Sains Malaysiana 52(10)(2023): 2843-2854
http://doi.org/10.17576/jsm-2023-5210-09

The Influence of Virgin Red Palm Oil on the Physical and Textural Properties of Various Vegetable Full-Fat Mayonnaise

(Pengaruh Minyak Sawit Merah Dara terhadap Sifat Fizikal dan Tekstur Pelbagai Mayones Sayuran Tinggi Lemak)

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Received: 3 May 2023/Accepted: 27 September 2023

ABSTRACT

Mayonnaise is a type 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 is based on various vegetable oils (sunflower oil, sesame oil, and coconut oil). Virgin red palm oil (VRPO), substituting sunflower oil, sesame oil, and coconut oil, was added to the mayonnaise formula as a 0%, 5%, 10%, and 15% bioactive component. The physical properties of the full-fat mayonnaise were investigated by measuring viscosity, pH value, color, and emulsion stability or creaming index. Textural properties including firmness, consistency, and cohesiveness were evaluated using a texture analyzer. This study aimed to identify the effect of adding VRPO to the mayonnaise formula on the physical and textural properties of the vegetable full-fat mayonnaise sample. The result of this study found that the pH value of added VRPO (5, 10, and 15%) in all mayonnaise samples was higher considerably ($p<0.05$) compared to the mayonnaise without VRPO addition. Moreover, the color of mayonnaise from different vegetable oils when supplemented with VRPO was significantly decreased ($p<0.05$) in the L* values, indicating a reduction in the lightness. Conversely, there was a significant increase ($p<0.05$) in the a* values, showing an increase in redness, and b* values that demonstrated an increase in yellowness, in all of the mayonnaise samples when added with the VRPO. This study also highlighted that there was a significant difference ($p<0.05$) in the texture between all mayonnaise samples, showing that supplemented VRPO in vegetable oils was giving a lower value of firmness and consistency and a higher value of viscosity index. In conclusion, the addition of VRPO increases the physical characteristics such as pH, color (redness and yellowness), and creaming index, as well as reduces the textural features (firmness, and consistency) in full-fat mayonnaise.

Keywords: Full-fat mayonnaise; physical properties; textural properties; virgin red palm oil

ABSTRAK

Mayones ialah jenis produk emulsi minyak dalam air yang mengandung minyak sayuran sebagai fasa minyak dan kuning telur (pengemulsi), cuka, garam, gula dan rempah (terutama mustard) sebagai fasa air. Dalam penelitian ini mayones tinggi lemak berbahan dasar berbagai minyak sayuran (minyak bunga matahari, minyak bijan dan minyak kelapa). Minyak sawit merah murni menggantikan minyak bunga matahari, minyak bijan dan minyak kelapa ditambahkan kepada formula mayones sebagai komponen bioaktif 5%, 10% dan 15%. Sifat fizikal mayones tinggi lemak dianalisis dengan mengukur viksositi, nilai pH, warna dan penstabil emulsi atau indeks krim. Sifat tekstur yang meliputi kekerasan, ketekalan dan keterpaduan dinilai menggunakan penganalisis tekstur. Penelitian ini bertujuan untuk mengenal pasti pengaruh penambahan minyak sawit merah dara ke dalam formula mayones terhadap sifat fizikal dan tekstur sampel mayones tinggi lemak. Hasil penelitian ini menunjukkan bahwa terdapat perbezaan sifat fisikal dan tekstur mayones tinggi lemak selepas mengaplikasikan penambahan minyak sawit merah dara ke dalam berbagai jenis minyak sayuran ($p<0.05$). Kesimpulannya, penambahan minyak sawit merah dara berpengaruh terhadap fizikal dan tekstur mayones tinggi lemak.

Kata kunci: Mayones tinggi lemak; minyak sawit merah dara; sifat fizikal; sifat tekstur

Introduction

Mayonnaise, due to its distinct flavor and creamy texture, is one of the most popular sauces in the world (Flamminii et al. 2020; Nikzade, Tehrani & Saadatmand-Tarzjan 2011). It is made by gradually combining a mixture of vegetable oil, egg yolk, vinegar, salt, sugar, and spices (especially mustard) to generate an oil-in-water emulsion with a 60 to 80% dispersed lipid phase (Morley et al. 2016). In particular, fat is the main ingredient of mayonnaise, which is typically produced from vegetable oils (Depree & Savage 2001; Gorji et al. 2016). Vegetable oils are mainly composed of triglycerides, which are ester compounds made up of glycerol and an assortment of saturated and unsaturated fatty acids. These triglycerides contain dietary fatty acids necessary for the human body (Kris-Etherton 2007). The fatty acids also vary in chain length, number, and position of double bonds, as well as isomerism (Kris-Etherton 2007). The variation of fatty acids within vegetable oils affects a variety of mayonnaise characteristics, such as nutritional, technological, physical, and textural properties (Basuny & Al Marzooq 2011; Kovalcuks, Straumite & Duma 2016; Lioe 2015). In general, vegetable oils contribute to the mouthfeel, appearance, flavor, aroma, taste, texture, creaminess, color, palatability, and even shelf life of the food emulsion (Boye 2013; Mun et al. 2009; Running, Craig & Mattes 2015; Schalde, Mittermaier & Sanahuja 2022).

Sunflower oil (SFO), sesame oil (SO), and coconut oil (CO) are types of vegetable oils widely used in mayonnaise products (Leahu et al. 2022; Muhialdin et al. 2019; Samsuri et al. 2022). Each of these oils has different fatty acid characteristics. SFO has the highest polyunsaturated fatty acids (PUFA) content among other vegetable oils at 68.70%. SO has the highest monounsaturated fatty acids (MUFA) content at 41.40%. On the other hand, CO has the highest saturated fatty acids (SFA) content at 92.00% (O'Brien 2009). Due to the different fatty acid compositions, these vegetable oils contribute to different properties of mayonnaise. For example, SFO provides a light flavor and a smooth texture (Patil & Benjakul 2019), SO adds a distinct flavor and aroma (Gómez-Zavaglia et al. 2010), and CO delivers a creamy texture and a slightly sweet flavor (Böhm et al. 2000). Other than sensory properties, the different fatty acid compositions in vegetable oils can also affect the physical properties of food products including rheological and viscosity characteristics as shown by Yalcin, Toker and Dogan (2012). Thus, these differences in fatty acid compositions from SFO, SO, and CO could contribute to the diverse physical properties of mayonnaise.

The properties of mayonnaise can be improved through the fortification of natural components high in antioxidant activity, which offer a health benefit effect. One of the natural antioxidant sources is red palm oil (RPO). RPO is one type of palm oil that does not experience a refining and bleaching process and thus retains its carotene (Tan et al. 2021). The carotene concentration in RPO is approximately 500 ppm and primarily consists of α-carotene (37%) and β-carotene (47%), lycopene (1.5%), and cis-α-carotene (6.9%). Additionally, this oil also contains approximately 800 ppm of vitamin E, with 70% of the content in the form of tocotrienols, including α-, β-, and γ-tocotrienols, and 30% as tocopherols (Mba, Dumont & Ngadi 2015; Qureshi et al. 2018; Van Rooyen et al. 2008). Carotene acts as a precursor of vitamin A that plays a vital role in sustaining epithelial and mucous membranes, immune and red blood cells, as well as the visual system (Pignitter et al. 2016). Since the human body cannot synthesize vitamin A, the provitamin A must be ingested through animal and plant-sourced foods (Pignitter et al. 2016).

Previous researchers have studied the effect of RPO addition on food products, such as snacks, biscuits, frying oil, margarine, shortening, spreads, and salad oil (Tan et al. 2021). Ayu et al. (2020) used a mixture of RPO and striped catfish oil to enhance the photo-oxidation stability of mayonnaise. Samsuri et al. (2022) studied the effect of high-shear homogenizer treatment on the physical properties and structural stability of RPO and palm oil (PO) based mayonnaise. Haniff et al. (2020) used Carotino, a brand of RPO in Malaysia to increase the oxidative stability of PO-based mayonnaise. These researches showed that RPO is suitable to be incorporated in mayonnaise and with acceptable sensory properties.

However, as far as we know, there is no study focusing on the influence of VRPO (VRPO) on the characteristics of full-fat mayonnaise based on edible vegetable oils other than PO. Thus, this study aimed to investigate the effect of VRPO addition on the physical and textural properties of SO, SFO, and CO-based full-fat mayonnaise. In this study, we used 12 formulas of SO, SFO, and CO mayonnaise with different VRPO concentrations (0, 5, 10, and 15%). This study is expected to give new insights into the possibility of VRPO utilization as a major ingredient of food products, especially mayonnaise.

Materials and Methods

Materials

VRPO was kindly provided by PT. Nutri Palma

Nabati, Bogor, West Java, Indonesia. SFO (Mazola, PT. Pan Pacific, Indonesia), SO (ABC, PT. Heinz ABC, Indonesia), CO (Barco, PT. Barco Indonesia, Indonesia), eggs, rice vinegar (Heinz, Indonesia), salt (Dolphin Salt, Indonesia), sugar (Gulaku, PT. Sugar Group Companies, Indonesia), mustard powder, xanthan gum, and seasoning powder were obtained from a local supermarket in South Tangerang, Banten Province, Indonesia.

MAYONNAISE PREPARATION

Twelve mayonnaise formulas were prepared from SFO, SO, and CO with different concentrations of VRPO (0,5, 10, and 15%). The oil phase consisted of a mixture of vegetable oils and VRPO, while the water phase included pasteurized egg yolk, rice vinegar, salt, sugar, mustard powder, water, and seasoning powder. Table 1 shows the ingredients of the water phase. Table 2 displays the ingredients of mayonnaise formulas containing water phase and oil phase composed of VRPO, SFO, SO, and CO.

A standardized five-step process was employed, utilizing both a lab-scale mixer (Turbo mixer, China) and a hand mixer (Phillips, Japan). Initially, the water phase ingredients, except xanthan gum, were combined using the turbo mixer for a duration of 2 min. The oil phase ingredients, subsequently, were then slowly introduced into the mixture, with vigorous mixing continuing for 5 min until complete oil incorporation was achieved. The previously dispersed xanthan gum was added gradually to the mixer as the third step. After combining all ingredients, the turbo mixer was operated for an additional 2 min , followed by 1 minute of mixing using a hand blender. Finally, to ensure objectivity instrumental methods were employed to evaluate the physical characteristics of the mayonnaise samples (Susanti et al. 2022).

VISCOSITY MEASUREMENT

To measure the viscosity of the mayonnaise sample, a viscometer (Brookfield, model DV-II+) was utilized at a temperature of 23 °C. A spindle number 5 was used at a speed of 2 rpm to measure the samples viscosity.

pH VALUE MEASUREMENT

To determine the pH value of the samples, a pH meter (Mettler Toledo, United States) was utilized. To ensure precise results, calibration was performed prior to pH measurement using pH 4.00, 7.00, and 9.00.

TABLE 1. Ingredients of water phase within 39 g of total weight

No	Ingredients	Weight (g)
1	Pasteurized egg yolk	15
2	Vinegar	9.8
3	Sugar	5
4	Salt	0.2
5	Xanthan gum	0.2
6	Mustard powder	0.2
7	Seasoning powder	0.6
8	Water	8
Total weight		39

TABLE 2. Ingredients of twelve types of mayonnaise are given per 100 g sample. The percentage value following the formula's name represents the concentration of VRPO (w/w)

No	Formula Name	Weight (g)					Total Weight (g)
		Water phase	VRPO	SFO	SO	CO	
1	SFO-0% VRPO	39	0	61	0	0	100
2	SFO-5% VRPO	39	5	56	0	0	100
3	SFO-10% VRPO	39	10	51	0	0	100
4	SFO-15% VRPO	39	15	46	0	0	100
5	SO-0% VRPO	39	0	0	61	0	100
6	SO-5% VRPO	39	5	0	56	0	100
7	SO-10% VRPO	39	10	0	51	0	100
8	SO-15% VRPO	39	15	0	46	0	100
9	CO-0% VRPO	39	0	0	0	61	100
10	CO-5% VRPO	39	5	0	0	56	100
11	CO-10% VRPO	39	10	0	0	51	100
12	CO-15% VRPO	39	15	0	0	46	100

COLOR EVALUATION

The evaluation of the mayonnaise sample color was conducted using a Chroma Meter CR-410 (Konica Minolta, Osaka, Japan) with illuminant D65. The sample was uniformly distributed into a glass container, and the color was measured at three distinct points. The colorimetric parameters (L*, a*, and b*) were analyzed based on the average of the three measurements. The CIE Lab color space was used, in which L* represents the lightness, ranging from 0 (black) to 100 (white); a* indicates the degree of redness, from green (-a*) to red (+a*); and b* denotes the degree of yellowness, from blue (-b*) to yellow (+b*).

CREAMING AND THERMAL CREAMING (EMULSION STABILITY TEST)

Each sample was weighed (8±1 g) and placed into a cylindrical plastic tube container, which was then subjected to centrifugation at 5,000 rpm for 20 minutes to measure the creaming value at room temperature. The creaming value was calculated by following Equation (1) based on the method described by Rahmati, Tehrani and Daneshvar (2014):

$$\%H = \frac{H}{H_0} \times 100 \tag{1}$$

where %H is the percentage of creaming; H represents the height of the separated cream from the emulsion and Ho represents the initial height of the emulsion in the tube container. To determine thermal creaming, the same procedure was followed, but the tube containers were incubated at 80 °C for 20 min before centrifugation.

TEXTURE ANALYSIS

The firmness, consistency, and cohesiveness of the samples were assessed using a TA-XT2 texture analyzer (Stable Micro Systems, United Kingdom) at 25 °C employing the back extrusion method according to the method of Fernandesa and Mercedes Salas Mellado (2018). The samples were carefully transferred to 150 mL cylindrical containers (80 mm height and 60 mm internal diameter) up to the 125 mL mark. Compression was applied using a 35-mm diameter disc (Stable Micro Systems, UK) at a constant speed (1 mm/s) until a depth of 40 mm was reached. Firmness, consistency, and cohesiveness were then calculated from the force-time curve. The maximum force, or peak force, was considered a measure of firmness. The area under the curve was taken as a measure of consistency, and the maximum negative force, which is the negative region of the graph produced on probe return, was taken as an indication of the cohesiveness of the sample.

STATISTICAL ANALYSIS

Past software 4.11 was used to analyze the data (Hammer, Harper & Ryan 2001). ANOVA test was used to analyze the difference among the vegetable full-fat mayonnaise groups. Next, the Tukey test was applied to examine the dissimilarity between groups. A significant value was set at $p<0.05$.

RESULTS AND DISCUSSION

VISCOSITY EVALUATION

Table 3 shows the viscosity properties of mayonnaise samples. There was a significant difference ($p<0.05$) observed in the viscosity between all mayonnaise samples. The study by Depree and Savage (2001) demonstrated that the addition of egg yolks, as well as other stabilizing agents such as dextrin and gum, could enhance the viscosity of mayonnaise by introducing a range of continuous phases.

Based on the viscosity properties measurements presented in Table 3, the addition of varying amounts of VRPO (5%, 10%, and 15%) to each mayonnaise sample had a significant impact on reducing the viscosity value of the mayonnaise samples. This result is in accordance with a previous study conducted by Kupongsak and Sathitvorapojjana (2017). Based on Kupongsak and Sathitvorapojjana's (2017) investigation, there is a correlation between the fatty acid composition and the viscosity level of mayonnaise. Specifically, their findings align with the notion that an elevated proportion of polyunsaturated fatty acid (PUFA) in the mixture leads to increased viscosity.

The SFA, MUFA, and PUFA compositions of the vegetable oils used in mayonnaise production as shown in Table 4 were calculated based on O'Brien's (2009) study. In this study, VRPO was used instead of RPO. Here, it is assumed that the fatty acid content of the VRPO we used was similar to the RPO in O'Brien's (2009) research. Table 4 indicated that SO had the highest MUFA content at 41.40%, SFO had the highest PUFA content at 68.70%, and CO had the highest SFA content at 92.00%. Moreover, the increase of VRPO concentration in mayonnaise samples resulted in a decreasing trend of polyunsaturated fatty acids (PUFA) content, as presented in Table 4. A study highlighted that viscosity was positively correlated with PUFA and negatively correlated with MUFA (Yalcin, Toker & Dogan 2012). Thus, the reduction in PUFA content ultimately led to a decrease in the viscosity value of all mayonnaise samples.

TABLE 3. Viscosity and pH value of mayonnaise samples

Samples	Viscosity (cP)	pH
SFO-0% VRPO	127,333 ± 1,222 ^{e}	4.00 ± 0.02 ^{d}
SFO-5% VRPO	121,000 ± 1,000 ^{f}	4.15 ± 0.02 ^{c}
SFO-10% VRPO	117,333 ± 416 ^{f}	4.16 ± 0.01 ^{b,c}
SFO-15% VRPO	109,333 ± 416 ^{g}	4.15 ± 0.02 ^{b}
SO-0% VRPO	187,066 ± 2,809^{a}	4.00 ± 0.03 ^{d}
SO-5% VRPO	151,067 ± 1,361 ^{b}	4.22 ± 0.01 ^{a,b}
SO-10% VRPO	142,067 ± 1,501 ^{c}	4.18 ± 0.01 ^{b,c}
SO-15% VRPO	136,333 ± 1,405 ^{d}	4.20 ±0.01 ^{a,b,c}
CO-0% VRPO	149,067 ± 2,213 ^{b}	3.91 ± 0.05 ^{e}
CO-5% VRPO	86,733 ± 611^{h}	4.25 ± 0.02 ^{a}
CO-10% VRPO	78,467 ± 902 ^{i}	4.20 ± 0.01 ^{a,b,c}
CO-15% VRPO	76,333 ± 305 ^{i}	4.18 ± 0.01 ^{b,c}

*Different letters within a column show significant differences between samples

TABLE 4. Calculated fatty acid composition from vegetable oils, which was adapted from O'Brein (2019)

Source of vegetable oil	Fatty acid composition (%)		
	Saturated Fatty Acid (SFA)	Mono Unsaturated Fatty Acid (MUFA)	Poly Unsaturated Fatty Acid (PUFA)
Sunflower oil (SFO)	12.60	18.70	68.70
Sesame oil (SO)	15.10	41.40	43.50
Coconut oil (CO)	92.00	6.50	1.50
Red Palm oil (VRPO)	51.40	38.90	9.70
95% SFO: 5% VRPO	14.54	19.71	65.75
90% SFO : 10% VRPO	16.48	20.72	62.80
85% SFO: 15% VRPO	18.42	21.73	59.85
95% SO: 5% VRPO	16.92	41.28	41.81
90% SO: 10% VRPO	18.73	41.15	40.12
85% SO: 15% VRPO	20.55	41.03	38.43
95% CO: 5% VRPO	89.97	8.12	1.91
90% CO: 10% VRPO	87.94	9.74	2.32
85% CO: 15% VRPO	85.91	11.36	2.73

pH VALUE

As shown in Table 2, a significant difference (*p<0.05*) was observed in the pH value of all mayonnaise samples ranging from 3.91 to 4.25. It has been established that maintaining the pH level of mayonnaise within the range of 2.4 to 4.5 can prevent microbial growth that leads to the degradation of mayonnaise products (McClements 2005). Thus, the pH of all mayonnaise samples was consistent with the pH range suggested by McClements (2005) to prevent microbial growth in mayonnaise. In addition, this study found that mayonnaise with CO oil had the lowest pH value (3.91) compared with SO and SFO (4.00 and 4.00), which can be explained that CO contains enormous saturated fatty acid that potentially causes acidity to the mayonnaise rather than SO and SFO that have high unsaturated oil fatty acids (O'Brien 2009).

COLOR EVALUATION

Food analysis commonly employs color measurement as a tool to evaluate product quality during storage and after specific process treatments (Al-Baarri et al. 2022, 2021; Susanti et al. 2021). Light absorption and scattering are affected by the refractive index, droplet concentration, size, and dispersion, as well as the presence of chromophoric materials (McClements 2005). The addition of VRPO to mayonnaise could decrease the L-value ($P < 0.05$), which might be attributed to variations in light scattering among the samples (Table 5). Conversely, the incorporation of VRPO resulted in rising a-value and b-value levels ($P < 0.05$), which indicate an increase in yellowness in all of the mayonnaise samples.

These findings support previous research reports, which indicated that red palm oil has a significant impact on decreasing lightness and increasing redness and yellowness in mayonnaise samples (Loganathan et al. 2020; Riyadi et al. 2016). This ability to induce such changes is attributed to the high carotene content in red palm oil, which has been estimated to range from 500 to 800 mg/kg (Loganathan et al. 2020; Riyadi et al. 2016). In addition, the correlation between color and fatty acid composition in this study is consistent with the findings of Kupongsak and Sathitvorapojjana (2017), which showed that the brightness value of mayonnaise produced from rice bran oil (RBO) with higher proportions than coconut oil was greater, as RBO is dominant in polyunsaturated fatty acids (PUFA).

STABILITY OF EMULSION (CREAMING INDEX EVALUATION)

In this section, the effect of adding VRPO to mayonnaise samples on emulsion stability was investigated. Figure 1A illustrates that the creaming index of mayonnaise samples at room temperature significantly varies between vegetable oils and mayonnaise with and without RVPO. However, the percentage of RVPO addition did not demonstrate significant differences among the samples. In addition, the mayonnaise emulsion stability with adding of VRPO tended to deteriorate when the temperature increased to 80 °C.

Creaming pertains to the separation of phases due to the upward movement of fat globules, which arises from the difference in density between the continuous and dispersed phases (McClements 2009; Nikzade, Tehrani & Saadatmand-Tarzjan 2012; Liu, Xu & Guo 2007; Rahmati, Tehrani & Daneshvar 2012). The extent of creaming in large globules is influenced by the duration of storage (McClements 2009; Liu, Xu & Guo 2007). Electrostatic repulsion is the primary mechanism that prevents droplet flocculation in protein-stabilized emulsions, which occurs when emulsion droplets possess electrically charged surfaces. This occurrence arises from the adsorption of ionic or ionizable components like surfactants, phospholipids, proteins, or polysaccharides (McClements 2009).

TABLE 5. Color evaluation of four types of mayonnaise

Sample Name	Value of Color (Mean ± SD)		
	L*	a*	b*
SFO-0% VRPO	110.23 ± 0.01[b]	-1.56 ± 0.02[k]	28.55 ± 0.01[l]
SFO-5% VRPO	79.00 ± 0.02[d]	5.85 ± 0.02[i]	58.64 ± 0.02[f]
SFO-10% VRPO	75.94 ± 0.02[f]	10.83 ± 0.01[e]	65.51 ± 0.02[d]
SFO-15% VRPO	73.66 ± 0.02[g]	14.04 ± 0.07[b]	67.47 ± 0.04[b]
SO-0% VRPO	88.26 ± 0.03[c]	5.52 ± 0.04[j]	29.34 ± 0.02[k]
SO-5% VRPO	66.30 ± 0.04[j]	6.86 ± 0.02[g]	43.83 ± 0.02[i]
SO-10% VRPO	64.45 ± 0.02[l]	9.27 ± 0.02[f]	49.98 ± 0.01[h]
SO-15% VRPO	64.57 ± 0.03[k]	11.37 ± 0.03[d]	53.68 ± 0.02[g]
CO-0% VRPO	110.85 ± 0.04[a]	-4.18 ± 0.01[l]	38.44 ± 0.03[j]
CO-5% VRPO	76.97 ± 0.02[e]	6.64 ± 0.04[h]	62.30 ± 0.03[e]
CO-10% VRPO	73.36 ± 0.02[h]	12.71 ± 0.05[c]	67.32 ± 0.04[c]
CO-15% VRPO	72.22 ± 0.01[i]	15.70 ± 0.02[a]	70.34 ± 0.03[a]

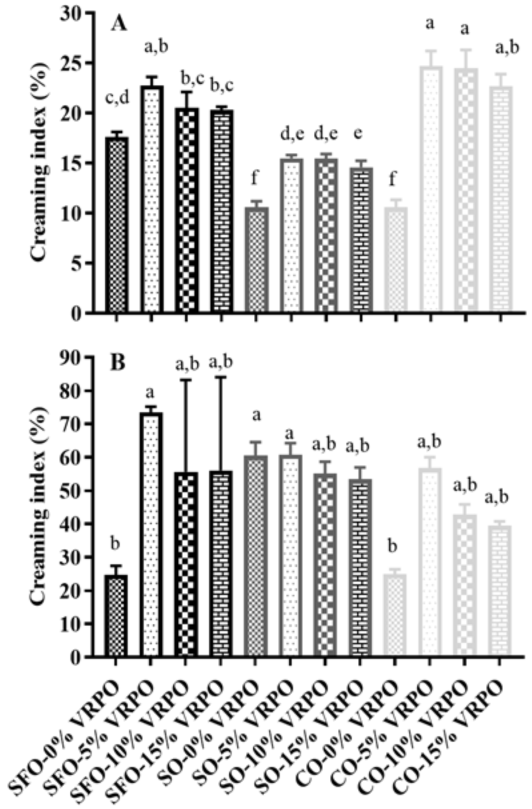

FIGURE 1. Creaming index of vegetable full-fat mayonnaises at room temperature (A), and hot temperature (B)

* Different letters within a column show significant differences between samples.

As indicated in Figure 1, all mayonnaise samples exhibited oil separation, with the separated oil portion ranging from 10.59% to 24.72% at room temperature and between 24.69% and 73.43% at 80 °C. This indicates that storage conditions at high temperatures may cause the emulsion system in mayonnaise samples to become unstable. The results of emulsion stability indicate that adding VRPO during testing at room temperature renders the emulsion system in mayonnaise samples slightly more stable, as demonstrated by a decrease in oil separation in the mayonnaise samples.

TEXTURAL PROPERTIES OF MAYONNAISE

The textural properties of all mayonnaise samples are presented in Figure 2. As shown in Figure 2, the decrease in firmness and consistency was related to the increasing levels of VRPO. The firmness, expressed as hardness, is the peak of the strength needed to change the dimensions and the form of the object during compression (Setiani et al. 2021), and consistency was quantified by evaluating the area of the curve up to a certain point as a proxy measure in this experiment (Liu, Xu & Guo 2007). The reduction in firmness and consistency values in various types of mayonnaise combined with 5%, 10%, and 15% VRPO might be influenced by the fatty acid composition (Kupongsak & Sathitvorapojjana 2017). The unsaturated fatty acid composition of mayonnaise products probably increased the firmness of mayonnaise. A study applying sunflower and soybean oil at 75%, 60%, and 45% in full-fat and low-fat mayonnaise found that sunflower mayonnaise had a firmer texture compared to soybean (Amin et al. 2014). Another study also found similar results, showing that sunflower mayonnaise could lead to higher firmness compared to soybean and sesame oils (Chetana 2019). In addition, applying virgin coconut oil that high in saturated oil for full-fat mayonnaise produced lower firmness compared to mayonnaise made with soybean oil (100%), and 50%:50% coconut oil and soybean oil, by 30.28 and 16.18 g (Muhialdin 2019). Therefore, mayonnaise formulations supplemented with VRPO at concentrations of 5%, 10%, and 15% displayed lower firmness values, which may be attributed to the corresponding decrease in the creaming index since the PUFA concentration in these samples was lower rather than without VRPO addition.

Prior to being combined with VRPO at varying percentages of 5%, 10%, and 15%, mayonnaise exhibited a significantly lower cohesiveness attribute compared to when it was combined with the mentioned oil. It is stated that a more negative cohesiveness value indicated a stickier sample (Liu, Xu & Guo 2007). Generally, different oil types could change the ratio of viscosity between continuous and dispersed phases, which furtherly governs the minimum size of droplets. However, the viscosity of the samples might partially reflect the texture parameters (Liu, Xu & Guo 2007). Figure 3 (From A to D) illustrates the textural properties which include firmness, consistency, cohesiveness, and index of viscosity of each mayonnaise sample.

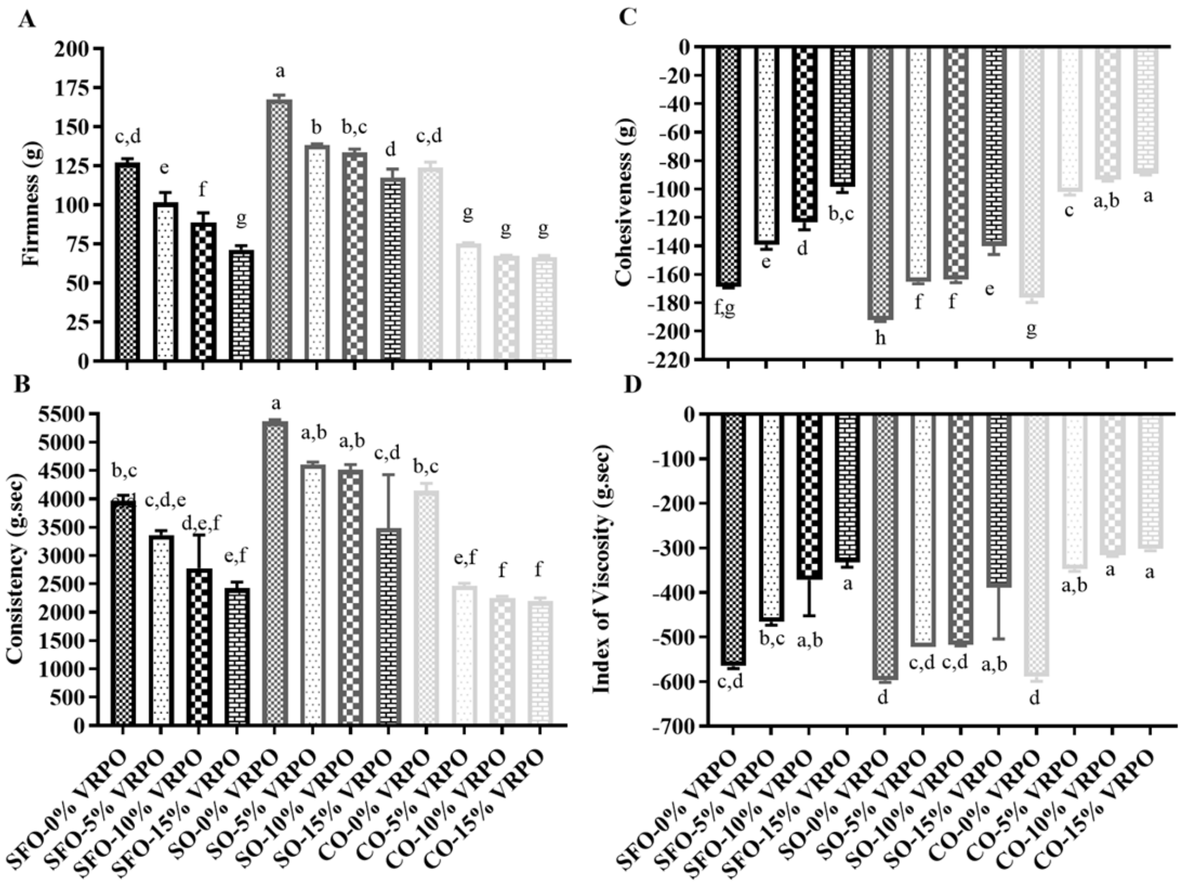

FIGURE 2. Characteristics of vegetable full-fat mayonnaises for firmness (A), consistency (B), cohesiveness (C), and index of viscosity (D)

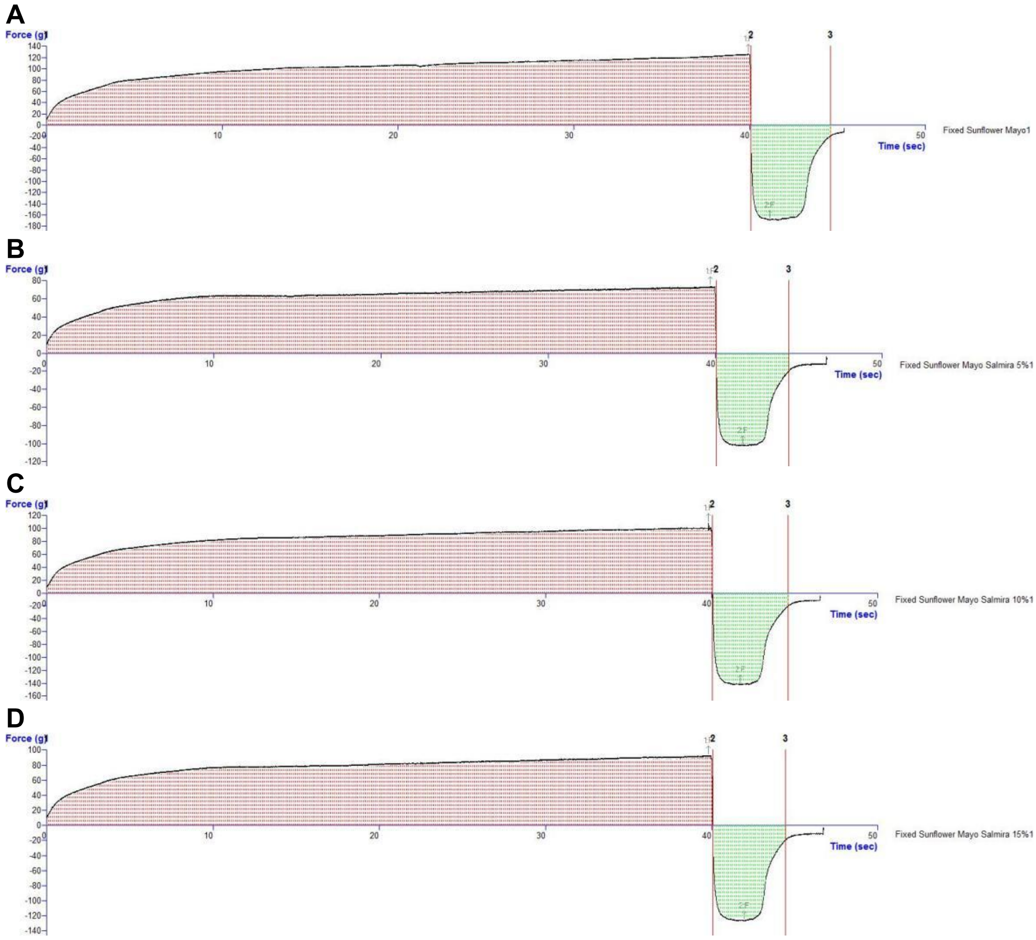

FIGURE 3. Textural properties of sunflower oil mayonnaise (A), sunflower + 5% VRPO (B), sunflower + 10% VRPO (C), and sunflower + 15% VRPO (D)

CONCLUSIONS

In summary, the addition of VRPO had significant impacts on the viscosity, color, pH, emulsion stability or creaming index, and textural properties of various vegetable full-fat mayonnaise. There was a significant difference ($p<0.05$) was observed in the viscosity between all mayonnaise samples. A significant difference ($p<0.05$) was observed in the pH value of all mayonnaise samples. A significant decrease ($p<0.05$) in the L* values, indicating a reduction in the lightness of all mayonnaise samples. Conversely, there was a significant increase ($p<0.05$) in the a* values, indicating a rise in redness, and b* values, corresponding to a yellowness increase, in all of the mayonnaise samples.

ACKNOWLEDGMENTS

The research was funded by Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN). The authors would like to deeply thank those who supported this research.

REFERENCES

Al-Baarri, A.N., Legowo, A.M., Widayat, Rizqiati, H., Hintono, A., Pramono, Y.B., Somantri, M., Broto, W., Hadipernata, M. & Santosa, V.C. 2021. Inhibition of color changes of raja banana (*Musa sapientum*) peel using specific acid. *IOP Conference Series: Earth and Environmental Science* 733:

012124. doi: 10.1088/1755-1315/733/1/012124

Al-Baarri, A.N., Hadipernata, M., Legowo, A.M., Abduh, S.B.M., Pratiwi, A.F., Setyadi, B., Ranini, A.A., Lestari, F.P., Pangestika, W., Afra Mawarid, A. & Somantri, M. 2022. Corn germ color detection during storage in kendal regency, central java. *IOP Conference Series: Earth and Environmental Science* 1024: 012034. doi: 10.1088/1755-1315/1024/1/012034

Amin, M.H.H., Elbeltagy, A.E., Mustafa, M. & Khalil, A.H. 2014. Development of low fat mayonnaise containing different types and levels of hydrocolloid gum. *Journal of Agroalimentary Processes and Technologies* 20(1): 54-63.

Ayu, D.F., Aminah, S. & Diharmi, A. 2020. Photo-oxidation stability of mayonnaise from striped catfish and red palm mixture oil. *IOP Conf. Series: Earth and Environmental Science, International Conference on Sustainable Agriculture and Biosystem* 757: 012052.

Basuny, A.M.M. & Al-Marzooq, M.A. 2011. Production of mayonnaise from date pit oil. *Food and Nutrition Sciences* 2(9): 938-943. doi: 10.4236/fns.2011.29128

Boye, I.J. & Ma, Z. 2013. Advances in the design and production of reduced-fat and reduced-cholesterol salad dressing and mayonnaise: a review. *Food Bioprocess Technology* 6:648–670. doi: 10.1007/s11947-012-1000-9

Böhm, V., Patzelt, H. & Kunz, B. 2000. Influence of vegetable oil type on the sensory properties and stability of mayonnaise. *European Journal of Lipid Science and Technology* 102(10): 674-680. https://doi.org/10.1002/1438-9312(200010)102:10<674::AID-EJLT674>3.0.CO;2-U

Depree, J.A. & Savage, G.P. 2001. Physical and flavour stability of mayonnaise. *Trends in Food Science & Technology* 12(5-6): 157-163. doi: 10.1016/S0924-2244(01)00079-6

Fernandesa, S.S. & de las Mercedes Salas-Mellado, M. 2018. Effect of oil replacement in mayonnaise by chia (*Salvia hispanica* L) mucilage. *Integrative Food, Nutrition and Metabolism* 5(3): 1-4. doi: 10.15761/ifnm.1000218

Flamminii, F., Di Mattia, C.D., Sacchetti, G., Neri, L., Mastrocola, D. & Pittia, P. 2020. Physical and sensory properties of mayonnaise enriched with encapsulated olive leaf phenolic extracts. *Foods* 9(8): 997.

Gómez-Zavaglia, A., Lareo, C. & Agregán, R. 2010. Influence of vegetable oil type on rheological and sensory properties of mayonnaise. *Journal of Food Quality* 33(6): 679-698.

Gorji, S.G., Smyth, H.E., Sharma, M. & Fitzgerald, M. 2016. Lipid oxidation in mayonnaise and the role of natural antioxidants: A review. *Trends in Food Science & Technology* 56: 88-102. doi: 10.1016/J.TIFS.2016.08.002

Hammer, Ø., Harper, D.A.T. & Ryan, P.D. 2001. Paleontological statistics software package for education and data analysis. *Paleontologia Electronica* 4(1): 1-9.

Haniff, M., Yahaya, S.A., Aziz, N.S., Wan Mustapha, W.A., Sofian-Seng, N.S., Rahman, H.A., Mohd Razali, N.S. & Lim, S.J. 2020. Development of carotenoid-rich mayonnaise using Carotino oil. *Journal of Food Processing and Preservation* 44(9): e14688. https://doi.org/10.1111/jfpp.14688

Kovalcuks, A., Straumite, E. & Duma, M. 2016. The effect of egg yolk oil on the chemical, physical and sensory properties of mayonnaise. *Rural Sustainability Research* 35(330): 24-31. doi: 10.1515/plua-2016-0004

Kris-Etherton, S.I. 2007. Position of the American Dietetic Association and Dietitians of Canada: dietary fatty acids. *Journal of the American Dietetic Association* 107(9): 1599.e1-1599.e15. doi: 10.1016/J.JADA.2007.07.024

Kupongsak, S. & Sathitvorapojjana, S. 2017. Properties and storage stability of o/w emulsion replaced with medium-chain fatty acid oil. *Polish Journal of Food and Nutrition Sciences* 67(2): 107-115. doi: 10.1515/pjfns-2016-0015

Leahu, A., Ghinea, C., Petraru, A. & Ropciuc, S. 2022. Defatted sesame seed cake: Influence on the physicochemical and textural characteristics of mayonnaise. *E-Health and Bioengineering Conference (EHB)*. https://doi.org/10.1109/EHB55594.2022.9991609

Loganathan, R., Tarmizi, A.H.A., Vethakkan, S.R. & Tiu, T.K. 2020. Retention of carotenes and vitamin E, and physicochemical changes occurring upon heating red palm olein using deep-fat fryer, microwave oven and conventional oven. *Journal of Oleo Science* 69(3): 167-183.

Lioe, H.N., Rahmawati, D. & Andarwulan, N. 2015. Development of taste and aroma attributes for mayonnaise by quantitative descriptine analysis. *Jurnal Mutu Pangan* 2(2): 80-86.

Liu, H., Xu, X.M. & Guo, S.D. 2007. Rheological, texture and sensory properties of low-fat mayonnaise with different fat mimetics. *LWT - Food Science and Technology* 40(6): 946-954. doi: 10.1016/j.lwt.2006.11.007

Mba, O.I., Dumont, M.J. & Ngadi, M. 2015. Palm oil: Processing, characterization and utilization in the food industry - A review. *Food Bioscience* 10: 26-41. doi: 10.1016/J.FBIO.2015.01.003

McClements, D.J. 2009. Biopolymers in food emulsions. In *Modern Biopolymer Science,* edited by Kasapis, S., Norton, I.T. & Ubbink, J.B. Massachusetts: Academic Press. pp. 129-166. doi: 10.1016/B978-0-12-374195-0.00004-5

McClements, D.J. 2005. *Food Emulsions (Principles, Practices, and Techniques)*. Second Edition. New York: CRC Press.

Morley, G., Caballero, B., Finglas, P.M. & Toldrá, F. 2016. Mayonnaise. *Encyclopedia of Food and Health*. Massachusetts: Academic Press. pp. 669-676.

Muhialdin, B.J., Li, L., Farouk, A.E. & Shobirin, A. 2019. Valorisation of virgin coconut oil in mayonnaise production as functional ingredient. *Journal of Food and Nutrition Research* 7: 65-70.

Muhialdin, B.J., Ying, L.L., Farouk, A.E. & Hussin, A.S.M. 2019. Valorisation of virgin coconut oil application in mayonnaise production as functional ingredient. *Journal of Food and Nutrition Research* 7(1): 65-70.

Mun, S., Kim, Y-L., Kang, C-G., Park, K-H., Shim, J-Y. & Kim, Y-R. 2009. Development of reduced-fat mayonnaise using 4αGTase-modified rice starch and xanthan gum. *International Journal of Biological Macromolecules* 44(5):

400-407. https://doi.org/10.1016/j.ijbiomac.2009.02.008

Nikzade, V., Tehrani, M.M. & Saadatmand-Tarzjan, M. 2012. Optimization of low-cholesterol-low-fat mayonnaise formulation: Effect of using soy milk and some stabilizer by a mixture design approach. *Food Hydrocolloids* 28(2): 344-352. doi: 10.1016/j.foodhyd.2011.12.023

O'Brien, R.D. 2009. *Fats and Oils: Formulating and Processing for Applications*. 3rd ed. Boca Raton: CRC Press.

Patil, U. & Benjakul, S. 2019. Physical and textural properties of mayonnaise prepared using virgin coconut oil/fish oil blend. *Food Biophysics* 14: 260-268. doi: 10.1007/s11483-019-09579-x

Pignitter, M., Hernler, N., Zaunschirm, M., Kienesberger, J., SOmoza, M.M., Kraemer, K. & Somoza, V. 2016. Evaluation of palm oil as a suitable vegetable oil for vitamin a fortification programs. *Nutrients* 8(6): 378. doi: 10.3390/nu8060378

Qureshi, A.A., Khan, D.A., Mushtaq, S., Ye, S.Q., Xiong, M. & Qureshi, N. 2018. δ-tocotrienol feeding modulates gene expression of EIF2, mTOR, protein ubiquitination through multiple-signaling pathways in chronic hepatitis C patients. *Lipids in Health and Disease* 17(1): 167. doi: 10.1186/s12944-018-0804-7

Rahmati, K., Tehrani, M.M. & Daneshvar, K. 2014. Soy milk as an emulsifier in mayonnaise: Physico-chemical, stability and sensory evaluation. *Journal of Food Science and Technology* 51(11): 3341-3347. doi: 10.1007/s13197-012-0806-9

Riyadi, A. H., Muchtadi, T. R., Andarwulan, N. & Haryati, T. 2016. Pilot plant study of red palm oil deodorization using moderate temperature. *Agriculture and Agricultural Science Procedia* 9: 209-216. doi: 10.1016/j.aaspro.2016.02.129

Rooyen, J.V., Esterhuyse, A.J., Engelbrecht, A.M. & du Toit, E.F. 2008. Health benefits of a natural carotenoid rich oil: A proposed mechanism of protection against ischaemia/reperfusion injury. *Asia Pacific Journal of Clinical Nutritional* 17(1): 316- 319.

Running, C.A., Craig, B.A. & Mattes, R.D. 2015. Oleogustus: The unique taste of fat. *Chemical Senses* 40: 507-516. doi:10.1093/chemse/bjv036

Samsuri, N.S., Abd Hadi, H.M., Ismail-Fitry, M.R., Ab Karim, N.A. & Mat Yusoff, M. 2022. Improved physical properties and structural stability of value-added mayonnaises based on red palm olein by using high-shear homogeniser. *International Food Research Journal* 29(4): 764-775. https://doi.org/10.47836/ifrj.29.4.04

Schalde, C.N., Mittermaier, S.B. & Sanahuja, S. 2022. Characterization of reduced-fat mayonnaise and comparison of sensory perception, rheological, tribological, and textural analyses. *Foods* 11: 806. https://doi.org/10.3390/foods11060806

Setiani, B.E., Dwiloka, B., Pramono, Y.B., Arroyan, T.N., Mardhika, H. & Puspitoasih, A.D. 2021. Physicochemical properties of steak made of post laying hen breast meat thawed using various methods. *IOP Conference Series: Earth and Environmental Science* 803(1): 170-177. doi: 10.1088/1755-1315/803/1/012033

Susanti, S., Bintoro, V.P., Hintono, A. & Nisa, K. 2022. Physical and chemical characteristics of beef marinated by cashew apple extract. *International Journal of Food Studies* 11(1): 98-105. doi: 10.7455/ijfs/11.1.2022.a9

Susanti, S., Murni, M., Silviana, A. & Arifan, F. 2021. Color appearance and chemical characteristic of vacuum fryer cooked Pemalang typical snack ogel-ogel. *IOP Conference Series: Earth and Environmental Science* 803: 012046. doi: 10.1088/1755-1315/803/1/012046

Tan, C.H., Lee, C.J., Tan, S.N., Poon, D.T.S., Chong, C.Y.E. & Pui, L.P. 2021. Red palm oil: A review on processing, health benefits and its application in food. *J. Oleo Sci.* 70(9): 1201-1210. https://doi.org/10.5650/jos.ess21108

Yalcin, H., Toker, O.S. & Dogan, M. 2012. Effect of oil type and fatty acid composition on dynamic and steady shear rheology of vegetable oils. *J. Oleo Sci*. 61(4): 181-187. https://doi.org/10.5650/jos.61.181

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