

Formulation and Shelf-Life Estimation of Ready-to-Drink Avocado Coffee Milk and Durian Coffee Milk Products

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ABSTRACT

Coffee is widely and regularly consumed in Indonesia. The trend towards practical lifestyle has driven the development of ready-to-drink (RTD) coffee products. Avocado and durian are commonly incorporated as additives due to their unique flavor profiles, creamy textures, and potential to enhance the functional properties of coffee-based drinks. This study aimed to identify the optimal formulation of RTD avocado coffee milk and durian coffee milk products based on sensory characteristics and to estimate their shelf life using the direct method. The formulations were developed by varying the fruit purée concentration: 5%, 7.5%, and 10% for avocado coffee milk, and 5%, 10%, and 15% for durian coffee milk. The hedonic rating test revealed that formulations containing 5% avocado purée and 15% durian purée were the most preferred by 50 panelists. These selected formulations were further analyzed to estimate product shelf life at 4°C and 18°C. Quality changes were evaluated through objective parameters (color change [ΔE], pH, viscosity, and physical stability) and subjective parameters (color, aroma, and flavor intensities). Products stored at 18°C deteriorated more rapidly and were excluded from further shelf life prediction. The estimated shelf life of avocado coffee milk stored at 4°C was 59 days based on flavor parameter ($R^2 = 0.9338$), while durian coffee milk had an estimated shelf life of 61 days based on pH ($R^2 = 0.9305$).



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1. Introduction

Coffee is one of Indonesia's leading agricultural commodities with a broad market both domestically and internationally. Indonesia ranks as the third-largest coffee producer in the world, with total production reaching 11.85 million bags, or approximately 711 thousand tons, during the 2022–2023 period. This production is predominantly composed of robusta coffee, accounting for 10.5 million bags, while the remainder consists of 1.3 million bags of arabica coffee (Badan Pusat Statistik, 2023). According to the International Coffee Organization in April 2023, Indonesia was also the second-largest coffee-consuming country in the Asia-Pacific region, with total consumption reaching 5 million bags. This consumption continues to rise annually, in line with the growing public interest in coffee as part of a lifestyle trend.

The development of the coffee industry has encouraged the emergence of various product innovations, including ready-to-drink (RTD) coffee beverages. RTD coffee is a packaged beverage that can be consumed directly without additional preparation. According to Euromonitor data cited by dataindonesia.id, the sales volume of RTD coffee in Indonesia has shown continuous growth, reaching 225 million liters in 2022 (Ryana & Haryanto, 2023). RTD coffee products in Indonesia possess substantial growth potential, driven by ongoing innovations in product development.

Avocado and durian fruits have been widely incorporated as flavoring agents in coffee beverages due to their unique taste profiles and creamy textures. Their addition to RTD coffee is also considered to enhance the functional value of the beverage. According to the Ministry of Agriculture (2023), Indonesia produced 865,780 tons of avocado in 2022, reflecting a 29.36% increase from the previous year. Durian production also increased by 16.93%, reaching 1,582,172 tons in the same period. The abundant production of these fruits provides promising potential for their utilization in the development of RTD coffee beverages.

Avocado pulp is rich in monounsaturated fatty acids (MUFA), as well as dietary fiber, minerals, vitamins, β -carotene, antioxidants, and a variety of phenolic compounds. MUFA plays a key role in cardiovascular health by lowering low-density lipoprotein (LDL) levels and increasing high-density lipoprotein (HDL) levels. Furthermore, the dietary fiber in avocado pulp supports digestive health, regulates blood glucose levels, and reduces the risk of colorectal cancer (Cheptoo et al., 2025). A previous study using Quality Function Deployment (QFD) developed an avocado coffee and identified that taste, texture, color as key attributes for customer satisfaction (Prihastari & Sabarisman, 2021). While this work focused on freshly-made coffee, the present study will focus on developing an RTD avocado coffee.

Durian pulp contains essential vitamins such as C, B1, B2, and E, as well as important minerals including potassium, phosphorus, calcium, and iron (Boonna et al., 2022). Durian is also rich in polyphenols, including flavonoids, phenolic acids, tannins, and other bioactive components such as carotenoids. These polyphenols are known for their health benefits, including reducing the risk of chronic diseases such as heart disease, cancer, and diabetes (Aziz & Jalil, 2019). Previous research showed that durian flesh fermentation of Arabica Gayo wine coffee significantly altered the ash and caffeine contents of the resulting coffee powder (Dinata et al., 2021). However, the effects of durian addition to ready-to-drink coffee, particularly on sensory properties and shelf-life, have not yet been explored.

Product development success is strongly influenced by consumer acceptance and selecting an appropriate formulation is a critical step, as it determines the resulting sensory characteristics of the final product. Furthermore, food products may undergo quality changes during storage that can impact both safety and consumer appeal. In this context, the present study investigates the effect of adding avocado and durian to ready-to-drink coffee and evaluates the products' shelf life to ensure they remain safe and acceptable throughout the intended storage period.

2. Methods

2.1. Materials

Robusta coffee powder sourced from the Al-Bayyinah Farmers Cooperative in Garut, Mentega avocado, local Medan durian, Greenfields brand pasteurized milk, Gulaku brand granulated sugar, and 280 mL glass bottles as packaging material. Additional materials used for product analysis including crackers, bottled drinking water, distilled water, and pH buffer solutions (pH 4 and pH 7).

The equipment utilized consisted of tools for product preparation, including a digital scale, 80 and 100 mesh sieves, knives, spoons, a food processor (Panasonic MK-5086M), a homogenizer (Silverson L4R Laboratory Mixer Emulsifier), a refrigerator, a thermometer, measuring glasses, saucepans, a gas stove, and stirring utensils. Instruments used for product analysis included a pH meter, Minolta CR-400 chromameter, Brookfield viscometer, hand refractometer, photo box, clear plastic cups, label paper, and supporting tools for sensory evaluation.

2.2. Raw Material Preparation

Avocado and durian fruits were sorted and cleaned prior to use. The fruit pulps were then blended using a food processor to obtain a smooth purée. Coffee extract was prepared according to the method of Nurhayati (2017) with modifications. Robusta coffee powder was brewed with hot water at $92 \pm 1^\circ\text{C}$ using a coffee-to-water ratio of 1:20 (w/w) for 5 minutes. The brewed coffee was filtered using a 100-mesh sieve.

2.3. Product Formulation and Preparation

The products were formulated using three variations of fruit purée concentration for each beverage: 5% (A1), 7.5% (A2), and 10% (A3) avocado purée for avocado coffee milk; and 5% (D1), 10% (D2), and 15% (D3) durian purée for durian coffee milk. Each product consisted of 200 mL coffee extract, 50 mL pasteurized milk, and 18 grams of granulated sugar. The coffee extract, pasteurized milk, and sugar were mixed and homogenized at 14,000 rpm for 3 minutes. Fruit purée was then added and further homogenized for 10 minutes. The homogenized mixture was filtered using an 80-mesh sieve and pasteurized at 85°C for 15 seconds according to the pasteurization method described by Hariyadi (2020). The product was hot-filled into 250 mL glass bottles and immediately inverted for 10 seconds. Shock cooling was carried out by immersing the bottles in flowing water. The resulting products from each formulation were analyzed for viscosity and total soluble solids to assist in selecting the preferred formulation.

2.4. Selection of the Preferred Formulation

The selected formulation was determined through a hedonic rating test to evaluate panelists' preference levels for the attributes of color, aroma, taste, thickness, and overall acceptability. The evaluation was conducted by 50 untrained panelists using a 7-point scale, ranging from extremely dislike (1), dislike (2), somewhat dislike (3), neutral (4), somewhat like (5), like (6), to extremely like (7). The selected formulation was identified as the most preferred based on all five attributes according to the results of Duncan's post hoc test.

2.5. Product Quality Analysis During Storage

The products with selected formulation were stored at 4°C and 18°C . Observations were conducted on days 0, 3, 6, 10, 14, and 21. The quality parameters observed included both objective and subjective measurements. Objective parameters consisted of pH measurement using a pH meter, viscosity measurement using a Brookfield viscometer (spindle No. 2, speed 60 rpm, at 25°C), and total color change (ΔE), calculated based on L^* , a^* , and b^* values

obtained from a chromameter. Total color change (ΔE) during storage was calculated using the following equation:

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

Product stability was also qualitatively observed using a photo box to assess the presence of sedimentation. Subjective parameters were evaluated using an attribute intensity rating test conducted by eight trained panelists to assess the aroma, taste, and color attributes. A 9-point scale was used, ranging from extremely light brown (1), very light brown (2), light brown (3), slightly light brown (4), brown (5), slightly dark brown (6), dark brown (7), very dark brown (8), to extremely dark brown (9) for color intensity. For aroma and taste intensity, a 9-point scale was also used, and from extremely weak (1), very weak (2), weak (3), slightly weak (4), neutral (5), moderately strong (6), strong (7), very strong (8), to extremely strong (9). Prior to evaluation, the trained panelists were introduced to the products through a focus group discussion (FGD) session, in which both fresh and deteriorated samples were presented to align the panelists' perception in assessing product quality parameters

2.6. Shelf Life Estimation

Shelf-life estimation was conducted using accelerated shelf life study (ASLT) with the Arrhenius method (Rusli et al., 2022).

2.6.1. Determination of Reaction Order

Reaction order was determined by constructing kinetic plots of product quality changes over storage time using linear regression curves for both zero-order and first-order reactions. The zero-order regression curve was obtained by plotting storage time on the x-axis and the average quality parameter values on the y-axis. The first-order regression curve was constructed by plotting storage time on the x-axis and the natural logarithm (ln) of the average quality parameter values on the y-axis. The reaction order was selected based on the model with the higher coefficient of determination (R^2) for each parameter.

2.6.2. Determination of Initial Quality Value (Q_0) and Final Quality Value (Q_s)

Initial and final quality values for subjective parameters were determined during the product introduction phase through a focus group discussion (FGD) session with trained panelists. The initial values for objective parameters were determined based on the measurement results on day 0. Final values for the objective parameters were determined by correlating objective and subjective parameters using Pearson correlation analysis.

The final value of color change (ΔE) was determined based on its correlation with the color attribute, while the final pH and viscosity values were determined based on their correlations with the aroma and taste attributes, respectively. The final value was obtained by substituting the storage time at which the product was rejected based on the strongest correlation between objective and subjective parameters and the higher-order reaction into the x-variable of the linear regression equation for the corresponding objective parameter.

2.6.3. Shelf-Life Calculation

Shelf life was calculated by substituting the quality degradation rate constant (slope) obtained from the linear regression of each quality parameter into either the zero-order or first-order reaction equation, as follows:

$$t = \frac{(Q_0 - Q_s)}{k} \quad \text{or} \quad t = \frac{(\ln Q_0 - \ln Q_s)}{k}$$

(zero-order) (first-order)

where:

t = shelf life (days)
 Q_0 = initial quality value
 Q_s = final quality value
 k = degradation rate constant

The product shelf life was determined based on the quality parameter with the highest correlation coefficient (closest to one) or the parameter that resulted in the shortest estimated shelf life.

2.7. Data Analysis

Sensory evaluation data for the determination of the selected formulation were analyzed using a two-way ANOVA followed by Duncan's multiple range test at a 5% significance level, conducted with IBM SPSS software version 26. Viscosity and total soluble solids data were analyzed using one-way ANOVA. Data processing for the analysis of quality parameters related to shelf life estimation was conducted using Microsoft Excel and IBM SPSS for Pearson correlation analysis. Linear regression analysis was applied to determine the appropriate reaction order model for the rate of quality deterioration during storage.

3. Results and Discussion

3.1. Results

3.1.1. Sensory Characteristics of Product Formulations

The sensory evaluation aimed to assess panelists' preferences and to determine the optimal formulation for each product. The results of the hedonic rating test for three formulations of RTD avocado coffee milk and durian coffee milk products are presented in Table 1 and Table 2.

Table 1 Hedonic rating results for RTD avocado coffee milk formulations (A1-A3) and durian coffee milk formulations (D1-D3)

Formulation	Aroma	Color	Thickness	Taste	Overall
<i>Avocado coffee milk</i>					
A1	5.51 ± 1.23 ^a	5.39 ± 1.22 ^a	5.10 ± 1.31 ^a	4.47 ± 1.53 ^a	4.92 ± 1.15 ^a
A2	4.65 ± 1.39 ^b	5.31 ± 1.14 ^a	4.90 ± 1.31 ^a	4.41 ± 1.69 ^a	4.53 ± 1.39 ^a
A3	4.73 ± 1.38 ^b	5.27 ± 1.30 ^a	5.20 ± 1.21 ^a	3.53 ± 1.68 ^b	4.02 ± 1.35 ^b
<i>Durian coffee milk</i>					
D1	5.16 ± 1.40 ^b	5.45 ± 1.08 ^a	5.22 ± 1.14 ^b	5.18 ± 1.38 ^b	5.37 ± 0.97 ^b
D2	5.65 ± 0.99 ^a	5.63 ± 0.86 ^a	5.59 ± 1.04 ^a	5.61 ± 1.27 ^a	5.55 ± 0.98 ^b
D3	5.39 ± 1.13 ^{ab}	5.63 ± 1.18 ^a	5.71 ± 1.04 ^a	5.69 ± 1.42 ^a	5.90 ± 1.07 ^a

Note: Different superscript letters within the same column indicate significant differences ($p < 0.05$). Comparisons are made only within each product group (A1-A3) or (D1-D3).

3.1.2. Viscosity and Total Soluble Solids Characteristics of Product Formulations

Viscosity and total soluble solids (TSS) tests were conducted on three formulations of ready-to-drink avocado coffee milk and durian coffee milk. The results of viscosity and TSS measurements for each product are presented in Table 3 and Table 4.

Table 2 Viscosity and total soluble solids of RTD avocado coffee milk formulations (A1-A3) and durian coffee milk formulations (D1-D3)

Formulation	Viscosity (mPa.s)	Total Soluble Solid (°Brix)
<i>Avocado coffee milk</i>		
A1	15.00 ± 0.00 ^c	10.50 ± 0.71 ^a
A2	23.75 ± 1.77 ^b	11.00 ± 0.00 ^a
A3	35.00 ± 0.00 ^a	11.00 ± 0.00 ^a
<i>Durian coffee milk</i>		
D1	13.75 ± 1.77 ^c	13.00 ± 0.00 ^b
D2	17.50 ± 0.00 ^b	14.00 ± 0.00 ^{ab}
D3	32.50 ± 0.00 ^a	14.50 ± 0.71 ^a

Note: Different superscript letters within the same column indicate significant differences (p<0.05)

3.1.3. Product Quality Changes During Storage

Product quality changes during storage were evaluated using several parameters, including color changes, acidity (pH), viscosity, physical stability, sensory attributes (aroma, taste, and color).

a. Color Change (ΔE)

Color changes of avocado coffee milk and durian coffee milk during storage, expressed as ΔE values in the CIE Lab* system, are summarized in Table 3.

Table 3 Average color change (ΔE) of ready-to-drink avocado coffee milk and durian coffee milk during storage

Temperature (°C)	Storage Time (days)	L* Value	a* Value	b* Value	ΔE
<i>Avocado coffee milk</i>					
4	0	36.55 ± 0.67	5.56 ± 0.22	21.29 ± 0.81	0.00
	3	35.56 ± 0.94	5.67 ± 0.21	20.07 ± 0.47	1.57
	6	35.52 ± 0.65	6.76 ± 0.53	22.23 ± 0.85	1.84
	10	34.41 ± 0.55	6.66 ± 1.12	22.61 ± 1.86	2.75
	14	34.03 ± 0.56	6.51 ± 0.79	22.39 ± 1.72	2.91
	21	33.94 ± 0.44	6.36 ± 0.29	22.43 ± 0.76	2.96
18	0	36.55 ± 0.67	5.56 ± 0.22	21.29 ± 0.81	0.00
	3	34.46 ± 2.22	7.12 ± 0.77	25.13 ± 2.05	4.64
<i>Durian coffee milk</i>					
4	0	43.25 ± 1.48	6.67 ± 0.20	22.63 ± 0.99	0.00
	3	42.73 ± 0.55	7.56 ± 0.76	23.16 ± 0.70	1.16
	6	42.61 ± 0.42	7.69 ± 0.71	23.93 ± 1.07	1.77
	10	41.26 ± 0.54	6.48 ± 0.79	22.99 ± 0.94	2.04
	14	41.19 ± 0.35	6.91 ± 0.40	22.58 ± 2.51	2.07
	21	40.81 ± 0.37	6.18 ± 0.79	22.72 ± 2.09	2.50

b. Acidity (pH), viscosity, and sensory attributes

The average changes in pH, viscosity, and sensory attributes of avocado coffee milk and durian coffee milk during storage at 4 °C and 18 °C are summarized in Table 4 and Table 5.

Table 4 Change of pH, viscosity, and sensory attributes (color, aroma, and taste) of products during storage at 4°C

Storage Time (days)	pH	viscosity	color	aroma	taste
<i>Avocado Coffee Milk</i>					
0	6.50 ± 0.01	15.00 ± 1.58	6.00 ± 0.00	7.00 ± 0.00	7.00 ± 0.00
3	6.34 ± 0.01	15.00 ± 2.24	6.29 ± 0.27	6.64 ± 0.48	6.71 ± 0.76
6	6.30 ± 0.03	14.58 ± 0.65	6.43 ± 0.19	6.29 ± 0.49	6.29 ± 0.49
10	6.23 ± 0.01	14.38 ± 0.68	6.50 ± 0.29	6.00 ± 0.00	6.21 ± 0.39
14	6.23 ± 0.03	14.38 ± 1.31	6.57 ± 0.53	5.93 ± 0.45	6.14 ± 0.38
21	6.06 ± 0.01	14.17 ± 1.02	6.64 ± 0.38	5.71 ± 0.27	5.64 ± 0.38
<i>Durian Coffee Milk</i>					
0	6.80 ± 0.01	32.50 ± 1.37	4.00 ± 0.00	8.00 ± 0.00	8.00 ± 0.00
3	6.70 ± 0.01	31.67 ± 1.29	4.14 ± 0.24	7.71 ± 0.49	7.71 ± 0.49
6	6.67 ± 0.01	31.46 ± 1.23	4.21 ± 0.27	7.29 ± 0.49	7.00 ± 0.58
10	6.65 ± 0.02	30.83 ± 1.02	4.36 ± 0.48	6.71 ± 0.27	6.86 ± 0.38
14	6.62 ± 0.03	30.83 ± 1.02	4.29 ± 0.27	6.57 ± 0.53	6.14 ± 0.24
21	6.47 ± 0.01	30.42 ± 1.29	4.36 ± 0.38	6.36 ± 0.38	6.07 ± 0.19

Table 5 Change of pH, viscosity, and sensory attributes (color, aroma, and taste) of products during storage at 18°C

Storage Time (days)	pH	viscosity	color	aroma	taste
<i>Avocado Coffee Milk</i>					
0	6.50 ± 0.01	15.00 ± 1.58	6.00 ± 0.00	7.00 ± 0.00	7.00 ± 0.00
3	5.80 ± 0.19	13.13 ± 1.05	5.64 ± 0.48	4.14 ± 0.24	—
<i>Durian Coffee Milk</i>					
0	6.80 ± 0.01	32.50 ± 1.37	4.00 ± 0.00	8.00 ± 0.00	8.00 ± 0.00
3	—	—	—	—	—

Note: "—" indicates that the sample was not analyzed due to spoilage.

c. Product Stability

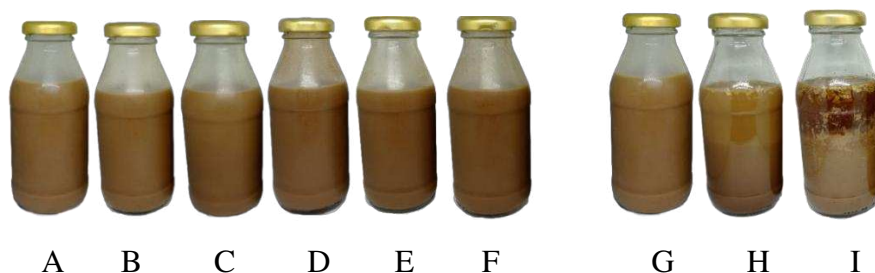


Figure 1 Physical stability of avocado coffee milk during storage at 4°C from day 0 to day 21 (A–F) and at 18°C from day 0 to day 6 (G–I)

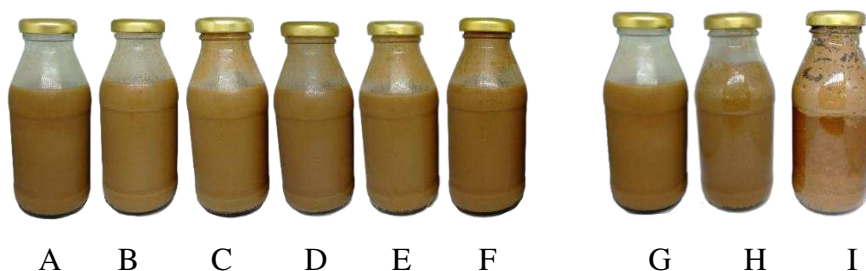


Figure 2 Physical stability of durian coffee milk during storage at 4°C from day 0 to day 21 (A–F) and at 18°C from day 0 to day 6 (G–I)

3.1.4. Kinetics of Product Quality Changes During Storage

The slope (k) and determination coefficient (R^2) values for each quality parameter of the ready-to-drink avocado coffee milk and durian coffee milk are presented in Table 6.

Table 6 Slope (k) values and R^2 values for each quality parameter of ready-to-drink avocado coffee milk

Parameter	Zero-order		First-order	
	k Value	R^2	k Value	R^2
<i>Avocado coffee milk</i>				
Color change (ΔE)	0.1279	0.7435	-	-
pH	-0.0180	0.9048	-0.0029	0.9091
Viscosity	-0.0422	0.8687	-0.0029	0.8728
Color intensity	0.0273	0.8088	0.0043	0.7974
Aroma intensity	-0.0591	0.8842	-0.0094	0.8999
Taste intensity	-0.0591	0.9246	-0.0094	0.9338
<i>Durian coffee milk</i>				
Color change (ΔE)	0.1017	0.7659	-	-
pH	-0.0136	0.9303	-0.0020	0.9305
Viscosity	-0.0908	0.8671	-0.0029	0.8729
Color intensity	0.0154	0.7348	0.0037	0.7310
Aroma intensity	-0.0820	0.9051	-0.0115	0.9165
Taste intensity	-0.0975	0.9017	-0.0141	0.9112

3.1.5. Shelf-Life Estimation

The principle of shelf life estimation for food products is essentially based on calculating the time interval between the initial quality value (Q_0) and the final quality value (Q_s), which indicates the threshold of product acceptability. The obtained values of Q_0 , Q_s , and the rate constant (k value) were used to calculate the shelf life based on both zero-order and first-order reaction models. The estimated shelf life of ready-to-drink avocado coffee milk and durian coffee milk based on each quality parameter is presented in Table 7.

Table 7 Shelf life estimation of ready-to-drink avocado coffee milk

Parameter	Order	R ²	Initial Quality (Q ₀)	Final Quality (Q _s)	k Value	Shelf Life (days)
Avocado coffee milk						
Color change (ΔE)	Zero	0.7435	0.00	10.22	0.1279	79.91
pH	Zero	0.9048	6.50	5.42	-0.0180	60.00
	First	0.9091			-0.0029	62.66
Viscosity	Zero	0.8687	15.00	12.59	-0.0422	57.11
	First	0.8728			-0.0029	60.40
Color intensity	Zero	0.8088	6.00	8.00	0.0273	73.26
	First	0.7974			0.0043	66.90
Aroma intensity	Zero	0.8842	7.00	4.00	-0.0591	50.76
	First	0.8999			-0.0094	59.53
Taste intensity	Zero	0.9246	7.00	4.00	-0.0591	50.76
	First	0.9338			-0.0094	59.53
Durian coffee milk						
Color change (ΔE)	Zero	0.7659	0.00	7.28	0.1017	71.58
pH	Zero	0.9303	6.80	6.01	-0.0136	58.09
	First	0.9305			-0.0020	61.75
Viscosity	Zero	0.8671	32.50	26.96	-0.0908	61.01
	First	0.8729			-0.0029	64.44
Color intensity	Zero	0.7348	4.00	5.00	0.0154	64.94
	First	0.7310			0.0037	60.31
Aroma intensity	Zero	0.9051	8.00	4.00	-0.0820	48.78
	First	0.9165			-0.0115	60.27
Taste intensity	Zero	0.9017	8.00	4.00	-0.0975	41.03

3.2. Discussion

3.2.1. Characteristics of Products' Formulations

This study demonstrated that formulation significantly influenced the sensory characteristics of ready-to-drink avocado coffee milk and durian coffee milk products. The formulation containing 5% avocado purée was selected as the most preferred based on hedonic rating results. Table 1 shows that variations in the percentage of avocado purée had a

significant effect ($p < 0.05$) on panelists' preference for aroma, taste, and overall attributes. According to Duncan's post hoc test, the formulation with 5% avocado purée (A1) received the highest score for aroma, which was significantly different from the other two formulations (A2 and A3). In terms of taste and overall acceptability, formulations with 5% and 7.5% avocado purée did not differ significantly and were more preferred than the 10% purée formulation. The 5% avocado purée formulation was selected as the best formulation for avocado coffee milk, as it obtained the highest preference scores across the evaluated attributes. Increasing the concentration of avocado purée led to a decline in taste preference due to the bitter aftertaste detected by panelists. According to Shivachi et al. (2023), this bitterness is associated with lipid oxidation during heating, which leads to the release of oxylipins that contribute to the bitter taste in avocado. Salvador-Reyes and Paucar-Menacho (2019) reported that heating avocado at temperatures above 78°C for more than five minutes significantly increases bitterness intensity. In contrast, increasing the percentage of durian purée enhanced the product's sensory attributes and was more favorably received by panelists.

Table 1 also shows that variations in durian purée concentration had a significant effect ($p < 0.05$) on panelists' preferences for aroma, thickness, taste, and overall attributes. Duncan's multiple range test indicated that the formulations containing 10% and 15% durian purée received the highest scores for aroma. In terms of thickness and taste, the 10% and 15% formulations were significantly preferred over the 5% formulation. The 15% durian purée formulation achieved the highest overall preference score and was statistically different from the other two formulations (5% and 10%). Therefore, the 15% durian purée formulation was selected as the best formulation for the durian coffee milk product.

The natural sugars in durian, such as sucrose, glucose, fructose, and maltose, contributed to a sweeter flavor that was preferred by the panelists. These sugars also resulted in increased total soluble solids (TSS) with higher purée concentrations as can be seen in Table 2. TSS represents the amount of dissolved solids in the product and correlates with sweetness, as sugar is the main component of soluble solids (Nurhayati, 2018). Table 2 shows variations in durian purée concentration significantly affected ($p < 0.05$) the TSS values among the durian coffee milk formulations. In contrast, variations in avocado purée concentration had no significant effect ($p > 0.05$) on TSS values among the avocado coffee milk formulations. The avocado coffee milk formulations with 5%, 7.5%, and 10% avocado purée yielded TSS values of $10.50 \pm 0.71^\circ\text{Brix}$, $11.00 \pm 0.00^\circ\text{Brix}$, and $11.00 \pm 0.00^\circ\text{Brix}$, respectively. The durian coffee milk formulations with 5%, 10%, and 15% durian purée resulted in TSS values of $13.00 \pm 0.00^\circ\text{Brix}$, $14.00 \pm 0.00^\circ\text{Brix}$, and $14.50 \pm 0.71^\circ\text{Brix}$, respectively.

In addition to that, the viscosity test results presented in Table 2 indicate that product viscosity increased proportionally with the increase in fruit purée concentration, whether avocado or durian. The avocado coffee milk formulations with 5%, 7.5%, and 10% avocado purée yielded viscosity values of 15.00 ± 0.00 mPa.s, 23.75 ± 1.77 mPa.s, and 35.00 ± 0.00 mPa.s, respectively. Meanwhile, the durian coffee milk formulations with 5%, 10%, and 15% durian purée resulted in viscosity values of 13.75 ± 1.77 mPa.s, 17.50 ± 0.00 mPa.s, and 32.50 ± 0.00 mPa.s, respectively. According to Salazar-López et al. (2020), avocado contains high levels of fat (12–24%) and dietary fiber (1.4–3%), with approximately 70% being insoluble fiber. Durian, on the other hand, contains more water-soluble components, with sucrose being the dominant sugar (Aziz & Jalil, 2019). Viscosity is positively correlated with the concentration of dissolved solids (Palupi et al., 2015). The addition of fruit purée increases the number of suspended particles and dissolved solids, thereby contributing to higher viscosity.

3.2.2. Products' Quality Changes during Storage

The quality of RTD avocado coffee milk and durian coffee milk product were evaluated while being stored at 4°C and 18°C. Over time, both products exhibited quality changes, as indicated by increasing ΔE values, sensory color changes, declining pH, reduced viscosity,

and decreasing aroma and taste intensity. Table 3 shows the observations on color changes of both products during storage. The avocado coffee milk and durian coffee milk products stored at 4°C and 18°C showed an increase in ΔE values over the storage period. This increase in ΔE corresponded with a decrease in L^* (lightness) values, indicating that the products became progressively darker. The a^* and b^* values fluctuated throughout storage, reflecting changes in the intensity of red and yellow hues in the products. Variations in L^* , a^* , and b^* values contributed to the extent of total color change (ΔE) in the products. For avocado coffee milk stored at 4°C, the ΔE value increased from 0.00 to 2.96 by day 21, while for durian coffee milk, the ΔE value rose from 0.00 to 2.50 on the same day. A greater increase in ΔE was observed in avocado coffee milk stored at 18°C, with a value of 4.64 recorded by day 3. These results indicate that higher storage temperatures accelerate color changes in the product. Increases in a^* and b^* values suggest enhanced intensity of red and yellow coloration during storage. Durian coffee milk stored at 18°C showed signs of spoilage as early as day 3, while avocado coffee milk exhibited signs of spoilage on day 6, with initial indications already apparent by day 3. Consequently, further observation was discontinued.

The increase in ΔE values reflected more pronounced color changes. This was attributed to non-enzymatic browning reactions, particularly the Maillard reaction, which occurs between amino groups from amino acids or proteins and carbonyl groups from reducing sugars. This reaction can proceed at low temperatures and is optimal at pH values between 6 and 10 (Julika., 2022; Jiang et al., 2014). The Maillard reaction produces reactive intermediates such as 5-hydroxymethylfurfural (HMF), which accelerate the formation of brown pigments during storage, causing the product to darken (Dube, 2015; Echavarría et al., 2012). HMF can also be generated through sugar degradation during thermal processing (Dube, 2015), and its accumulation is autocatalytic, promoting further reactions (Thakur, 2018).

Other quality products' parameters including pH, viscosity, and sensory attributes (color, aroma, and taste) were evaluated during storage at 4°C and 18°C as shown in Table 4 and Table 5 respectively. Sensory-evaluated color intensity also tended to become darker over the storage period at both temperatures. However, an increase in lightness was observed in avocado coffee milk stored at 18°C due to sedimentation, which altered the visual appearance of the product to appear lighter. According to Ly et al. (2020), the values obtained from chromameter instruments only represent color within a limited field of view, which can differ from human visual perception, thereby leading to interpretational differences. Hence, sensory testing of color intensity is necessary to validate instrumental measurements.

The pH value reflects the concentration of hydrogen ions, indicating the level of acidity in the product. A more rapid decline in pH was observed in products stored at 18°C, with the pH of avocado coffee milk reaching 5.80 ± 0.19 by day 3. These results indicate that higher storage temperatures accelerate the reactions responsible for pH reduction in the products. The pH decline during storage was associated with the accumulation of acidic compounds, primarily resulting from hydrolysis of intramolecular ester bonds in chlorogenic acid lactones (Lin et al., 2022). Lopane et al. (2024) reported that pH reduction can also result from the hydrolysis of 5-caffeoylquinic acid (5-CQA) into caffeic acid and quinic acid. Additionally, the Maillard reaction contributes through the formation of acids and CO_2 , which increases the concentration of H^+ ions in the product (Nursten, 2005). At 18°C, the pH decrease may also be caused by microbial activity, particularly yeasts, which ferment sugars into organic acids (Shankar et al., 2021). Yeasts grow optimally at pH 3.0–6.5 and utilize the product's high sugar content as a substrate. The observed pH decline in both avocado and durian coffee milk products aligns with the findings of Lin et al. (2022), who reported that the pH of Arabica RTD coffee declined from 4.92 to 4.76 after four months of storage.

Viscosity reduction may result from a decline in total soluble solids during storage (Kusmawati et al., 2020). The viscosity of avocado coffee milk stored at 4°C decreased from

15.00 $\pm$ 1.58 mPa.s to 14.17 $\pm$ 1.02 mPa.s, while the viscosity of durian coffee milk declined from 32.50 $\pm$ 1.37 mPa.s to 30.42 $\pm$ 1.29 mPa.s by day 21. A more rapid decrease in viscosity was observed at 18°C, with the avocado coffee milk reaching a viscosity of 13.13 $\pm$ 1.05 mPa.s as early as day 3. These results indicate that storage at higher temperatures can accelerate the reactions responsible for the decrease in product viscosity. The degradation of dissolved solids, including sugars, due to microbial activity or chemical reactions such as the Maillard reaction, may lower the concentration of soluble solids and reduce product viscosity (Kusuma et al., 2007). Viscosity reduction may also be linked to pectin degradation by pectinase enzymes. Certain yeast species can produce pectinase, which hydrolyzes pectin into simple sugars that are subsequently converted into acidic compounds (Brugnoni., 2013).

A decrease in aroma and taste intensity was also observed during storage. This was attributed to the degradation of volatile aroma compounds, particularly 2-furfurylthiol, a key component of fresh and roasted coffee aroma. This compound is highly susceptible to degradation during storage due to reactions with degradation products of chlorogenic acid and melanoidins, forming covalent phenol or thiol conjugates that compromise the stability of flavor and aroma (Müller & Hofmann, 2007; Quintero et al., 2021). Microbial activity, particularly from yeasts, may also produce volatile compounds such as ethanol and organic acids, which contribute to the development of off-odors (Sperber & Doyle, 2009). Sensory evaluation of aroma intensity for samples stored at 18°C was discontinued after day 3 due to the development of unpleasant odors, indicating product spoilage and rendering further sensory testing unfeasible.

Observations of product stability (see Figure 1 and Figure 2) showed that avocado coffee milk and durian coffee milk stored at 4°C did not exhibit any sedimentation during the 21-day storage period. In contrast, products stored at 18°C began to show signs of sedimentation on day 3, which became more pronounced by day 6. These findings indicate that storage at 4°C can maintain the physical stability of the products for up to 21 days. According to Stokes' law, sedimentation rate is influenced by particle size and the density difference between particles and the surrounding medium. Homogenization helps reduce particle or droplet size, thereby slowing sedimentation and creating a stable dispersion or emulsion system (Silva et al., 2010). Sedimentation at 18°C was likely associated with microbial activity, particularly yeasts, which can promote sediment formation (Sperber & Doyle, 2009). Fermentative yeasts also produce ethanol, CO₂, and organic acids, which may lower the product's pH to the isoelectric point of proteins such as casein, leading to protein coagulation and sedimentation.

3.2.3. Shelf-Life Estimation

Based on the observed quality parameters, both products were estimated to have a shelf life of approximately two months. This estimation was subsequently validated through sensory evaluation by trained panelists, who confirmed that the shelf life of both products was acceptable for up to two months. The kinetics of quality changes were determined by plotting the average values of quality parameters (y-axis) against storage time (x-axis) using linear regression curves based on zero-order and first-order reaction models. The reaction order was determined by selecting the model with the higher coefficient of determination (R²), preferably close to 1. Quality parameters used in shelf life estimation are expected to have a correlation coefficient greater than 0.75. The slope (k) and R² values of each quality parameter for ready-to-drink avocado coffee milk and durian coffee milk stored at 4°C are presented in Table 6. Table 6 indicates that the shelf life estimation of ready-to-drink avocado coffee milk and durian coffee milk based on pH, viscosity, as well as aroma and taste intensity parameters followed first-order reaction kinetics. This is evidenced by the higher coefficient of determination (R²) values for the first-order model compared to the zero-order model. In contrast, shelf life estimation based on color change (ΔE) and color intensity parameters followed zero-order reaction kinetics. The critical parameter for the avocado coffee milk product was taste intensity, with R² = 0.9338 and an estimated shelf life of 59 days, while for

the durian coffee milk product, the critical parameter was pH, with $R^2 = 0.9305$ and an estimated shelf life of 61 days. A parameter with a high correlation coefficient can be selected as the critical parameter, as a higher R^2 value indicates a stronger relationship between the quality parameter and storage time, resulting in more accurate shelf life estimation.

4. Conclusion

This study demonstrated that formulation had a significant effect on the sensory characteristics of ready-to-drink avocado coffee milk and durian coffee milk products. The hedonic rating test showed that the formulation containing 5% avocado purée and 15% durian purée was the most preferred by panelists. Product quality declined during storage, particularly in samples stored at 18°C. Quality deterioration was indicated by color changes, reductions in pH and viscosity, as well as decreases in aroma and taste intensity. These quality changes were attributed to non-enzymatic browning reactions, the accumulation of acidic compounds, and microbial activity. Low-temperature storage was proven to slow the rate of quality degradation. Shelf life estimation at 4°C indicated that the critical parameter for avocado coffee milk was taste intensity, with an estimated shelf life of 59 days, while for durian coffee milk, the critical parameter was pH, with an estimated shelf life of 61 days. Based on these findings, both products show potential for development as ready-to-drink coffee beverages with acceptable quality for up to two months under refrigerated storage.

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