CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

FORMULATION OF NATURAL HYDROCOLLOIDS AND VIRGIN COCONUT OIL AS A PLANT-BASED SALAD DRESSING

Nameer Khairullah Mohammed[1], Wan Hasyera Wan Omar[2], Anis Shobirin Meor Hussin[2,3]✉

[1]Department of Food Science, College of Agriculture, Tikrit University 3400, Tikrit, Iraq
[2]Faculty of Food Science and Technology, Universiti Putra Malaysia 43400 UPM Serdang, Selangor, Malaysia
[3]Halal Products Research Institute, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
✉shobirin@upm.edu.my

https://doi.org/10.34302/crpjfst/2022.14.4.1

Article history:
Received:
15 January 2022
Accepted:
15 September 2022
Published
December 2022

Keywords:
Salad dressing;
Egg yolk;
Cashew nut protein isolates;
Virgin coconut oil;
RSM.

ABSTRACT

Salad dressing is traditionally used as a seasoning to enhance consumers' appetite due to its creamy mouthfeel and special flavor. However, consumers are aware of the cholesterol level in egg yolk and the fat type applied in dressing products. This study aimed to produce low-fat and eggless salad dressing with virgin coconut oil (VCO). Hydrocolloids, including xanthan gum and modified starch, were used as independent variables by response surface methodology (RSM) to evaluate their impacts on the salad dressing's viscosity, stability, and firmness. The findings showed that optimum values for the hydrocolloids of xanthan gum and modified starch were 1.56% and 0.10%, respectively and the optimum experimental values were stability 0.33%, texture 1506.5 g, and viscosity 162.25 mpas. This optimized formulation's predicted and experimental data had no significant ($p>0.05$) differences that indicated this study's desired results. The proximate analysis of the optimized formulation was moisture content 47.91, ash 1.91, fiber 1.57, fat 21.97, protein 1.66, carbohydrate 24.98, and caloric values 296.29. The findings of this study were similar to the commercial products, which suggested a high potential for using optimum values for the hydrocolloids of xanthan gum and modified starch as an egg replacer and VCO in salad dressing to improve the quality and the biological functions of the product.

1.Introduction

Salad dressing is a kind of emulsion formulated with vegetable oil not less than 30% oil, egg yolk or emulsifier and stabilizer, flavoring agents, and acidifying ingredients (Ma et al., 2013a). The consumption of this product is growing as a preferable sauce worldwide due to its accepted flavor and sensory attributes resulting from the addition of starch or hydrocolloids, which gives the required consistency of that product (Ma and Boye, 2013b). Egg yolk is used in dressing products to improve the emulsion stability by decreasing interfacial tension and forming a layer that prevents the droplets from aggregation. However, its high content of high-density lipoproteins (HDL) and low-density lipoproteins (LDL) are associated with several cardiovascular diseases (Marventano et al., 2020). Besides, for vegans and vegetarians who wish to include plant-based fat in their diet for various reasons, a growing interest in developing egg-free food and low-in fat products has been generated according to the consumer's awareness. Vegan diets exclude all animal items, including meat, fish, dairy products, and eggs (Bradbury et al., 2017). The food industry has faced major challenges in producing varieties of salad dressing products that have reduced-calorie content, contain higher levels of plant-based ingredients, and are high in beneficial ingredients that can be used. Several studies have recently focused on producing a new salad dressing or mayonnaise formulation to reduce the fat content and replace the egg yolk associated with heart diseases (Ma et al., 2016; Tekin and Karasu, 2020). This could be done by applying plant-based alternatives with acceptable characteristics to meet the consumers' desires. According to Chivero et al. (2016), emulsion-based mayonnaise stabilized by Xanthan gum instead of the egg yolk could be applied as an alternative hydrocolloid emulsifier to formulate mayonnaise. Hydrocolloid is one of the important ingredients to increase the stability and physicochemical properties of the salad dressing.

In addition, using the hydrocolloid improves the characteristics of the food due to its ability to alter the rheology of the food system. In addition, they usually act as stabilizers (stabilizing agents) of oil-in-water emulsions (Dickinson, 2009). Moreover, fat used in dressing products is usually hydrogenated fats associated with heart diseases. Ban has been announced against trans and hydrogenated fat in food products, which was recently effective in different countries (Chen, 2020). Therefore, replacing fats with functional oils that contain nutritional value with biological activities contributes to healthy diets required by consumers. Virgin coconut oil (VCO) is an appropriate fat substitute for the salad dressing formulation (Dayrit and Nguyen 2020). The VCO is frequently used to produce oil/water emulsions. The previous study showed the VCO application in the emulsion to be used as a new nutritional food supplement. The findings demonstrated that the stability of the emulsion, which was stored at 4°C and 25°C throughout the storage period, had no alter in the free fatty acid composition of the VCO (Khor et al., 2018). According to the recent review study by Mirzanajafi-Zanjani et al. (2019), several studies have attempted to replace the egg with plant-based emulsifiers to produce egg-free mayonnaise (Muhialdin et al., 2021). Optimizing the specific ratios of Xanthan gum and modified starch acts as hydrocolloid agents with a low-fat content of VCO as a fat alternative is challenging to produce healthy sauces.

The main objective of this work was to develop egg-free and low-fat mayonnaise with a high nutritional fat alternative. In detail, the following effects were studied: (1) using VCO as a fat substitute and preparing the oil in water emulsion, (2) replacing the egg yolk with plant-based hydrocolloids, and (3) optimizing the hydrocolloids (Xanthan gum and modified starch) used as egg replacers and evaluate the approximate analysis and sensory characteristics.

2. Materials and methods

2.1. Materials

Virgin Coconut Oil (VCO), salt, sugar, mustard powder, lemon juice, and acetic acid were purchased from a local bakery shop in Selangor, Malaysia. Xanthan gum, modified starch, and analytical-grade solvents were purchased from Sigma–Aldrich Co (St. Louis, MO, USA). Commercialized products were presented for comparison with the optimum formulation, namely Mayolite Salad Dressing Lady's Choice, Kewpie Half Salad Dressing, Mayonnaise Lady's Choice, and Kimball mayonnaise, and coded as C1, C2, C3, and C4, respectively.

2.2. Preparation of VCO salad dressing

The virgin coconut oil (VCO) salad dressing was prepared at different concentrations of hydrocolloids, xanthan gum and modified starch, according to the experimental design following Fonseca et al. (2009) method with a slight modification. Table 1 shows the formulations of salad dressing containing sugar 4%, mustard powder 7.5%, and salt 1.5% added to a bowl containing lemon juice 5.5% and acetic acid 4.5%, then mixed homogeneously using the mixer and homogenized for 10 min. Subsequently, hydrocolloids consisting of xanthan gum 1-1.9% and modified starch 0.1-1% were added to the solution as per the experimental design

(Table 2) and then stirred using a magnetic stirrer at room temperature for at least 6 h to ensure complete emulsification in order to prepare the aqueous phase. Finally, 75 ml of virgin coconut oil as the oil phase was added gradually into the aqueous phase and homogenized for 20 min. As a result, the aqueous and oil phases had a ratio of 75:25.

Table 1. Shows all the formulations with different percentages of hydrocolloid in VCO salad dressing

Ingredients	Percent (%)
Virgin coconut oil (VCO)	31.80
Coconut milk	45.81
Lemon juice	4.46
Acetic acid	4.46
Mustard powder	6.78
Salt	1.25
Sugar	3.44
Xanthan gum	1-1.9 *
Modified starch	0.1-1*
Total	100.0

*Amount varied according to the experimental design

2.3. Emulsion stability test

The stability of the dressing formulations was evaluated after 24 hours of storage, referring to the method performed by de Melo et al. (2016) with slight modification. The salad dressing formulations were centrifuged at (3500 × g) for 30 min at 25˚C. The emulsion stability was determined by comparing the oil percentages before and after centrifuging. The less oil that was calculated shows the highest stability.

2.4. Determination of texture

The texture determination was done according to Ng et al. (2014) with slight modification. It was performed by using the equipment of Texture Analyzer TA. XT2i (Stable Micro Systems Ltd, Surrey, UK). The 5 kg load cell was used for this penetration test to measure firmness and consistency. Using a probe (P/36R), aluminum radiused AACC with 10 mm penetration, 1 mm/sec pre-test speed, 1 mm/sec test speed, and 10 mm/sec, all the samples of VCO salad dressing were placed in a round plastic container at a depth of 30 mm. Then, this test was performed in triplicate.

2.5. Determination of rheological properties (Viscosity)

The method by Jung (2011), with slight modification, was used to determine the viscosity of VCO salad dressing using the equipment of a rheometer (Physical Rheolab, Anton Paar, Austria). First, the samples were added to the viscometer cup at about 10g. Next, each sample was recorded once the value shown on the viscometer became stable, it was started. Finally, the constant room temperature (25˚C) was used, and all samples were performed in triplicate.

2.6. Proximate analysis

The determination of moisture, protein, ash, fat, fiber contents, and caloric value of the low-fat and eggless VCO salad dressing samples were conducted as the official methods ascribed by the Association of Official Analytical Chemistry (AOAC 2006).

2.7. Determination of color

The determination of color was measured by using a Colorimeter (Ultra Scan Pro, Hunter Lab, USA). The emulsion of each sample was measured by referring to the value of the color system, L* = 97.10, a* = −0.07, b*=+1.97, shows the lightness meanwhile a* (+a is the red coordinate, −a is the green coordinate) and b* (+b is the yellow coordinate, and−b is the blue coordinate) represents the color coordinates. The color becomes more saturated as the a* and b* values rise. However, the value in this test will approximately approach zero for neutral colors such as black, grey, or white. All the samples were done in triplicate (Ng et al., 2014).

Table 2. Emulsion stability, texture, and viscosity of formulation salad dressing using face-centered Central Composite Design

Std Order	Run Order	PtType	Xanthan %	Modified Starch %	Stability (%)	Texture (g)	Viscosity (mpas)
12*	1(c)	0	1.45	0.55	0.81	149.197	1192.50
5	2	-1	1.00	0.55	1.40	139.325	1107.5
8	3	-1	1.45	1.00	2.46	122.820	1479.10
10*	4(c)	0	1.45	0.55	0.81	149.197	1192.50
9*	5(c)	0	1.45	0.55	0.81	153.260	1050.25
3	6	1	1.00	1.00	0.79	178.495	1624.85
1	7	1	1.00	0.10	0.05	123.800	1470.65
7	8	-1	1.45	0.10	0.04	178.200	1471.61
4	9	1	1.90	1.00	0.47	67.017	1452.05
13*	10(c)	0	1.45	0.55	0.30	153.260	1050.25
2	11	1	1.90	0.10	0.00	123.530	2682.89
6	12	-1	1.90	0.55	0.02	103.520	1992.60
11*	13(c)	0	1.45	0.55	0.30	153.260	1050.25

(c) center point.

2.8. Sensory evaluation

The sensory evaluation was done according to Liu et al. (2007) method with some modifications. The optimized formulation salad dressing was compared with 3 different commercial products named Mayolite Salad Dressing Lady's Choice (C1), Kewpie Half Salad Dressing (C2) and Mayonnaise Lady's Choice (C3). In this sensory evaluation, 30 untrained students were asked to perform a sensory test for appearance, color, odor, texture, flavor, and overall acceptability on a 5-point scale, presenting 1 as the least preferred and 5 as the most preferred. Three-digit random numbers were used to code the optimized samples and three commercial items. It was given to panelists on a tray in individual booths to eliminate prejudice. During the sensory evaluation, water was provided between samples as palate cleanses for each untrained panelist.

2.9. Statistical analysis

Minitab 17.0 (Minitab, Inc, State College Pennsylvania, USA) was used for the optimization study. This optimization research used a face-centered central composite design (CCD) with two independent variables: xanthan gum (1-190%) (x_1) and modified starch (0.1-1%) ($x2$). In addition, the emulsion stability (y^1), texture or (firmness) (y^2), and viscosity (y^3) were set as response variables at three coded levels (-1, 0, +1) and 5 replicates at the center point was programmed by the software, which a complete design consisted of 13 experimental runs were automatically generated for each salad dressing (Table 2). As a result, the effect of the two independent variables on the RSM was obtained.

The polynomial regression model equation was utilized, and the performance of the response surface was examined. The generalized response surface model is given below:

$$y= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_{12} + \beta_{22} x_{22} + \beta_{12} x_1 x_2 \quad (1)$$

Where: y is the response calculated by the model; β_0 is a constant regression; and β_i, β_{ii} and β_{1j} are the linear, squared, and interaction coefficients, respectively. The $x_1$and x_2 is the coded independent variables. One-way analysis of variance (ANOVA) was used to find the differences using a method for all responses with a significant level of ($p < 0.05$) determined using Turkey's test. All the data were reported in mean ± standard deviation with a significance letter.

3. Results and discussions

3.1. Response surface analysis

RSM was applied with the 23 CCD to determine the optimum hydrocolloids (xanthan and modified starch) for salad dressing formulation. The emulsion stability, viscosity, and texture (firmness) were set as the response for this model. Table 2 shows the experimental data of emulsion stability, viscosity, and texture from the optimization study. The model summary, as shown in Table 3 divided into linear, quadratic and interaction. From the data obtained, R2 from the viscosity response was essentially high, 0.9315, compared to the texture (firmness) and stability, 0.8962 and 0.3805, respectively. Therefore, the models explained viscosity and texture (firmness) well and reached more than 0.8. However, the response of emulsion stability had no desirable results, although the lack of fit was better than both ($p>0.05$).

Table 4 depicts the significance probability of the p-value and F-value from the main linear, quadratic, and interaction effects after the final reduced models. In order to obtain the best results, the p-value should be significant ($p<0.05$). In addition, the insignificant results ($p>0.05$) must be excluded to improve the model before the final reduced model is constructed. Based on the results obtained, there was only a linear effect on emulsion stability on modified starch. However, the model explained all the effects well regarding viscosity, as there were significant differences ($p<0.05$). Meanwhile, regarding the texture (firmness), there was only a quadratic square effect on modified starch that was insignificant ($p>0.05$) as compared to all the effects. In short, all the responses give the desired results except for the emulsion stability.

3.2. Responses to the optimization conditions

Based on the data obtained, all the responses were dependent on the percentages of hydrocolloids named xanthan gum and modified starch in this study. In terms of emulsion stability, the lowest percentages of oil expelled give the higher emulsion stability of the salad dressing. The higher percentages of the xanthan gum, 1.90%, with lower percentages of modified starch, 0.10%, give the higher emulsion stability 0.00% among all of the runs Table 2.

Table 3. Regression coefficient, R^2, adjusted R^2, probability values, and lack of fit for the final reduced models

Regression coefficient	Stability (Y_1)	Texture (Y_2)	Viscosity (Y_3)
Constant			
b_0	0.635	151.31	1122.4
Linear			
b_1	-	-24.59	320.8
b_2	0.604	-9.53	-178.2
Square			
b_1^2	-	-28.70	389.4
b_2^2	-	-	314.9
Interaction			
b_{12}	-	-27.80	-346.3
R^2	0.3805	0.8962	0.9315
R^2 (adj)	0.3242	0.8444	0.8825
Regression (p-value)	-	-	-
Lack of fit (F-value)	5.96	57.00	8.36
Lack of fit (p-value)	0.052	0.001	0.034

*b_1= xanthan gum, b_2= modified starch

Table 4. The significance probability (p-value & F-value) of regression coefficients in the final reduced models

Variables		Main linear effects		Quadratic effects		Interaction effects
		x_1	x_2	x_1	x_2	x_1x_2
Emulsion Stability (Y_1)	p-value	-	0.025	-	-	-
	F-value	-	6.76	-	-	-
Texture (Firmness)(Y_2)	p-value	0.001	0.087	0.003	-	0.002
	F-value	25.26	3.80	18.52	-	21.52
Viscosity (Y_3)	p-value	0.002	0.029	0.005	0.013	0.003
	F-value	24.48	7.55	16.60	10.85	19.01

* x_1= xanthan gum, x_2= modified starch

On the other hand, the combination of xanthan gum and modified starch with the percentages 1.45% and 1.00%, respectively, gives the highest value of 2.46%, which shows that this run had the lowest emulsion stability. Therefore, xanthan gum was more important in having strong emulsion stability than modified starch. Cabeza et al. (2002) revealed that emulsion stability could be increased by adding emulsifiers to reduce the interfacial tension or hydrocolloid to increase the viscosity. Therefore, it can reduce drop mobility. As supported by the previous study by Dolz et al. (2007), the synergistic of xanthan gum and modified starch promotes good stability, texture, and acceptability in low oil content in mayonnaise formulations. Moreover, the xanthan gum stabilizes the starch gel since its dispersion is not thixotropic, defined as the isothermal slow reversible conversion from gel to solution.

To choose the suitable viscosity range, this study refers to the commercial products in the market named C1, C2, C3, and C4, which are 1450-2200 mpas. From the results obtained, the combination of xanthan gum and modified starch at 1.45% and 1.00%, 1.00% and 1.00%, 1.00% and 0.10%, 1.45% and 0.10%, 1.90% and 1.00%, respectively give the data in the range of the commercialized products which were desirable. Hence, this result depicted that the percentages of xanthan gum were flexible in all the runs to get desired viscosity but must be synergistic with the modified starch. Furthermore, according to Dickie & Kokini (1983), a strong link was discovered between shear stress on the tongue and sensory thickness. Therefore, it was also proposed that the measured gap be utilized as an indicator of oral texture when creating a new salad dressing product.

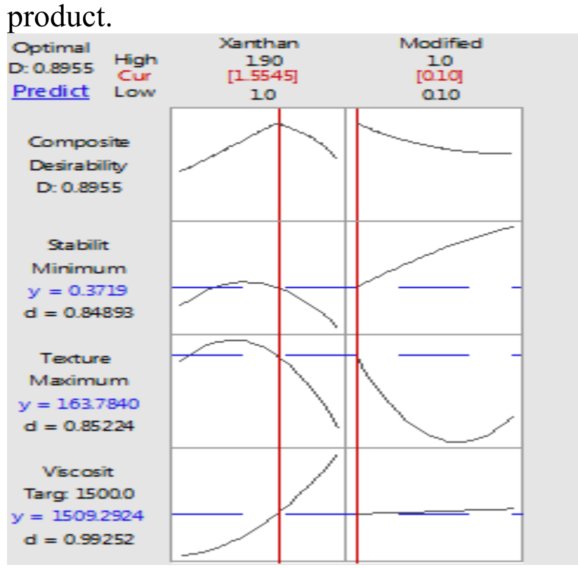

Figure 1. The optimization plot of the optimized formulation

Besides, the texture in terms of firmness was chosen for the response in this RSM. The maximum texture was chosen to be the desired firmness for the optimum condition. The highest firmness was the combination of xanthan gum (1.00%), and modified starch (1.00%) which was 178.495 g, while the lowest firmness was the combination of xanthan gum (1.90%) and modified starch (1.00%) was 67.017g. The combination of xanthan gum and modified starch of 1.45% and 0.10%, respectively, was the second highest which was 178.200 g, followed by xanthan gum (1.45%) and modified starch (0.55%) which was 153.260 g. The observation shows that the percentage of xanthan gum plays an important role compared to the modified starch. The percentages of xanthan gum are higher than modified starch to give the desired firmness of salad dressing. This was due to the addition of xanthan gum, which prevents the creaming phenomena by flocculating the emulsion droplets to create a weak particle network rather than showing its solution rheology on the dressing (Parker et al., 1995).

3.3. Optimization and validation condition

Figure 1 shows the optimization plot obtained from the RSM.

x1= xanthan gum, x2= modified starch, whereas y1= 0.3719%, y2= 163.784g, and y3= 1509.2924 mpas.

The optimization plot of the optimized formulation is shown in Figure 1. Based on the model analyzed, the factor of xanthan gum and modified starch that the model had optimized were 1.56% and 0.10%, respectively. Besides, the predicted data from the model predict the emulsion stability, texture (firmness), and viscosity as follows 0.37%, 1509.29 mpas and 163.78 g, respectively.

On the other hand, the emulsion stability was excluded due to the lowest R2, less than 0.8. The chosen parameter for the texture (firmness) was to get the maximum firmness of more than 160 g. Thus, this figure 1 explains that at the range 1.4-1.56% of xanthan gum and less than 0.2% of modified starch, or at the range 1.0-1.2 of xanthan gum and 0.8-1.0% of modified starch gives the desired firmness. Verbeken et al. (2006) reported that on cooling, modified starch forms thermally irreversible opaque gels, but xanthan gum exhibits high shear thinning and retains viscosity in the presence of electrolytes. Therefore, this combination of hydrocolloids can affect the firmness of the VCO salad dressing. This was supported by a previous study by Gibinski et al. (2006), which indicated that a thickening made up of starch and xanthan gum is a good choice for sauces with a shelf life of fewer than three months because it delivers consistent sensory and textural qualities. For the viscosity, the targeted parameter was 1500 mpas which was chosen based on the references from the commercial products. As reported by the previous study by Dolz et al. (2007), which looked at the effects of xanthan gum and locust bean gum on the flow and thixotropic behavior of food emulsions, including modified starch, found that the emulsion with the highest concentrations of gums had a greater viscosity than the modified starch reference emulsion.

Table 5. The validation of prediction and experimental optimization formulation salad dressing

	Emulsion Stability (%)	**Texture (Firmness) g**	**Viscosity (mpas)**
Prediction value	0.372[a]	163.78[a]	1509.29[a]
Experimental value	0.33 ± 0.119[a]	162.25 ± 1.129[a]	1506.5 ± 3.569[a]

Significance letter [a] shows insignificant differences between the standard and sample (p>0.05).

Table 5 shows the prediction and experimental value of the optimization formulation salad dressing to demonstrate the reduced models' accuracy and the validation of this RSM. Based on the results obtained for the experimental value, all the responses of emulsion stability, viscosity, and texture (firmness) showed an insignificant difference (p>0.05) as compared to the prediction values, as shown in Table 5. Therefore, this validation proved the appropriate model for optimizing the xanthan gum and modified starch percentage to produce low-fat and egg-free salad dressing.

3.4. Proximate analysis of optimized formulation salad dressing

Table 6 shows the proximate analysis results of the optimized formulation salad dressing, including moisture and ash content, fiber, fat, protein, carbohydrate, and caloric values. Based on the results, the moisture content was highest among all the proximate analyses, 48.33%, compared to ash, crude fiber, crude fat, protein and carbohydrate, which were 1.96%, 1.76%, 21.02%, 1.66%, and 23.32%, respectively.

Table 6. Proximate composition of optimized formulation salad dressing.

	Moisture (%)	Ash content (%)	Fibre (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Caloric values (kcal)
C1	47.91	1.91	1.57	21.97	1.66	24.98	296.29
C2	48.84	2.05	2.04	20.35	1.67	22.73	280.75
C3	48.24	1.93	1.67	20.75	1.65	22.24	282.31
C4	47.84	2.94	1.83	20.95	1.67	24.77	293.35
Total	48.33±0.47	1.96±0.08	1.76±0.25	21.02±0.84	1.66±0.01	23.32±1.46	286.45±8.56

*C1= Mayolite Salad Dressing Lady's Choice, C2= Kewpie Half Salad Dressing, C3= Mayonnaise Lady's Choice, C4= Kimball mayonnaise, VCO-salad dressing, Data are reported in mean ± standard deviation (n=3).

The higher moisture content was due to the high percentages of liquid content used in the formulation rather than solid content. Thus, these percentages increase the moisture content of this formulation. The second highest was the carbohydrate which depends on the composition of the others. The lower the composition, such as moisture, ash, fiber, fat, and protein, the increased carbohydrate content. Next, the fat was also relatively higher, 21.02%, due to the types of oil used. The ash, crude fiber, and protein were in the same range. According to the previous study by Babajide & Olatunde (2010), the proximate composition of salad dressing by using corn starch (Cs), cocoyam starch (Cy) with a different formulation of 100Cs, 75Cs: 25Cy, 50Cs:50cy, 25Cs:75Cy and 100Cy, respectively gives the results of moisture content, ash, fat, protein and carbohydrate at the range 48-49%, 0.59-0.79%, 27.04-27.99%, 2.63-3.28%, and 18.96-19.95%, respectively. These values were not too far from the optimized formulation of salad dressing from the present study. Besides, the different results obtained from the previous and present study can be due to the ingredients used in the formulations, such as types of oil, the addition of hydrocolloids, and others which contributed to the values of each composition in the products. This optimized formulation gives about 286.45 kcal for a 100 g serving caloric value. This caloric value is normal for salad dressing; usually, the consumer takes 20 g per serving, which will be 57.29 kcal.

3.5. Color Evaluation

The color of the low-fat and egg-less VCO salad dressing produced by the optimum percentages of xanthan gum and modified starch was evaluated. Besides, this formulation was compared with the commercialized products, which presented as C1, C2, C3, and C4. These color-system values of the formulated low-fat and egg-less VCO salad dressing and commercial products were expressed as lightness (L*), redness-greenness (a*), and yellowness-blueness (b*). Table 7 depicted that there was no significant difference ($p>0.05$) of L* for all the low-fat and egg-less VCO salad dressing and commercial products except for C1, which gives significant differences ($p<0.05$). It was the same goes for a*, which gave insignificant differences ($p>0.05$) for low-fat and egg-less VCO salad dressing and commercial products, except for C1, which gave significant differences ($p<0.05$).

Table 7. The color of all formulations

Formulations	**Color**		
	L*	***a****	***b****
C1	92.89 ± 0.348^a	-2.73 ± 0.09^b	16.2 ± 0.121^b
C2	90.08 ± 0.639^b	-1.46 ± 0.215^a	29.26 ± 0.558^a
C3	89.55 ± 0.449^b	-1.64 ± 0.131^a	16.867 ± 1.438^b
C4	90.22 ± 0.973^b	-1.73 ± 0.09^a	21.2 ± 0.897^b
VCO-salad dressing	90.12 ± 0.125^b	-1.45 ± 0.02^a	19.88 ± 0.062^b

*C1= Mayolite Salad Dressing Lady's Choice, C2= Kewpie Half Salad Dressing, C3= Mayonnaise Lady's Choice, C4= Kimball mayonnaise, VCO-salad dressing, Data are reported in mean ± standard deviation (n=3). Significant letter a to b shows a significant difference ($p<0.05$) among all the formulations.

However, the b* gave an insignificant difference ($p>0.05$) of b* for low-fat and egg-less VCO salad dressing and commercial products except for C2, which gives significant differences ($p<0.05$). Thus, the results show that low-fat and egg-less VCO salad dressing was acceptable in the range with all the commercialized products.

The commercial dressing had a lighter appearance as the value of L* was increased. In addition, as Ying (2015) reported, the oil had beaten consistently and vigorously during emulsion preparation, eventually making the oil droplet smaller. As a result, the bigger the surface of oil contact with the liquid phase, the smaller the oil droplet. Hence, it increased the lightness due to more network interaction with the liquid phase.

3.6. Sensory evaluation

Figure 2 shows the sensory evaluation using the spider web plot of optimized formulation salad dressing, which was compared with three different commercial products named C1, C2, and C3. This sensory evaluation measured some attributes: appearance, color, aroma, texture, flavor, and overall acceptability.

The results showed no significant difference ($p>0.05$) between the optimized formulation salad dressing and C2, 3.7 ± 1.236 and 4.73 ± 0.583, respectively. Besides, in terms of color, there was no statistically significant difference ($p>0.05$) between the improved formulation and the C2 formulation, which gave 2.7 ± 1.178 and 3.57 ± 1.135, respectively.

This showed that the panelist accepted the appearance and color of this optimized formulation of VCO-salad dressing. In addition, the aroma of the optimized formulation was 2.7 ± 1.178, which gave no significant differences with C1, 3.57 ± 1.135.

Therefore, these results show that the optimized formulation was still acceptable even though there was a significant difference between C3 and C4, which were 3.4 ± 1.248 and 3.53 ± 1.106, respectively.

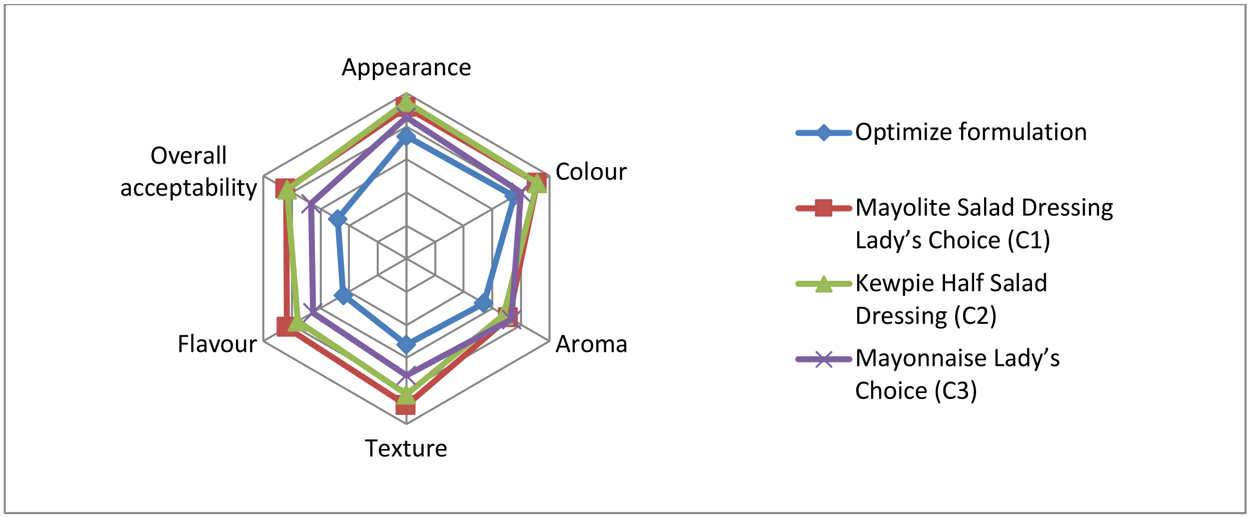

Figure 2. The sensory evaluation of optimized formulation salad dressing as compared with commercial products

Other than that, the optimized formulation salad dressing was 2.6 ± 1.102, which gave significant difference ($p<0.05$) with 3 different commercial products, C1, C2, and C3. This result shows that the consumer did not prefer the optimized formulation compared to the commercial products.

The same goes for the flavor, which gave the optimized formulation a significant difference ($p<0.05$) among C1, C2, and C3. This significant difference was maybe due to the presence of virgin coconut oil. According to Khor et al. (2018), because most customers detest the oily taste of pure VCO, creating a VCO-based emulsion product will indirectly enhance VCO use.

Therefore, the VCO-producing business will benefit from the transformation of VCO into a more pleasant and stable VCO-based emulsion product. On the other hand, some panelists do not like the flavor of the coconut as it can disturb the taste of salad dressing. In terms of overall acceptability, this obtained optimized formulation was significant ($p<0.05$) from all commercial products, C1, C2, and C3. This result shows that the panelist preferred this product, maybe due to the strong coconut presence.

4. Conclusions

The present study revealed that low-fat and egg-less virgin coconut oil salad dressing with optimum hydrocolloids of xanthan gum and modified starch showed desirable emulsion stability and physicochemical properties in viscosity, texture, and color. The optimum percentages of xanthan gum and modified starch were 1.56% and 0.10%, respectively. The validation of this optimized formulation was insignificant ($p>0.05$) between the predicted and experimental data, which indicated the desired results from this study. Besides, the physicochemical properties of the optimized formulation were compared with a few commercial products to choose the desired formulations based on these references. In addition, the proximate composition of the optimized formulation was reported. For the sensory evaluation, the optimized formulation had a significantly different score for texture, flavor, and overall acceptability ($p<0.05$) from the commercial products. However, the optimized formulation's appearance, color, and aroma are insignificant ($p>0.05$), with some commercial products still acceptable to the consumer. Hence, further study is required to improve the quality and evaluate the shelf life of the low-fat and egg-less VCO salad dressing.

5. References

AOAC (Association of Official Analytical Chemist), 2006. Official Methods of Analysis of the AOAC. In: Horwitiz, W. (Ed.). 18th Edn. *Association of Official Analytical Chemists*, Washington D.C., USA.

Babajide, J. M., and Olatunde, O. O. (2010). Proximate Composition, Rheology and Sensory Qualities of Corn-Cocoyam Salad Cream. *World Journal of Dairy & Food Science*. 5(1): 25–29. https://doi.org/10.4314/njns.v31i1.63892.

Bradbury, K. E., Tong, T. Y., & Key, T. J. (2017). Dietary intake of high-protein foods and other major foods in meat-eaters, poultry-eaters, fish-eaters, vegetarians, and vegans in UK Biobank. *Nutrients*, 9(12), 1317. https://doi.org/10.3390/nu9121317.

Cabeza, C., Alfaro, M. C., & Flores, V. (2002). Influence of the addition of gellan gum on the rheology of low-calorie mayonnaise stabilised with modified starch en Martínez Boza, Guerrero A, Partal P, Franco, JM, Muñoz, J.(Eds.) Progress in Rheology. *Theory and Applications*, 477-480.

Chivero, P., Gohtani, S., Yoshii, H., & Nakamura, A. (2016). Assessment of soy soluble polysaccharide, gum arabic and OSA-Starch as emulsifiers for mayonnaise-like emulsions. *LWT-Food Science and Technology*, 69, 59-66. https://doi.org/10.1016/j.lwt.2015.12.064.

Dayrit, F. M., & Nguyen, Q. (2020). Improving the Value of the Coconut with Biotechnology. In Coconut Biotechnology: Towards the Sustainability of the 'Tree of Life' (pp. 29-50). Springer, Cham. https://doi.org/10.1007/978-3-030-44988-9_3.

de Melo, A. N. F., de Souza, E. L., da Silva Araujo, V. B., & Magnani, M. (2015). Stability, nutritional and sensory characteristics of French salad dressing made with mannoprotein from spent brewer's yeast. *LWT-Food Science and Technology*, 62(1), 771-774. https://doi.org/10.1016/j.lwt.2014.06.050.

Chen, Y., She, Y., Zhang, R., Wang, J., Zhang, X., & Gou, X. (2020). Use of starch-based fat replacers in foods as a strategy to reduce dietary intake of fat and risk of metabolic diseases. *Food science & nutrition*, 8(1), 16-22. https://doi.org/10.1002/fsn3.1303.

De Cássia da Fonseca, V., Haminiuk, C. W. I., Izydoro, D. R., Waszczynskyj, N., de Paula Scheer, A., & Sierakowski, M. R. (2009). Stability and rheological behaviour of salad dressing obtained with whey and different combinations of stabilizers. *International journal of food science & technology*, 44(4), 777-783. https://doi.org/10.1111/j.1365-2621.2008.01897.x.

Dickinson, E. (2009). Hydrocolloids as emulsifiers and emulsion stabilizers. *Food hydrocolloids*, 23(6), 1473-1482. https://doi.org/10.1016/j.foodhyd.2008.08.005.

Jung, K. W., Kim, Y. K., and Lee, G. C. (2011). Effect of different levels of malt extract on antinutrients, in vitro digestibilities and viscosity during fermentation of Jeungpyun. *Food Science and Biotechnology*, 20(3), 679-685. https://doi.org/10.1007/s10068-011-0096-4.

Khor, Y. P., Koh, S. P., Long, K., Chong, G. H., & Tan, C. P. (2018). Stability Assessment of Virgin Coconut Oil-Based Emulsion Products. *Journal of the American Oil Chemists' Society*, 95(10), 1329-1339. https://doi.org/10.1002/aocs.12109.

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. https://doi.org/10.1016/j.lwt.2006.11.007.

Ma, Z., & Boye, J. I. (2013). Advances in the design and production of reduced-fat and reduced-cholesterol salad dressing and mayonnaise: a review. *Food and Bioprocess Technology*, 6(3), 648-670. https://doi.org/10.1007/s11947-012-1000-9.

Ma, Z., Boye, J. I., Fortin, J., Simpson, B. K., & Prasher, S. O. (2013). Rheological, physical stability, microstructural and sensory properties of salad dressings supplemented with raw and thermally treated lentil flours. *Journal of food Engineering*, 116(4), 862-872. https://doi.org/10.1016/j.jfoodeng.2013.01.024.

Ma, Z., Boye, J. I., & Simpson, B. K. (2016). Preparation of salad dressing emulsions using lentil, chickpea and pea protein isolates: A response surface methodology study. *Journal of Food Quality*, 39(4), 274-291. https://doi.org/10.1111/jfq.12190.

Ma, Z., Boye, J. I., Swallow, K., Malcolmson, L., & Simpson, B. K. (2016). Techno-functional characterization of salad dressing emulsions supplemented with pea, lentil and chickpea flours. *Journal of the Science of Food and Agriculture*, 96(3), 837-847. https://doi.org/10.1002/jsfa.7156.

Marventano, S., Godos, J., Tieri, M., Ghelfi, F., Titta, L., Lafranconi, A., & Grosso, G. (2020). Egg consumption and human health: an umbrella review of observational studies. *International journal of food sciences and nutrition*, 71(3), 325-331. https://doi.org/10.1080/09637486.2019.1648388.

Mirzanajafi-Zanjani, M., Yousefi, M., & Ehsani, A. (2019). Challenges and approaches for production of a healthy and functional mayonnaise sauce. *Food Science & Nutrition*, 7(8), 2471-2484. https://doi.org/10.1002/fsn3.1132.

Muhialdin, B. J., Mohammed, N. K., Cheok, H. J., Farouk, A. E. A., & Meor Hussin, A. S. (2021). Reducing microbial contamination risk and improving physical properties of plant-based mayonnaise produced using chickpea aquafaba. *International Food Research Journal*, 28(3).

Ng, S. P., Lai, O. M., Abas, F., Lim, H. K., & Tan, C. P. (2014). Stability of a concentrated oil-in-water emulsion model prepared using palm olein-based diacylglycerol/virgin coconut oil blends: Effects of the rheological properties, droplet size distribution and microstructure. *Food research international*, 64, 919-930. https://doi.org/10.1016/j.foodres.2014.08.045.

Tekin, Z. H., & Karasu, S. (2020). Cold-pressed flaxseed oil by-product as a new source of fat replacers in low-fat salad dressing formulation: Steady, dynamic and 3-ITT rheological properties. *Journal of Food Processing and Preservation*, 44(9), e14650. https://doi.org/10.1111/jfpp.14650.

Ying, L.L. (2015). The antioxidant, physiochemical and sensory properties of virgin coconut oil-based mayonnaise. Bachelor thesis. *University Putra Malaysia* (Selangor).

Acknowledgment:

Universiti Putra Malaysia supported this work under the Geran Universiti Putra Malaysia (GP-IPS/2017/9578000).