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Physicochemical and Sensory Evaluation of Strawberry Flavored Non-Dairy Rice Milk

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Abstract

Rice milk is a plant-based, non-dairy milk replacement prepared from rice. It is a popular selection for people who are lactose intolerant, allergic to cow's milk, or vegan. This research provided a comprehensive investigation of the physicochemical properties and sensory characteristics of strawberry flavoured non-dairy rice milk. Rice milk served as the base, providing a lactose-free and vegan alternative, with strawberry flavour added to harmonious the blend that balanced the inherent sweetness of strawberries with the neutral base of rice milk. Non-dairy rice milk (F1) had the natural flavour of plant milk derived from 84% rice and sweetened with brown sugar (15%) without strawberry flavour to create a naturally mild and cameral sweet taste, whereas strawberry flavoured non-dairy rice milk (F2) combined the neutral base of 76% rice milk with 17% sweet aroma and flavourful of strawberries. The texture analysis focused on four different types of textural properties, including hardness, consistency, cohesiveness, and index of viscosity, which highlight that F2 is more firm (16.02±0.71), and consistent as the pH revealed that in F2 appeared to be a decrease in pH (5.36±0.10) over the three days, indicated the progression of fermentation, potentially involved the conversion of sugars to acids by microorganisms. Furthermore, F2 appeared to have a little influenced on protein content (1.31%), while it may lead to a reduction in total fat content (0.43%). Overall, the research showed that F2 can corresponded to customer expectations and preferences.

1. Introduction

Rice milk, a popular dairy-free alternative, has gained popularity due to its nutritional advantages and acceptability for individuals suffering from lactose intolerance or other dietary limitations [1]. According to Boniface *et al.*, (2023), milk consumption in Malaysia has increased in recent years as a result of factors such as population growth, growing prices, and changing consumer preferences. Apart from the increasing need for milk in Malaysia, it is worth mentioning that the domestic dairy sector in Malaysia is very limited and cannot match the country's demand for dairy products [2]. As a result, a high-quality, nutritious rice milk product that overcomes these issues and fulfils the expectations of customers seeking a healthy and sustainable plant-based milk substitute is required. Besides that, the majority of probiotic foods on the market are milk-based, and few attempts have been made to create probiotic foods utilizing alternate fermentation substrates such as cereals [3].

Therefore, plant-based milk replacements are growing more popular as people seek more environmentally friendly and ethical eating options because it is considered to be the most hypoallergenic form of milk. Individuals who are allergic to soy milk or cow milk should consume rice milk instead [3]. Rice milk is recommended for those who are lactose intolerant because it is cholesterol free and high in unsaturated fat [1]. Since rice milk is high in carbohydrates, it boosts the immune system and gives resistance to germs and viruses as it may also include some protein, fat, and minerals. The selection of using basmati rice have reported to have a low glycemic index [4] and are rich in aroma content [5] created the flavour to developed by the aroma compound 2-acetyl-1- pyrroline. The grains of basmati rice contain about 0.009ppm of aroma compounds which are 12 times more as compared to the non- basmati rice varieties [5]. Along with adding probiotic capsules to provide beneficial bacteria and strawberry fruit to add the sweetness of strawberry flavour.

Therefore, this study focused on the research into the development of strawberry flavoured non-dairy rice milk and the physicochemical properties that are being conducted to promote the sensory attributes and consumer acceptability of strawberry flavoured rice milk. Strawberry flavoured non-dairy rice milk is a dairy-free milk replacement made from rice grains that is frequently consumed by individuals who are lactose intolerant, vegan or have other dietary restrictions while strawberry as a flavour is a popular flavour that is often added to dairy-based and plant-based milk products [6]. Overall, rice milk is the best alternative to dairy milk for persons with dietary limitations or preferences and when consumed in moderation it can be a nutritious supplement to a balanced diet.

2. Material and Methods

The non-dairy rice milk samples used in this study were Basmathi rice (Jasmine PusaGold 1121), fresh strawberry fruit from Johor local market, brown sugar (Gula Prai), tapioca starch (Cap Kapal ABC Tapioca Starch), probiotic powder (21st Century Probiotics).

2.1 Preparation of Rice Milk

1kg of Basmati rice, Jasmine PusaGold 1121, sourced from a Selangor market, was used to prepared rice milk following Atwaa *et al.*, (2019) method. The rice underwent meticulous washed, cooked in a 1:3 water ratio, and sievied for a smooth texture. Maintained a cooking temperature of 80°C for 15 minutes ensured a well-mixed and smooth rice milk while stirred rapidly on medium heat.

Table 1 *The formulation samples of non-dairy rice milk*

Ingredients	Formulation 1 (F1)	Formulation 2 (F2)
Basmathi rice	84%	76%
Strawberry puree	-	17%
Brown sugar	15%	6%
Tapioca starch	0.5%	0.5%
Probiotic powder	0.5%	0.5%

2.2 Sensory Evaluation

Wannasupchue, (2023) study employed a 9-point Hedonic scale for sensory assessment, evaluated non-dairy rice milk (F1) and strawberry-flavoured non-dairy rice milk (F2). The sensory evaluation, conducted by 60 panellists in Sensory Laboratory at Universiti Tun Hussein Onn Malaysia (UTHM), focused on attributes like colour, texture, flavour, appearance, mouthfeel, and overall acceptance.

2.3 Texture Analysis

The textural analysis utilized a TA. XT plus texture analyzer for compression tests on two formulations of non-dairy rice milk. Using a 35-mm cylindrical probe, parameters such as firmness, consistency, cohesiveness, and viscosity index were measured. Texture Profile Analysis (TPA) were compressed in triplicate using textural analyzer software for peak force determination.

2.4 Physicochemical Properties

2.4.1 Colour Analysis

Colour analysis utilized the HunterLab Miniscan EZ 4500L Color Spectrophotometer, following Milovanovic *et al.* (2020). Calibration in triplicate using black and white tiles was performed to D65/10^{o} measurement mode. CIELAB L*, a*, and b* color spaces were determined, measured brightness, greenness, and yellowness. Directly aimed to sample F1 and F2 as the spectrophotometer collected readings for l*, a*, and b* triplicate.

2.4.2 pH Analysis

The pH of F1 and F2 was assessed in triplicate using a digital pH meter following the AOAC [7]. The pH electrode was rinsed with distilled water and blot gently with a tissue to remove any excess water. Then, calibrated using standard buffer solutions of pH 4.0, 7.0 and 10.0 [8]. Afterwards the probe was placed into the sample and a constant reading was assessed as the final pH value. The probe provided consistent reading to determine acidity or alkalinity [9].

2.4.3 Nutritional Composition

Nutritional composition of F1 and F2 was analysed by UNIPEQ Sdn. Bhd., Universiti Kebangsaan Malaysia following standard AOAC 20th Edition methods for protein and total fat determination. The AOAC 981.10 method for protein analysis involved a dried and grinded of F1 and F2 sample, digested with a mixture of 0.7g potassium sulfate (K_2SO_4), 0.5g copper sulfate ($CuSO_4$), and 5mL sulfuric acid (H_2SO_4). It is then distilled and titrated the ammonia (NH_3) to estimate protein content [7]. While for the AOAC 905.02 method for total fat analysis involves the extraction of fat using a mojonnier extraction method by digested the F1 sample with 10mL sulfuric acid (H_2SO_4) and ether, centrifuged the mixture, decanted and washed the fat layer, evaporated the ether, and finally dried and weighted the flask. The process was repeated for F2 sample [7].

2.4.4 Statistical Analysis

Triplicated results for texture, colour, and pH analysis were analysed using Microsoft Excel 2019. Statistical significance was determined by T-test ($p < 0.05$) [3]

3. Results and Discussion

3.1 Sensory Evaluation

The sensory evaluation involved 60 panellists, aged 21 to 27, assessing F1 and F2. According to Fig. 3.1, F2 had a significantly higher colour of 8.17±1.05 compared to the F1 of 5.93±2.12. This indicated that F2 is more attractive in appearance or bright colour, most likely as a result of the addition of strawberry taste. As for the texture, both samples had relatively high scores, where F2 obtained a slightly higher rating of 7.47±1.28. This suggested that both samples are likely perceived as having a desirable and pleasing texture. This implied that both samples are regarded to have a desired and pleasant texture. However, flavour F1 is rated higher (7.10±1.60) than F2, which could indicate that the strawberry flavour in F2 did not enhance the overall flavour perception as expected, or it could be a matter of individual preference.

The findings for F2 are noticeably higher at 7.53±1.20, supporting the previous research from the colour evaluation that the strawberry taste appeared to contribute to a more visually attractive appearance. Continuing with the mouthfeel attributes, both samples had quite good mouthfeel ratings, with F1 earning a slightly higher rating of 7.13±1.50. This demonstrated that both samples created a pleasing and delightful experience in the mouth of the panellist. Overall, F1 received a greater approval (7.27±1.3) than F2 (6.90±1.32). This implies that, generally, the panellists prefer F1.

Furthermore, while F2 had a more appealing colour and appearance, F1 is favoured in terms of flavour and overall acceptability. Following the statistical tests, there are significant differences ($p<0.05$) between the two types of samples in colour, appearance, and overall acceptance, but no significant differences in texture, flavour, or mouthfeel. This demonstrated that panellist’s tastes may have a considerable impact on these ratings.

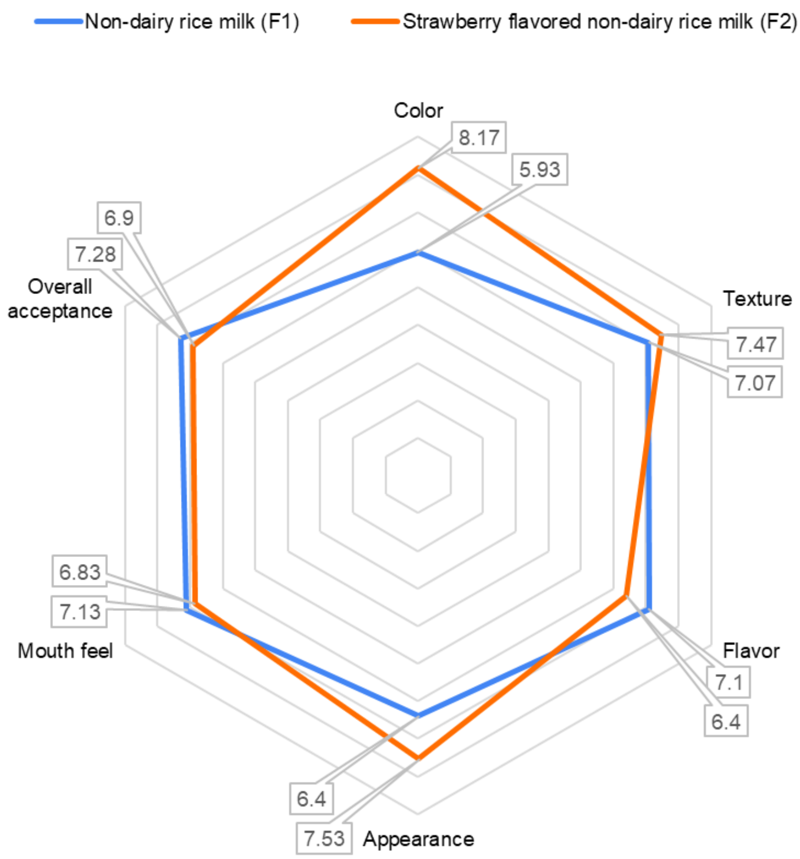

Fig. 1 *Quantitative descriptive analysis for two non-dairy rice milk samples*

3.2 Texture analysis

F1 and F2 had a different perceived hardness or resistance to deformation, as indicated by the firmness values. According to Mudgil *et al.*, 2017, the most essential quality in defining fermented milk texture is hardness or firmness. It is defined as the force necessary to achieve a specific deformation and is used to determine the product's hardness. In this case, F2 had a greater mean firmness of 14.90±0.34 than F1, which had a value of 16.02±0.71. The F2 is firmer than the F1 because the change in firmness can be caused by components such as the addition of strawberry flavouring ingredients, which may impact the texture and structure of the rice milk. The degree of thickness or firmness in two samples is often referred to as consistency. The consistency values for both samples are relatively close, with F2 having a slightly higher mean consistency (27.01±1.24) than F1. This is because, while both rice milks have comparable consistency values, the rice milk with strawberry flavour is viewed as more constant in thickness than the natural rice milk. Furthermore, Sah *et al.,* (2016) observed that a longer fermentation duration connected with a better uniformity of fermented samples. Lower fermentation times, in particular, might have an unfavourable impact on the product's textural qualities.

Continuing with the cohesiveness, it illustrated the strength of the internal connections that make up the body of the product as well as the degree to which a food may be distorted before breaking [10]. Both samples have a comparable degree of unity or stickiness, which evaluated how strongly the elements in a texture stay together. Because of the negative values, both samples may be seen to have some degree of fragmentation or lack of unity in their texture. The fact that the magnitudes of the cohesiveness values for both samples are identical showed the addition of strawberry taste had no major influence on this characteristic. In the index of viscosity, it reflected a substance's resistance to flow. When compared to F1, F2 has a reduced mean index of viscosity with −2.60±0.25. This demonstrates that the F2 has a lower index of viscosity than the F1, indicated that the strawberry flavouring had an effect on the flow characteristics of the rice milk, and the negative values for both samples imply a certain degree of resistance to flow, but the strawberry flavoured formulation has a slightly lower resistance than the natural rice milk.

As a consequence, the results highlight that F2 is firmer, somewhat more consistent, and has a similar level of cohesiveness to F1. Thus, there is no strong evidence to reject the null hypothesis for the index of viscosity but the difference in viscosity between F1 and F2 is not statistically significant at the 0.05 significance level as the strawberry taste appeared to have a minor effect on the viscosity of the rice milk, causing it to flow more freely.

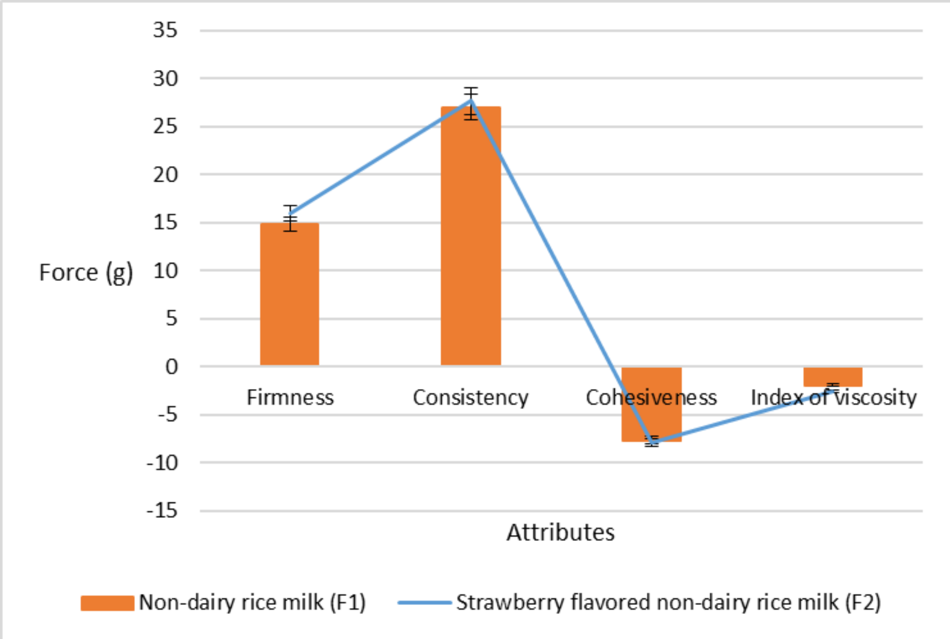

Fig. 2 *Texture profile analysis of four attributes for two non-dairy rice milk samples*

3.3 Colour analysis

The colour analysis for F1 and F2 during three days is outlined in Table 4.3, *L**, *a**, and *b** are colour parameters assessed where colour measurement indicated the quality and defect level of a certain food. Colour measurements using colorimeter L, a, and b values often detected only a small area of the food [11]. First and foremost, for the *L** (Lightness), the F1 values stayed generally stable across the three days of 40.85±0.00 to 40.37±0.00, showed that the colour does not vary much in terms of brightness. The lightness values of F2 are lower, ranging from 24.26±0.00 to 23.68±0.00, than those for F1, indicating a darker hue. Stated by Amini et al., (2019), the colour changed to a light greyish yellow, which was apparently observed as white. Thus, no significant colour changes were observed for control samples after days of storage [11].

Continued with *a** (Green to Red), for both F1 and F2, the *a** values reflected the shift from green to red, although F2 has lower *a** values ranged from 15.44±12.47 to 15.08±12.16, indicated a less strong red colour compared to F1 of 12.05±28.00 on day one to 20.81±27.66 on day three. In previous studies by Plengsaengsri *et al.* (2019), mentioned that the decreased of both a* and b* values of the natural plant-based model emulsion and homogenization reduced the fat granules and helped dispersion. This is because the amount of fat pellets increased, caused more light reflection, resulting in lighter colour. The colour of the sterilized milk can occur from Maillard reaction between free amino acids and reducing sugar at high temperature [8]. Thus, F1 and F2 represent a changed from blue to yellow for the *b** (Blue to Yellow) value as F1 had somewhat higher *b** values on the third day, displayed 17.05±20.62, indicating a stronger yellow component than F2 with 11.53±10.58.

Furthermore, for both formulations of non-dairy rice milk, the lightness (*L**) remained relatively consistent over the three days, and there are significant differences in the red-green colour component (*a**) for both samples, while the variance in the blue-yellow colour component (*b**) is generally less than in the red-green component. As a result, F2 has lower lightness values, showing a darker hue than F1. Therefore, the colour components shifted, with F2 constantly displayed deeper colours than F1.

Table 2 *Colour measurement L*, a* and b* values for two non-dairy rice milk samples*

Non-dairy rice milk (F1)			
Days	*L**	*a**	*b**
1	40.85±0.00	21.05±28.00	15.33±20.87
2	40.56±0.00	20.91±27.79	17.13±20.71
3	40.37±0.00	20.81±27.66	17.05±20.62

Strawberry flavoured non-dairy rice milk (F2)			
Days	*L**	*a**	*b**
1	24.26±0.00	15.44±12.47	11.81±10.83
2	23.35±0.00	14.91±11.94	11.41±10.38
3	23.68±0.00	15.08±12.16	11.53±10.58

*The data was presented in mean ± SD

3.4 pH Analysis

The graphs in Fig. 4.6 and Table 4.4 demonstrated the differences in pH values of the two samples given. The data provided the fermentation duration (in days), pH values, and the fermentation process comparison of F1 and F2.

The initial pH of F2 is somewhat lower from pH 5.45 to pH 5.29 on the first day of fermentation than F1 with pH 5.66 which when compared a study by Padma *et al.*, (2021), the pH values of the probiotic rice milk beverage decreased with increasing fermentation time from pH 6.21 to pH 4.95. Both F1 and F2 came across some pH alterations during the fermentation process, with fluctuations observed as the changes in pH levels during the fermentation process can offer information about the microbial activity. This is because bacteria use nutrients and created organic acids, which are discharged into the substrates, causing a fall in pH values [9]. A reduction in pH, for example, may indicate the generation of organic acids by fermentation. The addition of strawberries may have contributed to the lower pH values in F2 on day one and throughout the fermentation period. Furthermore, the pH differences between F1 and F2 may imply differences in fermentation interactions, which might be altered by the additional strawberry taste. Tangular *et al.*, (2012) mentioned that it is critical to examine the target pH for the specific fermentation process as well as the intended final product qualities.

In summary, the findings show the pH differences in F1 and F2 throughout a three-day fermentation period that the $p<0.05$, have rejected the null hypothesis. This suggests that there is a significant difference in taste ratings between F1 and F2 with impacts on the taste, texture, and overall quality of the fermented rice milk products.

Table 3 *pH values for two non-dairy rice milk samples of different fermentation period*

Fermentation period (day)	pH	
	Non-dairy rice milk (F1)	Strawberry flavored non-dairy rice milk (F2)
1	5.66±0.00	5.47±0.00
2	5.67±0.01	5.39±0.11
3	5.63±0.06	5.36±0.10

*The data was presented in mean ± SD

3.5 Nutritional composition

In protein content, F1 had a protein value of 1.37%, whereas F2 has a slightly lower protein content of 1.31%. This expressed that F2 has a little lower protein level than F1, but both samples had equal protein amounts. Magdy Mohamed Ismail, (2016) investigated the protein level of the created rice milk corresponds with the set low protein content for rice milk. When compared to other commercial plant-based milk, such as almond and soy milk, which have protein concentrations of 2.11% and 3.70%, respectively [9], this amount may be considered low. It had also been proved by Silva *et al.*, (2023) that plant-based milks based on different types of rice had a protein content ranging between 1.14±0.11 and 1.75±0.00%, and pasteurization did not significantly influence the protein level in samples.

Next, the total fat level of F1 is 0.74% with a significantly high standard deviation of 1.36 when compared to F2, which is lower at 0.43%. This demonstrated that F2 has a lower and more constant fat level than F1. Magdy Mohamed Ismail, (2016) demonstrated that the created product's total fat content was exceptionally low. To summarized, F1 has a greater protein content but a larger and more variable fat level than F2.

4. Conclusion

The successful development of strawberry-flavoured non-dairy rice milk (F2) was achieved through a comprehensive approach combining analytical measurements and sensory analysis. Physicochemical analysis indicated F2's superior texture and stability, with firmer consistency and enhanced flow. Colour analysis showcased a gradual darkening, possibly influenced by intrinsic strawberry colour, while F1 maintained stability. The decline in F2's pH, indicating increased acidity, suggested microbial activity influenced by added strawberry flavouring during fermentation. Sensory evaluation played a pivotal role, revealing F1's higher overall acceptability despite F2's positive colour and appearance impact. Nutritional analysis showed subtle differences, with F2 potentially impacting protein and fat content. This study contributes valuable insights for product optimization and positions strawberry-flavoured non-dairy rice milk competitively in the market. The findings enhance our understanding of non-dairy alternatives, catering to evolving consumer preferences and industry demands.

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Conflict of Interest

Declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper for ***conception and design, data collecting, result analysis, interpretation and draft article preparation****. The final draft of the manuscript was approved by the author, Anis Humaira and Saliza Asman after they had evaluated the findings.*

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