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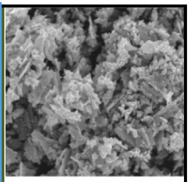

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Physicochemical and Rheological Properties of Palm-milk Cheese Analog Using Starches from Different Malaysian Rice Cultivars

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ABSTRACT

The development of new rice varieties in Malaysia (NMR and Putra 2) has presented the need to characterize their techno-functional properties in food production. Starch, a main component of rice, has been applied in developing plant-based cheese analogs to mimic the textural characteristics of conventional dairy cheese. This study aimed to determine the effect of different types of starch on the physicochemical, textural, and thermal properties of palm milk cheese analog (PMCA). A total of 4 samples were produced with 0% starch as negative control (Sample A), 2% Putra 2 rice starch (B), 2% NMR rice starch (C), and 2% corn starch as positive control (D). The samples were subjected to physicochemical analyses of water activity, pH, titratable acidity, colour. Results indicated that PMCA showed greater storage moduli than the loss moduli representing dense interlinked weak gels supported by a less compact structure, and a rough surface was observed in the microstructure of samples with starch. In conclusion, the incorporation of different types of starches had a significant effect on the rheological properties of the PMCAs while having no significant differences on their physicochemical properties.

INTRODUCTION

The main technological challenge in developing palm milk-cheese analog (PMCA) is to mimic the texture of conventional cheese analog. The complexity of interaction between protein and fat globules in animal milk leads to the obstacle in approaching a similar texture as conventional cheese analog. Starch is one of the functional ingredients used in cheese analog production to modify desired texture and functional properties. Starch can be added in the cheese analog formulation as a replacement for rennet with relatively low cost and great availability [1]. The incorporation of starch into cheese analog has gained interest for its potential health benefit and economic advantage; the starch-protein interaction influences the rheological properties of cheese analog. Mounsey & O'Riordan [2] concluded that among different types of starches (corn, potato, wheat, rice), rice starch showed the potential to replace casein partially in cheese imitation because of its low amylose content and limited swelling capacity resulting in products with acceptable rheological characteristics [2]. The properties of starch including the shape, size, swelling ability, and the amylose/amylopectin ratio are important factors in influencing and modifying the physicochemical and functional properties of the cheese analog [1]. Lyu et al. [3] reported that the majority of the commercially available plant-based cheeses are starch-based and associated with poor melting properties suggesting the addition of fat and protein to modify the structure and melting characteristics of the plant-based cheese. In this study, cheese analog with corn starch served as a positive control when compared with cheese analog made from two different types of rice starch (NMR and Putra 2). Due to the lack of data on the application of starches from Malaysian rice varieties in plant-based food product, the objective of this study was to determine the effect of starchers from different Malaysian rice cultivars on the physicochemical properties of palm-milk cheese analog.

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MATERIALS AND METHODS

NMR and Putra 2 rice were purchased from a wholesaler in Sekinchan, Selangor, Malaysia, while palm milk, vinegar, nutritional yeast, papain, carrageenan, and chickpea flour were purchased from local store in Putrajaya, Malaysia. The rice starch from the rice variety of NMR and Putra 2 was prepared according to the procedure used by Tangsrianugul et al. [4] through an alkaline steeping method. The palm milk cheese analogs were prepared according to Ferawati et al. [5]. The color of the sample was measured using a chromameter (CR-410, Konica Minolta, Inc., Osaka, Japan).

For other analyses, the sample was blended with distilled water at a ratio of 1:10. The water activity of the sample was determined using a water activity meter while the pH of the mixture was measured using a pH meter (BP3001, Trans Instruments, Singapore). The titratable acidity of the sample was acquired through the direct titration method [6]. The viscoelastic properties of the cheese analogs were measured using a dynamic oscillatory shear rheometer. The settings of the rheometer for analysis were based on Černíková et al. [7]. A plate-plate geometry of 35 mm diameter and a gap of 1 mm was used. The analysis was done in a control shear stress mode at 20 °C and frequency ranging from 1 to 100.00 Hz. The storage modulus (G´) and loss modulus (G´´) were the selected monitored parameters. The loss tangent (tan δ) and complex modulus (G^*) were calculated using Equation 8 and Equation 9 respectively. The loss tangent and complex modulus were reported at a frequency of 1 Hz.

$$\tan\delta = \frac{G''}{G'} \qquad \text{(Equation 8)}$$

$$G^* = \sqrt{(G')^2 + (G'')^2} \qquad \text{(Equation 9)}$$

Significant differences between mean values were established by using one-way ANOVA and Tukey's test at $p \leq 0.05$ with Minitab Statistical Software Version 21.4 (Minitab, LLC).

RESULT AND DISCUSSION

Physicochemical properties

During the production of cheese, pH is an important parameter to ensure its microbial safety and unique flavor profile with a slightly acidic taste. PMCA produced exhibited slightly acidic properties with pH values of 5.85 to 5.88 as shown in Table 1, which is slightly higher than the plant-based cheese analogues (pH = 4.19 to 4.31) as reported by AtlasScientific [8]. pH plays an important role in the ripening process. The cheese had a pH range of 5.0 to 6.5, declining as cheese ages due to the production of lactic acid associated with firmer and more pronounced flavor [8]. In addition, PMCAs have high water activity ranging from 0.967 to 0.971 which is comparable to the water activity of dairy cheese generally ranging from 0.92 to 0.99 [9]. The high-water activity of PMCA indicated it was a highly perishable food that required controlled storage conditions. During the studies, the PMCAs were stored at a chilled temperature (4°C).

Although the starch dehydrated the protein matrix by immobilizing water, however, there is no significant difference between sample A (without starch) with the other 3 samples. This might be due to the high value of water activity that reached almost 1 exhibited by all formulations.

Table 1. Physicochemical properties of cheese analog.

Sample	pH	Water activity	Titratable acidity %	Color		
				L^*	a^*	b^*
A	5.85 ± 0.02^a	0.97 ± 0.02^a	0.36	57.71 ± 1.39^b	1.55 ± 0.07^a	18.49 ± 0.98^a
B	5.88 ± 0.02^a	0.97 ± 0.01^a	0.36	62.12 ± 0.69^a	1.18 ± 0.01^b	18.18 ± 0.28^a
C	5.88 ± 0.01^a	0.97 ± 0.00^a	0.36	61.99 ± 0.19^a	1.30 ± 0.15^{ab}	19.08 ± 0.37^a
D	5.88 ± 0.02^a	0.97 ± 0.00^a	0.36	61.24 ± 0.56^a	1.55 ± 0.03^a	19.12 ± 0.36^a

Note: A = sample without starch, B = sample with rice starch of Putra 2 variety, C = sample with rice starch of NMR variety, D = sample with corn starch. L* = degree of brightness, a* = degree of redness or greenness, b* = degree of yellowness or blueness. Different superscript letters indicate a significant difference among the same column.

L* represents the lightness from black (scale = 0) to white (scale = 100). The PMCAs had comparable results on L* except for sample A with the lowest lightness (57.71 ± 0.068). The higher L* value might be due to the addition of starch and fat globules in the palm milk of the formulation which contributes to the whiteness of the final product. Besides, a* represents the red-green component of a color, and b* represents the yellow-blue component of a color. PMCAs had a* value ranging from 1.18 to 1.55 while b* value of 18.18 to 19.12. The positive values of a* and b* indicated the color of PMCA is located within the first quadrant as shown in **Fig. 1** (within the yellow and red region). The color of the product might be influenced by the source and concentration of fat linked with the quantity of light-scattering centers, natural pigments present in milk, and the manufacturing process [10]. In addition, the translucent appearance of cheese is influenced by its protein and moisture content.

Fig. 1. Color of the palm milk cheese analog. Note: A = sample without starch, B = sample with rice starch of Putra 2 variety, C = sample with rice starch of NMR variety, and D = sample with corn starch.

Rheological properties

The storage modulus (G'), loss modulus (G''), and loss tangent depending on frequency (0.1 to 100 Hz) are plotted in **Figs. 2A, 2B, and 2C,** respectively. A comparable trend of storage modulus (G') was observed among the PMCAs where the G' showed an increasing trend initially and declined at the end of the test (frequency = 68.13 Hz). A descending order of G' is Sample B, C, D, and A. The loss modulus (G'') showed the exact descending order as the storage modulus. The PMCAs showed a similar trend of loss modulus with increment initially and started to decline when the frequency was equal to 68.13 Hz. The PMCAs had a greater value of storage moduli (G') than the loss moduli (G'') which represent dense interlinked weak gels as reported by the previous studies [7,11,12,13]. Besides, the loss tangent of PMCAs is less than 1 with no significant difference, suggesting that all samples behave like solids [12].

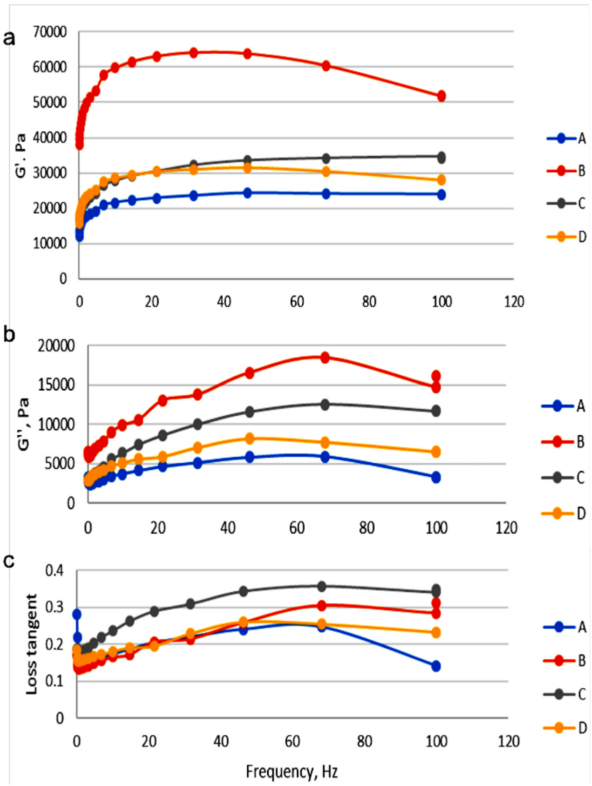

Fig. 2. (A) Storage Modulus of PMCAs, (B) Loss modulus of PMCAs and (C) Loss tangent of PMCAs. A = sample without starch, B = sample with rice starch of Putra 2 variety, C = sample with rice starch of NMR variety and D = sample with corn starch.

CONCLUSION

The results of this study demonstrated the potential of palm milk as a milk fat replacement while chickpea as an alternative protein in the production of low-fat, high-protein cheese analog. The incorporation of different types of starches had a significant effect on the rheological properties of the PMCAs while having no significant differences in their physicochemical properties. The NMR rice starch demonstrates its potential to be utilized in plant-based cheese products with its ability to mimic the textural characteristics of dairy cheese. However, the effect of the concentration of starch should be examined to optimize the physical and chemical characteristics.

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