Journal of Oil Palm Research
DOI: https://doi.org/10.21894/jopr.2023.0045

COMPARATIVE STUDY OF PALM-BASED MILK YOGHURT WITH DAIRY AND COCONUT MILK YOGHURT BASED ON PROXIMATE, TEXTURE AND AMINO ACID ANALYSIS

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ABSTRACT

Palm-based milk is one of the derivative products of the local palm oil industry. Currently, it is being sold as an alternative ingredient to coconut milk. However, palm-based milk is a potential ingredient and can be utilised to make new food products. This is in line with the Sustainable Development Goal (SDG) of using local resources to make food products. In this preliminary study, palm-based milk is being developed into a plant-based yoghurt. To assess the feasibility of the palm-based milk yoghurt, seven formulations consisting of a combination of three types of common yoghurt starter cultures were made. These seven formulations of palm-based milk yoghurts will be compared against dairy yoghurts and coconut milk yoghurts of the same formulation. Based on the result, palm-based milk yoghurt has the highest lipid content among the three types of yoghurt. As such, it can be marketed as an energy-dense yoghurt. However, it is lacking in several aspects of proximate and amino acid content, viscosity and high rate of syneresis when compared to the other yoghurt types in this study. Suggestions for mitigating this issue in palm-based milk yoghurt are also given in this study.

Keywords: Amino acids, palm-based milk, proximate analysis, yoghurt.

Received: 25 November 2022; **Accepted:** 25 June 2023; **Published online:** 8 September 2023.

INTRODUCTION

The Sustainable Development Goals (SDGs) are a blueprint for peace and prosperity for the people and the planet that was adopted by all United Nations Member states in 2015 (United Nations, 2015a). Among the 17 goals, two goals stress the need for developing sustainable food production using domestic resources, specifically Target 2.4 and Target 9.b. Target 2.4 of SDG Goal 2 is to ensure sustainable food production systems (United Nations, 2015b) while Target 9.b of SDG Goal 9 is to support domestic technology development (United Nations, 2015c). Therefore, research on developing new food products using local resources or products is an effort that followed the SDGs.

Malaysian palm oil is a sustainable resource (Mohd Hanafiah *et al.*, 2022) but still lacking in economic, environmental and social strategies (Wardhani and Rahadian, 2021). One underutilised palm oil product is palm-based milk (called *Santan* in the Malay language) which was developed by the Malaysian Palm Oil Board (MPOB). The palm-based milk is made with palm oil, emulsifier and coconut flavourings (Zaida Zainal *et al.*, 1997). Presently, palm-based milk is marketed in Malaysia as a raw material and healthier coconut milk replacement. The utilisation of palm-based milk as a replacement for coconut milk in one Malaysian rice dish was similar in the majority of its sensory attributes (Rafidah *et al.*, 2013). If a derivative food product can be made from palm-based milk, then a small food industry can be developed, and this should strengthen the palm oil industry in Malaysia.

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One potential derivative product from palm-based milk is palm-based yoghurt, a plant-based yoghurt. Non-dairy yoghurt is part of the non-dairy probiotic product market which involves inoculating prebiotic starter culture to non-dairy substrates (Kumar *et al.*, 2015). Examples of plant-based yoghurt such as coconut yoghurt (Yaakob Harisun *et al.*, 2012), and yoghurt-like beverages from mixture of cereal, soy and grape must (Coda *et al.*, 2012). Lactic acid bacteria had been found to be able to grow in non-dairy milks based on previous studies. Coconut milk had been found to be able to ferment lactic acid bacteria (Mauro and Garcia, 2019). Palm-based milk can also be developed into non-dairy yoghurt because yoghurt starter culture had been found to be able to grow within the palm-based milk. The lactic acid bacteria had been found to grew up to 8-9 log cfu/mL within the palm-based milk (Hadi Akbar Dahlan *et al.*, 2017). Mixed starter culture of lactic acid bacteria had been found to affect the physical quality of dairy milk (Hadi Akbar Dahlan *et al.*, 2017). However, study regarding the comparison of proximate quality of dairy yoghurts, coconut milk yoghurts and palm-based milk yoghurts formed by mixed lactic acid bacteria cultures into their proximate contents had not been performed. Thus, the objective of this study is to perform a preliminary study on the proximate, texture and amino acid intensity of palm-based milk yoghurt against dairy yoghurt and coconut yoghurt.

MATERIALS AND METHODS

Base Material for Yoghurt Production

Three types of yoghurt were made in this study, namely dairy yoghurt for control comparison, coconut milk yoghurt for comparison with alternative plant-based yoghurt and palm-based milk yoghurt. The dairy milk for dairy yoghurt was made with Farm Fresh Dairy Milk (Farm Fresh, Selangor, Malaysia). M&S brand of ultrahigh temperature (UHT) treated coconut milk was used for coconut milk yoghurt production. Khalis brand (Khalis Santan, Selangor, Malaysia) of palm-based milk were used for palm-based milk yoghurt. All three types of yoghurt base material were commercially available and were bought from a grocery store at Bandar Baru Bangi, Selangor, Malaysia.

Yoghurt Production

Yoghurt formulations for all three substrates were based on seven formulations shown in *Table 1*. The formulation was based on a combination of three yoghurt starter cultures: *Lactobacillus acidophilus*, *L. delbrueckii* sbsp. *bulgaricus* and *Streptococcus thermophilus*. All starter cultures were obtained commercially (Custom Probiotics, California USA). All yoghurts were incubated at 37°C for 20 hr with Trio Yoghurt Maker (Trio Sdn. Bhd., Selangor, Malaysia). All yoghurts were analysed within 3 days after incubation was completed.

Protein Analysis

Protein content of the yoghurt was analysed according to Kjedahl method (Chang, 2010). 1 g of yoghurt sample was placed in a Kjeldahl flask. Concentrated sulphuric acid (98%) was added into the flask and was soaked for 2 hr at 420°C. After digestion, a concentrated sodium hydroxide solution (40%) was added for neutralisation. It was filtrated after 5 min using the filtration system. The filtrate then underwent titration with 0.1 N hydrochloric acid. The titration will determine the nitrogen content. The percentage of nitrogen can be calculated using the following Equation (1):

TABLE 1. THREE COMPONENT MIXTURE DESIGN FOR SEVEN YOGHURT FORMULATION.

Sample: 100 mL substrate (dairy/ coconut/palm milk) Volume of inoculation: 1 g			
Formulation	*Lactobacillus acidophilus*	*Lactobacillus delbrueckii* sbsp. *bulgaricus*	*Streptococcus thermophilus*
1	1	0	0
2	0	1	0
3	0	0	1
4	1/2	1/2	0
5	1/2	0	1/2
6	0	1/2	1/2
7	1/3	1/3	1/3

$$\text{Nitrogen content} = \frac{0.1\ \text{N HCl} \times [(\text{mL } 0.1\ \text{N HCl in sample - mL } 0.1\ \text{N HCl blank})] \times 14 \times 100)}{(\text{Sample weight} \times 1000)} \quad (1)$$

The protein content can be determined by multiplying the nitrogen content with protein factor for dairy product 6.38.

Lipid Analysis

Lipid analysis was done according to the Rose-Gottlieb method (Min and Ellefson, 2010) for both yoghurt products. The lipid was extracted using ether petroleum. 1 g of yoghurt sample was placed inside a Mojonnier flask and was added with 6 mL of boiling water. The mixture was homogenised via vortex until it reached room temperature. After that, 1 mL of ammonia (25% concentrated) was added to the mixture and homogenised for 2 min.

After that, 7.5 mL methanol was added into the mixture and homogenised via vortex for 2 min. 17 mL of diethyl ether was added followed by 17 mL of petroleum ether. The ether mixture was then poured into Mojonnier bowl. The mixture was left to dry on top of a hot plate (C-Mag HP 7, IKA) at a temperature reaching 100°C. The dried matter was weighed after complete drying. The lipid determination was calculated in Equation (2) as follows:

$$\text{Lipid content} = 100 \times \left[\begin{array}{c}(\text{Weight of Mojonnier bowl + Sample})\\ \text{- (Weight of Mojonnier bowl)}\end{array}\right] - \text{Weight of yoghurt sample} \quad (2)$$

Crude Fibre Analysis

About 2-3 g of the yoghurt samples were taken and defatted by soaking in acetone (Sigma Aldrich, United States). After that, the sample was dried and placed into 200 mL of sulphuric acid. The flask was then connected to a condenser at boiling temperature for 30 min. The solution in the flask was whirled throughout the heating process.

The solution in the flask was filtered through a Buchner funnel equipped with filter paper. Residue from the filter paper was then placed into a flask containing 200 mL NaOH at boiling temperature for 30 min. The mixture was then filtered again and washed with boiling water and HCl solution in sequence three times. The final washed was done by washing with petroleum ether. The residue was then heated in the oven at 105°C for 12 hr before weighing (BeMiller, 2010).

Ash Content Determination

Ash content in the yoghurt sample was determined by calcination. About 5-10 g of yoghurt sample was placed in a clay bowl before being heated in a furnace oven (Lindberg/Blue M, Thermo Scientific) at 480°C overnight. The sample was weighed after it had cooled down to room temperature (Marshall, 2010).

Carbohydrate Content Determination

The carbohydrate content of yoghurt samples was determined through calculation. The carbohydrate content calculation which is also known as nitrogen free extract (NFE) calculation in Equation (3) as follows:

$$\text{Carbohydrate content} = 100 - \begin{array}{c}(\text{Protein content}\\ \text{+ Lipid content}\\ \text{+ Ash content +}\\ \text{Moisture content})\end{array} \quad (3)$$

Carbohydrate content calculated by NFE means carbohydrates that are not crude fibres. Monosaccharides and disaccharides are examples of non-crude fibres (Charalampopoulos *et al*., 2002).

Moisture Content

The moisture content in yoghurt samples was determined through the drying process via a drying oven. A total of 5-10 g of yoghurt samples were placed in a clay bowl before being dried in a drying oven at 100°C overnight. After overnight, the weight of the clay bowl was measured to determine the total water content of the yoghurt sample.

Amino Acid Analysis

Amino acid content was determined through acid hydrolysis according to Waters™ accQ.Tag method (Nancy Astephen, 1993). Approximately 0.3 g of sample was poured into a glass stoppered test tube and hydrolysed with 5 mL of 6 N HCl at 110°C for 24 hr. The sample was cooled to room temperature before it was filtered through a filter paper (Sartorius grade 292) into 100 mL volumetric flask. The internal standard (400 µL) (50 µmol/mL α-Aminobutyric Acid (AABA) in 0.1 M HCl) was added and made up to 100 mL with distilled water. The aliquot was filtered through 0.20 mm nylon microfilter.

As for derivatisation, 10 µL of filtered hydrolysated samples or standard were transferred into a 1.5 mL glass vial and 70 µL of borate buffer solution was added and mix well. Then, 20 µL of AccQ Flour reagent (3 mg/mL in acetonitrile) was added to the mixture and thoroughly mixed through vortex for several seconds. 10 µL of samples and standards were injected into the HPLC (Waters 2475, Waters Co., Milford, MA, USA) and the flow rate was set at 1 mL/min. Analysis of the amino acids was performed with AccQ Tag (3.9×150 mm) column. The mobile phase A was Eluent A (200 mL AccQ Tag to 2 L of Milli-Q water) and mobile phase B, was Eluent B (60% acetonitrile).

Yoghurt Viscosity

A rotational viscometer (Brookefield, model DV II, USA) was used to measure the viscosity of the dairy, coconut and palm-based milk yoghurts. Approximately 50 mL of yoghurt in a 50 mL beaker was used as sample during measurement. The viscosity measurements were made at room temperature (27°C) using 10 rpm. The spindle used was Brookefield LV spindle no. 4.

Yoghurt Syneresis

Syneresis is the ability of retaining water in food. About 10-20 g of yoghurt samples were taken and put into centrifuge tubes for analysis. The syneresis was done via centrifuge (Kubota, Japan) at 3300×rpm for 15 min at 4°C. Liquid that was separated from the yoghurt after the centrifugation was taken for weighting. The syneresis percentages was calculated by dividing the weight of separating liquid and weight of the sample and then multiply by 100 (Morell *et al*., 2015).

pH Value Determination

The pH analysis was carried out using a Benchtop pH meter (Mettler Toledo Inc., Parkway, USA). The pH meter calibrated prior to yoghurt pH measurement. Yoghurt samples were measured immediately after the end of the incubation period (Sadler and Murphy, 2010).

Statistical Analysis

Analysis of variance (ANOVA) was performed with Tukey-test using Minitab version 17 (Minitab Pty. Ltd., Sydney). Principal component analysis (PCA) was performed with SIMCA-P+ version 13 (Umetrics, Sweden). All analysis were done in triplicates except for amino acid analysis which were done in duplicate.

RESULTS AND DISCUSSION

Proximate and Texture Comparison

Three types of substrates namely palm-based milk, coconut milk and dairy milk were made into yoghurt by inoculating seven formulations of three types of yoghurt starter culture: *Lactobacillus acidophilus*, *L. delbrueckii* sbsp. *bulgaricus* and *Streptococcus thermophilus* (*Table 1*). The objective for comparing with dairy yoghurt is to compare the proximate and texture characteristics between palm-based milk and normal-type yoghurts (dairy yoghurts). The reason for comparing with coconut milk yoghurt is to observe the differences between palm-based milk yoghurt with another plant-based yoghurt (coconut milk yoghurt).

All seven formulations for each three types of substrates underwent proximate analysis which includes protein, lipid, ash, carbohydrate, and crude fibre content. Besides proximate, the yoghurt samples also underwent yoghurt texture analysis which include viscosity, moisture content, syneresis percentage and pH measurement. Yoghurt viscosity is a non-Newtonian fluid with shear-thinning characteristics (Loveday *et al*., 2013). Since yoghurt viscosity is usually associated with dairy yoghurt, additional measurements such as moisture content, syneresis percentage and pH measurement will be complementary to the texture description of both coconut and palm-based milk yoghurts. Syneresis is described as the expulsion of liquid from the gel matrix that forms the yoghurt texture (Walstra *et al*., 1993). A high syneresis percentage means that gel within the yoghurt structure could not hold liquid and requires additional ingredients such as an emulsifier. The pH of the yoghurt affected the yoghurt texture (Ozcan *et al*., 2015). Lower pH in dairy yoghurts usually indicates the formation of micelle globules that form the texture. It is possible that a similar trend can be seen in non-dairy yoghurts.

To visualise the overall results of proximate and texture among the 21 types of yoghurts, principal component analysis (PCA) was utilised. PCA is a proven dimensional reduction technique to visualise complex data sets into easier interpretation and discussion (Granato *et al*., 2018). *Figure 1* shows the PCA score and loading plot of all three types of yoghurts.

The PCA score plot (*Figure 1a*), shows three clusters of yoghurt samples separated along the PC1. The separation is based on the type of yoghurt (dairy yoghurt, coconut milk yoghurt, and palm-based milk yoghurt). The PCA loading plot (*Figure 1b*) indicates the variables of the analysis. The variables are the proximate and textural analysis performed in this study. The position of the variables in the loading plot corresponds to the position of clusters in the score plot. Based on the loading plot, dairy yoghurts formulations had the highest protein, carbohydrate, viscosity, moisture, and ash content. This can be seen based on the position of the selected variables

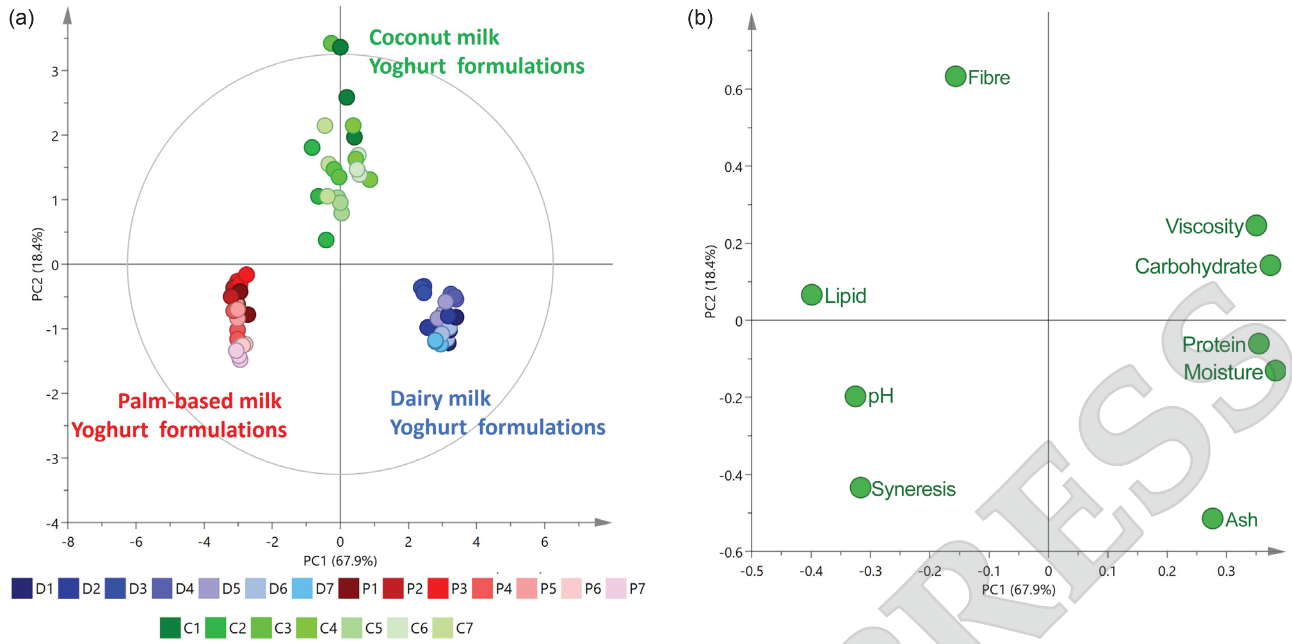

Figure 1. (a) PCA score and, (b) loading plot of all seven yogurt formulations for each dairy yoghurt, coconut milk yoghurt and palm-based milk yoghurt.

at the positive axis of PC1, which correspond to the position of the dairy yoghurts cluster in the score plot.

The loading plot also showed that coconut milk yoghurt formulations had higher fibre content (*Figure 1b*). This indicates that among the palm-based milk yoghurts and coconut milk yoghurts, coconut milk yoghurts had higher fibre content. Dairy milk yoghurts do not contain any fibre content. Palm-based milk yoghurts had the highest lipid content, pH and syneresis percentage. This indicates that palm-based milk yoghurts would be an energy-dense yoghurt but have less acidity and possibly watery. The axis of PC2 in the score plot also showed a trend among the three yoghurts clusters. Based on the clustering, yoghurts formulations with single starter culture inoculation (darker colour) were positioned on the upper part of each cluster. Meanwhile, the mixed starter culture inoculations trailed below in each yoghurt cluster. This indicates that starter culture formulation contributes to the variations of the proximate content and textural properties of the yoghurt. To observe the effect of starter culture formulations, single PCA plots for each yoghurt base were plotted.

The Effect of Starter Culture Formulations

The seven formulations of each yoghurt base influenced the proximate and starter culture. *Figure 2* shows the PCA of all seven formulations of dairy yoghurts and the individual bar graph of all proximate and measured texture parameters. Based on the score plot (*Figure 2a*), all single starter culture of *L. acidophilus* (D1), *L. delbrueckii* sbsp. *bulgaricus* (D2) and *S. thermophilus* (D3) are clustered separately in both PC1 and PC2 axis. This indicates that these starter cultures' ability to grow differed from each other in dairy milk. The capability of these single starter cultures to change the sensory quality and indirectly the proximate and texture quality of dairy yoghurt had been established (McSweeney and Sousa, 2000; Smit *et al.*, 2005). Meanwhile, the mix starter culture formulations (D4 to D7) are positioned from the central axis toward the positive axis of PC1 and PC2. The loading plot (*Figure 2b*) showed that the individual starter culture and mixtures of these starter cultures influenced the proximate and the measured textural qualities.

In this study, formulation 1 (D1) has the highest ash content (*Figure 2f*), viscosity (*Figure 2h*), and lowest syneresis (*Figure 2i*). Meanwhile, formulation 2 (D2) has the highest protein content (*Figure 2c*) and lowest pH (*Figure 2j*). Formulation 3 (D3) has the highest carbohydrate content (*Figure 2e*) but it has the highest syneresis percentage (*Figure 2i*). Formulations 4-7 (D4 to D7) are a mixture of starter cultures (*Table 1*) and each formulation led to different effects. Formulation 7 was a mixture of all starter cultures in the dairy yoghurt that had the highest lipid content (*Figure 2d*). Some starter cultures might have a dominant effect in the mixed formulation. For example, D4 contained *L. acidophilus* has lowered

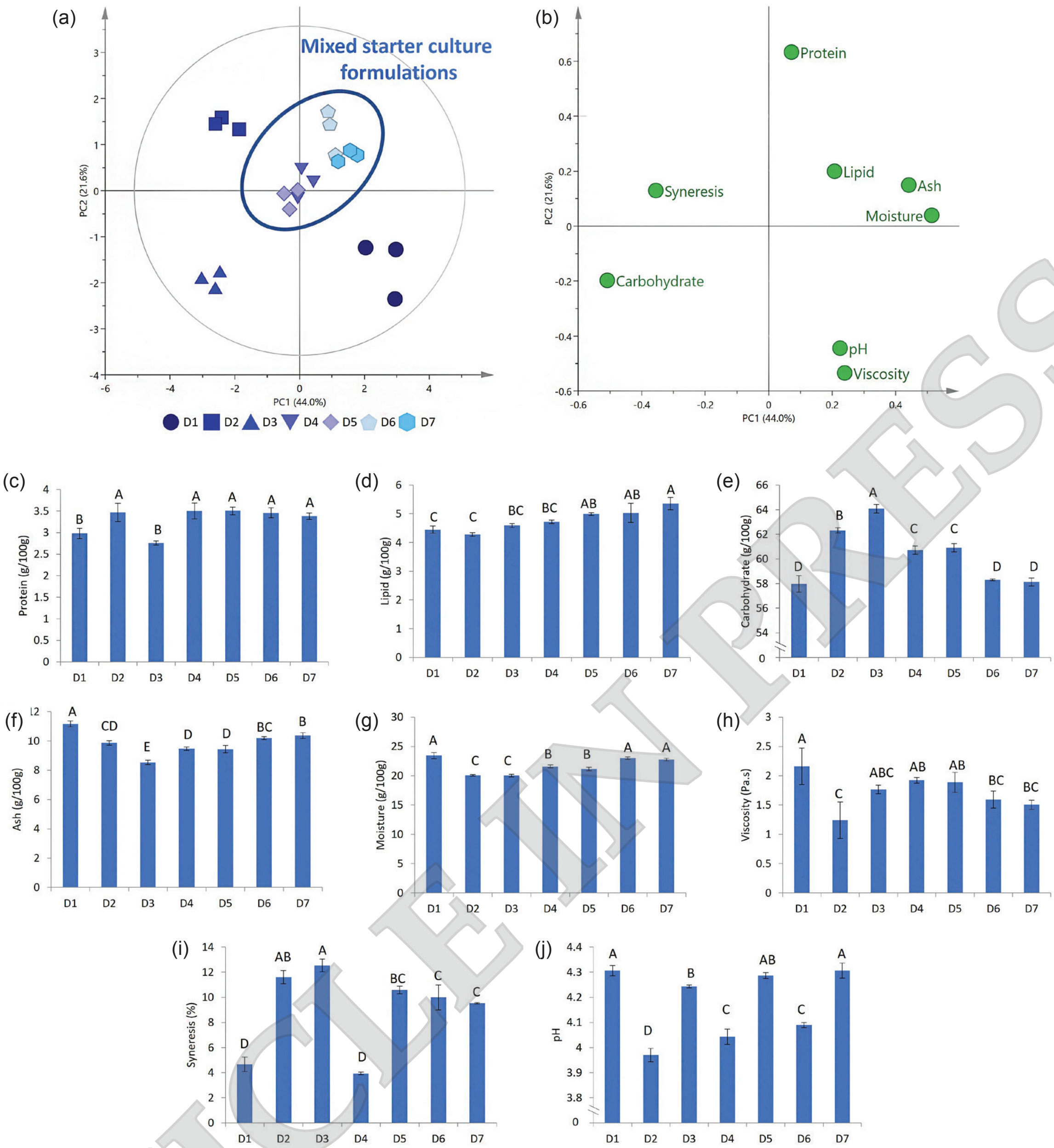

Figure 2. (a) PCA score and, (b) loading plot of all seven yogurt formulations of dairy yoghurts. Bar graph (c) to (j) shows the proximate and texture variables. Different letters between the bar graph denotes significant different (p<0.05) via Tukey's test.

syneresis percentage similar to D1. Another example is formulations that contained *L. delbrueckii* sbsp. *bulgaricus* had lowered pH values (D2, D4 and D6).

Figure 3 shows the PCA of all seven formulations of coconut milk yoghurts and the individual bar graph of all proximate and measured texture parameters. Single starter culture formulations (C1 to C3) were positioned on the negative axis of PC1. The difference of single starter culture was separated along the axis of PC2. Meanwhile, the mixed formulations (C4 to C7) were positioned from the central axis to the positive axis of PC1. Based on the loading plot (*Figure 3b*), the formulation of the starter culture influences the proximate and texture quality. However, based on single bar graphs of the proximate analysis (*Figure 3c-k*), the formulation variation does not affect protein content (*Figure 3c*), fibre (*Figure 3f*), and ash (*Figure 3g*) significantly (p>0.05).

Single starter culture affects the lipid content of the coconut milk yoghurts. Among the three types of starter culture, C2 yoghurt contains only *L. delbrueckii* sbsp. *bulgaricus* had the lowest lipid content (*Figure 3d*). However, C2 yoghurt had the highest carbohydrate content (*Figure 3e*) and pH above 5 (*Figure 3k*). Yoghurt C3 which contains *S. thermophiles* had the highest syneresis percentage (*Figure 3j*) when compared to the other single starter

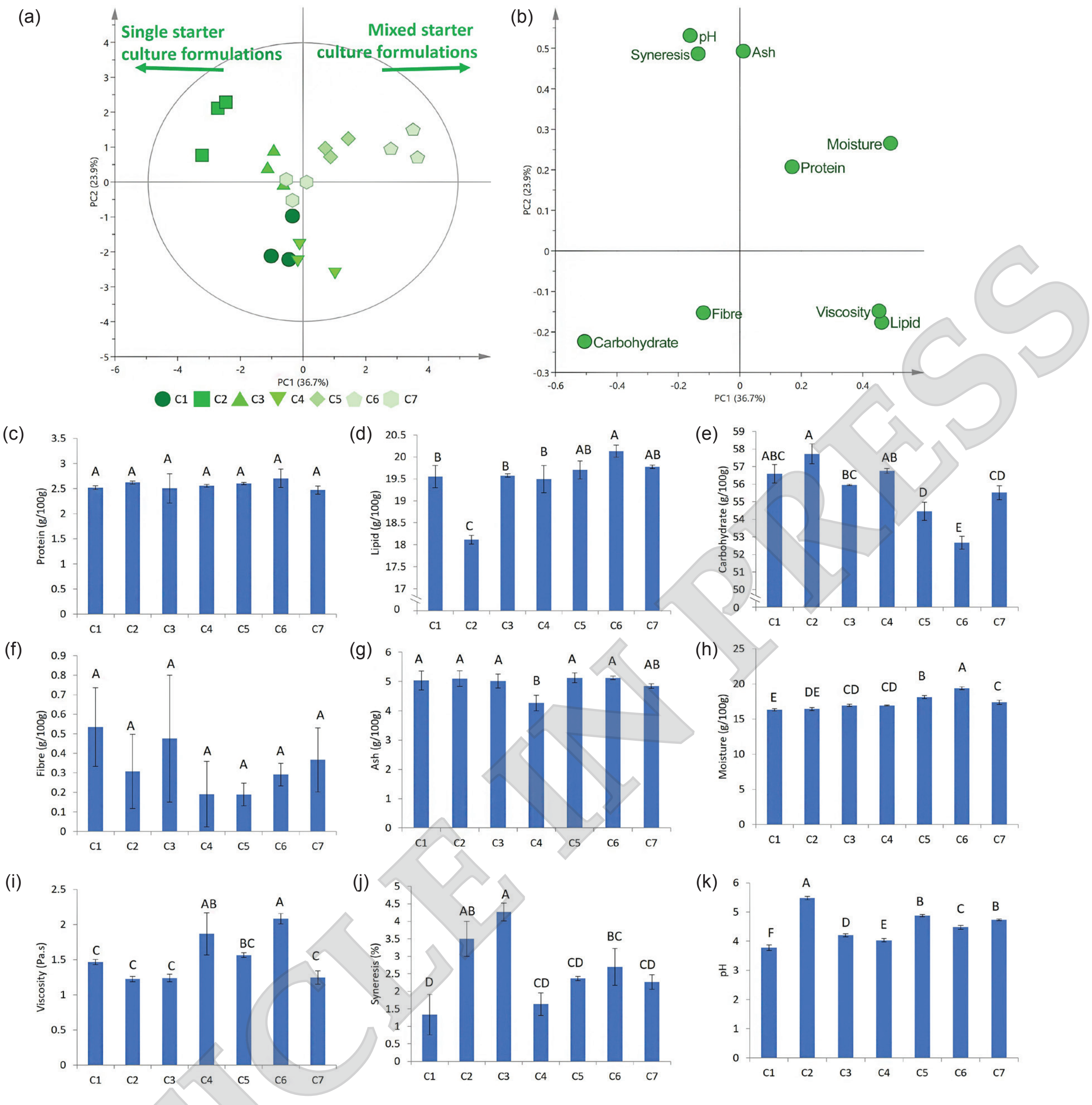

Figure 3. (a) PCA score and, (b) loading plot of all seven yogurt formulations of coconut milk yoghurts. Bar graph (c) to (k) shows the proximate and texture variables. Different letters between the bar graph denotes significant different ($p<0.05$) *via Tukey's test.*

culture formulations. Based on the bar graphs, the mixed starter culture yoghurts have higher lipid content (C6 in *Figure 3d*), moisture content (C6 in *Figure 3h*), contributing toward yoghurt viscosity (C4 and C6 in *Figure 3i*) and lowered syneresis percentage (*Figure 3j*).

Figure 4 shows the PCA of all seven formulations of palm-based milk yoghurts and the individual bar graph of all proximate and measured texture parameters. Based on the score plot (*Figure 4a*), all three single starter culture formulations (P1 to P3) were positioned on the positive axis of PC1. The majority of the mixed starter culture formulations (P4 to P7) were positioned on the negative axis of PC1. Similar to coconut milk yoghurts, the single starter culture formulation was separated along the axis of PC2.

Based on the bar graphs, the variation in starter culture formulation does not affect carbohydrate (*Figure 4e*) and ash content (*Figure 4g*) significantly ($p>0.05$). Single starter culture formulation of palm-based milk yoghurt (P1 to P3) had the highest protein content (*Figure 4c*) and was higher in fibre content (*Figure 4f*) than the mixed culture formulation yoghurts. Among the three types of starter culture, formulation with *L. delbrueckii* sbsp. *bulgaricus* (P2) has the highest lipid content (*Figure 4d*). However, P2 was also the yoghurt with the highest syneresis

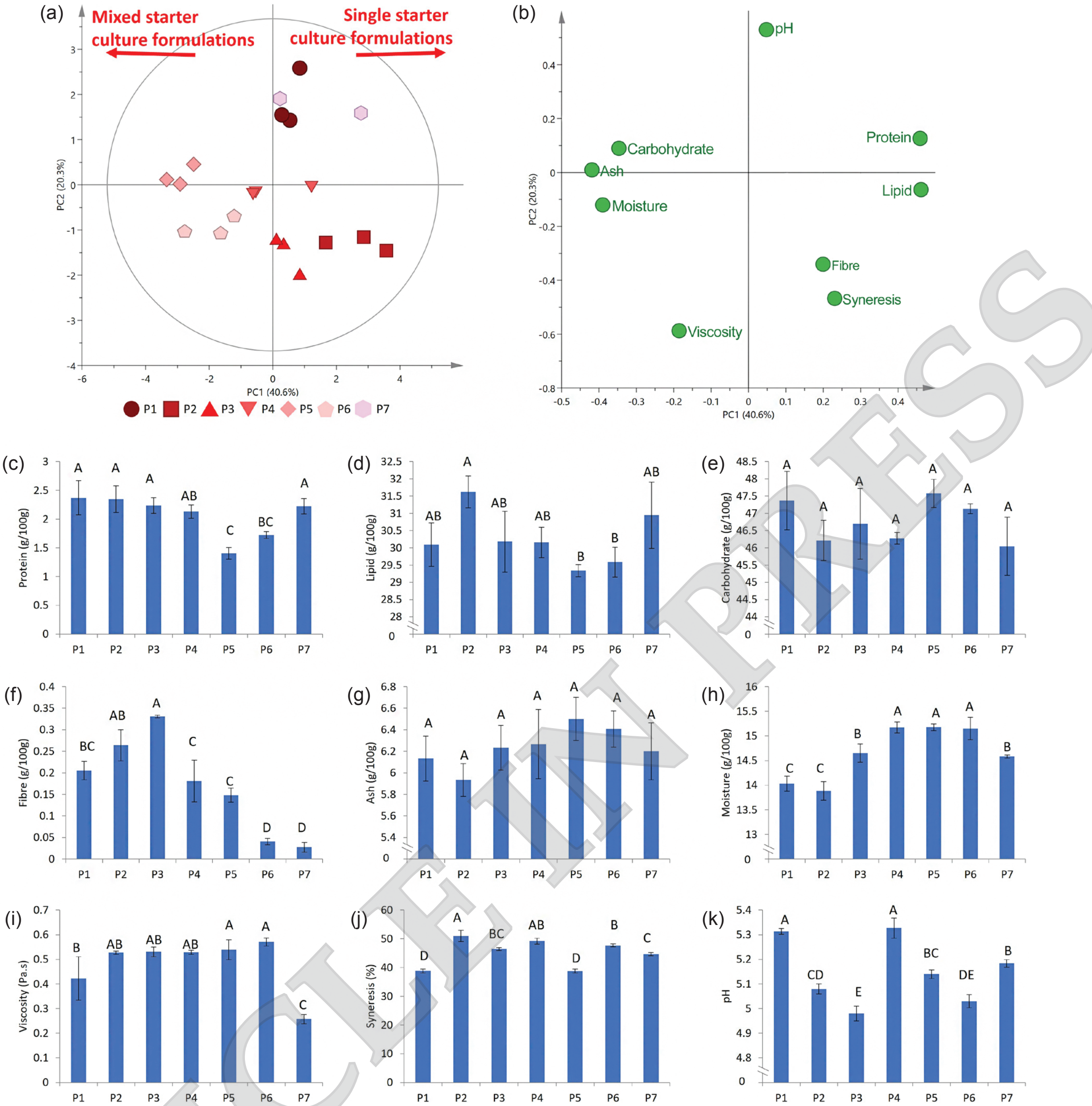

Figure 4. (a) PCA score and, (b) loading plot of all seven yogurt formulations of palm-based milk yoghurts. Bar graph (c) to (k) shows the proximate and texture variables. Different letters between the bar graph denotes significant different (p<0.05) via Tukey's test.

percentage (*Figure 4j*). The mixture of starter culture (P4 to P6) except P7 generally had low protein (*Figure 4c*), lipid (*Figure 4d*) and fibre content (*Figure 4f*). The mixture of starter culture (P4 to P6) also has a higher moisture content (*Figure 4h*), viscosity (*Figure 4i*) and lower pH (*Figure 4k*). Yoghurt P7 which contains all three types of starter culture equivalently (*Table 1*) had an inverse result to other mixed formulation yoghurts (P4 to P6).

Based on the PCA of each yoghurt type, starter culture formulation can influence the proximate content and the textural quality of yoghurts including palm-based milk yoghurts. The next section will discuss the comparison of amino acid contents in palm-based milk yoghurts against both dairy yoghurt and coconut milk yoghurt.

Amino Acid Content Analysis

The amino acid analysis of the yoghurt samples in this study detected 16 types of amino acids. The 16 amino acids are lysine, isoleucine, methionine, leucine, valine, threonine, tyrosine, histidine, serine, phenylalanine, glutamic acid, proline, aspartic acid, alanine, glycine, and arginine. *Figure 5* shows the PCA plot amino acid analysis. The score plot (*Figure 5a*) shows that three types

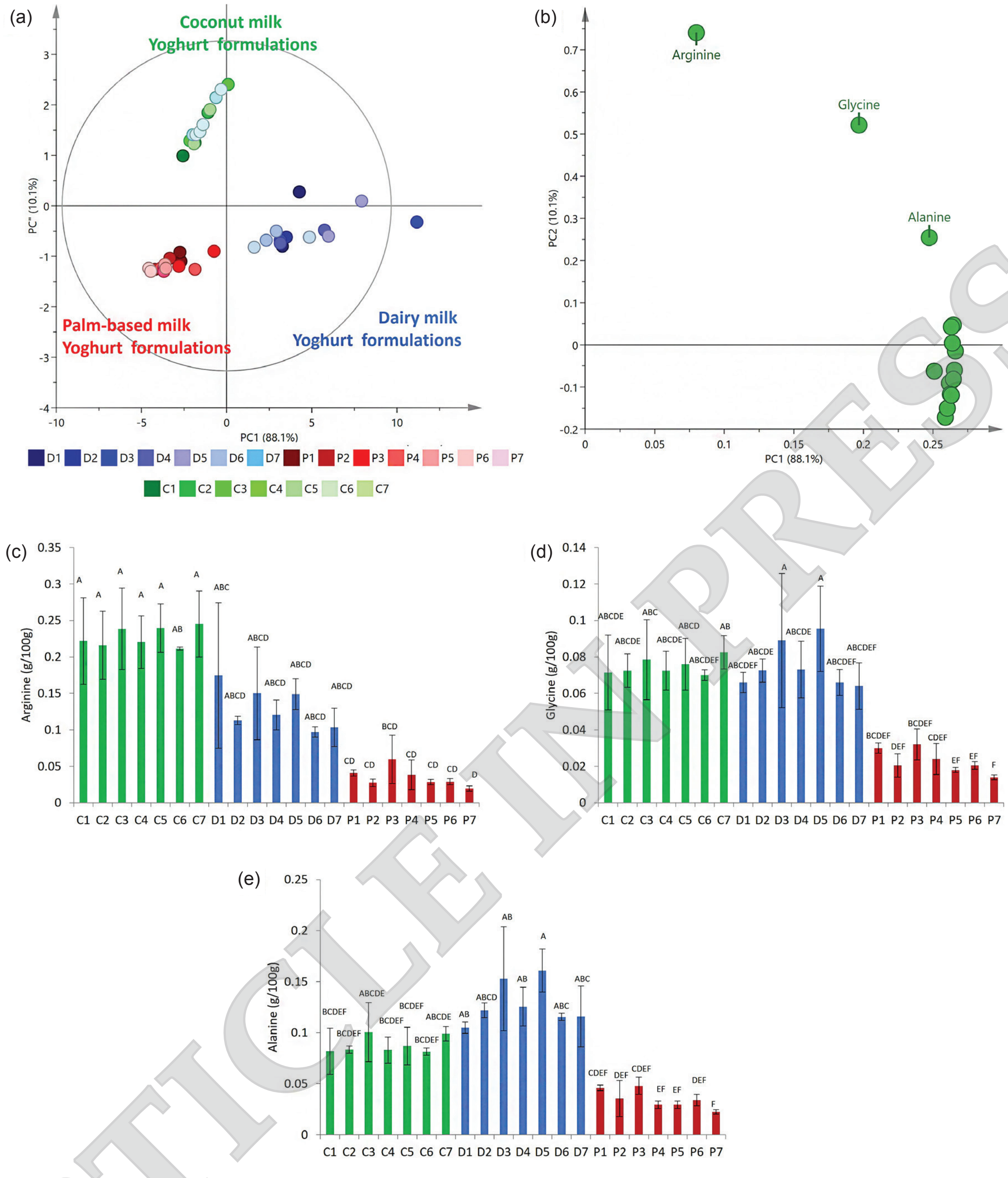

Figure 5. (a) PCA score and, (b) loading plot of amino acid analysis in all yoghurt samples. Bar graphs show selected amino acid of (c) arginine, (d) glycine and (e) alanine. Different letters between the bar graph denotes significant different (p<0.05) *via Tukey's test.*

of yoghurt were different based on the separation along both PC1 and PC2. The dairy yoghurts were positioned on the positive axis of PC1 while both coconut milk yoghurts and palm-based milk yoghurts were positioned on the negative axis of PC1. The axis PC2 separates the coconut milk yoghurts and palm-based milk yoghurts. The yoghurt samples of the same base substrate (dairy, coconut milk or palm-based milk) had similar amino acid profiles. This is shown when the formulations of the same base substrate were clustered together.

Based on the loading plot (*Figure 5b*), the majority of the detected amino acids were positioned on the positive axis of PC1. This indicates that dairy yoghurts have the highest intensity for these amino acids. Only arginine, glycine and alanine were positioned separately from the clusters of amino acids at the positive axis of PC1. The reason for deviation from the majority amino acid cluster can be seen in the bar graph (*Figure 5c-e*). Arginine (*Figure 5c*) content in the majority of coconut milk yoghurt formulations was found to be significantly

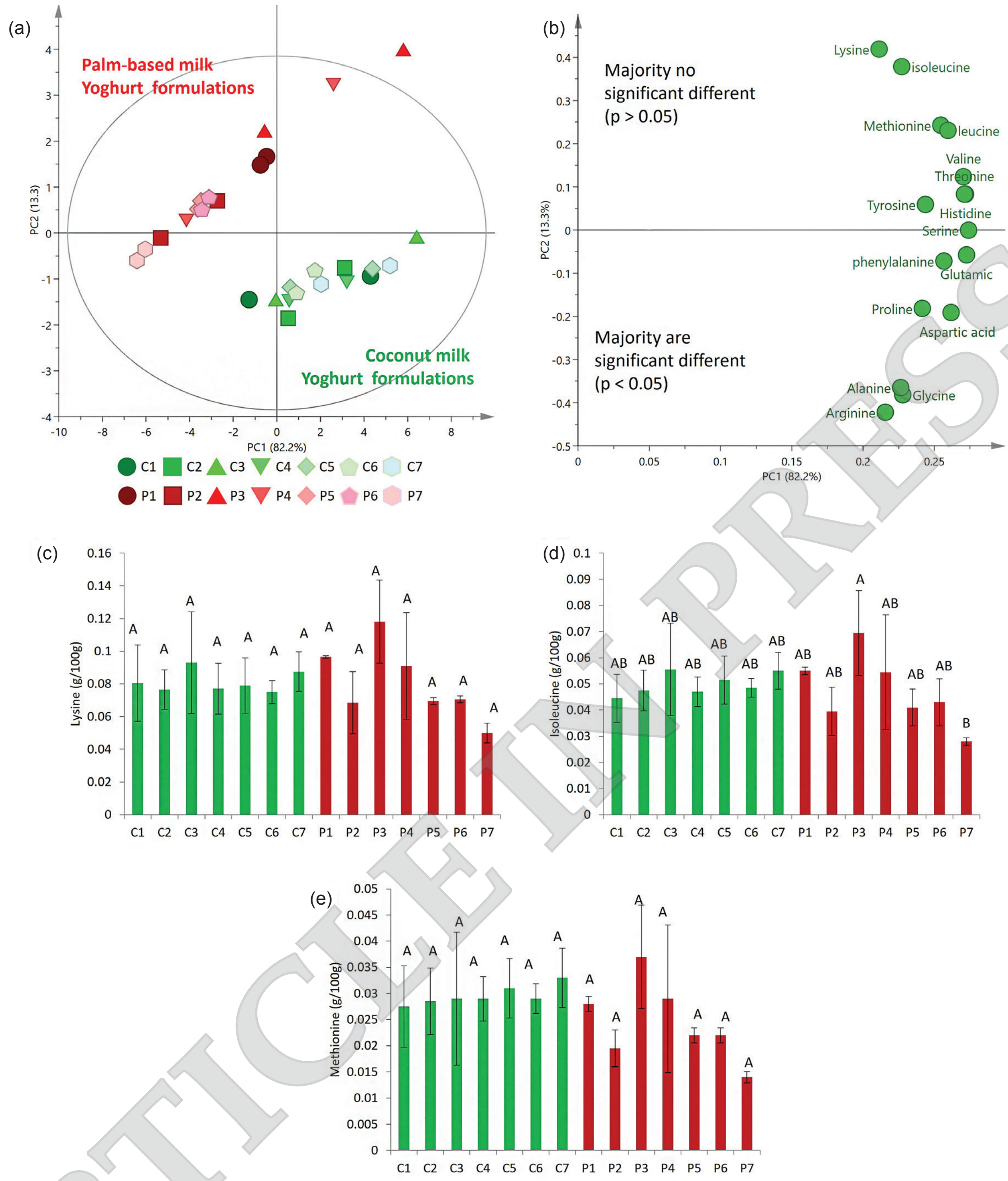

*Figure 6. (a) PCA score and, (b) loading plot of amino acid analysis of non-dairy yoghurt samples in this study. Bar graphs show selected amino acid of (c) lysine, (d) isoleucine and (e) methionine. Different letters between the bar graph denotes significant different (*p<0.05*) via Tukey's test.*

higher ($p<0.05$) than the dairy yoghurts. This result can be expected since coconut had been found to have higher arginine content (Nandanie, 1996; Salil *et al.*, 2011). However, this study is among the first to report this observation in a fermented coconut milk product. Both glycine (*Figure 5d*) and alanine (*Figure 5e*) in the majority of coconut milk yoghurts were found to be not significant ($p>0.05$) with the majority of dairy yoghurt formulations.

To observe the comparison of amino acid content between non-dairy yoghurts, the PCA of coconut milk yoghurts and palm-based milk yoghurts were plotted (*Figure 6*). The score plot shows that there is a separation between clusters of coconut milk yoghurts and clusters of palm-based milk yoghurts along PC1 and PC2 (*Figure 6a*). The separation between the clusters showed that there are differences in amino acid profiles for both types of yoghurts.

The loading plot (*Figure 6b*) shows that the amino acids were positioned on the positive side of the PC1 axis and spread throughout the PC2 axis. Amino acids on the positive side of the PC2 axis were found to be amino acids that are not significantly different (p>0.05) between the majority of palm-based milk and coconut milk yoghurt formulations. This is shown in the bar graph of lysine (*Figure 6c*), isoleucine (*Figure 6d*) and methionine (*Figure 6e*). Alternatively, amino acids on the negative axis of PC2 were found to be significantly higher (p<0.05) in coconut milk yoghurts. This can be seen in the bar graph of arginine (*Figure 5c*), glycine (*Figure 5d*) and alanine (*Figure 5e*). From the result, dairy yoghurts contain the highest intensity for the majority of amino acids except for arginine. Although palm-based yoghurts were found to be the least favourable in terms of amino acid intensity profile, half of the amino acids in palm-based milk yoghurts were comparable to coconut milk yoghurt's amino acid profile.

Suggestions for Palm-based Milk Yoghurt Improvement

Based on the United States Food and Drug Agency regulation for yoghurt, the majority of the palm-based milk yoghurt formulations can be

TABLE 2 PROXIMATE AND AMINO ACID ANALYSIS OF PALM-BASED MILK YOGHURT RECOMMENDED FORMULATION

Analysis	Formulation		
	P1	P2	P3
Protein (g/100g)	2.371 ± 0.297	2.346 ± 0.233	2.237 ± 0.136
Lipid (g/100g)	30.093 ± 0.632	31.624 ± 0.464	30.179 ± 0.882
Carbohydrate (g/100g)	47.371 ± 0.846	46.212 ± 0.586	46.698 ± 1.027
Fibre (g/100g)	0.205 ± 0.021	0.264 ± 0.036	0.331 ± 0.003
Ash (g/100g)	6.133 ± 0.208	5.933 ± 0.153	6.233 ± 0.208
Moisture (g/100g)	14.032 ± 0.153	13.884 ± 0.188	14.653 ± 0.185
Viscosity (Pa.s)	0.42 ± 0.09	0.53 ± 0.01	0.53 ± 0.02
Syneresis (%)	38.80 ± 0.72	50.97 ± 1.95	46.47 ± 0.50
pH	5.310 ± 0.010	5.080 ± 0.020	4.980 ± 0.030
Aspartic acid (g/100g)	0.096 ± 0.004	0.064 ± 0.016	0.105 ± 0.023
Serine (g/100g)	0.063 ± 0.005	0.044 ± 0.011	0.084 ± 0.023
Glutamic (g/100g)	0.225 ± 0.023	0.167 ± 0.045	0.311 ± 0.074
Glycine (g/100g)	0.030 ± 0.003	0.021 ± 0.006	0.032 ± 0.008
Histidine (g/100g)	0.028 ± 0.002	0.020 ± 0.004	0.041 ± 0.012
Arginine (g/100g)	0.041 ± 0.004	0.028 ± 0.005	0.059 ± 0.033
Threonine (g/100g)	0.051 ± 0.001	0.034 ± 0.009	0.06 ± 0.013
Alanine (g/100g)	0.046 ± 0.003	0.036 ± 0.018	0.048 ± 0.008
Proline (g/100g)	0.104 ± 0.013	0.079 ± 0.015	0.116 ± 0.083
Tyrosine (g/100g)	0.036 ± 0.009	0.027 ± 0.008	0.051 ± 0.037
Valine (g/100g)	0.071 ± 0.007	0.052 ± 0.011	0.093 ± 0.026
Methionine (g/100g)	0.028 ± 0.001	0.019 ± 0.004	0.037 ± 0.01
Lysine (g/100g)	0.097 ± 0.001	0.069 ± 0.019	0.118 ± 0.025
Isoleucine (g/100g)	0.055 ± 0.001	0.040 ± 0.009	0.070 ± 0.016
Leucine (g/100g)	0.096 ± 0.003	0.069 ± 0.016	0.130 ± 0.038
Phenylalanine (g/100g)	0.052 ± 0.002	0.038 ± 0.007	0.072 ± 0.023

Note: Mean ± standard deviation; P1 - *Lactobacillus acidophilus*, P2 - *L. delbrueckii* sbsp. *bulgaricus*, P3 - *Streptococcus thermophiles.*

defined as yoghurt. This is because the regulation requires the yoghurt before additional ingredients are added to contain lipids not less than 3.25% and a pH of 4.6 or lower (U.S. Food and Drug Administration, 2022). This can be considered acceptable unless a new ruling regarding the origin of the milk or non-dairy yoghurt will be enacted in the future. However, extensive modifications will be needed to improve the quality of yoghurt.

The proximate contents of palm-based milk yoghurts are lacking when compared to both dairy milk yoghurt and coconut milk yoghurts. The reason for lacking in proximate content is due to the deficiency within the base material itself. From comparison of ash content between non-dairy yoghurts, coconut milk yoghurts had higher ash content than palm-based milk yoghurts. This is because coconut milk itself had higher mineral contents (Santos *et al.*, 2014) and more variety of vitamins (Vitamin A, D and E) (Drewnowski, 2021) than palm oil, which contain lower intensity of mineral content (Li Shuping, 2020) and vitamin E (Abdul Gapor, 1990). Based on the proximate analysis, starter culture formulations do not affect carbohydrate and ash content. Among the seven formulations, single starter culture formulations (P1-P3) were among the recommended due to these formulations had high protein and fibre content. If palm-based milk yoghurt were to be developed into an energy-dense yoghurt, then formulation with *L. delbrueckii* sbsp. *bulgaricus* (P2) will be the recommended starter culture.

Since palm-based milk yoghurt had a low amino acid intensity profile, it should not be marketed to be comparable to the level of dairy yoghurt. This is because palm-based milk yoghurt is a non-dairy yoghurt, and the majority of its amino acid intensity was similar to coconut milk yoghurt, another alternative to dairy yoghurt. As such, it is highly recommended that palm-based milk yoghurt be fortified with other nutrients or enriched with amino acids for it to be on par with coconut milk yoghurts. *Table 2* shows the average and standard deviation of each analysis for the recommended formulation (P1 to P3).

Sensory evaluation was not conducted at this stage because palm-based milk yoghurts are very different from the dairy yoghurts and coconut milk yoghurts. This can be seen from the viscosity of the yoghurts themselves, in which the viscosity of the palm-based milk yoghurts are lesser than 1 Pa.s and significantly lesser than both dairy yoghurts and coconut milk yoghurts (both types has more viscosity (>1 Pa.s)). As such, sensory evaluation for the three types of yoghurt formulation was not perform because sensory evaluation between similar type of food samples that have clear physical differences between them will have apparent bias among the panelist and influence the final result (Kemisola and Olaide, 2021). To improve the textural quality of the palm-based yoghurt, it is recommended that a suitable emulsifier be added to mitigate the low viscosity and high syneresis.

Based on these preliminary analyses and suggestions for improvement, palm-based milk yoghurt is feasible to be developed into a new food product. Successful development of the palm-based milk yoghurt into the market will be a contribution toward sustainable food production by the Malaysian palm oil industry. Since palm-based milk yoghurt utilised local derivative palm oil by-product, this will also contribute toward United Nation's SDG, specifically Goal 2 and 9 of the SDG.

CONCLUSION

This is the first study to report the effect of various starter culture formulations in the development of palm-based milk yoghurt against dairy yoghurt and coconut milk yoghurt in terms of proximate analysis, texture quality and amino acid intensity. Based on the result, palm-based milk yoghurt has the highest lipid content among the three types of yoghurt. However, it is lacking in protein, ash, carbohydrate, fibre contents, viscosity, and high rate of syneresis when compared to the other yoghurt types in this study. The majority of palm-based milk yoghurt's amino acid profiles were comparable to coconut milk yoghurt's amino acid profile. Suggestions for improvement of palm-based milk yoghurt quality include adding a suitable emulsifier to mitigate low viscosity and high rate of syneresis and fortifying the yoghurt with a new nutrient or enriching the amino acids. Successful development of palm-based milk yoghurt into the market is an effort contributing toward the production of new food product using unconventional resources.

REFERENCES

Abdul Gapor (1990). Content of vitamin E in palm oil and its antioxidant activity. *Palm Oil Dev., 12*: 25-27.

BeMiller, J N (2010). Carbohydrate analysis. *Food Analysis*. Boston, MA, Springer US.

Chang, S K C (2010). Protein analysis. *Food Analysis*. Boston, MA, Springer US.

Charalampopoulos, D; Wang, R; Pandiella, S and Webb, C (2002). Application of cereals and cereal components in functional foods: A review. *Int. J. Food Microbiol., 79*: 131-141.

Coda, R; Lanera, A; Trani, A; Gobbetti, M and Di Cagno, R (2012). Yogurt-like beverages made of a mixture of cereals, soy and grape must: Microbiology, texture, nutritional and sensory properties. *Int. J. Food Microbiol., 155***:** 120-127. DOI: 10.1016/j.ijfoodmicro.2012.01.016.

Drewnowski, A (2021). Plant-based milk alternatives in the USDA branded food products database would benefit from nutrient density standards. *Nat. Food, 2***:** 567-569. DOI: s43016-021-00334-5.

Granato, D; Santos, J S; Escher, G B; Ferreira, B L and Maggio, R M (2018). Use of principal component analysis (PCA) and hierarchical cluster analysis (HCA) for multivariate association between bioactive compounds and functional properties in foods: A critical perspective. *Trends Food Sci. Technol., 72***:** 83-90. DOI: 10.1016/j.tifs.2017.12.006.

Hadi Akbar Dahlan; Abdullah Sani, N and Dahlan, I (2017). Logistic-like growth model of *Lactobacillus acidophilus, Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* in Palm Oil *Santan*. *Japan J. Food Eng., 18***:** 155-159. DOI: 10.11301/jsfe.16474.

Hadi Akbar Dahlan and Sani, N A (2017). The interaction effect of mixing starter cultures on homemade natural yogurt's pH and viscosity. *Int. J. Food Stud., 6*.

Kemisola, A and Olaide, A (2021). Understanding sensory evaluation of food (*Oluwatosin Ademola, I ed.). Food Science and Technology.* Berlin, Boston: De Gruyter.

Kumar, B V; Vijayendra, S V N and Reddy, O V S (2015). Trends in dairy and non-dairy probiotic products - A review. *J. Food Sci. Technol.***,** *52(10)*: 6112-6124.

Li Shuping (2020). Analysis of trace elements in palm oil using ICP-OES. *Agilent Application Brief.* Agilent Technologies, Inc.

Loveday, S M; Sarkar, A and Singh, H (2013). Innovative yoghurts: Novel processing technologies for improving acid milk gel texture. *Trends Food Sci. Technol., 33***:** 5-20. DOI: 10.1016/j.tifs.2013.06.007.

Marshall, M R (2010). Ash analysis. *Food Analysis.* Boston, MA, Springer US.

Mauro, C S I and Garcia, S (2019). Coconut milk beverage fermented by *Lactobacillus reuteri*: Optimization process and stability during refrigerated storage. *J. Food Sci. Technol., 56***:** 854-864. DOI: 10.1007/s13197-018-3545-8.

McSweeney, P L and Sousa, M J (2000). Biochemical pathways for the production of flavour compounds in cheeses during ripening: A review. *Le Lait, 80***:** 293-324.

Min, D B and Ellefson, W C (2010). Fat analysis. *Food Analysis.* Boston, MA, Springer US.

Mohd Hanafiah, K; Abd Mutalib, A H; Miard, P; Goh, C S; Mohd Sah, S A and Ruppert, N (2022). Impact of Malaysian palm oil on sustainable development goals: Co-benefits and trade-offs across mitigation strategies. *Sustain. Sci., 17***:** 1639-1661. DOI: 10.1007/s11625-021-01052-4.

Morell, P; Piqueras-Fiszman, B; Hernando, I and Fiszman, S (2015). How is an ideal satiating yogurt described? A case study with added-protein yogurts. *Food Res. Int., 78***:** 141-147. DOI: 10.1016/j.foodres.2015.10.024.

Nancy Astephen (1993). *WatersAccQ.Tag Method for Hydrolysate Amino Acid Analysis*. 1st edition. Milford USA: Milipore Corporation.

Nandanie, D E (1996). King coconut. *CORD, 12(2)***:** 34. DOI: 10.37833/cord.v12i02.304.

Ozcan, T; Horne, D S and Lucey, J A (2015). Yogurt made from milk heated at different pH values. *J. Dairy Sci., 98***:** 6749-6758. DOI: 10.3168/jds.2015-9643.

Rafidah, A H; Zaida, Z; Nur, I and Miskandar, M S (2013). A comparative study of the effects of processing conditions and formulations on the physical and sensory properties of frozen nasi lemak made of palm-based santan and coconut santan. *J. Oil Palm Res., 25***:** 170-179.

Sadler, G D and Murphy, P A (2010). pH and titratable acidity. *Food Analysis.* Boston, MA: Springer US.

Salil, G; Nevin, K G and Rajamohan, T (2011). Arginine rich coconut kernel protein modulates diabetes in alloxan treated rats. *Chem. Biol. Interact., 189***:** 107-111. DOI: 10.1016/j.cbi.2010.10.015.

Santos, D C M B; Carvalho, L S B; Lima, D C; Leão, D J; Teixeira, L S G and Korn, M G A (2014). Determination of micronutrient minerals in coconut milk by ICP OES after ultrasound-assisted extraction procedure. *J. Food Composit. Anal., 34***:** 75-80. DOI: 10.1016/j.jfca.2014.02.008.

Smit, G; Smit, B A and Engels, W J (2005). Flavour formation by lactic acid bacteria and biochemical flavour profiling of cheese products. *FEMS Microbiol. Rev., 29***:** 591-610.

U.S. Food and Drug Administration (2022). Sec. 131.200 Yogurt. *Code of Federal Regulations Title 21.* United States.

United Nations (2015a). *The 17 Goals*. New York, United States: United Nations. https://sdgs.un.org/goals, accessed on 30 October 2022.

United Nations (2015b). (Goal 2 - End hunger, achieve food security and improved nutrition and promote sustainable agriculture.) https://www.un.org/sustainabledevelopment/hunger/, accessed on 27 October 2022.

United Nations (2015c). *Goal 9* - Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. https://www.un.org/sustainabledevelopment/infrastructure-industrialization/, accessed on 27 October 2022.

Walstra, P; Noomen, A; Geurts, T and Fox, P (1993). Cheese: chemistry, physics and microbiology. *Chapmann and Hall, London***,** 141.

Wardhani, R and Rahadian, Y (2021). Sustainability strategy of Indonesian and Malaysian palm oil industry: A qualitative analysis. *Sustain. Account. Manag. and Policy J., 12***:** 1077-1107. DOI: 10.1108/SAMPJ-07-2020-0259.

Yaakob Harisun; Ahmed Nor Rashidah; Daud Siti Khairunnisa; Malek Roslinda Abd and Rahman Roshanida Abdul (2012). Optimization of ingredient and processing levels for the production of coconut yogurt using response surface methodology. *Food Sci. Biotechnol., 21***:** 933-940.

Zaida Zainal; Mohd Suria Affandi Yusoff; Noor Lida Habi; Muhammad Nor Omar and Burhanuddin Abd Salam (1997). Production and caharacterization of palm-based santan powder. *PORIM Information Series,* PORIM TT No. 45.