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Comparative Effects of Freeze-Drying and Spray-Drying on the Physicochemical, Microbiological, and Sensory Properties of Coconut Milk and Dairy Milk Yoghurts

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Abstract

Coconut milk yoghurt, rich in healthy fats, offers a sustainable alternative to dairy. Converting it into powder enhances shelf life, versatility, and probiotic retention for diverse food applications. This study evaluates the effects of spray-drying (SD) and freeze-drying (FD) on the physicochemical, microbiological, and sensory properties of coconut milk-based yoghurt (CMY) compared to dairy yoghurt (DY). Yoghurt powders were prepared by diluting the yoghurts with 64% distilled water and 6% maltodextrin for SD processing, conducted at 150°C inlet and 65–70°C outlet temperatures. For FD, liquid yoghurts were frozen overnight and lyophilized under vacuum at -50°C for four days. Analysis revealed that dried CMY exhibited significantly higher soluble solids and lactic acid levels than dried DY (<0.72%) in both drying treatments. Although protein content in dried CMY powders is significantly lower (<23%) compared to DY powders (27%), the LAB counts were consistently higher in CMY samples. Significant differences were noted in colour parameters (b*), though no differences were observed for L* and a*. All dried yoghurts produced microbiologically safe powders, with yeast, mould, and coliform counts within acceptable limits. Sensory evaluation by 60 panellists using a 9-point hedonic scale indicated greater acceptance for CMY over DY, with SD powders preferred over FD powders. In conclusion, CMY is more preferred over DY for producing high-quality yoghurt powders with enhanced probiotic retention, better sensory appeal, and improved functional properties.

INTRODUCTION

Consumer interest in plant-based dairy alternatives has grown rapidly in recent years due to concerns about animal welfare, lactose intolerance, and varied dietary preferences [1]. This trend now includes yoghurt, with coconut milk becoming a popular non-dairy base. Coconut milk, a creamy emulsion made from the grated flesh of mature coconuts, offers a rich texture and subtle sweetness that closely mimics traditional dairy yoghurt. In Malaysia, coconut milk is already a staple in many local dishes but remains underexplored as a direct substitute for dairy products. Although plant-based yoghurts generally cannot match the complete amino acid profile and high protein content of dairy, they compensate by containing lower total sugars, higher dietary fiber, and reduced saturated fat [2, 3, 4]. For individuals with lactose intolerance, coconut-based yoghurt provides a suitable alternative that supports a similar dietary pattern. Two common drying techniques are evaluated: freeze drying and spray drying. Freeze drying freezes the product and removes water through sublimation under high vacuum conditions [5], preserving nutritional, physical, and microbiological qualities because it avoids heat exposure [6, 7]. In contrast, spray drying atomizes the liquid into a chamber of hot air, rapidly evaporating water to yield a fine powder [8, 9].

While spray drying can compromise some quality parameters compared to freeze drying, it offers greater cost-effectiveness and throughput, making it an attractive option for large-scale production [10]. The objective of this study is to develop a ready-to-mix yoghurt powder by comparing the physicochemical, microbiological, and sensory properties of

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coconut-based and dairy-based yoghurt powders produced via both freeze and spray drying, as outlined in **Fig. 1**.

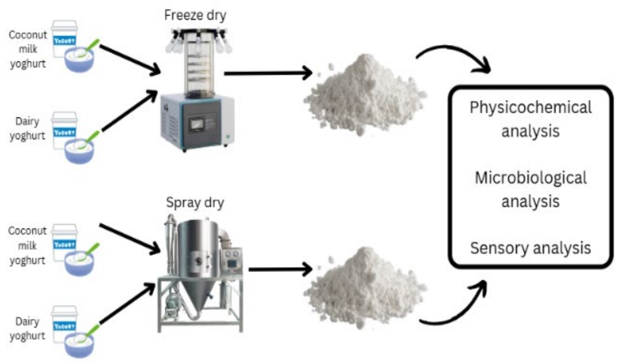

Fig. 1. Conceptual framework of overall experimental design.

MATERIALS AND METHODS

Preparation of coconut milk yoghurt and dairy milk yoghurt

The yoghurt was prepared using the formulation listed in **Table 1**, following the procedure by Pachekrepapol, Kokhuenkhan, and Ongsawat [11] with modifications. Each milk base was pasteurised for 2 minutes at 95 ºC before sugar, guar gum, and Carboxymethyl Cellulose (CMC) were added to the milk bases, respectively. The mixture was then allowed to cool until it reached the temperature of 33 ºC, prior to the addition of starter culture (Belle and Bella Non-dairy Yogurt Starter) in the mixture. The mixture was then incubated at 36 ºC for 18 hours in an incubator. After the incubation period, the yoghurt formed was stored in a cold storage room at 4 ºC.

Table 1. Formulation of coconut milk yoghurt and dairy milk yoghurt.

Type of yoghurt	Ingredients				
	Milk-base (mL)	Sugar (g)	Starter culture (g)	Guar gum (g)	Carboxymethyl Cellulose (CMC) (g)
Coconut milk yoghurt	1000 mL coconut milk (Mawa variant)	10	5	2.5	2.0
Dairy milk yoghurt	1000 mL cow milk (Dutch Lady®)	10	5	2.5	2.0

Spray drying of yoghurt

The yoghurt mixture was made with 64% distilled water, 30% yoghurt, and 6% maltodextrin as the carrier agent for the spray drying process. The mixture was homogenised (IKA® T18 Digital Ultra Turrax, Germany) for 45 seconds at 5 rpm before proceeding with the spray drying process. The drying was performed using a laboratory-sized model spray dryer (Büchi Mini Spray Dryer B-290, Switzerland) with 150 ºC inlet and 60-65 ºC outlet temperature, according to Koç, Sakin-Yilmazer [12]. The obtained powder, the spray-dried yoghurts (SD yoghurt), were stored in a vacuum pack under dry and dark conditions for further analysis. **Table 2** shows the formulations that had been prepared for the spray-dried coconut milk yoghurt (CMYSD) and spray-dried dairy milk yoghurt (DYSD).

Table 2. Formulation for feed preparation of spray-dried yoghurts.

Type of yoghurt	Ingredients		
	Yoghurt (%)	Water (%)	Maltodextrin (%)
Coconut milk yoghurt	30	64	6
Dairy milk yoghurt	30	64	6

Freeze Drying

The prepared yoghurt, with a volume of 35 mL, was filled into a 50 mL Falcon tube. A total of 500 mL of yoghurt was used to be freeze-dried. The filled tubes were arranged in a large plastic container in a standing manner before it was frozen overnight inside a freezer at -10 ºC. The frozen yoghurt was transferred into a freeze dryer (LaboGene ScanVac CoolSafe Freeze Dryer, Denmark) with -50 ºC ice condenser temperature and 0.841 Torr pressure. The obtained powder (FD yoghurts) was stored in a vacuum pack under dry and dark conditions for further analysis. The method was referred to as the procedure by Mat Sarif, Tang and Abd Ghani [13], with modifications.

Moisture Content Analysis

Moisture content of the SD and FD yoghurts was analysed by oven drying (Oven (Universal] Binder Model RD115) at 102°C for 24 h. Procedures were done according to the standard AOAC method with modifications [14]. The yoghurts were dried in crucibles covered with their lids. The percentage of moisture was calculated based on the percentage of wet weight using the following formula:

$$\% \text{ wet} - \text{weight} = \frac{a - b}{a} \; x \; 100$$

Titratable Acidity, pH, and ºBrix Analysis

Titratable acidity of SD and FD yoghurts was determined as lactic acid % (w/w) by titration with 0.1 N NaOH until pH reached 8.2 as the phenolphthalein endpoint [15]. The yoghurt samples were mixed with distilled water in a 1:10 ratio of yoghurt powder to water, before titration was done to measure the titratable acidity. The pH of SD and FD yoghurts was measured using a pH meter (JENWAY 3510 pH Meter) by reconstituting the yoghurt powders with water at a 1:10 ratio of yoghurt powder to water. ºBrix value was measured using a hand refractometer (Atago Hand-held Refractometer N-1 Brix 0.32%, Japan). The yoghurt samples were mixed with distilled water in a 1:10 ratio of yoghurt powder to water, before being dropped on the refractometer to be read. The procedures were done according to Mat Sarif, Tang, and Abd Ghani [13] with modifications.

Colour and Whiteness Index Analysis

The colour of dried yoghurts (SD and FD) was measured with a colorimeter (Konica Minolta, Japan). The results were obtained as L*, a*, and b* values. Whiteness index (WI) was calculated based on the following formula:

$$WI = 100 - \sqrt{((100 - L^*)^2) + a^{*2} + b^{*2}}$$

Crude Protein Analysis

The protein content of both SD and FD yoghurts was determined using the Kjeldahl method (**Fig.** 2) with a conversion factor of 6.38 for dairy-based yoghurt and 6.25 for coconut milk-based yoghurt. The content of protein was measured in percentage based on the following formula:

$$\% \, nitrogen = \frac{(Vs - Vb) x \; N \; x \; 1.4}{W}$$

$$\% \, protein = \% \; nitrogen \; x \; conversion \; factor$$

Where ;
W = weight of sample
Vs = volume of H_2SO_4 to titrate H_3BO_3
Vb = volume of H_2SO_4 to titrate blank

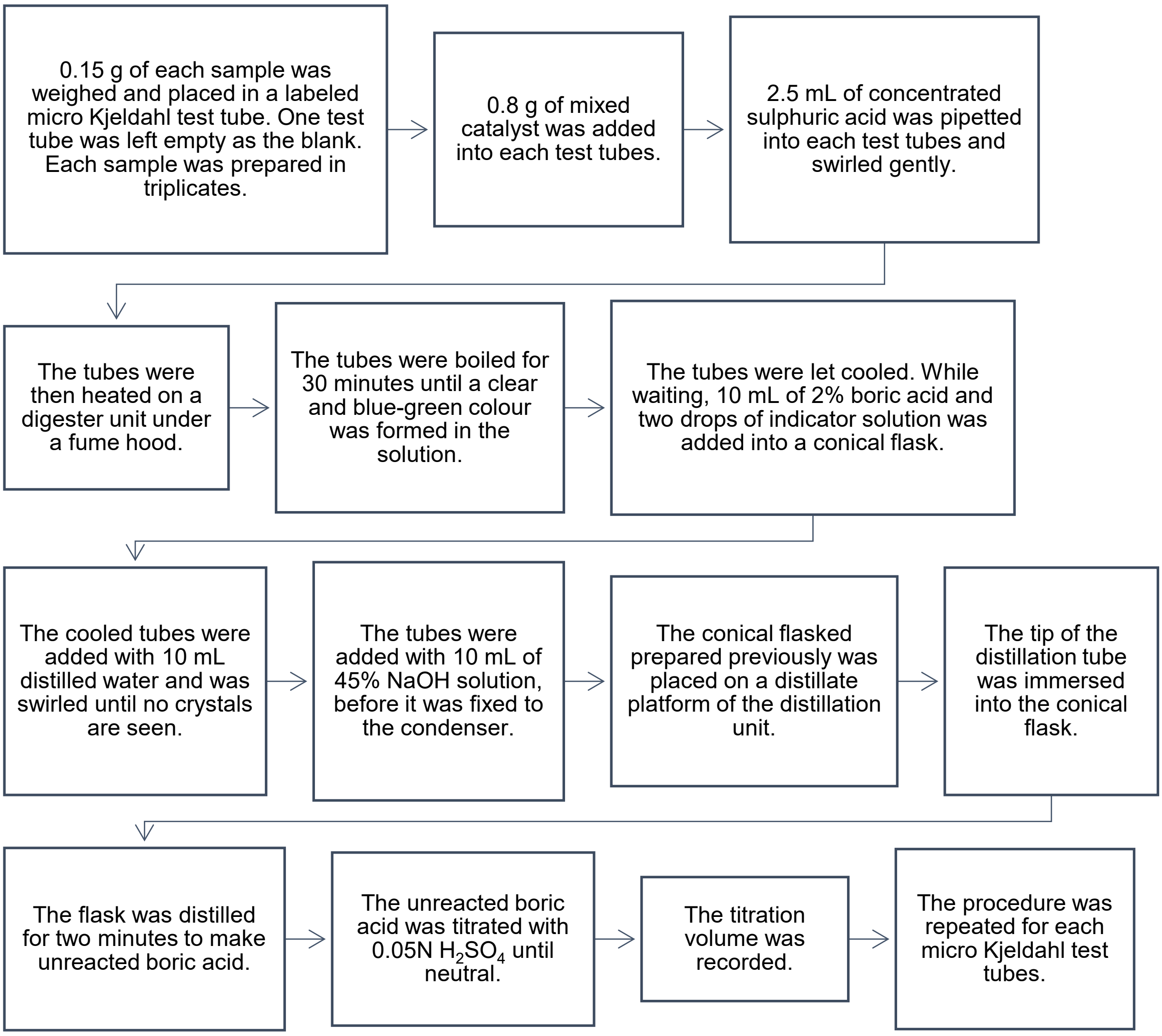

Fig. 2. Procedure of crude protein analysis using Kjeldahl method.

Total Plate Count
Total plate count (TPC) was enumerated on nutrient agar (NA). The samples were diluted in a 1:10 ratio of yoghurt powder to peptone water 0.1%, where 25 g of yoghurt powder was diluted with 225 mL of peptone water 0.1%. Pour plating methods were done, and the plates were incubated in aerobic conditions at 37 ºC for 48 h. The number of colonies was reported as log Colony Forming Unit/mL (log CFU/mL). Procedures were done according to Isa [16] with modifications.

Total Coliform Count
Total coliform count (TCC) was enumerated on Eosin Methylene Blue (EMB) agar. The samples were diluted in a 1:10 ratio of yoghurt powder to peptone water 0.1%, where 25 g of yoghurt powder was diluted with 225 mL of peptone water 0.1%. The pour plating method was done, and the plates were incubated in aerobic conditions at 37 ºC for 24 h. The number of colonies was reported as log Colony Forming Unit/mL (log CFU/mL). Procedures were done according to Isa [16] with modifications.

Total Fungal Count
Total fungal count (TFC) was enumerated on potato dextrose agar (PDA). The samples were diluted in a 1:10 ratio of yoghurt powder to peptone water 0.1%, where 25 g of yoghurt powder was diluted with 225 mL of peptone water 0.1%. Pour plating methods were done, and the plates were incubated in aerobic conditions at 37 ºC for 72 h. The number of colonies was reported as log Colony Forming Unit/mL (log CFU/mL). Procedures were done according to Isa [16] with modifications.

Total Lactic Acid Bacteria Count
Total Lactic Acid Bacteria (LAB) count was enumerated on MRS agar. The samples were diluted in a 1:10 ratio of yoghurt powder to peptone water 0.1%, where 25 g of yoghurt powder was diluted with 225 mL of peptone water 0.1%. The pour plating method was done, and the plates were incubated in an anaerobic condition at 37 °C for 48 h. The number of colonies was reported as log Colony Forming Unit/mL (log CFU/mL). Procedures were done according to Isa [16] with modifications.

Lactic Acid Bacteria (LAB) Survival Rate
The viability or survival rate of LAB was analysed for all powdered yoghurts. The survival rate of the LAB was measured according to a method by Izadi et al. [17], with some modifications, following the formula below :

$$LAB\ Survival\ Rate\ (\%) = \frac{Log\ N}{Log\ No} x\ 100$$

Where ;
Log N = number of LAB after drying in CFU/mL
Log No = number of LAB before drying in CFU/mL

Sensory Analysis
Sensory evaluation was performed on 60 untrained panelists at Universiti Putra Malaysia using a 9-point hedonic scale according to a method described by Santiago-García et al. [18]. The majority of the participants were not frequent yoghurt powder consumers. Two tablespoons of the yoghurt powders (SD and FD yoghurts) were reconstituted with 1 L of water. The prepared yoghurt powder drink was served in a 50 mL cup for each yoghurt powder, where the cup was coded with a 4-digit random number. Each panellist was given a score sheet to fill out their evaluation for each sample.

Statistical Analysis
The statistical analyses for all experiments were conducted by two-way analysis of variance (ANOVA) using Minitab® Statistical Software 22. Tukey's pairwise comparison was employed with a 95% confidence interval for all analyses. Pearson's correlation was done for the analyses between pH and lactic acid concentration, and between ºBrix and protein concentration.

RESULT AND DISCUSSION

Colour is a key attribute of the quality of food products as it can have a direct influence on consumer choice and acceptability [19]. Whiteness is a key attribute commonly associated with plain yoghurts, largely due to the natural colour of dairy milk. As shown in **Table 3**, significant differences ($p < 0.05$) were observed between dried coconut milk yoghurt (CMY) and dairy milk yoghurt (DY) in terms of lightness (L*), redness/greenness (a*), yellowness/blueness (b*), and overall whiteness index (WI). However, no significant differences in L* values were found between CMY and DY for both freeze-dried and spray-dried samples, indicating similar lightness levels. The a* values for both freeze-dried yoghurts were also not significantly different, reflecting comparable greenness. In contrast, a significant difference was noted in the a* values between the spray-dried samples, where DYSD showed a more negative value (-0.80) compared to CMYSD (-0.41), indicating a greener hue in DYSD.

All samples had positive b* values, signifying yellowness; however, these values were significantly different ($p < 0.05$), with dried CMY exhibiting lower yellowness compared to dried DY. This observation is in contrast with a study by Chetachukwu, Thongraung, and Yupanqui [20], where a higher b* value was observed for yoghurt with higher fat content. Coconut milk was studied to have a higher fat content [21], thus expected to have a higher b* value than yoghurt made with dairy milk. The resulting whiteness index (WI) is shown in **Table 3**. There were no significant statistical differences ($p>0.05$) for WI values between both freeze-dried yoghurts.

However, there is a significant difference observed between spray-dried yoghurts, where DYSD showed a significantly lower ($p<0.05$) value for whiteness index compared to CMYSD. The differences in drying method may affect the yoghurts differently, as thermal drying, such as spray drying, is likely to cause pigment degradations and inconsistent colour analysis, as indicated by Jafari et al. [22, 23]. Thus, different yoghurt compositions and drying methods can be observed to affect the colour attributes of dried yoghurts.

Table 3. Comparison of colour (L*, a*, b*) and whiteness index of yoghurt samples treated with two different drying techniques.

Treatment	Sample	Colour L*	a*	b*	Whiteness Index
Freeze dry	CMY	$87.95^{Aa} \pm 0.53$	$-0.42^{Aa} \pm 0.06$	$18.71^{Ab} \pm 0.14$	$77.73^{Aa} \pm 0.17$
	DMY	$86.93^{Aa} \pm 0.92$	$-0.53^{Aa} \pm 0.06$	$20.99^{Aa} \pm 0.28$	$77.23^{Aa} \pm 0.21$
Spray dry	CMY	$84.01^{Bb} \pm 0.29$	$-0.41^{Ba} \pm 0.03$	$13.65^{Bd} \pm 0.17$	$78.97^{Bb} \pm 0.33$
	DMY	$83.11^{Bb} \pm 0.48$	$-0.80^{Bb} \pm 0.02$	$15.24^{Bc} \pm 0.29$	$75.25^{Bc} \pm 0.33$

Note: CMY (Coconut milk yoghurt), DMY (Dairy milk yoghurt). Values with different superscripts in each of the columns are significantly different (p<0.05). Capital letter superscript indicates the difference between treatments, while lowercase indicates the difference between samples.

Table 4 shows the comparison of pH and lactic acid values for CMYFD, DYFD, CMYSD, and DYSD samples. A significant statistical difference ($p<0.05$) was observed for the pH value between freeze-dried yoghurts, but no significant difference for spray-dried yoghurts. A similar trend was observed for the lactic acid concentration between the dried CMY and DY. **Table 4** shows a lower pH value and higher titratable acidity in CMY compared to DY treated with freeze drying and spray drying, although the difference is not significant between the spray-dried CMY and DY. This observation is in line with previous studies by Priya [24] that showed a higher titratable acidity in plain yoghurt made from cow's milk, compared to coconut milk, due to the higher total solids in coconut milk that contribute to final acidity after fermentation. Thus, the composition of yoghurt plays an important role in the properties after drying.

Table 4. Comparison of pH, percentage of lactic acid, and ºBrix value of yoghurt samples treated with two different drying techniques.

Treatment	Sample	pH	Lactic acid (%)
Freeze dry	CMY	$4.34^{Bc} \pm 0.01$	$0.76^{Aa} \pm 0.02$
	DMY	$4.46^{Bb} \pm 0.01$	$0.72^{Ab} \pm 0.02$
Spray dry	CMY	$4.69^{Aa} \pm 0.01$	$0.30^{Bc} \pm 0.05$
	DMY	$4.71^{Aa} \pm 0.01$	$0.29^{Bc} \pm 0.02$

Note: CMY (Coconut milk yoghurt), DMY (Dairy milk yoghurt). Values with different superscripts in each of the columns are significantly different (p<0.05). Capital letter superscript indicates the difference between treatments, while lowercase indicates the difference between samples.

Lactic acid is the major contributor to the acidity of yoghurts, which can directly affect the pH of yoghurts. **Fig. 3** shows a strong correlation between pH and concentration of lactic acid ($R^2 = 0.9477$), with a positive inverse correlation. Observation of the correlation shows that the pH value decreases with increasing concentration of lactic acid in yoghurt samples. This observation is in line with a study by Hoxha et al. [25], where increasing lactic acid produced by lactic acid bacteria causes a decrease in pH of the food matrix. The increasing lactic acid shows a successful fermentation and a suitable acidic environment for LAB in yoghurt to be viable even after being dried into a powdered form. The percentage of lactic acid in FD yoghurts is in line with the International Food Standards, where the minimum concentration of lactic acid in yoghurts should be 0.6% [26]. However, the spray drying technique can only achieve a 0.3% lactic acid concentration.

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The observation is in contrast to a study by Sunitha et al. [27], where the spray drying process has no significant effect on titratable acidity and pH values of food. The significant reduction of lactic acid concentration in SD yoghurts may be due to the effect of diluting the yoghurt prior to drying, which reduces the concentration of organic acid in the yoghurt.

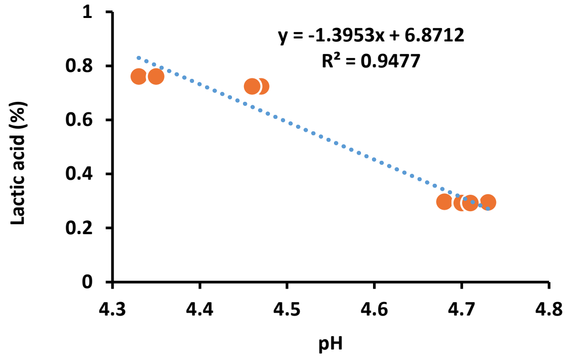

Fig. 3. Pearson correlation between pH and percentage of lactic acid on yoghurt samples treated with two different drying techniques.

Table 4 presents the mean moisture content of yoghurt samples treated with freeze drying and spray drying. A significant difference ($p < 0.05$) was observed between freeze-dried samples, with CMYFD and DYFD showing moisture contents of 11.76% and 11.47%, respectively. However, no significant difference was found between spray-dried samples, where CMYSD and DYSD recorded 8.16% and 8.02%, respectively. Although coconut milk yoghurt showed slightly higher moisture content in both drying methods, the difference was only significant in freeze-dried samples. Interestingly, this contrasts with previous findings, which reported lower moisture in coconut milk products due to their higher fat content [28-30]. However, those studies focused on fresh liquid yoghurt, and limited data exist on dried forms. Therefore, these results offer new insights into how drying methods may differently affect the moisture retention of coconut- versus dairy-based yoghurt powders. A similar trend was also observed for protein content.

Table 5 summarizes the comparison of protein content in yoghurt samples (CMY and DY) treated with two different drying techniques (FD and SD). Evaporation of liquid yoghurt has the ability to increase its protein content as described by Jørgensen et al. [31]. The highest protein content was observed in DYFD (27.29%) and the lowest in CMYSD (12.28%). Overall, dairy-based yoghurts showed significantly higher protein levels than coconut-based ones, reflecting the naturally lower protein content of coconut milk [21, 32]. Protein composition was also found to be influenced by the total soluble solids (°Brix) of the yoghurt base.

As seen in **Fig. 4**, an inverse correlation was observed—higher °Brix values corresponded to lower protein content. Moore et al. [33] reported that increasing the concentration of added sugar, such as flavourings will decrease the protein concentration in yoghurt. Similarly, in a study by Priya [24], it is proven that the composition of soluble solids affects the protein concentration, and higher total solids can be observed in coconut milk. This is also in line with the observation in **Table 5**, where total soluble solids measured as °Brix value were observed to be higher in dried coconut milk-based yoghurts.

It is also reported from previous studies that coconut milk contains higher total solids due to its high fat content [29, 34, 35]. Therefore, protein composition can be greatly affected by total soluble solids composition in yoghurt base.

Table 5. Comparison of moisture, protein, and °Brix content in yoghurt samples treated with two different drying techniques.

Treatment	Sample	Moisture content (%)	Protein content (%)	°Brix
Freeze dry	CMY	$11.76^{Aa} \pm 0.06$	$22.92^{Ab} \pm 0.31$	$8.87^{Bc} \pm 0.09$
	DMY	$11.47^{Ab} \pm 0.03$	$27.29^{Aa} \pm 0.61$	$7.67^{Bd} \pm 0.09$
Spray dry	CMY	$8.16^{Bc} \pm 0.18$	$12.28^{Bc} \pm 1.23$	$15.40^{Aa} \pm 0.33$
	DMY	$8.02^{Bc} \pm 0.09$	$13.89^{Bc} \pm 1.38$	$12.87^{Ab} \pm 0.19$

Note: CMY (Coconut milk yoghurt), DMY (Dairy milk yoghurt). Values with different superscripts in each of the columns are significantly different ($p<0.05$). Capital letter superscript indicates the difference between treatments, while lowercase indicates the difference between samples.

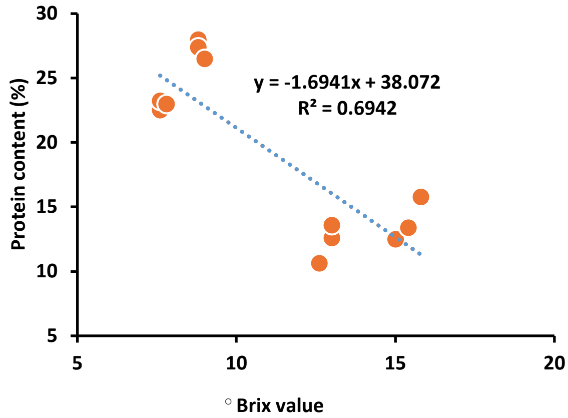

Fig. 4. Correlation between °Brix value and protein content (%) of yoghurts treated with two different drying techniques.

Table 6 summarizes the total plate count (TPC) and lactic acid bacteria (LAB) count for yoghurt samples (CMY and DY) treated with two different drying techniques (FD and SD). Total plate count is a general estimation of the total viable aerobic bacterial population in a sample [36]. A high count can be an indication of poor sanitary conditions in food production [37]. Based on **Table 6**, dried CMY treated with both FD and SD was observed to give higher TPC than dried DY, obtaining 4.60 – 5.00 log CFU/mL for dried CMY and 4.56 – to 4.79 log CFU/mL for dried DY. Although elevated TPC in SD yoghurts may indicate the presence of spoilage bacteria, there is also a high count of LAB observed in the SD yoghurts.

This positive correlation between TPC and LAB may indicate that the high count of TPC could be due to the high LAB count. This observation is aligned with a study by Isa [16], where a significant positive correlation can be observed between TPC and LAB count in cheese, indicating that the majority of the counted bacteria were lactic acid bacteria. Hong Kong Centre for Food Safety [38] stated that TPC or aerobic colony count (ACC) is better as an indicator of food quality, not safety. It helps provide useful information regarding the overall quality by setting a limit of satisfactory ACC level, where for powdered food products, including reconstituted powder foods must be less than 10^6 CFU/g. Thus, exceeding the limit can be unsatisfactory, demanding the need to improve storage and handling practices of the food.

Table 6. Microbiological quality assessments (TPC and LAB) of yoghurt samples treated with two different drying techniques.

Treatment	Sample	TPC (Log CFU/mL)	LAB (Log CFU/mL)
Freeze dry	CMY	$4.60^{Bc} \pm 0.15$	$4.78^{Bc} \pm 0.01$
	DMY	$4.56^{Bc} \pm 0.10$	$4.59^{Bd} \pm 0.01$
Spray dry	CMY	$5.00^{Aa} \pm 0.07$	$5.36^{Aa} \pm 0.01$
	DMY	$4.79^{Ab} \pm 0.04$	$5.21^{Ab} \pm 0.01$

Note: CMY (Coconut milk yoghurt), DMY (Dairy milk yoghurt). Values with different superscripts in each column are significantly different (p<0.05). Capital letter superscript indicates the difference between treatments, while lowercase indicates the difference between samples. TPC = Total Plate Count. LAB = Lactic Acid Bacteria.

Lactic acid bacteria (LAB) count is a key indicator of fermentation quality and probiotic viability in fermented foods like yoghurt. It reflects how well LAB survives after processing or storage. **Table 6** compares LAB counts in coconut milk (CMY) and dairy milk (DY) yoghurts after freeze drying (FD) and spray drying (SD). A significant difference ($p < 0.05$) was observed between CMY and DY, with CMY samples showing higher LAB counts (4.78–5.36 log CFU/mL) compared to DY (4.59–5.21 log CFU/mL). **Fig. 5** further illustrates LAB survivability rates, with CMY powders reaching up to 80.85%, significantly higher than DY powders, which recorded a maximum of 68.58%. These results suggest that coconut milk provides a more favorable environment for LAB survival during the drying process.

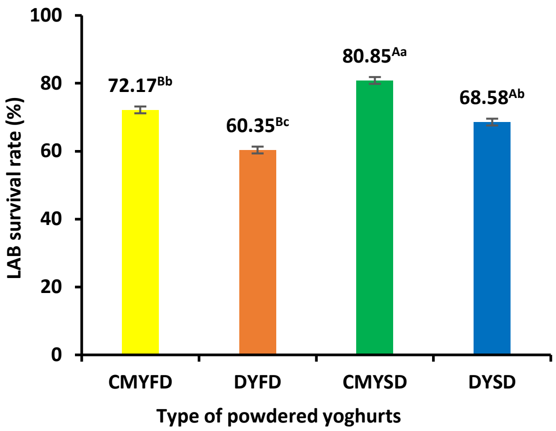

Fig. 5. The LAB survival rate for yoghurt powders treated with two different drying techniques. Values with different superscripts in each column are significantly different (p<0.05). Capital letter superscript indicates the difference between treatments, while lowercase indicates the difference between samples.

The viability of LAB depends on several factors, with the composition of the yoghurt base playing an important role in fermentation efficiency [39]. The higher LAB count observed in dried coconut milk yoghurts may be due to the composition of coconut milk helps to provide a protective environment for the growth of LAB. Coconut milk contains an abundant source of lauric acid as the main source of fats and sucrose as the main source of sugar. A study by Vitheejongjaroen et al. [40] observed the ability of lactic acid bacteria to utilize sucrose for the fermentation of coconut milk. Another study by Huang et al. [41] also observed similar potential of LAB strain in utilizing sucrose in almond milk and found that the fermentation efficiency is better compared to dairy milk fermentation.

Thus, coconut milk can be effectively used as a yoghurt base, retaining high viability of lactic acid bacteria (LAB) due to its unique composition, which enhances the survival and stability of LAB during fermentation and drying processes. Total Coliform Count (TCC) and Total Fungal Count (TFC) are two important microbiological quality assessments that act as indicators of hygiene and sanitation. The presence of coliform in food products indicates poor hygiene of food handlers, as coliform suggests contamination from faecal matter [42]. Coliforms can be pathogenic, particularly *Escherichia coli,* which can lead to foodborne illness [43]. Results from **Table 7** indicate a safe limit of coliform presence, referring to the safe limit set by the Singapore Food Agency for powdered beverages, which states the limit of 100 CFU/g for *Escherichia coli* and 10,000 CFU/mL for Enterobacteriaceae.

A similar result of the safe limit is shown for the TFC, where the general standard regulation has stated that food products must have less than 10 yeasts and moulds/mL [44]. Results obtained showed high sterility being maintained during the processing of the powdered yoghurts. The only growth observed was in the CMYSD sample (3.81 log CFU/mL), which indicates possible contamination during handling of the sample. However, analysis was made on the fresh yoghurt powder, and as El-Sayed et al. [45] suggested, the potential growth of yeast and mould can happen during the storage period.

Table 7. Microbiological quality assessments (TCC and TFC) of yoghurt samples treated with two different drying techniques.

Treatment	Sample	TCC (log CFU/mL)	Presence of *Escherichia coli*	TFC (log CFU/mL)
Freeze dry	CMY	0	Absent	0
	DMY	0	Absent	0
Spray dry	CMY	3.81 ± 0.05	Absent	0
	DMY	0	Absent	0

Note: CMY (Coconut milk yoghurt), DMY (Dairy milk yoghurt).TCC = Total Coliform Count. TFC = Total Fungal Count

Consumer acceptance is one of the major considerations in determining the success of a food product. The attributes in sensory analysis, such as flavour, texture, and appearance, were studied to influence consumer choice [46, 47]. Seven attributes (colour, aroma, taste, sweetness, sourness, aftertaste, and overall acceptability) were rated by sixty untrained panelists using a 9-point hedonic scale for powdered CMY and DY, each of which was prepared by spray-drying (SD) or freeze-drying (FD) (**Fig. 6**).

Overall acceptability scores were found to range from 3.5 (DYFD) to 5.3 (CMYSD), with the same ranking observed across all attributes: CMYSD was rated highest, followed by DYSD, CMYFD, and DYFD. For example, colour ratings were 5.4 for CMYSD and 4.8 for DYFD; aroma ratings were 5.5 to 4.2; taste ratings were 5.2 to 3.9; sweetness ratings were 4.8 to 3.3; sourness ratings were 5.0 to 3.6; and aftertaste ratings were 5.1 to 3.7. From these results, spray-dried CMY was shown to be the most preferred among dried yoghurts, although additional testing is recommended. Although all powdered yoghurts only obtained the average highest score of 5, which interprets as 'Neither like nor dislike', various previous studies have proved the acceptability of coconut milk as a plant-based yoghurt alternative [24, 48, 49], and the low score might be due to the unfamiliarity of powdered yoghurt, as the product is not yet available in Malaysia.

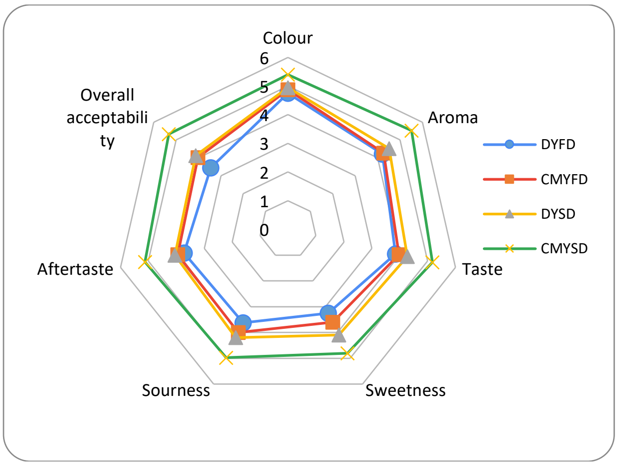

Fig. 6. Sensory evaluation of yoghurt samples treated with two different drying techniques. 1 = 'Dislike extremely' 2 = 'Dislike very much' 3 = 'Dislike moderately' 4 = 'Dislike slightly' 5 = 'Neither like nor dislike' 6 = 'Like slightly' 7 = 'Like moderately' 8 = 'Like very much' 9 = 'Like extremely'.

CONCLUSION

The comparison of coconut-milk (CMY) and dairy-milk (DY) yoghurts dried by two methods reveals clear compositional and functional differences. Coconut milk's higher soluble solids, mainly sucrose and lauric acids, alter the powder's color and reduce its protein content compared to dairy-based yoghurts. However, CMY still supports robust lactic acid bacteria (LAB) fermentation and post-drying viability, thanks to its unique sucrose profile. Both CMY and DY maintain high acidity, which preserves probiotics and extends shelf life. A key limitation is powder stability: oxidation during storage can skew analyses, so assessments must use freshly dried samples. Future work should investigate how storage affects LAB viability and other physicochemical properties in CMY versus DY powders.

CONFLICT OF INTEREST

The authors have declared that no conflict of interest exists.

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