

Physical and Textural Properties of Soy Oil-Based Full-Fat Mayonnaise Enriched with Virgin Red Palm Oil

B Wiguna, J Kahfi*, D Rachman, A S Nasori, E Maryana, Muhamaludin, T Hidayat, G K Aji, M Soraya, W Purwanto, I B Susetyo, W E Widodo

Research Center for Agroindustry, National Research and Innovation Agency (BRIN), Puspipstek Street, Building No. 610-612, LAPTIAB, Puspipstek Serpong Office Area, South Tangerang, Banten, 15314

*Email: jord001@brin.go.id

Abstract. Mayonnaise is a kind of semi-solid oil in water emulsion containing vegetable oil as the oil phase and egg yolk (emulsifier), vinegar, salt, sugar, and spices (especially mustard) as the water phase. In this study, full-fat mayonnaise based on soybean oil was made. Virgin red palm oil was added to the mayonnaise formula as a bioactive component of 5%, 10%, and 15%. Physical properties of the full-fat mayonnaise were investigated by viscosity, pH value, color, and emulsion stability or creaming index. Textural properties including firmness, consistency, and cohesiveness were evaluated by using a texture analyzer. This study aims to identify the effect of adding virgin red palm oil to the mayonnaise formula on the physical and textural properties of the full-fat mayonnaise sample. The results of this study show that there are differences in physical and textural properties of full-fat mayonnaise by using different types of vegetable oil. The addition of virgin red palm oil concentration also has an effect on the physical and textural properties of full-fat mayonnaise.

Keywords: full-fat mayonnaise, physical properties, textural properties, virgin red palm oil, vegetable oil

1. Introduction

A traditional condiment known as mayonnaise is created by gradually blending oil, egg yolk, vinegar, salt, and spices to produce an oil-in-water emulsion with a dispersed lipid phase that ranges from 60 to 80 percent. Due to its distinctive flavor and creamy smoothness, it is one of the most widely used sauces worldwide [1]. Mayonnaise's main ingredient is fat, which is typically derived from vegetable oils [2], [3]. Fat or oil has been shown to influence the physical and sensory properties of the resulting mayonnaise, including taste, aroma, texture, appearance, and creaminess [4]–[6].

Soybean oil is a type of vegetable oil that is widely used in the food industry for the production of mayonnaise. Amertaningtyas and Jaya [7] have also investigated the use of soybean oil in the production of popular mayonnaise. The Indonesian food industry's demand for soybean oil has not been fully met [8]. As a result, Indonesia continues to rely on soybean oil imports, causing the market price of soybean oil to be relatively high. The United States and Argentina are the two countries that provide Indonesia with the most soybeans in the form of seeds and oil, respectively. While Indonesia is a producer of palm oil and coconut oil. Therefore, the production of mayonnaise using raw materials for these two oils is a challenge for the food industry in Indonesia.

Mayonnaise's properties and characteristics are heavily influenced by its constituent ingredients, one of which is vegetable oil. Although low-fat mayonnaise is currently being developed [9], and the role of fat has been partially replaced by gum the use of vegetable oil in the manufacture of mayonnaise can reach 50-75 percent of the total raw material for mayonnaise [4], [7]. The high percentage of oil used has a significant impact on the physical and textural properties of the mayonnaise product.

Vegetable oils contain dietary fatty acids that the body requires [10]. Oil is a triglyceride, which is an ester compound of glycerol and various saturated and unsaturated fatty acids. Fatty acids differ in chain length, the number of double bonds, the position of double bonds, and isomerism [10]. This difference causes the diversity of physical properties of fatty acids and fats formed.

Palm oil extracted from the mesocarp of the fruit of the oil palm plant contains phytonutrient compounds including carotenes 500-700 ppm, tocopherols 500-600 ppm, tocotrienols 1000-1200 ppm, phytosterols 326-527 ppm, phospholipids 5-130 ppm, squalene 200-500 ppm, ubiquinone 10-80 ppm, aliphatic alcohol 100-200 ppm, triterpene alcohol 40-80 ppm, methyl sterols 40-80 ppm and aliphatic hydrocarbons 50 ppm [11]. Phytonutrient compounds that are beneficial for health such as carotene (pro-vitamin A) function to reduce free radicals [12], tocopherols and tocotrienols (vitamin E) have activities as hypocholesterolemic, anti-inflammatory, anticancer, antioxidant, neuroprotective, protective. skin and bone health [13]. However, phytonutrient compounds are degraded during the processing of palm oil into cooking oil. However, the phytonutrient compounds from palm oil have not been utilized optimally.

In Africa, the country of origin of palm oil, palm oil is consumed directly as an ingredient in processed foods without further processing [11], [14]. Meanwhile, in Indonesia, red palm oil has yet to gain acceptance as a healthy food oil because people are accustomed to consuming pale yellow oil. Hashem et al. [15] also discovered that combining soybean oil and sunflower oil with the olein fraction of palm oil (palm olein) significantly increased the oil's oxidative stability during storage.

According to this background, a study was conducted on the relationship between the addition of virgin red palm oil with the physical and textural properties of mayonnaise. Quality assessment of such physical characteristics is done using the instrumental method in order to avoid any subjectivity [16]. A total of four samples of mayonnaise have been developed to see differences in physical and textural properties with the addition of virgin red palm oil. The four samples included soybean oil mayonnaise (control), soybean oil mayonnaise with 5% virgin red palm oil, soybean oil mayonnaise with 10% virgin red palm oil, and soybean oil mayonnaise with 15% virgin red palm oil.

2. Materials and methods

2.1. Materials

Virgin red palm oil was kindly donated by PT. Nutri Palma Nabati, Bogor, West Java. Soybean oil, eggs, rice vinegar, salt, sugar, mustard powder, xanthan gum, and seasoning powder were purchased from a local supermarket in South Tangerang, Banten Province, Indonesia. Four types of mayonnaise were prepared, soybean oil mayonnaise, soybean oil with 5% virgin red palm oil mayonnaise, soybean oil with 10% virgin red palm oil mayonnaise, and soybean oil with 15% virgin red palm oil mayonnaise. The oil phase consisted of soybean oil and virgin red palm oil. The water phase consisted of pasteurized egg yolk, rice vinegar, salt, sugar, mustard powder, water, and seasoning powder. Table 1 shows the composition of water and oil phases of four types mayonnaise, respectively.

Table 1. Ingredients of four types mayonnaise.

Materials	Recipe (%)			
	Soybean oil mayonnaise	Soybean oil with 5% virgin red palm oil	Soybean oil with 10% virgin red palm oil	Soybean oil with 15% virgin red palm oil
Water Phase				
Pasteurized egg yolk	15.00	15.00	15.00	15.00
Vinegar	9.80	9.80	9.80	9.80
Sugar	5.00	5.00	5.00	5.00
Salt	0.20	0.20	0.20	0.20
Xanthan gum	0.20	0.20	0.20	0.20
Mustard powder	0.20	0.20	0.20	0.20
Seasoning powder	0.60	0.60	0.60	0.60
Water	8.00	8.00	8.00	8.00
Total Water Phase	39.00	39.00	39.00	39.00
Oil Phase				
Soybean oil	61.00	56.00	51.00	46.00
Virgin red palm oil	0.00	5.00	10.00	15.00
Total Oil Phase	61.00	61.00	61.00	61.00
Total Water Phase and Oil Phase	100.00	100.00	100.00	100.00

2.2. Mayonnaise Preparation

Four types mayonnaise samples were prepared according to the recipe shown in Table 1. The samples were prepared using a lab-scale mixer (Turbo mixer) and hand mixer (Phillips) in a five-step standardized process. In the first step, water phase materials except xanthan gum were preliminarily mixed using a turbo mixer for 2 minutes. In the second step, oil phase material was then slowly added under vigorous mixing for 5 minutes, allowing complete oil incorporation. In the third step, xanthan gum, previously dispersed with the oil phase, was added slowly to the mixer. In the fourth step, continue mixing for 2 minutes after all of the ingredients have been combined by using a turbo mixer. The last step, continue mixing for 1 minute by using a hand blender.

**Figure 1.** Preparation of mayonnaise samples

2.3. Viscosity Measurement

Viscosity measurement was performed by using a viscometer (Brookfield, model DV-II+) at 23°C. The viscosity of the mayonnaise sample was measured using a spindle number 5 and a speed of 2 rpm

in the viscosity test. The mayonnaise sample was measured by setting the sample's height in the glass so that the line mark on the spindle was immersed in the mayonnaise sample.

2.4. pH Value Measurement

The pH value of the samples was measured by using a pH meter (Mettler Toledo). Before measuring the pH value, calibration was carried out using pH 4.00, 7.00, and 9.00 in order to obtain accurate results.

2.5. Color Evaluation

The color of the mayonnaise sample was evaluated with a Chroma Meter CR-410 (Konica Minolta, Osaka, Japan), illuminant D65; each sample was homogeneously distributed into a glass vessel and the color was recorded at three different points. The average of the three measurements was assessed for all the colorimetric parameters (L^* , a^* , and b^*). In the CIE Lab color space, L^* represents the lightness within the range of 0 (black) to 100 (white); a^* is the redness, from green ($-a^*$) to red ($+a^*$); and b^* is the yellowness, from blue ($-b^*$) to yellow ($+b^*$).

2.6. Creaming and Thermal Creaming Evaluation

A fixed amount of each sample (8 ± 1 g) was transferred into a cylindrical plastic tube container and centrifuged at 5,000 rpm for 20 minutes to determine the creaming value at room temperature. Then emulsion creaming at room temperature was determined by following Equation (1) according to Kobra Rahmati et.al. [17]:

$$\%H = \frac{H}{H_0} \times 100 \quad (1)$$

Where %H is the percentage of creaming, H is the height of the cream separated from emulsion and H_0 is the initial emulsion height in the tube container. The same procedure was used to determine thermal creaming, but tube containers were incubated at 80°C for 20 minutes before centrifugation.

2.7. Texture Analysis

Firmness, consistency, and cohesiveness of samples were evaluated using a texture analyzer TA-XT2 (Stable Micro Systems, UK) at 25°C by back extrusion method according to the method of Fernandes and de las Mercedes Salas Mellado [18]. The samples were gently transferred into 150 ml cylindrical containers (80 mm height and 60 mm internal diameter) up to the 125 ml mark. A 35-mm diameter disc was applied for compression (Stable Micro Systems, UK). The applied cycle consisted of constant speed (1 mm/s), till reaching the 40 mm depth. From the force-time curve, firmness, consistency, and cohesiveness were calculated. The peak or maximum force is taken as a measurement of firmness. The area of the curve is taken as a measurement of consistency. The negative region of the graph, produced on probe return, considered as the maximum negative force is taken as an indication of the cohesiveness of the sample.

3. Results and discussion

3.1. Viscosity value evaluation

The results of viscosity analysis of this study are consistent with the viscosity reported in the literature, which is 4762 cp [5] and 3202 cp [19]. According to [7], commercial mayonnaise on the market has a viscosity of 3347 cp. Mayonnaise in this study has a higher viscosity characteristic than commercial mayonnaise, which is due to differences in the formulation and ingredients used in mayonnaise production. According to [2], mayonnaise's viscosity can be increased by adding a number of continuous phases (egg yolks) and other stabilizers such as dextrin and gum. Viscosity parameter on food products is also affected by total dissolve solid content and measure content. Food product with

high measure content results in low viscosity. Inversely, the higher total dissolved solid results in higher viscosity [20] . However, this research did not measure both the total dissolved solid and measure content of the mayonnaise.

According to Table 2 and Figure 2, soybean oil mayonnaise has the highest viscosity value of any mayonnaise sample. Meanwhile, the viscosity of soybean oil mayonnaise with 15% virgin red palm oil is the lowest. The concentration of virgin red palm oil in mayonnaise products can affect the viscosity value of the mayonnaise.

According to Kupongsak and Sathitvorapojjana's study [19] , the relationship between fatty acid composition and viscosity value in this study is consistent with their finding that the higher the PUFA content, the higher the mayonnaise's created viscosity. O'Brein [21] asserts that the PUFA content in palm oil is lower than the PUFA content in soybean oil. The composition of PUFA in palm oil is 9.70, while that in soybean oil is 61.00, as shown in Table 3. The high PUFA composition in soybean oil allows mayonnaise products to have a higher viscosity value.

Table 2. Viscosity value of mayonnaise samples

Sample	Viscosity Value (Spindel Number 5, 2 rpm)			Average	St.Dev
	Point 1	Point 2	Point 3		
Soybean oil mayonnaise	158,400.00	154,000.00	151,400.00	154,600.00	3,538.36
Soybean oil mayonnaise with 5% virgin red palm oil	155,400.00	154,400.00	153,800.00	154,533.33	808.29
Soybean oil mayonnaise with 10% virgin red palm oil	122,200.00	121,400.00	120,400.00	121,333.33	901.85
Soybean oil mayonnaise with 15% virgin red palm oil	117,000.00	116,800.00	116,400.00	116,733.33	305.51

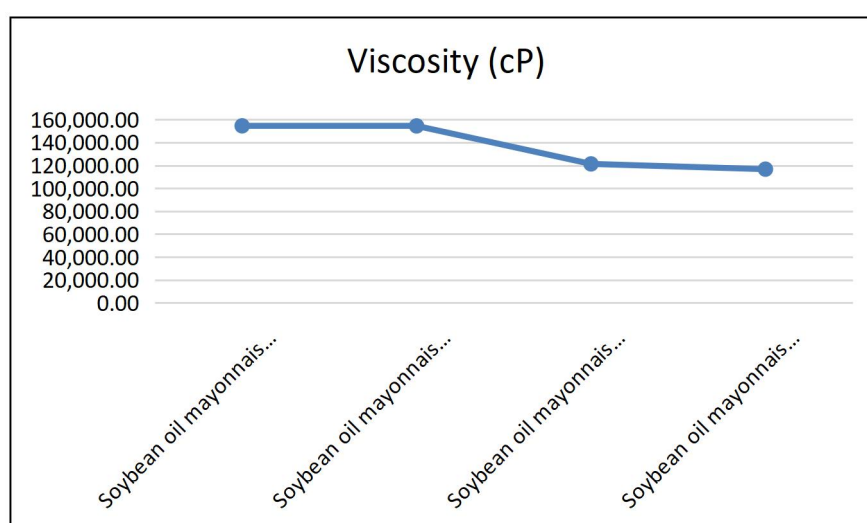


Figure 2. Viscosity value of mayonnaise samples

Table 3. Fatty acid composition from vegetable oil

Source of Vegetable Oil	Fatty Acid Composition (%)		
	Saturated Fatty Acid (SFA)	Mono Unsaturated Fatty Acid (MUFA)	Poly Unsaturated Fatty Acid (PUFA)
Soybean oil	15.50	23.50	61.00
Palm oil	51.40	38.90	9.70

3.2. pH Value Analysis

According to [22], maintaining the mayonnaise pH between 2.4 to 4.5 can avoid the microbial development that degrades mayonnaise products, therefore the pH range obtained in this study is still within the mayonnaise pH range that should be attained. As shown in Table 4 and Figure 3, soybean oil mayonnaise is the lowest pH value at 3.89 and soybean oil mayonnaise with 5% virgin red palm oil is the highest pH value at 4.23. According to pH value data, as shown in Table 4 and Figure 3, the addition of virgin red palm oil can reduce the pH value

Table 4. pH Value of mayonnaise samples

Sample	pH Value			Average	St.Dev
	Point 1	Point 2	Point 3		
Soybean oil mayonnaise	3.90	3.86	3.90	3.89	0.02
Soybean oil mayonnaise with 5% virgin red palm oil	4.24	4.22	4.22	4.23	1.16
Soybean oil mayonnaise with 10% virgin red palm oil	4.21	4.20	4.20	4.20	0.01
Soybean oil mayonnaise with 15% virgin red palm oil	4.13	4.15	4.17	4.15	0.02

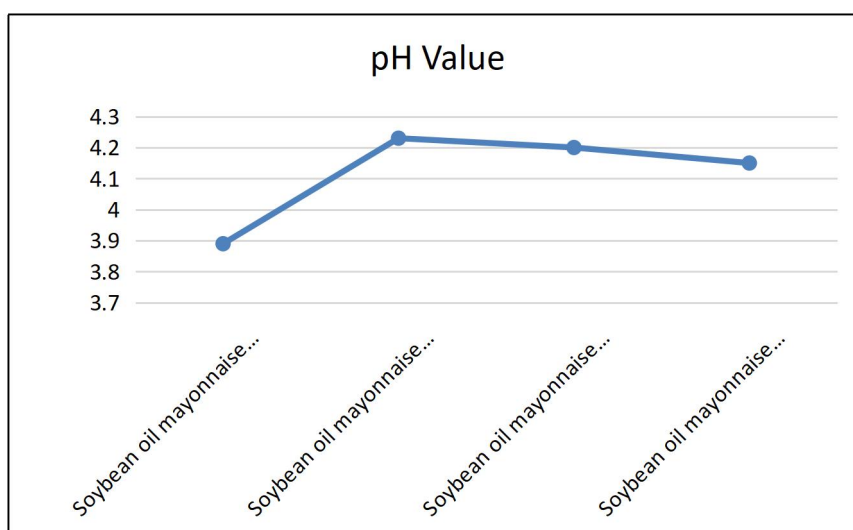


Figure 3. pH Value of mayonnaise samples

3.3. Color Evaluation

Color measurement in food analysis has been widely used to determine the quality of product during storage and after certain process treatments [23]–[25]. As shown in Table 5 and in Figure 4, soybean oil mayonnaise is the lightest sample with a higher L-value probably due to the greater proportion of soybean oil. Kupongsak and Sathitvorapojjana [19] discovered that mayonnaise with a high PUFA content had a higher L brightness value. This indicates that the brightness level or L-value has an effect on the fatty acid composition. As shown in Table 3, the PUFA composition of soybean oil was higher than that of palm oil.

According to Table 5 and Figure 4, the addition of virgin red palm oil in mayonnaise can increase the L-value. Differences in lightness may be caused by differences in light scattering among samples. Light absorption and scattering are affected by the refractive index, droplet concentration, size, and dispersion, as well as the presence of chromophoric materials [26]. Another factor affecting the lightness of emulsions is particle size. According to Mc Clements, the emulsions color changes from a bright white color to an increasingly gray color as the droplet size increases [26]. On the other hand, the addition of virgin red palm oil concentration reduces the a-value and b-value as well.

Table 5. Color evaluation of four types mayonnaise

Sample Name	Value of Color	Repetition			Average	Deviation Standard
		1	2	3		
Soybean oil mayonnaise (control)	L^*	111.10	111.10	111.11	111.10	0.006
	a^*	-1.55	-1.54	-1.53	-1.54	0.010
	b^*	33.41	33.341	33.342	33.36	0.040
Soybean oil mayonnaise with 5% virgin red palm oil	L^*	74.57	74.49	74.45	74.50	0.061
	a^*	12.75	12.83	12.93	12.84	0.090
	b^*	66.65	66.65	66.61	66.64	0.023
Soybean oil mayonnaise with 10% virgin red palm oil	L^*	76.46	76.41	76.41	76.43	0.029
	a^*	10.27	10.25	10.27	10.26	0.012
	b^*	64.84	64.81	64.82	64.82	0.015
Soybean oil mayonnaise with 15% virgin red palm oil	L^*	79.45	79.44	79.41	79.43	0.021
	a^*	5.74	5.75	5.78	5.76	0.021
	b^*	57.49	57.50	57.47	57.49	0.015

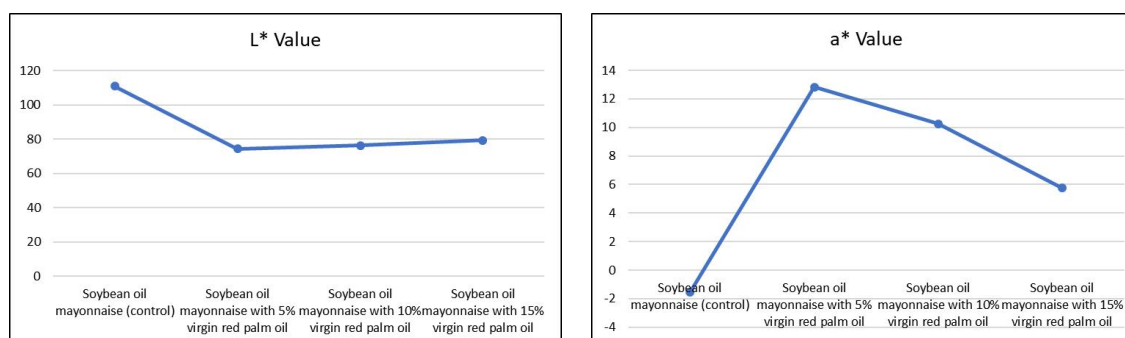


Figure 4. Color evaluation of mayonnaise samples

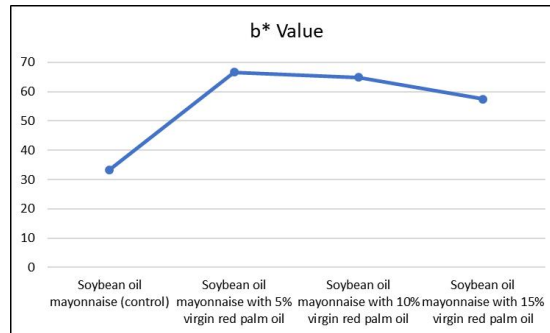


Figure 4. Color evaluation of mayonnaise samples

3.4. Stability of Emulsion (Creaming Index Evaluation)

Creaming data are shown in Table 6 and Figure 5. Creaming refers to phase separation due to the upward rise of fat globules due to differences in density between the dispersed and the continuous phase [27]. For large globules, the extent of creaming will depend upon the duration of storage time of the product. Thermal creaming results of samples are shown in Table 6 and Figure 5, describing accelerated flocculation the results in more creaming caused by the high-temperature samples were placed in.

As shown in Figure 5, at room temperature the creaming index decreased with the addition of virgin red palm oil concentration. This indicates that the addition of virgin red palm oil to mayonnaise products can maintain the stability of the emulsion at room temperature. Unlike at room temperature, the stability of emulsion at 80°C tends to deteriorate as the concentration of virgin red palm oil increases. Based on Table 6, the most stable emulsion at room temperature is soybean oil mayonnaise. While the weakest emulsion stability at room temperature is soybean oil with 5% virgin red palm oil.

At 80°C, the best emulsion stability is soybean oil mayonnaise with 5% virgin red palm oil and the weakest emulsion stability at 80°C is soybean oil mayonnaise with 15% virgin red palm oil.

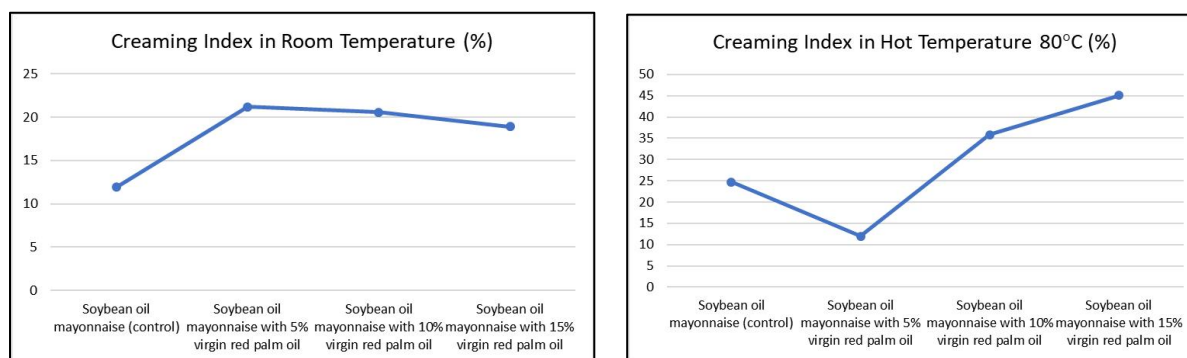
The major mechanism preventing droplet flocculation, in protein stabilized emulsions is electrostatic repulsion and it occurs between emulsion droplets with electrically charged surfaces, which may occur in emulsions due to the adsorption of ionic or ionizable components such as surfactants, phospholipids, proteins or polysaccharides [27].

Table 6. Creaming index evaluation of mayonnaise samples

Sample Name	Repetition	Creaming Index (%)	Average of Creaming Index (%)	Deviation Standard
Room Temperature				
Soybean oil mayonnaise (Control)	1	11.90	11.91	0.74
	2	12.65		
	3	11.18		
Soybean oil mayonnaise with 5% virgin red palm oil	1	21.90	21.21	0.60
	2	20.83		
	3	20.88		
Soybean oil mayonnaise with 10% virgin red palm oil	1	21.07	20.57	1.64
	2	18.74		
	3	21.90		

Table 6. Creaming index evaluation of mayonnaise samples

Sample Name	Repetition	Creaming Index (%)	Average of Creaming Index (%)	Deviation Standard
Soybean oil mayonnaise with 15% virgin red palm oil	1	19.25	18.89	0.37
	2	18.91		
	3	18.5		
Hot Temperature (80°C)				
Soybean oil mayonnaise (Control)	1	27.77	24.69	2.69
	2	22.80		
	3	23.49		
Soybean oil mayonnaise with 5% virgin red palm oil	1	7.94	12.00	4.00
	2	12.13		
	3	15.93		
Soybean oil mayonnaise with 10% virgin red palm oil	1	33.57	35.87	2.37
	2	38.31		
	3	35.71		
Soybean oil mayonnaise with 15% virgin red palm oil	1	46.75	45.07	1.79
	2	45.28		
	3	43.19		

**Figure 5.** Creaming index evaluation of mayonnaise samples

3.5. Texture Analysis

Textural properties of mayonnaise prepared using soybean oil and virgin red palm oil 5%, 10%, and 15% are presented in Table 7 and Figure 6. As shown in Table 7, the highest firmness value was soybean oil mayonnaise of 143.744 (g). While the lowest firmness value was soybean oil mayonnaise with 15% virgin red palm oil of 97.635 (g). Firmness value were decreased with increasing levels of virgin red palm oil. The firmness also expressed as hardness, is the peak of the strength needed to change the dimensions and the form of the object during compression [28].

Kupongsak and Sathitvorapojjana [19] also reported that firmness values are influenced by fatty acid composition. The unsaturated fatty acid composition of mayonnaise products probably increased the

firmness of mayonnaise. As shown in Table 3, soybean oil has a higher PUFA value than palm oil. This gives soybean oil mayonnaise a firmer texture than other types of mayonnaise.

The consistency showed similar tendencies to firmness. The highest consistency was observed for soybean oil mayonnaise by 4521.540 (g.sec) when compared to all mayonnaise samples. The lowest consistency was observed for soybean oil mayonnaise with 15% virgin red palm oil by 3341.148 (g.sec).

Soybean oil mayonnaise exhibited the highest negative value for cohesiveness attribute, compared with other samples. More negative cohesiveness value indicated more sticky sample [29].

Generally, different oil types can change the ratio of viscosity between continuous and dispersed phase, that further governs the minimum size of droplet. However, the viscosity of the samples can partially but not totally reflects the texture parameters [29]. Figures 7 to 10 illustrate the textural properties which include firmness, consistency, cohesiveness, and index of viscosity of each mayonnaise sample.

Table 7. Result of texture analysis

Sample Name	Repetition	Firmness (g) Force 1	Consistency (g.sec) Area F-T 1:2	Cohesiveness (g) Force 2	Index of Viscosity (g.sec) Area F-T 2:3
Soybean oil mayonnaise	1	143.287	4685.177	-195.245	-641.925
	2	144.507	4467.585	-194.024	-645.246
	3	143.439	4411.858	-190.667	-634.854
Average		143.744	4521.540	-193.312	-640.675
Deviation Standard		0.665	144.427	2.371	5.307
Soybean oil mayonnaise with 5% virgin red palm oil	1	123.831	4169.153	-170.067	-564.307
	2	122.610	4214.319	-168.312	-553.744
	3	114.980	3868.219	-161.674	-534.831
Average		120.474	4083.897	-166.684	-550.961
Deviation Standard		4.796	188.143	4.427	14.934
Soybean oil mayonnaise with 10% virgin red palm oil	1	106.740	3669.600	-150.993	-497.800
	2	104.451	3568.493	-148.170	-487.768
	3	103.154	3502.173	-146.644	-482.626
Average		104.782	3580.089	-148.602	-489.398
Deviation Standard		1.816	84.313	2.206	7.717
Soybean oil mayonnaise with 15% virgin red palm oil	1	100.026	3429.885	-143.134	-466.972
	2	96.974	3336.916	-139.853	-459.857
	3	95.906	3256.642	-138.404	-453.762
Average		97.635	3341.148	-140.464	-460.197
Deviation Standard		2.138	86.699	2.424	6.611
Average		116.659	3881.668	-162.266	-535.308
S.D.		17.833	469.228	20.429	69.521
C.V.		15.286	12.088	-12.590	-12.987

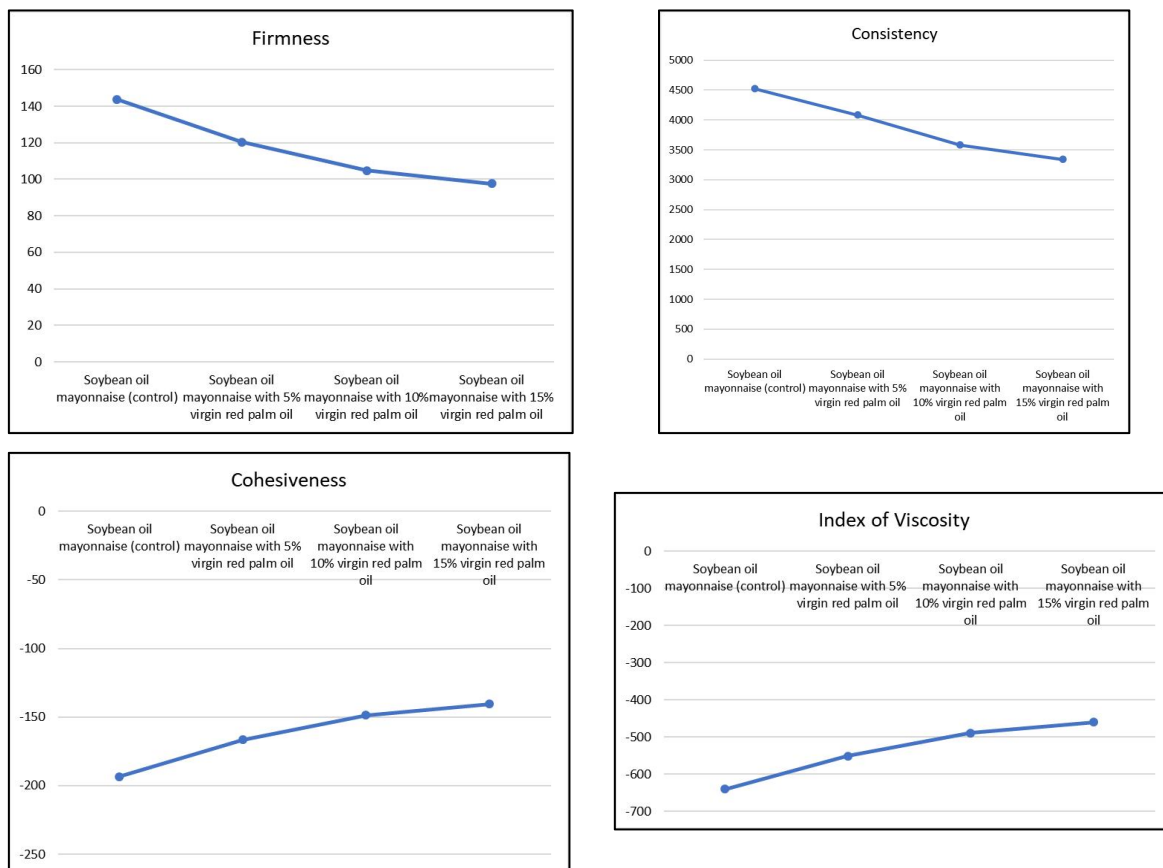


Figure 6. Textural attributes of mayonnaise samples

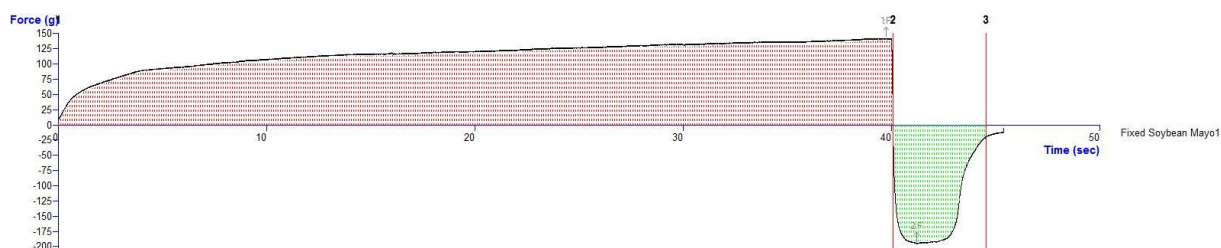


Figure 7. Textural properties for soy oil mayonnaise (control)

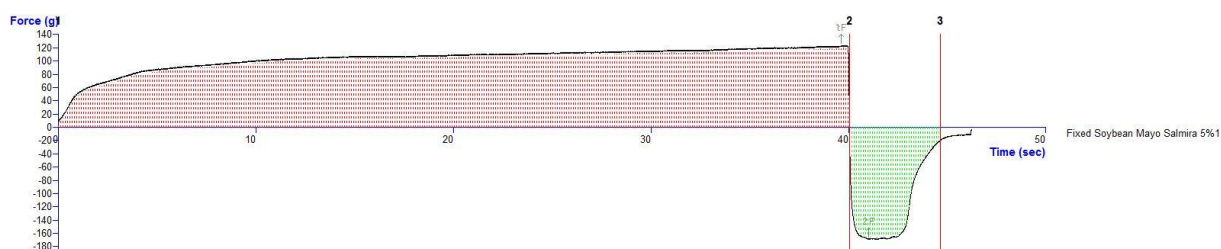


Figure 8. Textural properties for soy oil mayonnaise enriched 5% virgin red palm oil

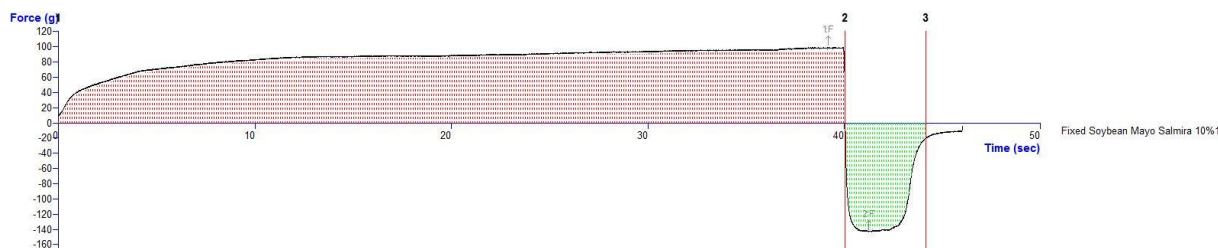


Figure 9. Textural properties of soy oil mayonnaise enriched 10% virgin red palm oil

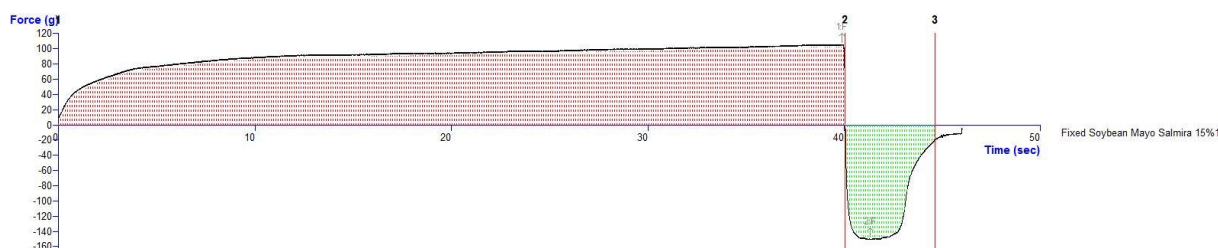


Figure 10. Textural properties of soy oil mayonnaise enriched 15% virgin red palm oil

4. Conclusions

The different fatty acid compositions of SFA, MUFA, and PUFA as a result of the use of different vegetable oils in the production of mayonnaise primarily can affect the viscosity, color, pH, stability of emulsion or creaming index, and textural properties. A higher PUFA composition will result in higher viscosity. In this study, soybean oil mayonnaise with a higher PUFA composition gave a higher viscosity value than other mayonnaise. A higher L-value or a brighter mayonnaise color will be obtained with a dominant PUFA composition. The concentration of virgin red palm oil also correlated with a decrease in the pH value of the mayonnaise product. At room temperature, the creaming index decreased with the addition of virgin red palm oil concentration. This indicates that the addition of virgin red palm oil to mayonnaise products can maintain the stability of the emulsion at room temperature. Unlike at room temperature, the stability of emulsion at 80°C tends to deteriorate as the concentration of virgin red palm oil increases. The firmness value is influenced by fatty acid composition. The unsaturated fatty acid composition of mayonnaise products probably increased the firmness of mayonnaise. Mayonnaise with a dominant PUFA composition showed the highest negative value for the cohesiveness attribute, compared to other samples.

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