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Functional Properties of Some Fat-Replacers and Their Uses in Preparation of Reduced-Fat Mayonnaise

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Abstract: Application of xanthan, flaxseed mucilage and their mixture as a fat replacers for preparing reduced fat mayonnaise was studied. Functional properties of the aqueous solution of the fat replacers such as water and oil absorption capacity (WAC, OAC), emulsifying capacity and stability, gelling, dynamic viscosity were measured. Results indicated that (WAC) of xanthan was 1.79 times more than flaxseed mucilage while the mixture of xanthan and flaxseed mucilage (1:1w/w) have recorded high value of WAC and OAC. Flaxseed mucilage can form gel with different strength depending on its concentration. Addition of high concentration of xanthan (0.5 and1%) had completely 100% emulsifying capacity and stability. On the other hand, flaxseed mucilage gave high emulsifying capacity and stability (100%) at 1% but a sharp decrease was observed at 0.1 and 0.5%. Dynamic viscosity of flaxseed mucilage increased with increase of concentration but it was lower than the dynamic viscosity of the xanthan. On the other hand, the mixture of 0.5% xanthan and 1% flaxseed mucilage recorded high dynamic viscosity than xanthan or flaxseed mucilage alone. Flaxseed mucilage and xanthan also showed high solubility in water with increase in temperature. Moisture of mayonnaise samples was affected by replacing oil with xanthan and flaxseed mucilage and their mixture. About 34, 48 and 61% reduction in caloric values was achieved when xanthan, flaxseed mucilage and their mixture was used, respectively. The viscosity of different reduced fat mayonnaise samples which contain (25, 35 and 45g) oil were lower than the control sample which contain all amount of fat (70g oil). Reduced fat mayonnaise samples gave a higher stability than full-fat mayonnaise. The reduced fat mayonnaise samples made by reduced (35,25 and 45g oil) with 0.7% xanthan, 1% flaxseed mucilage and 0.5%of xanthan and flaxseed mucilage respectively gave high acceptablility to consumers and has no significant difference with full –fat mayonnaise. Therefore it is possible to use the xanthan and flaxseed mucilage (both alone or together) as a fat replacers in mayonnaise.

Key words: Fat replacer · Xanthan · Flaxseed mucilage · Mayonnaise

INTRODUCTION

Consumers demand for more natural, more nutritional and healthier food products presenting both nutritional and health benefits has increased over the years. In view of the general consensus that the amount and type of fat consumed is of importance to the aetiology of several chronic diseases (e.g. obesity, cardiovascular diseases, cancer), it is not surprising that consumers readily adhere to nutritional guidelines concerning fat consumption. Largely influenced by health related concerns, there has been pressure on the food industry to reduce the amount of fat, sugar, cholesterol, salt and certain additives in the diet. Food manufacturers have responded to consumer demand and there has been a rapid market growth of products with a healthy image [1]. One of the major trends is to reduce the fat content of salad dressings, which has led to popular "reduced fat", "light", "low fat", or "fat free"versions of these traditional products. However, as a food component, fat contributes to the flavor, appearance, texture and shelf life of food products. Therefore, it is difficult to imitate traditional product quality when preparing reduced-fat foods. Thus, to establish the formulation of reduced- fat products, it is necessary to use a combination of non fat ingredients with different functional roles to replace the quality attributes lost when fat is removed. Thus to establish the formulation of the low fat (LF) products, food technologists have focused their efforts essentially on fat replacers [1]. Biopolymers, such as gums, starches and

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proteins are often incorporated into fat-reduced products to provide some of these functional attributes [2]. Fat replacer is an ingreadient that can be used to provide some or all of the functions of fat yielding fewer calories than fat [3]. Fat replacers are either fat substitutes or fat mimetics depends on its role in food products. There are several types of fat replacers such as xanthan, guar gum, arabic gum, carrageenan, inulin, flaxseed gum,..etc, which can play similar role of fat in food [4]. Xanthan gum is a commercially important heteropolysaccharide produced by strains of *xanthomonas campestris*. Because of its rheological properties, xanthan is widely used as a suspension, thickening and stabilising agent as well as an emulsifier, mainly in the food, cosmetics and pharmaceutical industries [5, 6]. Flaxseed contains many nutrients and functional components such as polyunsaturated fatty acid, lignans, protein and gum [7-10]. Flaxseed gum, which comprises about 8% of the seed, yields L-galactose, D-xylose, L-arabinose, L-rhamnose and D-galacturonic acid by acid catalyzed hydrolysis [11, 12]. Flaxseed gum has good water holding capacities and the water binding ability and rheological properties of flaxseed gum are similar to those of guar gum [13-15]. Flaxseed gum also shows weak gel properties, so that it can be used to replace most of the non-gelling gums for food and non-food applications [16, 17]. Traditional mayonnaise is an oil-in-water emulsion containing 70-80% fat [18].

Therefore to produce a dietetic mayonnaise, it is necessary to decrease the dispersed phase and to increase the water content. Some fat replacers such as modified starch, [19] and microcrystalline cellulose [20], some thickeners [21] were generally used to stabilize the emulsion and to increase the viscosity of light mayonnaise. The "light" mayonnaise products, marketed only in recent years, contain about 36% fat. There is currently interest in producing reduced-fat (RF) mayonnaise and substituting fat without altering the consistency of the product. In some researches, fat replacers based on starch, protein and gum were used in RF mayonnaise or salad dressing [2]. Physicochemical, rheological, texture analysis and sensory evaluation of the full fat (FFM) and low fat (LFM) mayonnaises were performed by Liu *et al*. [1].

The results indicated that all LF mayonnaises had significantly lower energy content, but higher water content than their FFM counterpart. In terms of texture, the formulation with pectin weakgel as fat mimetic showed similar texture values as those of the FFM sample. Both FFM and LFM mayonnaises exhibited thixotropic shear thinning behavior under steady shear tests and were rheologically classified as weak gels under small amplitude oscillatory shear tests. Sensory evaluation demon strated that mayonnaises substituted with low-methoxy pectin were acceptable. Therefore, the objective of this study was measured functional properties of xanthan and flaxseed mucilage (both alone or together) and investigate the effects of partial substitution of fat with xanthan and flaxseed mucilage (both alone or together) as a fat replacers on stability, rheological and sensorial properties of the reduced fat (RFM) mayonnaise. The full fat (FFM) mayonnaise was used as control.

MATERIALS AND METHODS

Materials: Xanthan (bacterial source), flaxseed mucilage produced from flaxseed were used in this study as sources of fat replacers. Xanthan was obtained from Sigma Chemical Co. (St. louis, Mo), USA. Flaxseed (*Linum usitatissimum* L.) was obtained from Agric. Research center,Giza, Egypt (season 2008). Different spices used for mayonnaise manufacture were purchased from local market, Cairo, Egypt. Commercially available corn oil was obtained from Crystal Arma Food Industries, Egypt. Commercial white vinger (5%) was obtained from Egyption Sugar and Distillation Company, Cairo, Egypt.

Preparation of Flaxseed Mucilage: The flaxseed mucilage was prepared according to the method described by Zhang *et al*. [10]. The Flaxseed mucilage was extracted by mixing the seeds with boiling distilled water (1:7w/v), shaking the seed-water mixture at 200 strokes per min for 4h at 25°C and separating the mucilage extract from the seed by filtration through a cheese cloth, then the mucilage extract was precipitated with acetone (1:1v/v), dried at 50°C over night and milled to pass through a 20 mesh screen.

Preparation of Full and Reduced-Fat Mayonnaise: Full fat mayonnaise (FFM) and reduced fat mayonnaise (RFM) samples were prepared using the suggested formula according to Mun *et al*. [2] as mentioned in Table 1. For production of full fat mayonnaise (FFM), The salt, sugar, mustard, white pepper and potassium sorbate were first mixed with whole egg, vingar and lemon juice using blender on low velocity for 1min. The previous mixture called the aqueous phase. The oil was slowly added to the system until the emulsion formed. For production of reduced-fat mayonnaise (RFM) different concentrations

Table 1: Suggested formula of full and reduced-fat mayonnaise with different concentration of selected fat replacers

		(RFM)**							
		Xanthan (%)			Flaxseed Mucilage (%)			Xanthan: Mucilage %	Xanthan: Mucilage %
Ingredient (g)	(FFM)*	0.5	0.7	1	0.5	0.7	1	0.5:0.5	0.5:1
Oil	70.00	35.00	35.00	35.00	45.00	45.00	45.00	25.00	25.00
Whole egg	22.17	22.17	22.17	22.17	22.17	22.17	22.17	22.17	22.17
Lemon juice	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20
Vinegar	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Mustard	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
Salt	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Sugar	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
White pepper	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Potassium sorbate	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Water	--	34.50	34.30	34.00	24.30	24.00	23.50	44.00	43.50
Xanthan	--	0.50	0.70	1.00	--	--	--	0.50	0.50
Flaxseed mucilage	--	--	--	--	0.5	0.7	1	0.50	1.00

(FFM)*: Full -Fat Mayonnaise
(RFM)**: Reduced-Fat Mayonnaise

of fat replacers (e.g. xanthan, flaxseed mucilage and their mixture) were first dispersed in a calculated amount of water and then added to aqueous phase of the basic mayonnaise formula and using the blender at low velocity for 1min to homogenize the formula. The calculated amount of oil was slowly added to the system until the emulsion formed. Different mayonnaise samples were filled in 200 ml glass filled and stored at room temperature until analysis.

Functional Properties of Fat Replacer

Water Absorption Capacity: Water absorption capacity (WAC) was determined according to AACC [22]. A 0.5g fat replacer samples or a mixture of them was weighed in a tube and distilled water was added until it was completely wet. The tubes were centrifuged at 6400 rpm for 10min, the supernatant discarded and the swollen sample weighed. The WAC was calculated as:

$$\mathbf{WAC = (s_{sw}-s_w) / s_w}$$

where:
s_{sw} : Is the swollen sample weighed.
s_w : Is the sample weighed.

Oil Aabsorption Capacity: Oil absorption capacity (OAC) was determined according to AACC [22]. A 0.5g fat replacer samples or a mixture of them was weighed in a tube and oil was added until it was completely wet. The tubes were then centrifuged at 6400 rpm for 10min, the supernatant discarded and the swollen sample weighed. The OAC was calculated as:

$$\mathbf{OAC = (s_{sw}-s_w) / s_w}$$

where:
s_{sw} : Is the swollen sample weighed.
s_w : Is the sample weighed.

Gel Formation: The ability of the fat replacers solutions to form gel at different concentrations (0.2, 0.4, 0.6, 0.8, 1 and 2%) was determined according to the method of Coffman and Garcia [23]. Suspensions of different concentration of the fat replacers in 100 ml of distilled water were prepared. About 10 ml of each dispersion was transferred into a t est tube, heated in a boiling water bath for 1h, followed by rapid cooling in a cold water bath. The tubes were further cooled at 4°C for 2h. The least gel concentration (LGC) was determined as the concentration when the sample from the I nverted test tube did not slip or fall. The effect of 0.2% level of divalent ($CaCl_2$) cation on gel formation of xanthan, flaxseed mucilage at different concentrations of (0.1,0.2,0.3,0.4 and 0.5%) was also studied.

Solubility: Solubility of the fat replacers was determined according to Betancur-Ancona *et al.* [24]. The suspension of the fat replacers (30ml,1%w/v) was placed in a water bath at 30, 60, 70, 90°C for 30min and continuosly stirred. The suspension was then centrifuged at 3200 rpm for 15min. Aliquots (10 ml) of the supernatant were dried in an air oven at 125°C over night until constant weight was reached.

$$\%Solubility = (w_f / w_i)\ 30/10)100$$

where:

w_i : Is the initial weight.

w_f : Is the final weight

Emulsifying Properties: The procedure described by Sciarini *et al.* [25] was used for determination of both emulsifying capacity (EC) and emulsifying stability (ES). Fat replacers suspensions (60 ml) of different concentrations (0.1,0.5 and 1% w/v) were mixed with 6ml of commercial corn oil and homogenized for 1 min. The suspensions were then centrifuged at 3200 rpm for 10 min. The Emulsifying Capacity (EC) was calculated as:

$$EC = (e_v / t_v)100$$

where:

e_v : The emulsion volume

t_v : The total volume

Emulsion Stability (ES) of different concentration (0.1,0.5 and 1%) of fat replacers emulsions aganist high temperatures were determined in the emulsions that were heated in a water bath at 80°C for 30 min according to Sciarini *et al.* [25]. ES was calculated as:

$$ES = (fev / iev)100$$

where:

f_{ev} : Is the final emulsion volume.

i_{ev} : Is the initial emulsion volume.

Thickening Properties: Thickening ability of aqueous solutions of the fat replacers due to their ability to record high values of dynamic viscosity was studied. Dynamic viscosity measurements of aqueous solutions of 0.2,0.4,0.6,0.8 and 1% levels of the tested samples were determined by using the rotational viscometer (Rheotest 2-Germany) according to Swiderski *et al.* [26] at shear rates 27, 48.6, 81, 145.8, 243, 437, 729 and 1312 s^{-1} at room temperature. The dynamic viscosity was calculated according to Krumel and Sarkar [27] as follows:

$$\eta = \tau / \gamma \quad (1)$$

$$\tau = z.\ \alpha \quad (2)$$

where:

η : Dynamic viscosity (cp)

τ : Shear stress ($dynes/cm^2$)

z : Cylinder constant

α : Read out value

γ : Shear rate (sec^{-1})

Mayonnaise Quality Evaluation

Chemical Analysis and Caloric Values: Moisture, ash, lipid and protein of fat replacers and different mayonnaise samples and caloric values of the full fat mayonnaise (control) and the reduced fat mayonnaise were determined according to AOAC [28].

Dynamic Viscosity: Rheological properties of different mayonnaise samples were measured by using the rotational viscometer (Rheotest 2- Germany). The rheological properties of mayonnaise samples were based on measuring the shear stress developed at shear rates of 16.2, 27, 48.60, 81, 145.8, 243 and 437.4 sec^{-1}, respectively at room temperature [27].

Stability Rate: Stability rate of mayonnaise samples was determined according to Mun *et al.* [2]. About 15g of each sample (F_0) were transferred to test tubes that were then tightly sealed with plastic caps and stored at 50°C for 48hr After storage, the samples were cooled to room temperature and centrifuged at 3200 rpm for 10 min. The separated fat was discarded. and the weight of precipitated fraction (F_1) was measured.

Emulsion stability was characterized as:

$$\text{Stability rate } \% = (F_1 / F_0) X\ 100$$

Sensory Evaluation: Sensory evaluation was conducted on the mayonnaise samples after one day storge at room temperature according to Liu *et al.* [1]. Sensory characteristics: appearance, colour, flavour, consistency and overall acceptability were evaluated by 20 trained panel. All mayonnaise samples were coded with three digit random numbers and presented to panelists on a tray in individual boths. Orders of serving were completely randomized.Water was provided between samples to cleanse the palate.

Statistical Analysis: All measurement were carried out in triplicate for each samples. A one way analysis of variance (ANOVA) and Duncan s test were used to establish the significance of differences among the mean values at ($p \leq 0.05$). The data were analyzed according to user s Guide of Statical Analysis System [29] at the computer center of Faculty of Agriculture, Ain Shams University.

RESULTS AND DISCUSSION

Proximate Chemical Analysis of Selected Fat Replacers: The proximate chemical analysis of the selected fat replacers was presented in Table 2. It can be observed that flaxseed mucilage showed a higher protein and ash content (3.52% and 8.67% respectively), oppositely xanthan gum contained a lower protein and ash content (0.59 and 7.67%, respectively). However, xanthan was higher in its fat content when compared to flaxseed mucilage. These results were similar to those obtained by Liu *et al.* [1] and Garcia-Ochoa *et al.* [6].

Some Functional Properties of Selected Fat Replacers: Water and Oil Absorption Capacity: Water absorption capacity (WAC) of selected fat replacers used in this study was given in Table 3. Results showed that WAC of xanthan 40.62 was higher than flaxseed mucilage 22.63. Xanthan gum was 1.79 times WAC more than flaxseed mucilage. On the other hand, the mixture of xanthan and flaxseed mucilage (1:1w/w) has recorded high value of WAC 80.00 compared to xanthan or flaxseed mucilage. These results were closed with those of Fedeniuk and Biliaderis [15] where they showed that flaxseed mucilage has high water absorption capacity, which they related this to the presence of polysaccharides in the seed coat. Also, results in Table 3 showed that the highest OAC was obtained for xanthan 4.25 and the mixture of two replacers (3.95).

Gel Formation: Xanthan and flaxseed mucilage cannot form gel at different concentration (0.2, 0.4, 0.6, 0.8, 1.0, 2.0%) but formed highly viscous solutions. In contrast, authors like [17] suggested that flaxseed gum solutions could not form cold-set gels. Results in Table 4 represented the influence of 0.2% divlatent $CaCl_2$ on gel forming of xanthan and flaxseed mucilage at different concentrations of (0.1,0.2,0.3,0.4 and 0.5%). Flaxseed mucilage can form gel with different strength depending on their concentration. Similar results was obtained by

Table 2: Proximate chemical analysis of selected fat replacers (dry weight basis)

	Selected fat replacers	
Constituents (%)	Flaxseed mucilage	Xanthan
Moisture	9.17±1.44*	9.00±1.00
Ash	8.67±0.58	7.67±0.08
Protein	3.52±0.39	0.59±0.21
Fat	1.37±0.53	4.47±0.04
Total carbohydrate**	77.28±0.32	78.33±0.14

*:Means (n=3) ±SD

**: Total carbohydrates were calculated by difference

Table 3: Water and oil absorpation capacity (WAC, OAC) of selected fat replacers

Selected Fat replacers	WAC	OAC
Xanthan	40.62±0.22	4.25±0.18
Flaxseed mucilage	22.63±0.52	2.58±0.36
Xanthan and flaxseed mucilage (1:1w/w)	80.00±0.33	3.95±0.42

Table 4: Gel formation of selected fat replacers at different concentration with 0.2% $CaCl_2$

	(Gel formation)				
Selected fat replacers	0.1(%)	0.2(%)	0.3(%)	0.4(%)	0.5(%)
Xanthan	-	-	-	-	-
Flaxseed mucilage	-	+	+	++	+++
		Mixture of fat replacers			
Xanthan and flaxseed mucilage (0.5:0.5 %)			+ +		
Xanthan and flaxseed mucilage (0.5:1,0 %)			+ + +		

1. (-) cannot formed gel

2. formed gel with different strength:
(+) weak
(++) medium
(+++) very strong

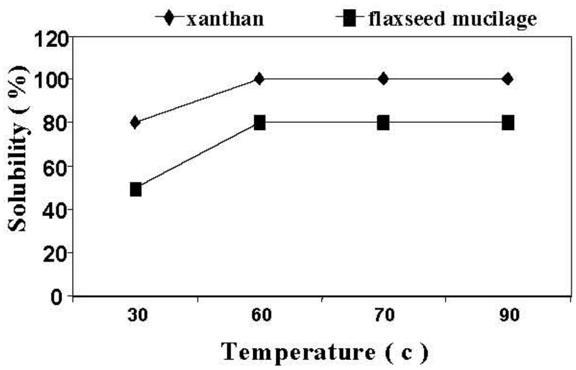

Fig. 1: Solubility of selected fat replacers at different temperature

Chen *et al.* [17] who suggested that flaxseed gum solutions could form cold-set gels by adding differential valence mineral salts. The high strength of gel was observed for flaxseed mucilage at concentration of 0.4 and 0.5%. On the other hand, xanthan cannot form gel in the presence of $CaCl_2$ at all concentration but can make medium gel when mixed with flaxseed mucilage at concentration of 0.5% of each of them in the presence of 0.2% of $CaCl_2$, while a mixture of 0.5%and 1%of xanthan and flaxseed mucilage can form very strong gel in the presence of 0.2% of $CaCl_2$.

Solubility: The solubility of the selected fat replacers was determined at different temperature 30, 60, 70, 90°C. Results in Fig. 1 showed that both of xanthan and flaxseed mucilage have high solubility properties and their solubility was increased with increasing the temperature. The minimum solubility of flaxseed mucilage and xanthan was 50% and 80% respectively at 30°C. However, at 60°C the solubility was increased to 80 and 100% for flaxseed mucilage and xanthan, respectively. No change was observed in solubility of fat replacers with increasing the temperature over 60°C. This data is close to that observed by Garcia-Ochoa *et al.* [6] who found that xanthan gum is highly soluble in both cold and hot water and this behavior is related with the polyelectrolyte nature of the xanthan molecule. Also, Mazza and Biliaderis [11] found that flaxseed mucilage has high solubility ranged between 70 to 90%.

Emulsifying Capacity and Stability: The influence of the selected fat replacers at different concentration on emulsifying capacity (EC) and emulsion stability (ES) was given in Figs. 2 and 3. The EC was affected as a result of adding different concentration of xanthan and flaxseed mucilage (Fig. 2). Addition of high concentration of

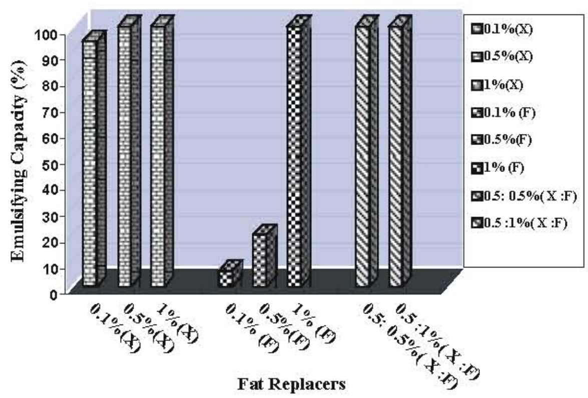

Fig. 2: Emulsifying capacity of different concentrations of xanthan(x) and flaxseed mucilage (F) and their mixture (x: F).

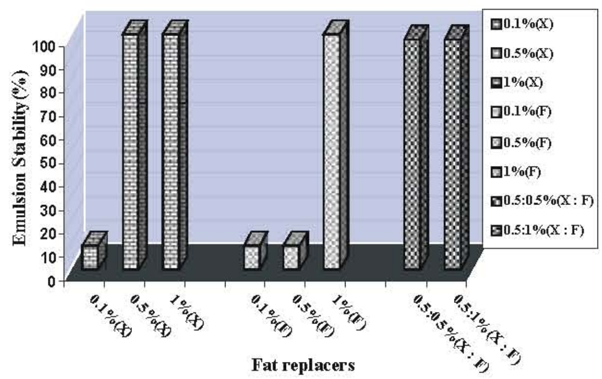

Fig. 3: Emulsion stability of different concentrations of xanthan(x) and flaxseed mucilage (F) and the mixture (x:F).

xanthan (0.5and 1%) completely had 100% emulsifying capacity but at low concentration 0.1%, emulsifyng capacity was decreased to 94.4%. On the other hand, flaxseed mucilage gave high emulsifying capacity 100% at high concentration 1%, but a sharp decrease was obtained for the emulsifiying capacity (5.8% and 20%) at 0.1 and 0.5% concentrations, respectively. The maxiumum emulsifying capacity (100%) was achieved when a mixture of flaxseed mucilage and xanthan was used emulsion stability (ES) of different concentration of fat replacers emulsions aginst high temperature was illustrated by Fig. (3). From these data, it can be clearly noticed that the xanthan gum had a good emulsion stability (100%) comparing with the flaxseed mucilage (20%) at concentration 0.5%. A sharp reduction of ES was obtained when low concentration 0.1% of fat replacers was used. In conclusion, xanthan and flaxseed mucilage and their mixture had the ability to stabilize the emulsion efficiently at high concentration and this may

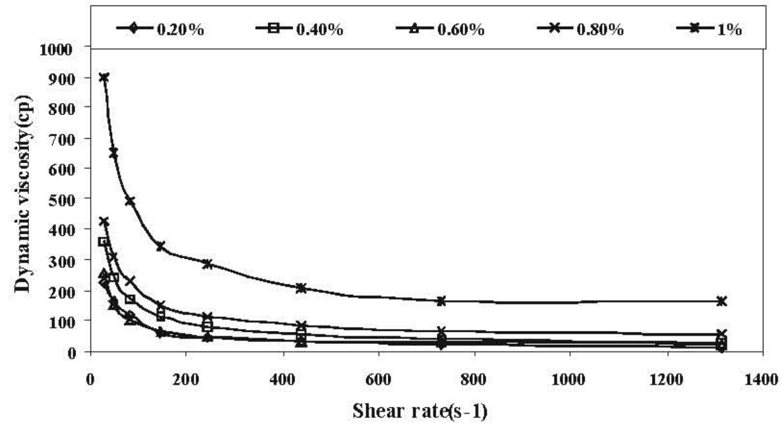

Fig. 4: Effect of shear rates on the dynamic viscosity of different concentration of xanthan at 25°C

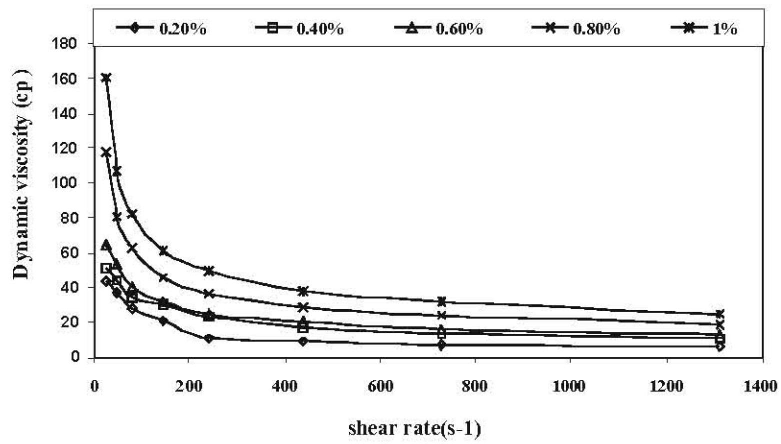

Fig. 5: Effect of shear rates on the dynamic viscosity of different concentration of flaxseed mucilage at 25°C.

probably due to their high EC. Similar results were obtained by Sciarini *et al.* [25] and Garti [30]. They found that gum molecules move slowly to the dispersion interface, showing certain surface and interface activities. Emulsion stability was also increased in low concentration of flaxseed mucilage by additing a concentration of xanthan and flaxseed mucilage together.

Thickening Properties: The ability of thickening aqueous solutions (refer to dynamic viscosity) is one of the most important application of polysaccharides in food. Therefore, the dynamic viscosity of different aqueous solutions of selected fat replacer was measured at different shear rates at 25°C and the results are presented in Figures 4-6. Results show that with increasing shear rate, a considerable decrease of dynamic viscosity was stated in all different concentration of used fat replacers. These results are close to the results observed by Garcia-Ochoa, *et al.* [6], who showed that xanthan gum has high viscosity resists flow and xanthan solutions are pseudoplastic, or shear thining and viscosity decreased with increasing shear rate. The results in Fig. 4 showed that the viscosity of the xanthan solutions increasing with increasing concentration of xanthan and this results agree also with Garcia-Ochoa *et al.* [6], who showed that the viscosity of the xanthan solutions increased with increasing concentration of the polymer. This behavior is attributed to the intermolecular interaction or entanglement, increasing the effective macromolecule dimensions and molecular weight. The results in Fig. 5 show also that flaxseed mucilage viscosity increased with increase in the concentration of flaxseed mucilage but the viscosity of flaxseed mucilage was lower than the viscosity of the xantnan gum.

The dynamic viscosity values of fat replacers mixtures obtained at different shear rates was presented in Fig. 6. From this figure, it could be seen, the mixture of 0.5% xanthan and1% flaxseed mucilage recorded high dynamic viscosity than xanthan or flaxseed mucilage alone. As mentioned before, that mixtures of flaxseed

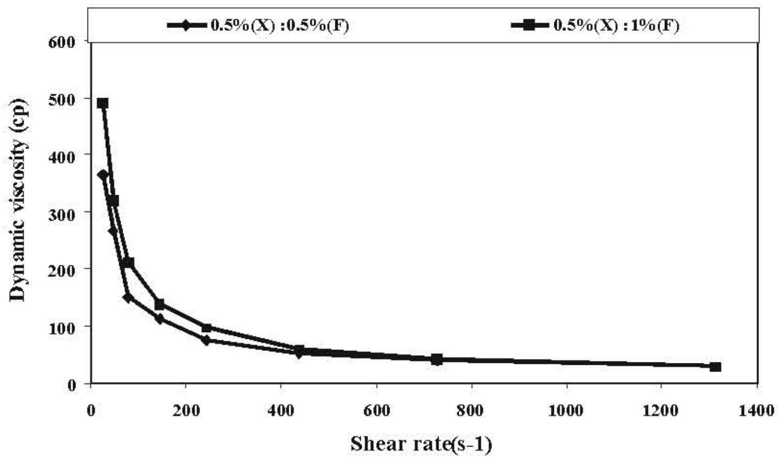

Fig. 6: Effect of shear rates on the dynamic viscosity of different mixed concentration of xanthan and flaxseed mucilage at 25°C

mucilage with xanthan lead to increase in the dynamic viscosity values of these mixtures, which means enhancement in the thickening and stabilizing effect of these mixtures in food system.

Full and Reduced- Fat Mayonnaise Analysis

Proximate Chemical Analysis and Caloric Values: The proximate chemical analysis and caloric values of the reduced-fat mayonnaise (RFM) containing different levels of fat replacers and full-fat mayonnaise (FFM) (control) are given in Table 5. Results showed that moisture of mayonnaise samples was affected by replacing oil with xanthan and flaxseed mucilage and their mixture. An increase in moisture content was associated with the increase of the fat replacers concentrations. The increase in moisture content with addition of fat replacers was due to very high moisture content of fat replacers preparation, which were typical characteristic of carbohydrate based fat replacers, because of the difference of the oil content addition of (FFM) and (RFM) samples. It was found that addition of different fat replacers significantly reduced the oil required to form oil in water emulsion from 70g to 35g for xanthan, 45g for flaxseed mucilage and 25g for eash in the mixture of them. The ash and protein contents of (RFM) mayonnaise samples were little higher than those of (FFM) mayonnaise sample. Carbohydrate contents in (RFM) samples were higher than the (FFM) samples, which could be explained by the addition of fat replacers to increase the consistency lost with the oil reduction. About 34,48 and 61 % reduction in caloric values was achieved when xanthan, flaxseed mucilage and their mixture were used as fat replacers in(RFM)mayonnaise production. Similar results were obtained by Liu *et al.* [1].

Rheological Analysis: Samples of full fat mayonnaise samples and reduced fat mayonnaise samples prepared with different concentration of fat replacers were subjected to rheological examination. The shear stress response of the tested samples was calculated and used for the analysis of rheological behaviour of the mayonnaise samples.

Table 5: Proximate chemical analysis and caloric values of full and reduced-fat mayonnais Samples.

		Xanthan			Flaxseed mucilage			Xanthan: Mucilage %	
Constituents (%)	FFM	0.5%	0.7%	1%	0.5%	0.7%	1%	0.5:0.5%	0.5:1%
Moisture	22.66±0.15	57.21±0.28	57.02±0.19	56.57±0.25	47.01±0.18	46.72±0.25	46.25±0.26	66.76±0.15	66.30±0.28
Ash	1.67±0.14	1.71±0.17	1.72±0.85	1.75±0.14	1.71±0.22	1.73±0.17	1.76±0.22	1.70±0.65	1.80±0.14
Protein	1.84±0.08	1.84±0.65	1.84±0.15	1.85±0.05	1.86±0.05	1.87±0.08	1.88±0.05	1.86±0.08	1.88±0.05
Fat	71.5±0.24	35. 02±0.28	35.03±0.85	35.04±0.24	45.00±0.26	45.01±0.25	45.01±0.85	25.02±0.85	25.03±0.24
Carbohydrate*	2.33±0.14	4.22±0.18	4.39±0.22	4.61±0.32	4.42±0.11	4. 67±0.22	5.10±0.15	4.66±0.18	4.99±0.22
Caloric values**	660.18	339.42	340.19	341.20	430.12	431.25	433.01	251.26	252.75

*: Total carbohydrate was calculated by difference

** Caloric values= (4xprotien)+ (9xfat)+(4x carbohydrate

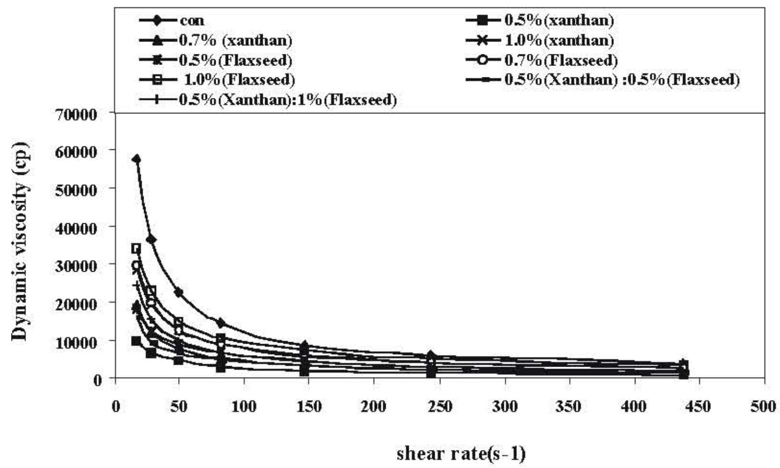

Fig. 7: Effect of shear rate on the dynamic viscosity of reduced fat mayonnaise containing different concentrations of selected fat replacers

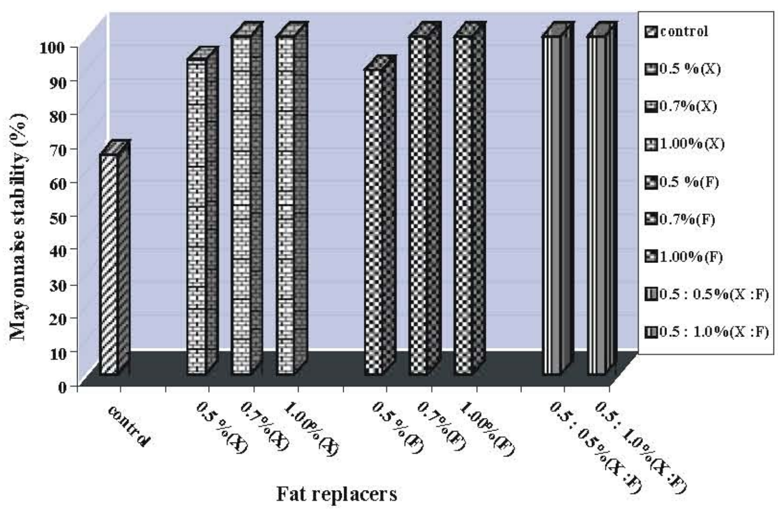

Fig. 8: Effect of different concentrations of fat replacers on the stability of reduced-fat mayonnaise.

Dynamic Viscosity: The dynamic viscosity was calculated by dividing shear stress by the corresponding shear rate values between 16.20 to 437.4 (s^{-1}). The results of calculation were presented in Fig. (7). As seen from the fig, the relationship between dynamic viscosity and shear rate was not linear indicating that all mayonnaise samples followed non-Newtonian behaviour. The effect of different concentration of fat replacer used to prepare reduced fat mayonnaise on viscosity were also showed in Fig. 7. The viscosity of different reduced fat mayonnaise samples were lower than the control sample which contain all amount of fat (70g oil) perhaps this decrease in viscosity of reduced fat mayonnaise samples attributed to replace oil with fat replacer and water. On the other hand, there are different in viscosity among the reduced fat mayonnaise samples. For example, at shear rate 48.6s^{-1} the dynamic viscosity of reduced fat mayonnaise sample contain 1%xanthan was 12774.49 cp, but in the sample contained 1% flaxseed mucilage it was 15079.12 cp and in the sample contained 0.5% xanthan and 0.5% flaxseed mucilage was 6967.901cp compared with control which did not contain any fat replacer, where the value was 22645.68 cp. These results could be referred to amount of water which was added to the samples to complete the amount to 100.

Mayonnaise Stability: Mayonnaise stability usually involves preventing droplets coalescence, flocculation and creaming. Creaming is not usually problem in mayonnaise that have high fat content because the droplets are so closely packed together so that they cannot move. However, in products which have low fat

Table 6: Mean scores value of sensory evaluation of reduced-fat mayonnaise samples containing different concentrations of selected fat replacers.

		Xanthan			Flaxseed mucilage			Xanthan : mucilage %	
Sensory properties	Control	0.5%	0.7%	1%	0.5%	0.7%	1%	0.5:0.5%	0.5:1%
Consistency	9.00^{ab}	5.50^{de}	8.50^{ab}	6.75^{cd}	4.75^{e}	6.50^{d}	8.57^{ab}	9.50^{a}	8.00^{bc}
Appearance	10.00^{a}	5.50^{ef}	8.50^{bc}	6.75^{de}	4.75^{f}	6.50^{e}	8.75^{abc}	9.50^{a}	8.00^{cd}
Color	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}
Aroma	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}	8.50^{a}
Overal acceptability	10.00^{a}	5.50^{ef}	8.50^{bc}	6.75^{de}	4.75^{f}	6.50^{e}	8.75^{abc}	9.50^{ab}	8.00^{cd}

a,b…..Means in the column showed different superscrpt letters are significantly different ($p \leq 0.05$)

content, creaming is usually prevented by adding thickening agent such as gum or starch to the aqueous phase to slow down the droplet movement. Fig. 8 describe the effect of different fat replacers on the stability of reduced fat mayonnaise. The reduced fat mayonnaise samples showed a higher stability than full fat mayonnaise samples. This is because of the increased viscosity of the aqueous phase from addition of xanthan and flaxseed gum which slowed down oil droplet movement. The obtained results were close to the results obtained by Mun *et al.* [2].

Sensory Evaluation of Full and Reduced-Fat Mayonnaise: Sensory evaluation of reduced-fat mayonnaise samples compared with full-fat mayonnaise sample was indicated in Table (6). The results showed that there is no significant difference in color and aroma between reduced -fat mayonnaise samples and full- fat mayonnaise and the reduced-fat mayonnaise samples which contain (0.7,1,0.5 and 0.5), respectively, of xanthan, flaxseed mucilage and mixture of xanthan and flaxseed mucilage.

CONCLUSION

Functional properties of xanthan, flaxseed mucilage and mixture of them are useful and that may employed as guidelines in formulating reduced fat food products. Partial substitution of fat with 0.7%xanthan, 1% flaxseed mucilage and 0.5 % mixture of them will produce reduced fat mayonnaise with a good consistency, high stability, high acceptability and low caloric values.

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