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Development of a Fermented Coconut-based Dessert as a Fine Alternative to Dairy-based Yoghurts

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DEVELOPMENT OF A FERMENTED COCONUT-BASED DESSERT AS A FINE ALTERNATIVE TO DAIRY-BASED YOGHURTS

Abstract: This study aimed at developing a fermented dessert prepared entirely using coconut milk, especially for non-dairy consumers including vegans. The development was done in 2 sensory evaluation stages, selecting the best plant gum composite out of Xanthan: CMC and guar gum: CMC composites, selecting the optimum sweetening capacity for the formulation out of 10%, 15%, and 20% at a 5:1 sugar: stevia ratio. The sweetness was enhanced, using stevia with cane sugar, keeping the moderate sugar level indication unchanged. The formulation accepted from the sensory evaluation stages was taken for further analysis with/without the preservative. The physicochemical parameters including pH, total soluble solids, water holding capacity, and syneresis, were varied within the range of 5.47-4.95, 20.9-20.6%, 94.49-85.81%, and 5.46-13.68 % respectively. Concerning proximate analyses, the product reported a lower protein content (2.20 ± 0.01 %) and a significant amount of fat content (19.17 ± 0.05 %). Nonetheless, a high proportion of saturated fatty acids, particularly lauric acid, were reported from the GC-FID analysis. Coconut milk and stevia contributed to significant antioxidant potential for the product. The product showed an ideal probiotic potential on the non-dairy matrix.
Keywords: Vegan, Non-dairy, Coconut milk, Probiotic, Stevia

Introduction

In the modern world, the tendency to move towards vegan culture as well as plant-based milk alternatives is rapidly increasing among consumers (Daszkiewicz *et al*, 2023). This can be attributed to several factors including ethical concerns for animal welfare, health consciousness, environmental sustainability, and the availability of diverse plant-based options (Raikos *et al*., 2020). Another fact is that, even though milk and dairy products have been considered for a long time as a class of food with essential compounds for human nutrition, which are hardly found, people suffering from health problems related to high cholesterol intake in the diet, lactose intolerance, or malabsorption, and allergy to milk proteins, should consume alternative products (Sethi *et al*., 2016; Vanga and Raghavan, 2018) of non-dairy origin. Hence, in addition to the overall consumers' awareness about the effects of their food choices on the environment and health, the limited use of dairy products by some population sectors has led to higher demand for plant-based milk derivatives.

Yoghurt is one of the dairy products consumed worldwide because of various health benefits, including supporting the function of the digestive system which primarily links to live microorganisms (Buttriss, 1997). Although cow milk produces good-quality yoghurt, there are certain limitations for non-dairy consumers to consume. Even though lactose gets converted into lactic acid by the bacteria during the fermentation stage, some people show allergic reactions by consumption (Priya, 2016). It was also realized that strict vegetarians are also limited in their interest in probiotic yoghurts when there is the confinement only towards animal-based yoghurt (Sanful, 2009). These facts have paved the way for the world's emergence of plant-based yoghurt-like products.

Coconut (*Cocos nucifera*) is one of the major economic crops in Asian tropical countries, especially in Sri Lanka, Indonesia etc. which is increasingly being used for many types of food products worldwide nowadays. Recently, much attention has been paid to coconut milk as a plant-based milk substitute. Even though several studies have been carried out by replacing milk with other plant-based substitutes like soy (Lee *et al*., 2018), almond (Shi *et al*., 2020), oats (Demir *et al*., 2021), rice (Cáceres *et al*., 2019) etc., due to the higher cost of such non-dairy plant-based substrates and some plant sources like soy, almond being allergenic ingredients to some people, the consumption of such products have been limited. Nevertheless, coconut being a less cost substrate as well as allergy to coconut is rare and not directly linked with nut allergy, coconut milk can be effectively utilized in production of yoghurt like fermented products (Anagnostou, 2017).

Coconut milk contains 31–35% fat and 3.5–4.0% protein, is high in essential amino acids, calcium, phosphorus, potassium, vitamin C, E and B6 and easily digested (Góral *et al*., 2018). Along with the rising global trend towards plant-based milk derivatives, promoting the use of coconut in the production of yoghurt is one of the best sustainable and environmentally friendly strategies.

Hence, the study's primary purpose was to develop a vegan, and gut-friendly fermented probiotic dessert using coconut milk as a fine alternative to dairy yoghurt. Through the evaluation of organoleptic properties, physicochemical characteristics, and proximate composition as well as employing analytical techniques such as GC-FID analysis, this research provides insights to assess the range of acceptability as well as the overall nutritional profile of the developed product.

Materials and Methods

2.1 Raw materials

Fresh middle-aged (7-8 months old) coconuts (Colombo, Sri Lanka), and Sugar were obtained from a local retail store in Colombo, Sri Lanka. Stevia, the non-caloric sweetener (Sugar Free, India) was purchased from a local supermarket in Colombo, Sri Lanka. Xanthan gum, Guar gum, and Carboxy methyl cellulose were purchased from Pettah Essence Suppliers Pvt Ltd., Colombo, Sri Lanka. The non-dairy favored yoghurt starter culture, ABT-5, containing a mixture of probiotic microorganisms; *Bifidobacterium BB-12*, *Lactobacillus acidophilus LA-5*, and *Streptococcus thermophilus*, was purchased from Aletek International (Pvt.) Ltd., Colombo, Sri Lanka.

2.2 Preparation of gum composite

The plant gum composites using both xanthan gum (XG) and guar gum (GG) with CMC were prepared according to (El-Sayed *et al*., 2002) with some modifications. Xanthan gum with CMC mixture (treatment I) and Guar gum with CMC mixture (treatment II) were added to different aliquots of coconut milk at 1% (w/v) concentration at a 1:1 ratio of each stabilizer. As a result of multiple preliminary trials carried out with different concentrations and ratios, as well as based on certain literature reviews on similar studies; (El-Sayed. *et al*., 2002; Salih *et al*., 2020), 1% concentration with a 1:1 ratio of each stabilizer was selected to be applied.

2.3 Preparation of fermented coconut-based dessert

The product preparation was carried out according to (El-Sayed *et al*., 2002) in both stages adhering to some modifications. Coconut milk extract was prepared according to (Belewu *et al*., 2005).

2.3.1 Preparation of fermented coconut-based dessert with coconut milk, gum composites, and sugar

Initially, the prepared coconut milk extract with sugar was heated to 90 °C for 10 minutes followed by adding the gum composite. The gum composite was added in two different composite mixtures of 1% concentration at a 1:1 ratio of each stabilizer (Xanthan, CMC composite and Guar gum, CMC composite). Once the mixture was cooled down to 40 °C, 0.02% (w/v) yoghurt starter was added. They were then distributed into 120 mL plastic cups and incubated at 42°C for about 4 hours. The yoghurt cups were then transferred to refrigerated storage and analysed for their sensory properties to select the best gum composite.

2.3.2 Preparation of fermented coconut-based dessert with coconut milk, xanthan: CMC gum composite, sugar, and stevia

Here, sugar and stevia mixes were added to the coconut milk extract at three different sweetening capacities; 10%, 15%, and 20% (w/w) at a 5:1 sugar-to-stevia ratio with the objective of increasing the sweetening capacity at a cost-effective low caloric approach. The three different percentages of sugar and stevia mixes were selected as a result of multiple preliminary trials conducted incorporating different percentages of the sugar and the sweetener. Then the prepared coconut milk extract with sugar and stevia mixtures was heated at 90 °C for 10 minutes followed by adding gum composite. The Xanthan: CMC gum composite was added in 1% concentration at a 1:1 ratio of each stabilizer. Once the mixture was cooled down to 40 °C, 0.02% (w/v) yoghurt starter was added. As the preservative, Sodium benzoate was added below its maximum limit; 1000 mg/kg. (Based on Codex Alimentarius; International food standards, Standards for aqueous coconut products). They were then distributed into 120 mL plastic cups and incubated at 42 °C for about 4 hours. The yoghurt cups were then transferred to refrigerated storage and analysed after 1, 7, 14, 21, 28, 35 and 42 days of storage for their physicochemical, microbiological, microbiological, and sensory properties.

2.4 Sensory evaluation tests

Sensory evaluation was conducted on semi-trained panelists (n=30) from the University of Sri Jayewardenepura, using a 5-point hedonic scale. The panel members were frequent yoghurt consumers and each of the panelist was asked to score the products that were stored at 4°C for 24 h from 1 (dislike extremely) to 5 (like extremely) on 5 attributes, appearance, aroma, texture, taste, and overall acceptability. The sensory evaluation tests were conducted in 2 stages.

2.4.1 Sensory evaluation stage - 1

Sensory evaluation stage 1 (SE1) was conducted to determine the best gum composite for the product out of the two selected gum composites; Xanthan gum, CMC composite and Guar gum, CMC composite after a series of preliminary trials. There, two products containing the two different gum composites at 1% w/v, 1:1 ratio were given to each member and asked to rank sensory properties (appearance, odour, texture, taste, overall acceptability) based on a five-point hedonic scale where, 5-Extemely like, 4 – Like, 3 – Neither like nor dislike, 2 – Dislike, 1- Extremely dislike.

2.4.2 Sensory evaluation stage - 2

Sensory evaluation stage 2 (SE2) was conducted to determine the best sugar, stevia mix for the product out of the three selected sugar, stevia capacities after a series of preliminary trials. To determine the best concentration of sugar, and stevia mix, three products were prepared in three different percentages of sugar, and stevia mix (10%, 15%, and 20%) at 5:1 sugar, stevia ratio. Then those products were given to each member separately and asked to rank sensory properties (appearance, odor, texture, taste, overall acceptability) based on a five-point hedonic scale which, 5-Extemely like, 4 – Like, 3 – Neither like nor dislike, 2 – Dislike, 1- Extremely dislike.

The serving temperature of the samples was maintained at 4 °C to mimic consumer behaviour. The scores obtained from the sensory evaluation were analysed using the Friedman test, and SPSS statistical software packages. Radar graphs were also plotted according to the mean rank values of each sample using the corresponding Friedman test results and then the sensory characteristics were compared accordingly. Consequently, the product containing Xanthan: CMC with 15% sweetening capacity was selected as the best sensorial accepted composition and was taken for quantitative analyses as the preservative-added (sodium benzoate) product and the control.

2.5 Physicochemical analysis of the product

pH, Water holding capacity (WHC), syneresis, and Total soluble solids (TSS) of preservative added and the control products were determined on the days 1,7, 14, 21, 28, 35, and 42 of storage, at the temperature of 4°C. pH values of the products were measured by using the digital pH meter (AE-PH811, China). Water holding capacity (WHC) was determined according to (Pavalakumar *et al*., 2020) with the use of a centrifuge machine (HERMLE Z 306, Labortechnik GmbH, Germany). Initially, 20g of the product was accurately weighed into a separate centrifuge tube and was centrifuged at 4000g for 20 minutes at 4°C. Then the supernatant was filtered using Whatman 1 filter paper – No.42., and then by applying the weight of the precipitate to Eq (1), WHC was calculated. Syneresis was determined according to (Pachekrepapol *et al*., 2021a) with some modifications and was determined by the weight percentage of the supernatant after centrifugation at 4000g at 4°C for 20 minutes. The total soluble solids were determined using the handheld refractometer (ATAGO.N-1a, Japan) according to AOAC (2005) method. The texture profile of the product was determined according to (Pachekrepapol *et al*., 2021b) with slight modifications. A texture analyser (Brookfield, CT3 50K, USA) was used to assess the texture profile including hardness, adhesiveness, gumminess, springiness, chewiness, and cohesiveness based on the conditions; probe: TA4/1000, test type: TPA, trigger load: 1000 g, target: 10 mm, target type: distance, pre-test speed: 2 mm/s, test speed: 0.5 mm/s, post-test speed: 3 mm/s. Initially, the test run was carried out to locate the base. After that each product sample was placed on the base and the test was run. This procedure was triplicated and at the end of the test, raw data was analysed by using Minitab 18.

$$WHC\ \% = \frac{Weight\ of\ the\ precipitate}{Weight\ of\ the\ analyzed\ product} \times 100 \qquad (1)$$

2.6 Proximate analysis of the product

Proximate analyses were carried out for the product accepted from the final sensory evaluation and the tests were triplicated. Oven drying (Sand pan method) was followed to determine the moisture content of the product. Total fat content was determined using the Mojonnier method according to AOAC 989.05 (2012). Total ash content was determined using the gravimetric method using the muffle furnace according to the AOAC 923.03 (2012). Total crude protein content was determined according to SLS 735 Part 7 Section 5:2012 using the Kjeldahl digestion kit VELP Scientifica UDK 129). Crude fiber c ontent was determined according to AOAC method 985.29 (AOAC, 2012). At last, the carbohydrate content was determined by subtracting the total of the above components from 100.

2.7 Mineral analysis of the product

The dry ashing method was used for the preparation of the fermented coconut-based dessert sample for the analysis of the minerals; Na, K, Mg, Ca, and Fe). Mineral analysis was carried out using an Atomic Absorption Spectrometer (Thermo Scientific iCE 3500) according to AOAC Method 975.03 (2012).

2.8 Determination of Antioxidant properties of the product

The antioxidant potential of the formulated coconut-based fermented dessert was determined in terms of total phenolic content (TPC), 2,2- diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging ability and 2, 2’-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical- scavenging activity.

2.8.1 Sample preparation

The sample (2.5000g) was dissolved in 80% methanol (25.0 mL) in a centrifuge tube and the mixture was agitated using a shaker for 30 minutes. Then they were centrifuged at 1600 rpm for 30 minutes at room temperature. The supernatant was filtered with Whatman 01 filter paper from the centrifuge tube and stored in the refrigerator at 4°C.

2.8.2 Total polyphenolic content (TPC) assay

The total phenolic content assay was determined according to the method described by (Ainsworth and Gillespie, 2007; Ramos-Escudero *et al*., 2012) with slight modifications. The methanolic extract (200 µL) containing 2.5g of the sample was mixed in a test tube with 1.5 mL of freshly prepared 0.2 N Folin Ciocalteu (FC) reagent. Then 1.5 mL of 7.5% (w/v) Na_2CO_3 solution was added to the sample after a 5-minute reaction time. After that, the solution was allowed to react by keeping it in a dark place for 30 minutes. The absorbance of the resulting blue intensity was measured at 725 nm against a blank sample using a UV-Visible spectrophotometer (UV 1900I, Shimadzu, Japan). Here, Gallic acid was used as the standard and the TPC content was expressed as mg Gallic acid equivalent (GAE) per 1g of solution.

2.8.3 DPPH radical scavenging activity assay

The total DPPH radical scavenging activity was determined according to the method described by(Maduwanthi and Marapana, 2021) with slight modifications. A volume of 3.0 mL of DPPH solution was added to 0.3 mL of methanolic extract containing 2.5 g of sample. The mixture was shaken well and allowed to stand under darker conditions for 30 minutes. A control sample was prepared by replacing the 0.3 mL sample with 80% methanol (0.3 mL), keeping other conditions constant. The absorbance was measured at 517 nm wavelength using a UV-Vis spectrophotometer (UV 1900I, Shimadzu, Japan). The percentage of radical-scavenging ability was calculated by using Eq. (2):

$$\%\ of\ radical\ scavenging\ activity = \frac{A_0 - A_1}{A_0} \times 100 \qquad (2)$$

A_0 – Absorbance of the control sample

A_1 – Absorbance of the test sample

2.8.4 ABTS radical scavenging activity assay

The ABTS assay was performed according to the method described by Wetwitayaklung *et al*., 2007 with slight modifications. A stable stock solution of ABTS radical cation was prepared by reacting 1:1 of 7 mM aqueous solution of ABTS with 2.45 mM potassium persulfate in the dark at room temperature for 12–16 h. The working solution of ABTS was prepared by adjusting the absorbance of the stock solution to 0.70 ± 0.01 at 734 nm using methanol (80%). This solution (4 mL) was then mixed with (0.2 mL) of the sample, and the absorbance at 734 nm of the mixture was measured after 10 min reaction time. The control for this assay was prepared by reacting 0.2 mL of methanol (80%) with 4 mL of cation solution for 1 min. The capacity of scavenging free radicals was calculated by using Eq. (3).

$$ABTS\ scavenging\ activity\ \% = \frac{A_0 - A_S}{A_0} \times 100 \qquad (3)$$

A_0 – Absorbance of the control sample

A_1 – Absorbance of the test sample

2.9 Fatty Acid Profile Analysis using gas chromatography flame ionization detector (GC–FID) analysis

The fatty acid profile of the fermented coconut-based dessert was analysed according to the AOAC 996.06 method. The fatty acid methyl esters (FAMEs) were analysed by gas chromatography (Agilent model 7890A GC) with the flame ionization detector (FID), using a capillary fused silica column with a cyanopropyl polysiloxane stationary phase (HP-88, 60 m x 0.25 mm id, 0.20 µm film thickness - Agilent Technologies, USA).

2.10 Microbial analysis of the fermented coconut-based dessert

2.10.1 Viability of Lactic acid bacteria (LAB)

Lactic acid bacteria in fermented coconut-based dessert samples were enumerated on MRS agar according to pour plate method and they were incubated at 37°C on day 1, 7, 14, 21, 28, 35, and 42 during storage at 4°C. Then the lactic acid bacteria count was expressed as log CFU/g (Pachekrepapol *et al*.,2021a).

2.10.2 Yeast and Mold count

The count of yeast and mold was determined according to the method described by ISO 6611:2004 and the results were expressed in terms of colony forming unit per g (CFU/g).

Results and Discussion

3.1 Sensory evaluation tests

Under SE1, the effect of sensory properties such as appearance, aroma, taste, texture and overall acceptability of two formulas of dessert with two different gum composites were evaluated. Since p-values of all tested sensory parameters were less than 0.05 (α), a significant difference was proven between the two samples in terms of above-mentioned sensory parameters. As seen in Figure 1, the results indicated that the product containing Xanthan: CMC gum composite (435) had the highest mean rank for appearance, odor, texture, taste, and overall acceptability.

In SE2, the effect of sensory properties such; appearance, aroma, taste, texture and overall acceptability of the three formulae of dessert with stevia were evaluated. Since p- values for texture, taste and overall acceptability were less than 0.05 (α), a significant difference was proven between the three samples in terms of above sensory parameters. Nevertheless, for appearance, and odor, there was no significant difference observed among the three samples ($p > 0.05$). According to Figure 2, the product with 15 % sugar, stevia mix at 5:1 ratio had the highest mean rank for texture, taste, and overall acceptability. Since stevia was added along with cane sugar to increase the overall sweetening capacity, the calculated sugar/final product (w/w %) was 13.03%. Therefore, the product could still be given the amber color code indicating moderate sugar level in the product. (Food Act, No. 26 of 1980).

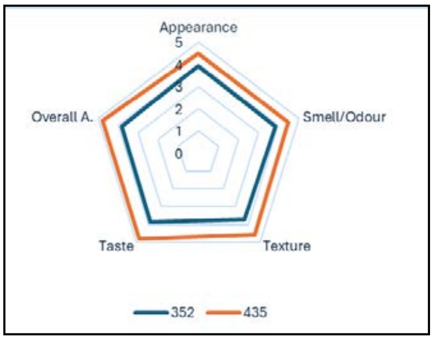

Figure 1-Web diagram for the sensory evaluation for selecting the best plant gum composite (stage 1); 352 - Product with Guar gum: CMC gum composite, 435 - Product with Xanthan: CMC gum composite.

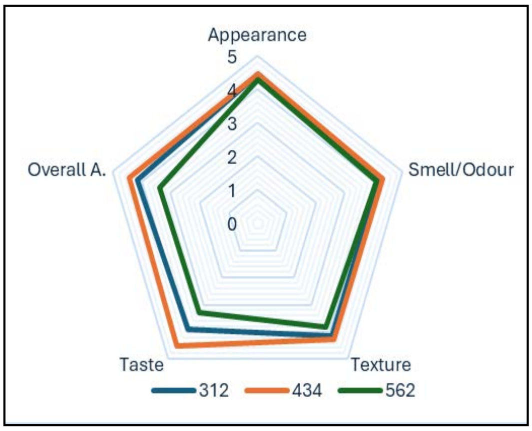

Figure 2- Web diagram for the sensory evaluation for selecting the best sweetening capacity % (stage 2); 312, 434, 562 – product containing 10%, 15%, 20% sugar: stevia mix

3.2 Physicochemical analysis of the product

3.2.1 pH during storage

A significant difference was observed among the two desserts according to the statistical inferences (one-way ANOVA). According to the graphical interpretation shown in Figure 3, it was observed that pH of the two treatments significantly decreased throughout the shelf-life period, yet all the values fell in-between 5.48 and 4.95 throughout the tested shelf-life period. Lactic acid development throughout the storage period causes a reduction in pH value. This also refers to the post-acidification stage caused by the LAB present in the sample which harms the product shelf life causing undesirable changes in the product; high acidity and syneresis (Deshwal *et al*., 2021). The decrease in the pH in the preservative-added product was slightly lower than in the non-preservative product. That is due to the preservative action of sodium benzoate and these results are slightly aligned with (Bansode *et al*., 2012). According to the SLSI recommendation and guidelines (SLS 824: Part 2: 1989), the pH value should not be less than 4.2 for a yoghurt. Since the developed fermented coconut-based dessert similarly aligns with yoghurt-like products and the pH range is above 4.2, all the two types of desserts were in an acceptable range.

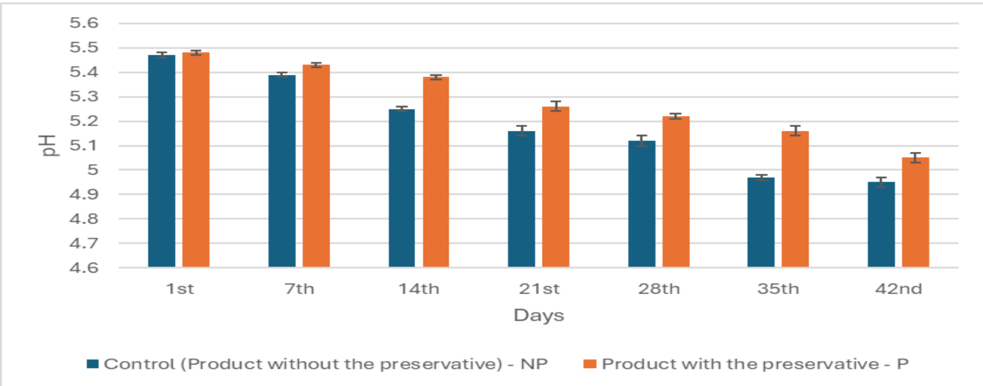

Figure 1- Mean values of pH of the two dessert samples; P – Product with the preservative; NP – Control.

3.2.2 Water holding capacity and syneresis

The water-holding capacity in a yoghurt-like product is mainly determined by the microstructure of the protein network (Pavalakumar *et al*., 2020). In fact, if the water holding capacity is insufficient, the watery or whey (if dairy) portion will be expelled on the product surface during the storage period, and this result in syneresis. So, the water holding capacity must be improved to prevent syneresis in these types of fermented dairy or non- dairy products. Freshly produced products typically have a high capacity to retain water, but as syneresis progresses, mainly due to continuous rearrangement within the protein network, this capacity decreases during prolonged storage (Mortensen *et al*., 2010).

Table 1-Mean values of WHC % of the desserts throughout the tested shelf-life period.

Days of storage	Control - NP (%)	P (%)
1st	94.49 ± 0.02 a	94.49 ± 0.02 a
7th	94.19 ± 0.01 a	94.22 ± 0.01b
14th	93.75 ± 0.01 a	93.87 ± 0.02 b
21st	92.86 ± 0.02 a	92.96 ± 0.01 b
28th	89.88 ± 0.02 a	90.45 ± 0.01 b
35th	87.88 ± 0.02 a	88.66 ± 0.02 b
42nd	85.81 ± 0.02 a	86.85 ± 0.02 b

Table 2- Mean values of Syneresis % of the desserts throughout the tested shelf-life period.

Days of storage	Control – NP (%)	P (%)
1st	5.46 ± 0.01 a	5.46 ± 0.02 a
7th	5.58 ± 0.01 a	5.55 ± 0.01b
14th	6.38 ± 0.01 a	6.34 ± 0.01 b
21st	6.93 ± 0.01 a	6.89 ± 0.01 b
28th	9.93 ± 0.02 a	8.88 ± 0.02 b
35th	11.12 ± 0.02 a	10.87 ± 0.02 b
42nd	13.68 ± 0.03 a	12.11 ± 0.02 b

Since a natural plant gum composite; xanthan: CMC was used as the stabilizer in the product, the water holding capacity had been improved to a greater extent. So, the rate of syneresis had also been slightly decreased in like manner. It was observed that in both the products, the water holding capacities were at higher values; above 85 % whereas the maximum syneresis observed was around 13 % for 6 weeks of the study. These results were similar to the study conducted by (Daszkiewicz *et al*., 2023), where around 87% WHC was observed in normally colored yoghurt analogue made from coconut flesh. Moreover, the study conducted by (El-Sayed *et al*., 2002) showed that their control yoghurt produced without the stabilizer had an increased rate of syneresis whereas, the yoghurts produced with plant gums or gum composites had a low rate of syneresis. These results show that the susceptibility to syneresis decreased with the addition of plant gum composite as the stabilizer. It has also been reported that the use of thickening agents such as xanthan gum has been regarded as a method of controlling syneresis in fermented milks (Harwalkar and Kalab, 1986; El-Sayed *et al*., 2002).

3.2.3 Total soluble solids

According to the results of Table 3, the total soluble solids of the two products were in the range of 20-21 %. When compared to a similar study conducted by, (Amirah *et al*., 2020), it was observed that the value obtained for the Coconut yoghurt prepared without the raisin puree and incorporated with 0.25% xanthan gum had a lower value (13%). This might be because the developed coconut-based dessert comprises around 4 times of xanthan and CMC gum composites (1%) as well as added sugar and stevia. As the gum composite increased, total soluble solids of the product also increased probably due to xanthan containing several pentasaccharides (Sharma *et al*, 2014) and CMC containing several polysaccharides and cellulosic materials (Rahman *et al*., 2021). Since the preservative was added at a ppm level, while all other factors remained the same, that ppm level is negligible and does not make a considerable difference in TSS value between the samples. However, the TSS values of the two treatments were observed to be slightly decreased throughout the shelf-life period. That may be due to the metabolism of sugars by lactic acid bacteria under the controlled refrigerated storage condition which also been stated in a similar study by (Osundahuns *et al*., 2007).

Table 3 - Mean values of TSS of the two fermented desserts throughout the tested shelf-life period.

Days of storage	Control (Product without the preservative) – NP (%)	Product with the preservative – P (%)
1st	20.9 ± 0.1 [a]	20.9 ± 0.1 [a]
7th	20.8 ± 0.1 [a]	20.8 ± 0.1 [a]
14th	20.9 ± 0.1 [a]	20.8 ± 0.1 [a]
21st	20.7 ± 0.1 [a]	20.8 ± 0.1 [a]
28th	20.7 ± 0.1 [a]	20.8 ± 0.1 [a]
35th	20.6 ± 0.1 [a]	20.7 ± 0.1 [a]
42nd	20.6 ± 0.1 [a]	20.6 ± 0.1 [a]

3.2.4 Texture profile analysis of the product

The mean values obtained for the tested textural attributes are depicted in Table 4. It is commonly known that the structure of a particular food has a significant impact on a variety of its attributes, including texture, functionality and appearance. The structural organization and microstructure of the protein network of fermented products, especially in dairy products determine their rheological and structural characteristics (Ozcan, 2013). However, there are additional challenges associated with producing non-dairy yoghurt from plant-based sources, such as inconsistent texture. The dairy and non-dairy industries have struggled with structural improvement, but these problems can be alleviated by using plant-based stabilizers in plant-based yoghurt-like products, such as inulin, acacia gum, xanthan gum and pectin etc. (Chetachukwu *et al.*, 2018; Baskar *et al.*, 2022). The most crucial factors for evaluating the textural qualities of yoghurt and other fermented milk products are their hardness, adhesiveness, cohesiveness, gumminess, chewiness and springiness (Mousavi *et al.*, 2019). Hardness, also known as firmness, is the key factor which determines the consistency of yoghurt-like products. It is thought of as a measure of the hardness of yoghurt and is defined as the force needed to achieve a particular deformation (Mudgil *et al.*, 2017). The obtained hardness value for the developed product (24.29 ± 0.72) mJ was comparatively similar to the dairy yoghurt (21.07 ± 0.72) mJ prepared in the study done by Pavalakumar *et al.* in 2020. When the hardness values are compared with similar studies on coconut yoghurt, our results were higher than the value determined by (Qingke, 2019). These differences were thought to be as a result of changes in the incubation temperature, time and the amount of culture, like factors (Köse and Köse, 2018). According to the results determined for the dairy yoghurt by Pavalakumar *et al.*, in 2020, the obtained adhesiveness value was higher and the chewiness value was lower in our product. The springiness value of the sample indicates its ability to recover from the initial deformation used during the analysis. Food products are known to undergo deformations due to various forces applied during storage and transportation. Therefore, the springiness value of the product is crucial to achieve the appropriate level of product quality (Yildiz *et al.*, 2015). However, the obtained value was similar to the values determined for the dairy yoghurt by (Pavalakumar *et al.*, 2020).

Table 4 - Mean values of texture parameters of the fermented coconut-based dessert.

Texture parameters	Mean values obtained
Hardness (mJ)	24.29 ± 0.72
Adhesiveness (mJ)	17.87 ± 0.61
Gumminess (g)	182.40 ± 0.95
Springiness (mm)	57.9 ± 0.06
Chewiness (mJ)	22.44 ± 0.05
Cohesiveness	0.19 ± 0.01

However, according to the results obtained by (Qingke, 2019), it states that, unlike commercial yoghurt, coconut yoghurt had a higher viscosity and cohesiveness relative to its hardness; however, its chewiness value was lower. These results are aligned with the developed product except for cohesiveness value and these differences suggest that the overall coagulation of the developed product is better and thicker, conforming to the texture characteristics of solidified yoghurt.

3.3 Proximate analysis of the product

Fermented foods have gained a lot of attention in recent years due to their potential health benefits, including improved digestion and better nutrient absorption. This can be attributed to the microbial fermentation process, which not only enhances the flavour and texture of the food but also improves its nutritional profile (Szparaga *et al*., 2019). As summarized in Table 5, the creamy texture of the product could be attributed to its moderate moisture content (40.02%). Furthermore, the lower ash content of the product (0.51%) suggests that no inorganic contaminants were present. Furthermore, the fermented coconut-based dessert had a relatively high fat content (19.17%). Those looking to include healthy fats in their diet may find this helpful due to the presence of lauric acid (Ekanayaka *et al*., 2013). However, the product has relatively a lower protein content (2.20%), suggesting that it may not be a substantial source of protein. Therefore, adequate protein content will not be provided by the serving size of this dessert compared to the same serving size of a dairy yoghurt. Hence, further studies may be required to enhance the protein content of the product utilizing the fortification of a protein-rich plant source.

The results obtained except for moisture content were slightly aligned with the results obtained in the study done by Amirah *et al*. in 2020. Typically, dairy milk and coconut milk contain a lower amount of fibre (Tulashie *et al*., 2022), therefore a low-value fibre content was reported in the product. After the determination of moisture, ash, protein, fat and fibre content of the product, carbohydrate content was obtained. Accordingly, the estimated carbohydrate content was around 37.9 % which was due to the contribution of carbohydrates which are naturally present in coconut milk and added sugar and stevia.

Table 5 - Mean values of nutritional properties of the fermented coconut-based dessert.

Proximate parameters	Mean values obtained
Moisture %	40.02 ± 0.25
Ash %	0.51 ± 0.02
Fat %	19.17 ± 0.05
Protein %	2.20 ± 0.01
Fibre %	0.12 ± 0.01
Carbohydrate %	37.98

3.4 Mineral analysis of the product

According to the results summarized in Table 6, sodium and potassium were observed to be higher in concentration out of the analysed minerals. This higher potassium concentration in the product was observed due to the presence of higher potassium content in coconut milk (146.0 mg/100g) (Astolfi *et al*., 2020). The high sodium content could be attributed to the natural sodium content in coconut milk as well as added sodium benzoate for preservation purposes. The calcium content of the product was 19.359 mg/100g and this value was slightly aligned with the result reported for coconut milk in the study done by (Ahmed *et al*., 2024).

Table 6 - Mineral profile of the fermented coconut-based dessert. (Data presented as mean values ± SD on wet basis.

Mineral	Concentration (mg/100g)
Na	247.53 ± 7.44
K	218.1 ± 13.1
Mg	44.057 ± 0.88
Ca	19.359 ± 0.6
Fe	1.364 ± 0.06

3.5 Determination of antioxidant properties

Based on the results as seen in Table 7 and relative literature, it was observed that the fermented coconut-based dessert also had a notable antioxidant potential closer to dairy yoghurt. However, the DPPH inhibition percentage was observed to be lower compared to a dairy yoghurt made of skim milk powder (Unal *et al*., 2013). This could be attributed to differences in composition between coconut milk and dairy milk, highlighting the influence of the ingredients on antioxidant properties. However, coconut meat is known to have a variety of phenolic compounds: salicylic acid, caffeic acid, p-coumaric acid, and gallic acid which prevent cells from oxidative damage through free radical scavenging activity (Ameer et al., 2014). Furthermore, despite of usage as a common sweetener, stevia extracts offer therapeutic and nutritional benefits, including essential amino acids, vitamins, minerals, fibre as well as its polyphenol content (Wölwer-Rieck, 2012; de Carvalho *et al*., 2019). Given the fact that the stevia leaves and extracts have been shown to have antimicrobial, antihypertensive, antihyperglycemic, and immunoregulatory properties due to their bioactive phytoconstituents (Wölwer-Rieck, 2012), it can be proved that incorporated stevia not only aided in low caloric effect but also notably improved the overall antioxidant potential of the product. As a matter of fact, a comparison with a similar study summarized under Table 8, investigating the development of a dairy yoghurt incorporated with stevia further highlighted the higher antioxidant activity of coconut-based dessert (de Carvalho *et al*., 2019).

As far as the above reported values from the comparative study as well as the fact that higher incorporation of stevia (2.5 %) in the product are concerned, it can be proven that the substitution of coconut milk and the incorporation of a relatively high percentage of stevia had aided in increasing the antioxidant potential of the product. Overall, the findings of this analysis highlighted the antioxidant capacity of the fermented coconut-based dessert and its potential as a functional food with health-promoting properties. So, it can be suggested as a probiotic food with an antioxidant potential for health-conscious consumers.

Table 7 - Antimicrobial properties of the fermented coconut-based dessert.

	DPPH % of inhibition	ABTS (µmol Trolox/g)	TPC (mg GAE/g)
Product	71.11 ± 0.31	2.69 ± 0.03	0.97 ± 0.01

Table 8 - TPC and antioxidant activity (ABTS) values of control yogurts and stevia-fortified yoghurts supplemented with 0.25% (S1) and 0.5% (S2) on day 1. Extracted from (de Carvalho et al., 2019).

	ABTS (µmol Trolox/g)	TPC (mg GAE/g)
Control	0.40 ± 0.04	0.14 ± 0.01
S1	3.63 ± 0.08	0.43 ± 0.02
S2	5.34 ± 0.23	0.65 ± 0.02

3.6 Fatty acid profile of the product through GC-FID analysis

The fatty acid profile of yoghurt-like products mainly depends on the concentration of fatty acids in the raw material used for production (Chen *et al*., 2017). The overall results of the fatty acid profile (Table 9) were similarly aligned with the study conducted by (Daszkiewicz *et al.*, 2023) for an analog of plain yoghurt made from coconut flesh extract. As seen in Table 9, the fatty acid profile for the fermented coconut-based dessert exhibited a high proportion of saturated fatty acids (SFA) particularly, lauric acid (44.01%) and myristic acid (20.02%) and these characteristics are in line with the natural fat composition of coconut milk. Coconut milk is known for its richness in medium-chain saturated fatty acids; especially lauric acid (Belewu and Belewu, 2007).

Lauric acid helps to raise HDL cholesterol levels, which in turn helps to lower the LDL cholesterol levels in the bloodstream (Ekanayaka *et al*., 2013; Vanga and Raghavan, 2018). In addition to lauric acid, a notable percentage of several antimicrobial fatty acids was also observed in the fatty acid profile of the product. They were, Caprylic acid (9.65%), Capric acid (6.19%), Myristic acid (20.02%), Palmitic acid (9.09%), and Oleic acid (5.78%). In fact, it is stated that Caprylic acid has been used as a remedy for intestinal yeast infections due to the potential of caprylic acid to kill such harmful fungi such as Candida albicans and Candida tropicalis (Suyitno, 2003).

(Hewlings, 2020) recommends analyzing the health effects of SFAs based on their total content and individual proportions in the diet. Due to the differences in the metabolism of medium-chain and long chain fatty acids, medium-chain SFAs improve metabolic and cognitive function by reducing oxidative stress (Mett and Müller, 2021; Roopashree *et al.*, 2021). Even though SFA content is prominent in coconut milk as well as in bovine milk, the majority of the SFAs in coconut milk are medium chain fatty acids whereas the majority of SFAs in bovine milk are long-chain fatty acids (Daszkiewicz *et al*., 2023). The fact that coconut milk is derived from mature coconuts containing medium-chain triglyceride fatty acids makes it easily digestible compared to other milk alternatives that contain long-chain fatty acids (Tulashie *et al*., 2022).

Here, ABT-5 culture was used in the preparation of fermented coconut-based dessert. (Ismai, 2017), had conducted a study to investigate the influence of utilization of coconut milk and ABT (*L. acidophilus + B. bifidum + S. thermophiles*) culture on various yoghurt properties. Based on study, it was reported that the utilization of ABT culture in yoghurt production lowered SFA and increased UFA contents in the overall fatty acid profile. Given the fact that ABT culture influenced increasing unsaturated fatty acid content, utilization of ABT 5 culture in the fermented coconut-based dessert had become an important aspect which contributed to overall nutritional profile of the product. Extracts had been shown to have antimicrobial, antihypertensive, antihyperglycemic, and immunoregulatory properties due to their bioactive phytoconstituents (Wölwer-Rieck, 2012).

Table 9 - Proportion of fatty acids (%) in the total content of fatty acids in the fat of fermented coconut-based dessert.

Parameter	Results (% by mass of extracted fat)
Saturated fat	
Caproic Acid (C6:0)	0.89
Caprylic Acid (C8:0)	9.65
Capric Acid (C10:0)	6.19
Lauric Acid (C12:0)	44.01
Myristic Acid (C14:0)	20.02
Palmitic Acid (C16:0)	9.09
Stearic Acid (C18:0)	3.38
Monounsaturated Fat	
Oleic Acid (C18:1)	5.78
Poly Unsaturated Fat	
Linoleic Acid (C18:2)	0.84
Trans Fat	
Elaidic Acid(C18:1)	0.10
Linoledic Acid(C18:2)	0.00

3.7 Microbial analysis

3.7.1 LAB viability

According to the results obtained from the one-way ANOVA test, all the p-values e were greater than 0.05 (at 95% confidence interval). Hence, no significant difference in mean values of LAB counts was observed between the two products. So that, there was no effect of the preservative, sodium benzoate on LAB viability. The LAB counts of the two products throughout the 6 weeks were greater than 10^6 CFU (Akin and Ozcan, 2017; Jeske, Zannini and Arendt, 2018; Szparaga *et al*., 2019), the minimum value of LAB count required to be present throughout the shelf-life period as per FAO/WHO guidelines. As per Table 10, it was observed that the growth of LAB ranged between 6.86 log (CFU/g) and 6.26 log (CFU/g) within the storage duration. A higher LAB count was observed within the 1st and 7th day whereas a lower LAB count was observed on the 42nd day in both the products conforming that the freshly produced product contains more active LABs than the aged product. These results were confirmed in (Sanusi *et al*., 2023).

Table 10 - LAB viability of the fermented coconut-based dessert.

Days of storage	LAB count of control (Product without the preservative) – NP (log CFU/g)	LAB count of product with the preservative – P (log CFU /g)
1st	6.86 ± 0.01	6.85 ± 0.01
7th	6.84 ± 0.05	6.83 ± 0.02
14th	6.68 ± 0.03	6.69 ± 0.02
21st	6.62 ± 0.03	6.65 ± 0.03
28th	6.58 ± 0.02	6.54 ± 0.02

35^{th}	6.39 ± 0.03	6.34 ± 0.02
42^{nd}	6.24 ± 0.01	6.26 ± 0.01

3.7.2 Yeast and Mold

As given in the SLSI recommendations (SLS 516 part 2), yeast and mold count for a normal set yoghurt should be less than ten colony forming units per millilitre (CFU/mL) of yoghurt. Since the maximum count observed throughout the shelf life was below this level, both the products could be accepted for consumption within the tested shelf-life period. Even in the absence of preservatives, the product was at the consumer safety level due to several factors like, heat treatment (pasteurization) given for coconut milk, fermentation treatment, and especially the continuous provision of refrigerated conditions throughout its shelf-life period.

Conclusion

Along with the presence of coconut milk and stevia, the final product was observed to have a good antioxidant potential concerning ABTS and TPC assays, when compared to dairy yoghurts. The fatty acid profile of the fermented coconut-based dessert exhibited a high proportion of saturated fatty acids (SFA) particularly, lauric acid (44.01%) and myristic acid (20.02%) which are medium-chain fatty acids referred to as healthy fats compared to long-chain saturated fatty acids. The probiotic potential of both the preservative added and control product showed promising characteristics for the growth of lactic acid bacteria and their viability was higher than 10^6 CFU/g, (the minimum value of lactic acid bacteria count required to be present to be called a probiotic), throughout the 42 days of the studied shelf-life period. Overall, based on the results from the sensory, microbiological, physicochemical and nutritional analysis, it can be concluded that in the presence / even in the absence of the preservative, this product made by utilizing an Asian economic crop can be cited as one of the best sustainable dairy-free alternatives to probiotic dairy-based yoghurts which provides a variety of health benefits.

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