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Development of low fat mayonnaise containing different types and levels of hydrocolloid gum

Sensory optimization of low fat mayonnaise (different oils and gums)

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Abstract

Various types of oil (sunflower, soybean, corn, sesame and olive oil) were preliminary used in mayonnaise formulation. The most sensorially acceptable oils were used in production of LF mayonnaise. Low-fat (LF) mayonnaise was produced at different levels of oil with different types (xanthan gum, XG; guar gum, GG; and a combination of XG and GG, 1:1) and levels (0.00, 0.25, 0.50, 0.75 and 1.00%) of hydrocolloid gums. All samples were compared to traditional full fat (FF) mayonnaise.

Sunflower (SfO) and soybean (SyO) oils were the most sensorially acceptable oils. The best LF mayonnaise was formulated with SFO or SyO at 60% and 45% with 0.75% XG/GG (1:1). These LF mayonnaises showed lower caloric values, higher water activity, and pH values than the FF. It also showed higher lightness (L^*), similar participation of green color ($-a^*$), lower yellowness (b^*) higher firmness, adhesiveness, adhesive force, cohesiveness and gumminess compared to FF mayonnaise.

Keywords: Low fat mayonnaise; Oil level; Xanthan gum; Guar gum; Sensory evaluation

1. Introduction

Mayonnaise is a kind of a semi-solid oil-in-water emulsion containing 70-80% fat. Commercial mayonnaises typically contain oil, vinegar, egg yolk, thickening agents, salt and flavoring materials [1, 2]. Fat as one of the main ingredients, has positive influence on the rheological properties and sensory characteristics of the final product. fat contributes to flavor, taste, texture, creaminess, appearance, palatability, and shelf life of the food emulsion [3].

The adverse health effects of overconsumption of certain types of lipids have led to a trend within the food industry toward the development of low fat mayonnaise [3-5]. The demand for low fat mayonnaise has greatly increased in the recent years due to consumers' concern about high fat diets [6]. High fat intake is associated with increased risk of obesity, some types of cancer, cardiovascular diseases, and hypertension [4]. The American Heart Association suggested limiting fat consumption to less than 30% of the overall consumed calories [7].

The production of low fat mayonnaise is normally associated with some technical problems such as poor texture, flavor, appearance, stability, and mouth feel [8]. To produce low fat mayonnaise, fat from the basic formula shall be replaced by fat substitutes with different functionalities in order to obtain a product with the same quality attributes as the original full fat product.

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From a physical point of view, it is necessary to decrease the dispersed phase and to increase the water content in the emulsion to create a low fat product [9]. Some fat replacers such as modified corn starch, inulin, pectin, microcrystalline, cellulose, carrageenan, and some thickeners [3-5, 10,11] were generally used to stabilize the emulsion and to increase the viscosity of light mayonnaise. Polysaccharide gums like guar gum (GG) and xanthan gum (XG) have been increasingly studied as fat replacers in food processing e.g. in low fat meat products. Combined different types of gum might show better functional properties than the sum of those properties measured separately [5].

There is little published data in the literature on the application of hydrocolloid gums in fat replacement in mayonnaise. The current study was designed to incorporate different types of oil in the production of low fat mayonnaise. The most organoleptically acceptable oil types were selected to be involved in the preparation of different low fat mayonnaise formulas using different hydrocolloid gums alone and/or in combination. The chemical, physical, and physicochemical characteristics of the sensory most approved low fat formulations were evaluated.

The objective of this study was to develop a low fat mayonnaise containing xanthan gum (XG), guar gum (GG), and a combination of xanthan and guar gums (1:1) as functional ingredients. In addition, to determining the best oil level for substitution as well as the best type and level of gum to produce low fat mayonnaise with ideal properties close to that of the traditional mayonnaise. The full fat formulation was used as reference.

2.Materials and methods

2.1.Materials

Xanthan gum and sodium benzoate were purchased from Alpha Chemika Co. Mumbai, India. Guar gum and potassium sorbate were obtained from Loba Chemie Pvt. Ltd. Mumbai, India. Alpha tocopherol was purchased from MP Biomedicals Inc. Ohio, USA. Vinegar and mustard were purchased from Heinz - Cairo Food Industrial Heinz Egypt, 6th Of October, Giza, Egypt. Extra virgin olive oil was obtained from Al-Durra Co. Damascus, Syria. Refined corn oil was purchased from ARMA Oil Industries (AOI) 10th of Ramadan City, Egypt. Refined sunflower oil and soybean oil were acquired from Oil Tec Co. Sadat city, Egypt. Virgin sesame oil (extracted from roasted seeds) was obtained from Lee Kum Kee International Holdings Ltd. Hong Kong, China. Dried egg yolk was purchased from The French Co. For Edible IND. (Royal Pack) 6th of October City, Giza, Egypt. Other ingredients like salt, sugar and lemon were bought from the local market. Commercial mayonnaise was also obtained from the local market.

2.2.Methods

2.2.1.Mayonnaise preparation. The recipes of the full fat (FF) mayonnaise as control and the low fat (LF) mayonnaise are shown in table 1. Mayonnaise was prepared using Multiquick 5 kitchen machine K700 (Braun GmbH, Germany). The FF mayonnaise was prepared by mixing the dried egg yolk and water together thoroughly for 3 min. to reconstitute the egg yolk fully. Then all the dry ingredients (*i.e.* salt, sugar, sodium benzoate and potassium sorbate) were added and mixed for 2 min. The mustard was then added and mixed for 30 sec. Antioxidant was added to all mayonnaise samples (240 mg α-tocopherol per Kg mayonnaise). The α-tocopherol was dissolved in sunflower oil (FF control) and added gradually while mixing at 2000 rpm. After adding all the oil, vinegar and fresh lemon juice gradually to the mixture it was mixed for 3 min. Finally, the resulted mayonnaise was mixed again for 5 min. The LF mayonnaise was prepared using the same method of FF mayonnaise except that the hydrocolloid gum was added to water to turn it into gel, mixed thoroughly with the other ingredients for 5 min before adding the oil to achieve the proper texture.

To investigate the effect of oil types on the development of low fat mayonnaise, five different types of oil (sunflower oil, corn oil, soybean oil, olive oil and sesame oil) were incorporated in the formulation of low fat mayonnaise at 45% oil level and xanthan gum was added at concentration of 0.75%. The concentration of xanthan gum was determined by conducting a pre-experiment for the formation of low fat emulsion using various levels of xanthan gum (0.5 – 0.9).

Xanthan gum level was chosen as having the most similar viscosity to the standard full fat (75% fat).

Table 1. Percentage recipes of the mayonnaise (wt. %)

Ingredients %	FF[1]	LF[2]
Oil	75	45
Xanthan	0	0.75
water	7.7	36.95
Vinegar 5%(w/w)	11	11
Dried egg yolk	2	2
Salt	2	2
Sugar	1	1
Mustard	1	1
Potassium sorbate	0.1	0.1
Sodium benzoate	0.1	0.1
Lemon juice	0.1	0.1

1. The full fat mayonnaise was prepared with sunflower oil.
2. Low fat mayonnaise was prepared with different types of oil (sunflower oil, corn oil, soybean oil, olive oil and sesame oil).

The most two organoleptically acceptable oils (based on the sensory analysis) were used in the preparation of different low fat mayonnaise emulsions using different levels of oils (30%, 45%, 60%, and 75%), different types of hydrocolloid gums (XG, GG, and XG/GG 1:1), at different levels (0.0%, 0.25%, 0.50%, 0.75%, and 1%) as illustrated in table 2.

All mayonnaise samples were aseptically transferred to sterile 200 ml glass jars tightly sealed and stored for 24 hrs. at room temperature (25 – 30ºC) before testing. All treatments were prepared in three batches 500gm each.

Other ingredients were the same in all formulations (vinegar (5% w/w) 11%; dried egg yolk 2%; salt 2%; sugar 1%; mustard 1%; lemon juice 0.1%; potassium sorbate 0.1%; sodium benzoate 0.1%; α-tocopherol 240 mg/Kg mayonnaise).

*2.2.2.Sensory Evaluation***.** Sensory evaluation was conducted on mayonnaise samples after one-day storage at room temperature. The panelists consisted of four trained men and four trained women -selected based on their interest and availability- who were graduate students and staff members in the Department of Food Science and Technology, Minufiya University, Egypt evaluated the sensory characteristics (appearance, color, odor, texture, taste, and overall acceptability) of mayonnaise.

Three training sessions (1hr each) were conducted prior to evaluation in which the panelists were trained to be familiar with attributes and scaling procedures of mayonnaise samples. Sensory attributes were evaluated using a nine point hedonic scale with 1= the lowest or extremely dislike and 9= the highest or extremely like. All mayonnaise samples were randomly coded and presented to the panellists on white plates at room temperature. Lighting of the room was the same throughout the analysis, which was conducted in the laboratory of Sensory Evaluation in the Department of Food Science and Technology, Minufiya University, Egypt. Bread and water were provided to the panelists to cleanse their palates between samples.

2.2.3.Proximate Composition. Moisture, protein and ash contents were determined according to AOAC (2003) official methods. Fat was determined according to Egan [12]. Carbohydrates were calculated by difference. All determinations were performed in triplicates.

*2.2.4.Color Measurement.*Mayonnaise samples were measured for color using a Minolta Colorimeter CR-300 (Konica Minolta Business Technologies, Inc., Langenhagen Hannover, Germany) as CIE L^*, a^*, b^* values. The color parameters were defined as L^*, a^*, b^* system (psychometric light L^*, psychometric tone a^* and Chroma b^*). In this coordinate system L^* value is a measure of lightness ranging from black to white, a^* value ranges from – (greenness) to + (redness) and b^* ranges from – (blueness) to + (yellowness).

2.2.5.Texture Profile Analysis. Texture measurements were determined with the TA.XT2i Texture Analyzer (Stable Micro Systems Ltd, Surrey, UK) with a 5 kg load cell. Back extrusion cell with 35 mm diameter compression disc was used. The samples were carefully transferred into acrylic cylindrical containers (50 mm internal diameter and 75 mm height) to a depth of 55 mm. One cycle was applied, at a constant crosshead velocity of 1 mm/s, to a sample depth of 40 mm, and then returned. From the resulting force–time curve, the values for texture attributes, *i.e*. firmness, adhesiveness, adhesive force, cohesiveness and gumminess were obtained using the Texture Expert for Window Version 1 equipment software.

Table 2. Percentage recipes of mayonnaise (wt.%) formulated with different types and levels of oil and hydrocolloid gum

Ingredients	Emulsion of fat content																			
	75					60					45					30				
	Gum Level (GL)[1]					Gum Level (GL)					Gum Level (GL)					Gum Level (GL)				
	GL_1	GL_2	SL_3	GL_4	GL_5	GL_1	GL_2	GL_3	GL_4	GL_5	GL_1	GL_2	GL_3	GL_4	GL_5	GL_1	GL_2	GL_3	GL_4	GL_5
Oil[2]	75	75	75	75	75	60	60	60	60	60	45	45	45	45	45	30	30	30	30	30
Gum[3]	0.0	0.25	0.50	0.75	1.00	0.0	0.25	0.50	0.75	1.00	0.0	0.25	0.50	0.75	1.00	0.0	0.25	0.50	0.75	1.00
Water	7.70	7.45	7.20	6.95	6.70	22.70	22.45	22.20	21.95	21.70	37.70	37.45	37.20	36.95	36.70	52.70	52.45	52.20	51.95	51.70
Other ingredients[4]																				

1. Gum levels (five levels were used 0.0; 0.25; 0.50; 0.75; 1.00).
2. Two types of oil (the most organoleptically acceptable oils).
3. Three types of gums were used (xanthan gum, guar gum, xanthan/guar 1:1).

Table 2. Sensory scores[1] of low fat mayonnaises developed with five different types of oil at 45% oil level and 0.75% xanthan gum

Samples[2]	Color	Taste	Odor	Texture	Appearance	Overall acceptability
FF SfO	7.24^{c}	8.29^{a}	8.28^{a}	8.09^{a}	7.94^{a}	7.97^{a}
LF SfO	8.31^{a}	8.15^{a}	7.13^{b}	7.91^{a}	7.39^{b}	7.78^{b}
LF OO	4.03^{d}	5.85^{c}	5.76^{d}	6.20^{d}	5.33^{e}	5.43^{e}
LF SyO	7.96^{b}	6.80^{b}	7.38^{b}	7.59^{b}	6.65^{c}	7.28^{c}
LF CO	7.38^{c}	6.65^{b}	6.63^{c}	7.09^{c}	6.33^{d}	6.82^{d}
LF SmO	3.88^{d}	1.79^{d}	2.78^{e}	4.59^{e}	3.96^{f}	3.40^{f}
LSD	0.21	0.23	0.43	0.22	0.20	0.14

Means in the same column with different letters are significantly different ($P \leq 0.05$).

1. Each value in the table is the mean of three replicates.
2. FF SfO = full fat mayonnaise (75% sunflower oil, 0% gum), LF SfO = low fat mayonnaise (sunflower oil), LF OO= low fat mayonnaise (olive oil), LF SyO = low fat mayonnaise (soya oil), LF CO = low fat mayonnaise (corn oil), LF SmO = low fat mayonnaise (sesame oil).

Table 3. Sensory characteristics of low fat mayonnaise as influenced by sunflower oil levels and gum types and levels[1]

Sample	Effect of oil concentration				LSD	Effect of gum type[2]			LSD	Effect of gum concentration					LSD
characteristics	30%	45%	60%	75%		XG	GG	XG/GG		0%	0.25%	0.5%	0.75%	1%	
Color	4.65^{d}	6.54^{b}	6.67^{a}	5.43^{c}	0.07	5.35^{c}	5.99^{b}	6.13^{a}	0.06	4.99^{e}	5.74^{d}	5.86^{c}	6.11^{b}	6.41^{a}	0.07
Appearance	2.84^{d}	3.79^{b}	5.18^{a}	3.15^{c}	0.06	4.04^{b}	2.92^{c}	4.26^{a}	0.06	3.48^{d}	3.07^{e}	3.76^{c}	4.11^{b}	4.30^{a}	0.07
Texture	2.42^{d}	3.34^{b}	3.66^{a}	3.04^{c}	0.06	3.49^{b}	2.20^{c}	3.65^{a}	0.05	3.25^{b}	2.76^{e}	2.93^{d}	3.47^{a}	3.16^{c}	0.07
Odor	3.64^{c}	3.59^{c}	5.28^{a}	4.63^{b}	0.08	4.04^{c}	4.21^{b}	4.62^{a}	0.07	3.79^{d}	4.17^{c}	4.24^{c}	4.81^{a}	4.43^{b}	0.09
Taste	2.16^{d}	3.75^{b}	4.77^{a}	2.99^{c}	0.07	3.08^{c}	3.41^{b}	3.77^{a}	0.06	3.28^{c}	2.97^{e}	3.14^{d}	4.23^{a}	3.48^{b}	0.08
Overall acceptability	3.14^{d}	4.20^{b}	5.11^{a}	3.84^{c}	0.03	3.99^{b}	3.75^{c}	4.49^{a}	0.03	3.76^{d}	3.73^{d}	3.99^{c}	4.55^{a}	4.36^{b}	0.03

Mean values in the same row with different letters are significantly different ($P \leq 0.05$).

1. Each value in the table is the Mean of three replicates.
2. Gum types, XG= xanthan gum, GG= guar gum, and XG/GG = mixture of xanthan gum and guar gum 1:1.

Table 4. Sensory characteristics of low fat mayonnaise as influenced by soybean oil levels and gum types and levels[1]

Sample	Effect of oil concentration				LSD	Effect of gum type[2]			LSD	Effect of gum concentration					LSD
characteristics	30%	45%	60%	75%		XG	GG	XG/GG		0%	0.25%	0.5%	0.75%	1%	
Color	4.74^{d}	6.64^{b}	6.76^{a}	5.53^{c}	0.06	5.42^{c}	6.07^{b}	6.27^{a}	0.06	5.06^{e}	5.84^{d}	5.96^{c}	6.23^{b}	6.52^{a}	0.07
Appearance	2.60^{d}	3.82^{b}	5.21^{a}	3.18^{c}	0.06	4.12^{b}	2.80^{c}	4.19^{a}	0.05	3.50^{d}	3.09^{e}	3.79^{c}	4.15^{a}	3.99^{a}	0.07
Texture	2.36^{d}	3.25^{b}	3.62^{a}	3.00^{c}	0.07	3.44^{b}	2.07^{c}	3.66^{a}	0.06	3.14^{b}	2.68^{d}	2.91^{c}	3.42^{a}	3.15^{b}	0.08
Odor	3.56^{c}	3.43^{d}	5.20^{a}	4.64^{b}	0.08	3.96^{c}	4.08^{b}	4.58^{a}	0.07	3.75^{d}	4.09^{c}	4.17^{c}	4.65^{a}	4.37^{b}	0.09
Taste	2.07^{d}	3.47^{b}	4.64^{a}	2.93^{c}	0.07	2.91^{c}	3.18^{b}	3.74^{a}	0.06	3.14^{c}	2.89^{d}	3.06^{c}	3.91^{a}	3.39^{b}	0.08
Overall acceptability	3.06^{d}	4.13^{b}	5.10^{a}	3.88^{c}	0.03	3.98^{b}	3.63^{c}	4.52^{a}	0.03	3.73^{d}	3.73^{d}	3.98^{c}	4.49^{a}	4.28^{b}	0.04

Mean values in the same row with different letters are significantly different ($P \leq 0.05$).

1. Each value in the table is the Mean of three replicates
2. Gum types, XG= xanthan gum, GG= guar gum, and XG/GG = mixture of xanthan gum and guar gum 1:1

Table 5. Chemical composition analysis (w/w %) and caloric values of full fat and low fat mayonnaise[1]

samples	Moisture	Lipid	Protein	Carbohydrate[2]	Ash	Caloric values(Kcal/100g)[3]
FF SfO 75%	18.54 ±0.70^{c}	76.10 ± 0.82^{a}	2.07 ± 0.78^{a}	2.13 ± 0.28^{a}	1.17 ± 0.42^{a}	701.68± 3.99^{a}
FF SyO 75%	18.54 ± 0.69^{c}	76.00± 0.42^{a}	2.03 ± 0.82^{a}	1.80 ± 0.81^{a}	1.14± 0.63^{a}	699.30± 2.21^{a}
LF SfO 60%	33.46 ± 2.10^{b}	60.90 ± 0.57^{b}	2.04 ± 0.42^{a}	1.54 ± 0.71^{a}	1.57± 0.25^{a}	562.40± 7.78^{b}
LF SfO 45%	49.91 ± 1.27^{a}	44.88 ± 1.20^{c}	2.05 ± 0.63^{a}	1.74 ± 0.70^{a}	1.43± 0.91^{a}	418.99± 11.46^{c}
LF SyO 60%	34.01 ± 1.41^{b}	60.47± 2.10^{b}	2.07 ± 0.53^{a}	2.40 ± 0.37^{a}	1.57 ± 0.37^{a}	562.03± 2.77^{b}
LF SyO 45%	49.55± 0.21^{a}	45.06 ± 0.55^{c}	2.10 ± 0.28^{a}	2.09 ± 0.47^{a}	1.21± 0.24^{a}	422.24± 1.56^{c}
LSD	3.07	2.56	0.12	0.98	0.53	25.30

Mean ± SD in the same column with different letters are significantly different ($P \leq 0.05$).

1. Each value in the table is the Mean ± SD of three replicates and two determinations were conducted for each replicate.
2. Calculated by difference.
3. Caloric values = (9× fat) + (4 × protein) + (4 ×carbohydrate).

Table 6. pH and aw values of full fat and low fat mayonnaise[1]

samples	pH	Water activity (a_w)
FF SfO 75%	3.29 ± 0.02^{c}	0.89 ± 0.01^{b}
FF SyO 75%	3.30 ± 0.02^{c}	0.89 ± 0.03^{b}
LF SfO 60%	3.34 ± 0.01^{b}	0.92 ± 0.02^{ab}
LF SfO 45%	3.37 ± 0.02^{a}	0.94 ± 0.03^{a}
Lf SyO 60%	3.35 ± 0.01^{b}	0.93 ± 0.01^{ab}
Lf SyO 45%	3.38 ± 0.02^{a}	0.94 ± 0.02^{a}
LSD	0.02	0.04

Mean ± SD in the same column with different letters are significantly different ($P \leq 0.05$)

1. Each value in the table is the Mean ± SD of three replicates and two determinations were conducted for each replicate.

Table 7. Color measurements of full fat and low fat mayonnaise[1]

Samples	L^*	a^*	b^*
FF SfO 75%	70.43 ± 3.58^{c}	-1.42 ± 0.16^{a}	11.17 ± 0.39^{a}
FF SyO 75%	70.06 ± 0.56^{c}	-1.38 ± 0.21^{a}	9.89 ± 0.45^{b}
LF SfO 60%	73.92 ± 1.20^{bc}	-1.55 ± 0.30^{a}	9.19 ± 0.26^{c}
LF SfO 45%	75.77 ± 4.13^{b}	-1.48 ± 0.24^{a}	8.66 ± 0.21^{cd}
LF SyO 60%	71.92 ± 2.80^{bc}	-1.71 ± 0.16^{a}	9.04 ± 0.37^{c}
LF SyO 45%	84.09 ± 3.50^{a}	-1.49 ± 0.23^{a}	8.1 ± 0.49^{d}
LSD	5.22	0.39	0.57

Mean ± SD in the same column with different letters are significantly different ($P \leq 0.05$)

1. Each value in the table is the Mean ± SD of three replicates and
2. two determinations were conducted for each replicate.

- Color parameters system where L^* = Lightness,
- a^* = tone (+a red color, -a green color) and b^* = Chroma (+b yellow color, -b blue color).

Table 8. Texture profile analysis of full fat and low fat mayonnaise[1]

sample	Firmness (N)	Adhesiveness($\times 10^{-3}$ Nm)	Adhesive Force (N)	Cohesiveness	Gumminess
FF SfO 75%	1.89 ± 0.02^{e}	10.27 ± 0.02^{e}	-1.0 ± 0.02^{b}	0.53 ± 0.02^{e}	0.96 ± 0.02^{d}
FF SyO 75%	1.61 ± 0.05^{f}	9.68 ± 0.05^{f}	-0.94 ± 0.05^{a}	0.60 ± 0.05^{d}	0.92 ± 0.05^{d}
LF SfO 60%	3.02 ± 0.02^{a}	47.35 ± 0.02^{a}	-1.93 ± 0.02^{e}	0.91 ± 0.02^{b}	2.81 ± 0.02^{a}
LF SfO 45%	2.37 ± 0.02^{c}	29.52 ± 0.02^{b}	-1.35 ± 0.02^{c}	1.22 ± 0.02^{a}	2.84 ± 0.02^{a}
LF SyO 60%	2.57 ± 0.02^{b}	18.30 ± 0.05^{c}	-1.43 ± 0.05^{d}	0.71 ± 0.02^{c}	1.7 ± 0.02^{b}
LF SyO 45%	1.95 ± 0.05^{d}	17.05 ± 0.02^{d}	-1.40 ± 0.02^{cd}	0.68 ± 0.05^{c}	1.31 ± 0.05^{c}
LSD	0.05	0.06	0.05	0.05	0.05

Mean ± SD in the same column with different letters are significantly different ($P \leq 0.05$)
Each value in the table is the Mean ± SD of three replicates and two determinations were conducted for each replicate

2.2.6.pH Measurements. The pH values of mayonnaise was determined at room temperature (~ 25ºC) using Jenyway pH meter (Model 3510, Bibby Scientific Limited, UK) as described in AOAC (2003).

*2.2.7.Water activity (a_w) measurements.*Water activity (a_w) was determined at room temperature (~ 25ºC) using HygroLab 2 (Rotronic AG, Bassersdorf, Switzerland). Each sample was placed in a 14mm disposable container and the HC2-AW probe was lowered immediately on the container measuring the a_w of the sample.

2.2.8.Statistical Analysis. Data were recorded as means of triplicate measurements and analyzed using a completely randomized 4 (oil level) × 3(gum type) × 5(gum level) × 3 (replication) factorial designs [13] for the determination of the most acceptable low fat mayonnaise formulations. Data were analyzed by the analysis of variance. When a significant main effect was detected, the means were separated with the Student-Newman-Keuls test. Significant differences were determined at ($P \leq 0.05$).

An analysis of variance and means separations were conducted to analyze the data of the chemical

composition, physical and sensory characteristics of mayonnaise. Comparisons among treatments were analyzed using the Least Significant Difference (LSD). Treatments means were considered significant at (P≤0.05). All data was analyzed using statistical analysis software (Co Stat version 6.4, Co Hort software, CA, USA).

3.Results and discussion

3.1. Sensory evaluation

3.1.1.Effect of oil type. Sensory scores of LF mayonnaise were significantly (P≤0.05) affected by oil types (table 3). The overall acceptability of the FF mayonnaise had the highest (P≤0.05) sensory scores followed by the LF mayonnaise formulated with sunflower oil and soybean oil respectively, however the lowest (P≤0.05) overall acceptability scores were found in LF mayonnaise formulated with sesame oil and olive oil. The LF mayonnaise produced using sunflower oil and soybean oil showed higher (P≤0.05) color rating scores than that of the FF mayonnaise. This might be attributed to the higher moisture content of the LF mayonnaise which consequently diluted the color of the sample producing off white color, which was more preferred by the panelists than the yellow color of the FF mayonnaise resulted from the high concentration of oil. Contradictory results were obtained by Liu, Xu [4] who stated that the dark yellow color of the FF mayonnaise was more acceptable than the off white color. The lowest (P≤0.05) color scores were found in LF mayonnaise prepared with sesame oil and olive oil. The color of both types was judged as unacceptable. This might be due to the presence of unfamiliar color shades in the oils used which led to darker or strange color such as brownish color in sesame oil and greenish color in olive oil.

The FF and LF mayonnaise produced using sunflower oil showed the highest (P≤0.05) taste and texture scores followed by LF mayonnaise formulated with soybean oil. Whereas, the highest (P≤0.05) odor and appearance scores found in with FF mayonnaise followed by LF mayonnaise prepared with sunflower and soybean oil respectively. On the other hand, the LF mayonnaise made with sesame oil showed the lowest (P≤0.05) scores for all attributes and judged to be sensorial unacceptable.

From the sensory scores, it could be noticed that the LF mayonnaise produced with sunflower oil and soybean oil exhibited the closest sensory properties to the FF mayonnaise. Therefore, these two types of oils were selected in the preparation of various LF emulsions using different oil levels as well as different types and levels of hydrocolloid gums.

3.1.2.Effect of oil levels and hydrocolloid gum types and levels. Data presented in tables 4 and 5 show the sensory characteristics of LF mayonnaise formulated with different levels of either sunflower or soybean oils as well as different types and levels of hydrocolloid gum. The LF mayonnaise prepared with 60% sunflower oil or soybean oil showed the highest sensory scores for all attributes followed by that formulated with 45% level of both types of oil. Sensory characteristics scores of LF mayonnaise formulated with sunflower or soybean oil at 60% and 45% level were higher (P≤0.05) than that of the FF mayonnaise except for odor of the LF mayonnaise prepared with sun flower oil which was lower (P≤0.05) than that of FF mayonnaise. Sensory scores of LF mayonnaise were influenced (P≤0.05) by hydrocolloid gum types. The combination of XG and GG (1:1) showed the highest sensory scores for all attributes of LF mayonnaise prepared with sunflower or soybean oils (table 4 and 5). The overall acceptability of LF mayonnaise produced with XG was higher (P≤0.05) than that of GG.

Nikzade, Tehrani [14] reported that the addition of XG as stabilizer increased the overall acceptance of LF mayonnaise. The LF mayonnaise produced with hydrocolloid gums at 0.75% level showed the highest overall acceptability. The best texture, odor and taste of LF mayonnaise was obtained using 0.75% hydrocolloid gum, however the best color and appearance resulted at 1% hydrocolloid gum. On the other hand, the lowest overall acceptability was found in mayonnaise produced without gum addition (0 % gum).

Sensory data (table 4 and 5) indicated that LF mayonnaise might be developed by reducing the oil level to 60% and 45% and adding a combination of XG and GG (1:1) at 0.75% level. The resultant LF mayonnaise formulations were judged as the most sensorially acceptable samples.

Therefore, these formulations will be selected for further chemical, physicochemical and physical studies.

3.1.3.Chemical composition and Caloric values. The chemical composition analysis and caloric values of both LF and FF mayonnaise are presented in table 6. The LF mayonnaise formulations had higher (P≤0.05) moisture content than the FF mayonnaise. Generally, the moisture content increased with increasing the levels of fat substitution. Akoh and Min [15] reported that the moisture content level in LF mayonnaise formulated with carbohydrate based fat replacer increased significantly since the reduction of oil level is compensated by raising the moisture level.

No significance differences (P > 0.05) were detected between the FF and the LF mayonnaises in protein, carbohydrate and ash. This might be due to the constant ingredients types and levels in all formulations except for oil, water and gum.

The caloric value of the LF mayonnaise was significantly (P≤0.05) reduced by increasing the level of fat substitution. The LF mayonnaise prepared with sunflower oil or soybean oil at 45% level showed the lowest (P≤0.05) caloric values among all mayonnaise formulations. The reduction in caloric values could be attributed to the substitution of oil in FF mayonnaise with water and hydrocolloid gums (non-caloric ingredients because they are not digested or absorbed in the human digestive tract) in LF mayonnaise. Water is considered a key component when replacing fat using a carbohydrate based fat replacer. Water forms a gel like structure with the hydrocolloid gum, which enhances the texture of the LF mayonnaise.

3.2.Physicochemical analysis

The chemical composition analysis and caloric values of both LF and FF mayonnaise are presented in table 6. The LF mayonnaise formulations had higher (P≤0.05) moisture content than the FF mayonnaise. Generally, the moisture content increased with increasing the levels of fat substitution. Akoh and Min [15] reported that the moisture content level in LF mayonnaise formulated with carbohydrate based fat replacer increased significantly since the reduction of oil level is compensated by raising the moisture level.

No significance differences (P > 0.05) were detected between the FF and the LF mayonnaises in protein, carbohydrate and ash. This might be due to the constant ingredients types and levels in all formulations except for oil, water and gum.

The caloric value of the LF mayonnaise was significantly (P≤0.05) reduced by increasing the level of fat substitution. The LF mayonnaise prepared with sunflower oil or soybean oil at 45% level showed the lowest (P≤0.05) caloric values among all mayonnaise formulations. The reduction in caloric values could be attributed to the substitution of oil in FF mayonnaise with water and hydrocolloid gums (non-caloric ingredients because they are not digested or absorbed in the human digestive tract) in LF mayonnaise. Water is considered a key component when replacing fat using a carbohydrate based fat replacer. Water forms a gel like structure with the hydrocolloid gum, which enhances the texture of the LF mayonnaise.

3.3.Physicochemical analysis.

Data presented in table 7 show the pH values and water activity (a_w) of FF and LF mayonnaise. The pH values of LF mayonnaise were significantly (P≤0.05) higher than that of FF mayonnaise. Increasing the level of fat substitution in mayonnaise formulations resulted in significant (P≤0.05) increases in the pH values. The increases in pH values might be due to the dilution of acetic acid in the aqueous phase of the LF formulations since there were significant (P≤0.05) increases in the moisture content as the level of fat substitution increased (table 6). These results are in good agreement with those obtained by [Hathcox, Beuchat [16], Karas, Skvarca [17]]. Radford and Board [18] recommended the use of vinegar as acidulant to achieve a pH of 4.1 or less as a major inhibitory substance against microorganisms. Smittle [19] also suggested that the pH of mayonnaise should be 4.1 or less to maintain a product free from Salmonella. From the microbiological safety point of view, it is important to note that the pH values of the mayonnaise in the current study ranged from 3.34 to 3.38.

The a_w of LF mayonnaise prepared with sunflower oil or soybean oil at 45% level was higher ($P \leq 0.05$) than that of the FF mayonnaise. The increase in a_w values might be due to the increase of water holding capacity of the LF mayonnaise resulted from the addition of hydrocolloid gum. Chirife, Vigo [20] reported that the a_w of FF mayonnaise (77 – 79% oil) was about 0.93 and that of LF mayonnaise (37 - 41% oil) was higher, *i.e.* close to 0.95.

3.4. Color analysis

Color measurements of LF and FF mayonnaises are shown in table 8. The lightness (L value) of mayonnaise has a major impact on the perceived appearance of the product. The L^* values of LF mayonnaise prepared with sunflower oil and soybean oil at 45% level, were significantly ($P \leq 0.05$) higher than those of FF mayonnaises. The highest ($P \leq 0.05$) lightness among all mayonnaise formulations was found in LF mayonnaise formulated with soybean oil at 45% level and XG/GG (1:1) combination at 0.75% level as indicated by L^* value ($L^* = 84.09$). This is in good agreement withMun, Kim [3] who stated that the L-value of the FF mayonnaise was the lowest and by increasing the level of starch and xanthan gum, the L-value of the LF mayonnaise increased.

The a^* values showed no significant ($P > 0.05$) differences among all FF and LF mayonnaise formulations. The a^* values were with a negative denomination, ranging from -1.38 to -1.71, which implies the presence of a green pigment. The participation of the green color in LF mayonnaise was similar to that in FF mayonnaise.

The LF mayonnaise prepared with either sunflower oil or soybean oil showed lower ($P \leq 0.05$) b^* values than those of FF mayonnaises. The b^* values were with a positive denomination which indicate the presence of yellow color. The LF mayonnaise prepared with soybean oil and sunflower oil at 45% level had the lowest ($P \leq 0.05$) participation of yellow color ($b^* = 8.1$ and 8.66) among all mayonnaise formulations. This might be attributed to the reduction in oil level that decreased the yellowness of LF mayonnaise.

3.5.Texture profile analysis

Texture profile analysis of FF and LF mayonnaise is shown in table 9. The LF mayonnaise products had higher ($P \leq 0.05$) firmness, adhesiveness, adhesive force, cohesiveness and gumminess compared to the FF mayonnaise products. This result is probably caused by increasing the viscosity of the emulsion due to the addition of hydrocolloid gums to the LF formulations. It seems that, the presence of gums might create a gel like structure that trap oil droplets, slow down their movements and raising the viscosity [3]. Similar results were obtained by Nikzade, Tehrani [14] who reported that low fat mayonnaise formulated with mixture of xanthan gum, guar gum and mono-diglyceride emulsifiers had more firmness, adhesiveness, and adhesive force values compared with mayonnaise formulated with any of them separately. In addition, data in table 9 indicated that the highest firmness, adhesiveness and adhesive force values occurred in LF mayonnaise formulated with sunflower oil at 60% level. However, the highest cohesiveness and gumminess values were found in LF mayonnaise formulated with sunflower oil at 45% level. On the other hand, the lowest values for all texture attributes were recorded in FF mayonnaise formulated with either sunflower oil or soybean oil. The effect of adding gums to the LF formulations on textural characteristics was reported by Worrasinchai, Suphantharika [6] who indicated that gum may increase the elasticity of the emulsion as a result of the formation of a strong gel-like structure in the continues phase. This imports a more firm and adhesive structure and yielding smaller oil droplet diameters because of a reduced coalescence process during emulsification. Also, Liu, Xu [4] stated that decreasing of the droplet diameter leads to greater contact surface area between droplets, and therefore to an increased viscosity which resulted in firmer emulsion.

It is worthy to note that adding gum to the LF formulations is very important to have a product with good textural characteristics and high emulsion stability due to the increase in viscosity.

Conclusion

From the results of the present work, it could be concluded that a combination of XG and GG (1:1) at 0.75% concentration considered as a good fat substitute, resulted in LF mayonnaise product with lower calories, better texture characteristic properties and higher sensory scores than FF mayonnaise.

Compliance with Ethics Requirements: Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human and/or animal subjects (if exists) respect the specific regulations and standards.

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