58-6.83% pH: 3.67-4.01; Acidity: 1.20-1.35% Soy milk incorporation increases the percentage of protein content with level of inclusion of yoghurt and mango pulp. Addition of fruit pulp also caused an increase in lactose content.	(Jayalalitha, 2015)
Lemon juice	1:9 2:8 3:7	Protein: 4.45-5.36% Fat content decreases with the juice addition from 1.74% to 1.64% Lactose content decreases with the juice addition from 1.35% to 0.67%; In fortified yoghurt- antioxidant content: 40.04 %	(Supriyanti, 2017)

Soy yoghurt with lemon juice

In accordance with the USDA National Nutrient Database, lemon (*Citrus limon*) typically contains approximately 53 mg of vitamin C per 100 grams, accounting for approximately 88% of the recommended daily intake. In this study, soy yoghurt fortified with vitamin C derived from lemon juice was produced. Previous research has not investigated the impact of adding lemon juice to soy yoghurt fortified with vitamin C on parameters such as protein, fat, lactose content, and the level of probiotics. The objective of Supriyanti et al. (2017) study was to examine the impact of incorporating lemon juice into soy yogurt. Various ratios of lemon juice were added to soy yogurt, in four different formulations: 0:10 (L0), 1:9 (L1), 2:8 (L2), and 3:7 (L3) followed by an analysis of their nutritional composition, including protein, fat, lactose, and probiotics. The resulting fortified yoghurt products were then evaluated to determine their respective levels of protein, fat, lactose, and probiotics. The study findings indicate that fortified yoghurt exhibited higher protein content compared to its original state. Moreover, among the probiotic yoghurt variants, L1 showed superior content compared to the L2 and the L3. From these observations, it can be inferred that L3 stands out as the most favorable option, boasting elevated protein levels, lower fat and lactose content compared to L1 and L2, while also containing probiotics

(Supriyanti, 2017). Table 2 presents more conclusive findings regarding the results.

4.3. Soy yoghurt enriched with aromatic plants

Aromatic plants used for enriching plant-based yogurt include *Moringa oleifera*, lemongrass, and *Ocimum gratissimum*, utilized as root powder, leaves, essential oils, and extract.

Soy yoghurt with Moringa Oleifera root powder

Utilizing *Moringa oleifera* root powder (MRP), rich in essential minerals and macronutrients, presents an innovative approach, when combined with soymilk, to enhance the nutritional profile of commonly consumed food items like yoghurt. However, it's crucial to meticulously remove the bark of moringa roots since it contains alkaloids, which can be toxic if ingested excessively (Alli et al., 2017).

The objective of the research of Ponka (2022) was to assess the sensory and physical characteristics of soy milk yoghurt fortified with moringa root powder. Incorporating soy milk enriched with Moringa notably elevates the fat, fibre, protein, copper, manganese and iron levels in the samples (Ponka et al., 2022). Other results are described in Table 2.

Soy-based yoghurt incorporated with scent leaf (Ocimum gratissimum) essential oil microcapsules

Scent leaf (*Ocimum gratissimum*) essential oil (OGEO) have been proven to possess antioxidants, antiseptics, antibacterial and antifungal activities (Olabiran et al., 2023).

The addition of OGEO microcapsules to soy-based yoghurt enhanced both its antioxidant and physicochemical characteristics, leading to an extended shelf life for the product. (Olabiran, 2023). The soy-based yoghurt containing *Ocimum gratissimum* essential oil (OGEO) microcapsules exhibited satisfactory physicochemical properties. Microcapsules encapsulating the essential oil extracted from *Ocimum gratissimum leaves*, along with cassava starch, gum arabic as cell wall material, and emulsifier, demonstrated potent antioxidant, free radical scavenging, and antibacterial properties when incorporated into soy-based yoghurt (Olabiran et al., 2023). Other important results are present in Table 2.

Lemon grass leaves extracts enriched soy yoghurt

Soybean-based food is a challenge in their utilization due to the undesirable associated flavours. The study of Angelique et al. (2024) focused on the preparation of soybean based yoghurt with different concentrations of lemon grass extract: 0, 25, 50, 75 and 100 μL/L.

The research findings indicate that adding lemon grass extract to soy yoghurt does not alter the basic nutritional composition of the yoghurt. However, it does elevate the content of soluble crude fibre and total phenolic compounds, while also leading to a decrease in pH. Furthermore, the inclusion of lemon grass extract enhances the sensory attributes of the yoghurt, including aroma, mouthfeel, and overall acceptance. Particularly noteworthy is the significant improvement in aroma and taste resulting from the addition of lemon grass extract to soy yoghurt, suggesting that the extract could potentially mitigate flavour-related issues commonly encountered in soy-based products (Angelique et al., 2024). The results more detailed are presented in Table 2.

CONCLUSIONS

The surge in interest for non-dairy plant-based yoghurts stems from various factors, including concerns for sustainability, health consciousness and dietary preferences, such as lactose intolerance and veganism. Scientific research emphasizes the significant positive impact of plant-based diets on ecosystems, biodiversity preservation, and climate change mitigation. Furthermore, studies analysing the health effects of plant-based diets indicate potential benefits, driving consumer demand for non-dairy alternatives.

Ingredients such as soy, oats, coconut, and innovative additions like tapioca, pineapple, strawberries, and lemon grass extract enhance the texture, flavour, and nutritional profile of plant-based yoghurts. Research on the production of non-dairy yoghurts highlights the importance of stabilizers, thickeners, and fortifying ingredients to achieve desired texture, stability, and nutritional content.

Innovations such as incorporating probiotics, fruit pulps, and functional ingredients like *Moringa oleifera* root powder and scent leaf essential oil microcapsules contribute to the development of diverse and nutritious non-dairy yoghurt options. While challenges exist, such as texture limitations compared to dairy yoghurts and the need for optimal fermentation conditions, ongoing research and innovation continue to address these issues, paving the way for further advancements in the field. In conclusion, the increasing popularity of non-dairy plant-based yoghurts reflects a broader shift towards sustainable, health-conscious food choices. With continued research and innovation, non-dairy yoghurts have the potential to meet the diverse dietary needs and preferences of consumers while contributing to a more sustainable and environmentally friendly food system.
As observed, there are still relatively few studies regarding the addition of functional ingredients in the production of soy yoghurts. However, there is a trend towards expanding consumer horizons to consume non-dairy products, to try new products that have functional properties that enhance a healthy lifestyle and help prevent the increasingly common effects of intolerances, with cases increasing from year to year. Transitioning to a more plant-based diet is crucial for promoting health and sustainability.

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