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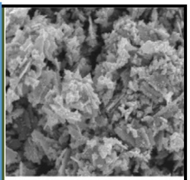

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Physicochemical, Microbiological, and Sensory Properties of Almond Milk Yogurt-Like Products with Varied Concentrations of Tapioca Starch as Stabilizer

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ABSTRACT

This study investigates the impact of tapioca starch concentrations on almond milk yoghurt-like products, aiming to enhance their physicochemical and sensory properties. Almond milk with varying tapioca starch levels (0%, 1%, 2%, 3%) underwent pasteurization, and development into yoghurt. The findings indicated that, among the variables examined, tapioca starch emerged as a significant factor influencing specific physicochemical properties, notably viscosity, whereas the fermentation period demonstrated less notable impact. While commercial dairy yoghurt exhibited superior texture attributes, tapioca starch did not significantly affect color or lactic acid bacteria viability. Almond milk yoghurt-like products with 3% tapioca starch showed improved texture but still lagged behind commercial dairy yoghurt in overall sensory acceptance. The study suggests further development is necessary to enhance almond milk yoghurt-like products' consumer acceptability.

INTRODUCTION

Plant-based milk alternatives, derived from various sources like almonds, face challenges such as phase separation affecting texture. Almond milk's oil-in-water emulsion structure makes it susceptible to instability, and prone to issues like phase separation, creaming, flocculation, and particle agglomeration due to physicochemical mechanisms [1]. To address texture issues, hydrophilic gums like xanthan gum are added as stabilizers, also acting as gelling agents. However, plant-based yogurts encounter limited popularity due to textural differences compared to dairy yogurts [2]. Consumer preferences for plant-based milk alternatives hinge on positive qualities like sweetness and creaminess, while off-flavors, such as those from lipoxygenases, detract from acceptance [3]. The study aims to test two hypotheses: first, that almond milk yogurt-like (AYML) with varying stabilizers (tapioca starch) differs in physicochemical and microbiological properties compared to dairy yogurt (DY), and second, that AYML has inferior sensory acceptance compared to DY. Objectives include investigating the impact of tapioca starch concentrations on physicochemical, microbiological, and sensory properties of AYML, and assessing consumer acceptance through sensory evaluation, comparing it with DY.

MATERIALS AND METHOD

Almond milk (Farm Fresh Milk Sdn Bhd, Johor, Malaysia), fine granulated sugar (MSM Prai Berhad, Pulau Pinang, Malaysia), tapioca starch (Cap Kapal ABC, Pulau Pinang, Malaysia), commercial dairy yoghurt (Malaysia Milk Sdn. Bhd., Selangor, Malaysia) and yogurt starter culture containing *Streptococcus thermophilus*, *Lactobacillus bulgaricus* (Belle+Bella, Canada) were sourced locally. Yogurt-like products were formulated by

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adjusting tapioca starch concentrations (**Table 1**), with commercial dairy yogurt as a positive control and a tapioca starch-free AYML as a negative control. The production process involved pasteurization, inoculation with a 0.5% (w/v) starter culture, and an 8 h incubation at 40-43°C. The samples were then quickly cooled and stored at 4°C for a maximum of 14 days [4].

Table 1. The formulations of the almond milk yogurt-like (AYML).

Ingredients	Formulations			
	0%	1%	2%	3%
Almond milk	100	100	100	100
Sugar	5	5	5	5
Tapioca starch	-	1	2	3
Starter culture	0.5	0.5	0.5	0.5

Physicochemical properties, including pH, colour (expressed in CIELAB coordinates L*, a*, b*), viscosity (texture analyzer model TA.XT2i), and texture profile analysis, were assessed. The microbiological analysis involved measuring total lactic acid bacteria (LAB) count (log CFU/g) using De Man, Rogosa, and Sharpe (MRS) agar under anaerobic conditions. Sensory evaluation, conducted by 50 untrained panelists aged 19-22 years old, employed a 9-point hedonic scale to rate attributes such as color, aroma, texture, taste, and overall acceptability. Statistical analysis, performed using Minitab® Version 21.3.1, included a One-way Analysis of Variance (ANOVA) and Paired T-test, with Tukey's test for post hoc analysis. Significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

The physicochemical properties in almond milk yoghurt-like (AMYL) and dairy yoghurt (DY) are summarised in **Table 2**. Notably, significant differences emerged between AMYL and DY on day 1, with DY consistently maintaining a lower pH, attributed to post-acidification by acid-resistant *L. bulgaricus* [5]. Interestingly, the control (0% AMYL) exhibited higher pH (5.06) than other AYML treatments, contrary to a study by Altemimi (2018) where the addition of a stabilizer increased the pH due to lack of water for LAB fermentation [6]. Viscosity in AMYL, influenced by increased tapioca starch, significantly differed on day 1, aligning with Pachekrepapol et al. (2021) [7]. Tapioca starch enhanced the gel network by expanding starch granules and absorbing water, improving particle interactions. In comparison, DY consistently maintained significantly higher viscosity, attributed to greater molecular interaction in DY [8]. Storage time had an insignificant effect on viscosity for both AMYL and DY.

LAB counts in AMYL varied from 0 to 7 log CFU/g on days 1 and 14. 3% AMYL showed no detectable LAB on day 1, likely due to starch concentration inhibiting bacterial viability. Over 14 days, all samples exhibited a non-significant decrease in LAB, potentially influenced by low storage temperature inhibiting bacterial growth [8]. Tapioca starch concentrations did not affect AMYL color parameters, while significant differences existed between DY and AMYL. DY had higher L* values, indicating brighter yogurt, influenced by the particle size of protein clusters and fat globules affecting light reflection [9]. AMYL had higher b* values on day 1, attributed to almond milk's brown color leaning towards yellowness. Over time, L* and b* values increased, while a* values decreased, except for 3% AMYL. Storage time insignificantly affected AMYL color parameters, except for 0% AMYL.

DY demonstrated significantly higher firmness, consistency, and cohesiveness compared to AMYL. Firmness, an essential parameter for yogurt texture, was significantly different between DY and AMYL, with DY being firmer due to its higher protein content. The superior texture of dairy yogurt compared to almond milk yogurt is attributed to the thicker viscosity inherent in dairy products, providing a more consistent and desirable mouthfeel.

The addition of tapioca starch, however, did not significantly affect the consistency of almond milk yogurt, suggesting that other factors such as the unique composition and structure of almond milk may limit the effectiveness of starch in modifying its texture. Likewise, tapioca starch did not affect cohesiveness, unlike DY which had significantly lower cohesiveness, contributing to smoother yoghurt texture correlated with internal bond strength [10].

Table 2. pH of almond milk yogurt-like (AYML) products and dairy yogurt (DY) on Day 1 and Day 14.

Parameters	Day	Samples (% indicates tapioca starch with AYML)				
		0%	1%	2%	3%	DY
pH	1	5.06 ± 0.01^{aA}	4.94 ± 0.01^{cA}	5.03 ± 0.03^{abA}	4.97 ± 0.02^{bcA}	4.32 ± 0.03^{dA}
	14	5.05 ± 0.04^{aA}	4.89 ± 0.03^{bA}	4.95 ± 0.05^{bA}	4.90 ± 0.03^{bA}	4.24 ± 0.04^{cA}
Viscosity (m.Pas)	1	11.00 ± 0.56^{dA}	12.23 ± 0.47^{cdA}	13.20 ± 0.17^{bcA}	14.33 ± 0.25^{bA}	53.90 ± 1.04^{aA}
	14	11.60 ± 0.10^{bA}	12.87 ± 0.42^{bA}	14.43 ± 0.06^{bA}	15.6 ± 0.30^{bA}	48.27 ± 6.79^{aA}
LAB count (log CFU/g)	1	7.08 ± 0.55^{aA}	5.48 ± 0.07^{bA}	7.74 ± 0.47^{aA}	6.12 ± 0.50^{bA}	4.37 ± 3.94^{abA}
	14	4.20 ± 1.66^{bA}	4.52 ± 1.14^{bA}	6.76 ± 1.12^{aA}	6.77 ± 1.20^{aA}	3.71 ± 3.22^{aA}
Firmness		25.95 ± 0.00^{aA}	27.26 ± 0.72^{aA}	29.48 ± 4.11^{aA}	30.62 ± 3.18^{aA}	73.23 ± 17.01^{bA}
Consistency	1	145.21 ± 0.22^{bA}	144.41 ± 4.42^{bA}	154.42 ± 15.03^{bA}	142.89 ± 0.28^{bA}	324.42 ± 17.10^{aA}
Cohesiveness		-7.16 ± 0.40^{aA}	-6.61 ± 0.34^{aA}	-10.57 ± 6.66^{aA}	-6.80 ± 0.41^{aA}	-29.66 ± 6.49^{bA}
Firmness		27.28 ± 0.28^{bA}	27.16 ± 0.65^{bA}	49.07 ± 11.25^{abA}	57.32 ± 1.38^{abB}	72.10 ± 23.20^{aA}
Consistency	14	148.28 ± 4.49^{bA}	148.58 ± 5.05^{bA}	169.13 ± 14.19^{bA}	336.11 ± 5.08^{aB}	313.54 ± 12.06^{aA}
Cohesiveness		-8.01 ± 0.93^{aA}	-7.62 ± 0.31^{aA}	-5.86 ± 2.81^{aA}	-24.40 ± 0.41^{bB}	-31.42 ± 10.19^{bA}
L*		57.44 ± 1.07^{bA}	55.91 ± 1.68^{bA}	57.88 ± 1.86^{bA}	57.30 ± 1.30^{bA}	70.04 ± 0.28^{aA}
a*	1	5.14 ± 0.05^{aA}	4.94 ± 0.25^{aA}	5.06 ± 0.07^{aA}	4.93 ± 0.09^{aA}	-0.27 ± 0.16^{bA}
b*		9.03 ± 0.32^{aA}	8.71 ± 0.46^{abA}	9.22 ± 0.32^{aA}	9.06 ± 0.28^{aA}	8.07 ± 0.23^{bA}
L*		66.19 ± 1.19^{bB}	66.02 ± 1.78^{bA}	65.20 ± 1.19^{bA}	67.38 ± 2.33^{bA}	79.72 ± 3.11^{aA}
a*	14	4.03 ± 0.02^{cB}	4.10 ± 0.08^{cA}	4.51 ± 0.14^{bA}	5.02 ± 0.07^{aA}	-1.92 ± 0.19^{dB}
b*		12.25 ± 0.12^{cB}	12.25 ± 0.45^{cA}	12.84 ± 0.31^{bcA}	13.99 ± 0.51^{bA}	15.30 ± 0.77^{aA}

Values are expressed as mean ± SD, (n = 3). [a-d] Means with different superscripts within the same row were significantly different ($p < 0.05$). [A-B] Means with different superscripts within the same column are significantly different ($p < 0.05$).

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Table 3 highlights the sensory attributes of AMYL products and DY. Significant differences existed in sensory scores, with AMYL showing no significant variation in color, aroma, taste, and overall acceptability. DY's preferred white color influenced sensory preference, while AMYL's brownish hue, attributed to almond milk color, impacted likability. DY had a very pleasant aroma, surpassing AMYL's slightly pleasant nutty aroma. In terms of texture, DY ranked the highest, followed by decreasing concentrations of AMYL (3%, 1%, 2%). Higher tapioca starch concentrations enhanced AMYL's thickness, positively impacting likeliness scores [11-12]. DY received the highest taste and overall acceptability scores, outperforming all AMYL samples.

Table 3. Sensory attributes of almond milk yoghurt-like (AYML) products and dairy yoghurt (DY).

Samples	Colour	Aroma	Texture	Taste	Overall acceptability
0%	6.38 ± 1.55^a	5.54 ± 1.73^a	4.38 ± 1.86^a	4.40 ± 2.13^a	4.74 ± 1.83^a
1%	6.04 ± 1.67^a	5.20 ± 1.91^a	5.30 ± 1.80^{ab}	4.22 ± 1.80^a	4.62 ± 1.68^a
2%	6.22 ± 1.48^a	5.70 ± 1.74^a	4.46 ± 1.64^a	4.70 ± 1.89^a	5.02 ± 1.67^a
3%	6.42 ± 1.44^a	5.12 ± 1.84^a	6.10 ± 2.15^b	4.92 ± 1.87^a	5.36 ± 1.58^a
DY	8.10 ± 1.06^b	7.76 ± 1.33^b	8.02 ± 1.08^c	8.16 ± 1.20^b	8.22 ± 0.89^b

Values are expressed as mean ± SD, (n = 3). $^{a-b}$ Means with different superscripts within the same row were significantly different ($p < 0.05$). $^{A-B}$ Means with different superscripts within the same column are significantly different ($p < 0.05$).

CONCLUSION

Tapioca starch as a stabilizer influenced the physicochemical and sensory aspects of almond milk yogurt-like products, highlighting the potential as a dairy yogurt substitute. Despite improvements, the lower consumer acceptance suggests the need for further optimization to compete effectively with traditional dairy yogurt.

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