Comparison of flow behavior and physicochemical characteristics of low-cholesterol mayonnaises produced with cholesterol-reduced egg yolk

M. Yüceer,[†,1] H. İlyasoğlu,[‡] and B. Özçelik[*]

[*]*Department of Food Engineering, Istanbul Technical University, Istanbul, Turkey, TR-34469;* [†]*Department of Food Processing, Canakkale Onsekiz Mart University, Canakkale, Turkey TR-17020; and* [‡]*Department of Nutrition & Dietetic, Gumushane University, Baglarbasi, Gumushane, Turkey, TR-29100*

Primary Audience: Egg Researchers, Egg Processing, Plant Managers

SUMMARY

Egg yolk is common functional ingredient in food production, mainly in mayonnaise as an emulsifier. Egg yolk cholesterol was removed using β-cyclodextrine, treated with α-amylase, and low-cholesterol mayonnaise produced. The flow behavior of cholesterol-reduced mayonnaise was investigated at different cholesterol-reduced egg yolk and xanthan gum content. The aim of this study was to evaluate the effects of different formulations at various percentages of egg yolk (**EY**; 4 and 6 percent by weight) and xanthan gum (**XG**; 0.5 and 0.7 percent by weight) on flow behavior and physicochemical properties of reduced-fat and low-cholesterol mayonnaise prepared with cholesterol-reduced liquid egg yolk and to obtain suitable model for mayonnaise formulations. The aim of the study was to develop a reduced-fat and low-cholesterol mayonnaise with properties similar to those of typical mayonnaise in the market. For this purpose, four reduced-fat and low-cholesterol mayonnaise formulations were prepared in the laboratory using cholesterol-reduced EY. They were compared with a commercial mayonnaise from a local market as a control sample. According to results, color parameters and flow behaviors of the samples compared with the control sample indicated that the samples had higher values of lightness and yellowness, and presented lower values of yield stress and flow behavior index and higher values of consistency coefficient with respect to the commercial product, except recipe that included 6% of EY and 0.7% of XG, which exhibited similar values to the typical commercial one in the market. The Herschel Bulkley model was employed in order to evaluate the effect of EY and XG ratios on mayonnaise rheological behavior. In general, the results obtained suggest that the recipe with EY (6 wt%) and XG (0.7 wt%) had better rheological characteristics and physicochemical properties those prepared with various formulations, maintaining the reduced-fat and low-cholesterol mayonnaise prepared with β-cyclodextrine-treated cholesterol-reduced EY. It can be interpreted that the developed product may have potential use in industrial application.

Key words: liquid egg yolk, β-cyclodextrine, reduced-fat/low-cholesterol, mayonnaise, flow behavior, physicochemical properties, color parameters

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[1]Corresponding author: myyuceer@gmail.com

DESCRIPTION OF PROBLEM

Eggs are a natural, excellent, and inexpensive source of easy-to-digest, high-quality proteins, as well as containing phospholipids, essential fatty acids, and bioactive compounds [1, 2], and thus can play an important role in the diet. Egg is one of the most-consumed foods worldwide due to their multifunctional (e.g., foaming, gelling and emulsifying) properties [3]. Egg industry and liquid egg processing market has seen a continuing growth in last two decades. There is an increasing demand to value-added and functional egg products in the market. Liquid egg yolk (**EY**) products are used as a critical emulsifying ingredient in various food products such as mayonnaise, salad dressings, and salads with high emulsion capability. Mayonnaise, a type of semi-solid, typical oil-in-water emulsion, is a mixture of EY, oil, vinegar, salt, sugar, spices, and thickening agents [4, 5]. Egg yolk, a crucial ingredient in the mayonnaise formulation, contains high amounts of cholesterol with 1.6 g/100 g of fresh liquid EY [3, 6, 7]. It has been recommended to reduce the intake of saturated fatty acids and cholesterol in order to limit coronary heart diseases [8, 9]. However, the association of egg consumption with subclinical coronary atherosclerosis remains unknown. Over the past years, the production of low-cholesterol foods has gained importance due to health-related concerns of consumers [4, 10–12].

Physical, chemical, and biological methods have been proposed to remove cholesterol from liquid EY. The applied methods include supercritical fluid extraction [13, 14], extraction with organic solvents such as acetone, diethyl ether, hexane, chloroform and ethanol [15, 16], extraction with methoxy pectin [17] or supercritical carbon dioxide (CO_2) [18–20], microbial degradation [21, 22], ultrasound treatment [23], enzymatic degradation [6], cholesterol complex formation with beta-cyclodextrine [1, 12, 24–28] or gamma-cyclodextrine [29], extraction of egg-yolk granules [30], and others [31, 32].

Cyclodextrine, a natural cyclic oligosaccharide compound derived from starch, has been shown to form a stable complex with cholesterol [6]. Numerous studies have been carried out on removal of cholesterol from foods such as butter [9, 33], cream [34, 35], cheddar cheese [36], EY [10, 26, 30, 37], milk [38, 39], and mayonnaise [25]. About 90% of cholesterol can be removed by β-cyclodextrine treatment. β-cyclodextrine (**β-CD**) is non-toxic and edible and has no adverse effect on functional properties of foods, which are advantages of β-CD treatment over different methods [1, 25].

The objective of this present study was to develop reduced-fat and low-cholesterol mayonnaise using EY with low cholesterol content obtained by β-CD treatment. The mayonnaise prepared with cholesterol-reduced EY as emulsifier was compared with a commercial and laboratory prepared sample. Flow behaviors and color parameters of mayonnaise samples were also determined.

MATERIALS AND METHODS

White shell (Lohmann LSL Lite- White laying hen breed), large size, unfertile, freshly laid (1-day-old) clean-shell eggs weighing 58–60 g were supplied by local egg processing plant (A.B. Foods Inc., Bandirma, Turkey).

Preparation of Cholesterol-reduced Egg Yolk (CREY)

Fresh shell eggs were broken to separate yolk from the white as described in Abu-Salem and Abou-Arab [40] without separating EYplasma and granule. After breaking the egg by hand, EY was separated from egg albumen and chalazae. Egg yolks were homogenized for 20 s in a blender (Model 32 BL 80, Waring, Torrington, CT, USA). The pH of the EY was adjusted to 3.5 with citric acid (0.5 mol/L). Then the EY was diluted with water (7:100 v/v) and 0.2%, w/v β-cyclodextrine (Cavamax W7 Food, Wacker Biochemicals AG, München, Germany) was added directly to liquid EY to remove cholesterol from EY. The mixture was stirred at 35°C for 15 min with a magnetic stirrer (H+P Labortechnick AG, Germany). After the solution was kept at 4°C for 10 min, the mixture was centrifuged at 2.000 rpm of relative centrifugal force for 10 min to separate β-CD from liquid EY. 0.001%, v/v bacterial origin (*Bacillus stearothermophillus*) α-amylase (Multifect AA, Genencor Inc. Rochester, NY, USA) added to the supernatant was incubated

Table 1. Formulations of low-cholesterol and low-fat mayonnaises (wt, %).

Ingredients	F1	F2	F3	F4
Corn oil	4	4	4	4
Egg yolk	4	6	4	6
MCS*	2.5	2.5	2.5	2.5
Starch	5	5	5	5
Vinegar	2	2	2	2
Sugar	3	3	3	3
Salt	2.5	2.5	2.5	2.5
Xanthan gum	0.5	0.5	0.7	0.7
Lemon juice	1	1	1	1
Lactic acid	0.4	0.4	0.4	0.4
Corn syrup	5	5	5	5
Potassium sorbate	0.1	0.1	0.1	0.1
Water	70	68	69.8	67.8

*Microcrystalline cellulose.

at 45°C for 30 min to degradate residual β-CD in the EY phase with low cholesterol content. The prepared CREY was pasteurized with high-temperature, short-time using a plate heat exchanger (Stok Ltd, Bursa, Turkey) at 60°C for 3.5 min according to the USDA pasteurization norm [41].

Preparation of Low-cholesterol Mayonnaise

Mayonnaise formulations were prepared in duplicate with hydrocolloid ingredients using microcrystalline cellulose (Avicel-plus XP 3604, FMC Biopolymer, Haugesund, Norway) and XG (NovaXan dispersible food T) was purchased from ADM Inc. (Ireland) used in the study. The ingredients used in mayonnaise production were corn oil, starch, vinegar, sugar, salt, lemon juice, citric acid, corn syrup and potassium sorbate were purchased from local supplier. After preparation 200 g of each mayonnaise, samples were packed in same-size glass jars (250 g) with screw cap and stored at 25°C in the dark room for analysis. Four mayonnaise formulations formed to the preliminary study are presented in Table 1. First, the water phase was prepared by mixing of the ingredients. Second, the oil was added slowly to the water phase in a Hobart mixer (N50CE, Hobart Foster Scandinavia A/S, Aalborg, Denmark) to form the emulsion. Microcrystalline cellulose was used as a stabilizer and a fat replacer in low-cholesterol/fat mayonnaises. In order to prevent the breakage of emulsion and separation, pre-study was performed to determine the working ranges of XG and EY. The experimental design was used as 0.5 to 0.7 wt% and 4 to 6 wt% for XG and EY, respectively. The products were stored at 4°C. A commercial low-cholesterol mayonnaise and raw EY were used as control samples.

Mayonnaise samples were taken in three replications for measuring compositional analysis, cholesterol content, color parameters, and flow behaviors. This study was carried out according to a completely randomized typical experimental design with 4 treatments F1 (EY 4%; XG 0.5%), F2 (EY 6%; XG 0.5%), F3 (EY 4%; XG 0.7%) and F4 (EY 6%; XG 0.7%) of three replicates for each cholesterol-reduced mayonnaise recipe.

Proximate Composition Analyses

Total lipid, crude protein and ash were analyzed according to Abu-Salem and Abou-Arab [40]. Total carbohydrate values were calculated by subtracting from total weight after protein, lipid, and ash measurement. The pH values of CREY and mayonnaise samples were measured with a pH meter (210 model pH meter, Hanna Instruments, Woonsocket, RI) [42]. Three replicates were used in each analysis.

Cholesterol Analysis

Cholesterol analyses were performed using Boehringer Mannheim enzymatic-colorimetric test method (139050, R-Biopharm AG, Darmstadt, Germany) to determine the cholesterol content in liquid EY samples. The method is based on oxidation of the cholesterol into cholesteron in presence of catalase and after several steps with occurrence of yellow compounds. Sample preparation and measurements were carried out using an UV-Vis spectrophotometer (Hitachi U-1800, Japan) at absorbance of 405 nm wavelengths, and the cholesterol concentration was expressed as g cholesterol/100 g of EY [43].

Color Measurement

The color of liquid EY and mayonnaise samples was determined by colorimetric method using a colorimeter (Konica Minolta Chroma Meter CR-400, Osaka, Japan) at room temperature. The measurement device was calibrated with white Minolta calibration plate before measurements. The color space L^*, a^*, b^* values was used according to Mun, Kim, Kang, Park, Shim and Kim [5]. Measurement results were expressed as a color characteristics of L^* (lightness), a^* (green to red; higher positive a^* values indicate red color), and b^* (blue to yellow; higher positive b^* values indicate a more yellow color) values were recorded in the study. All measurements were performed in triplicate [30].

Rheological Measurements

All rheological measurements were carried out with a Haake Rheo Stress 1 (Thermo Electron, Germany) rotational rheometer. The flow behaviors of the samples were analyzed at $25 \pm 0.1^{\circ}$C using a parallel-plate equipped with a sensor probe and fitted with a rotor-diameter of 35 mm (PP35Ti) geometry with a gap of 1 mm (volume area of liquid sample 1 cm^3) [44]. The sample temperature was internally controlled by Peltier element (1162A, VWR International Ltd., Lutterworth, UK) attached with water circulation unit and jacket surrounding the sample cup, which allows rapid temperature control of mayonnaise sample. A thixotropic loop analysis carried out with increasing shear rate logarithmically from 0 to 150 s^{-1}, held at 150 s^{-1} for 240 s and decreased it logarithmically back from 150 to 0 s^{-1}. The plot of shear rate versus shear stress was crossed to evaluate the flow behaviors of the mayonnaises. All the flow behaviors were carried out in triplicate and rheological results were calculated using data analysis software program Reowin (Pro Data Manager Version 3.3). Steady flow measurements were performed using two curves in the range of shear stress corresponding to shear stress form 0 to 80 per second during 300 s and rheological parameters (shear stress, shear rate, apparent viscosity) were obtained from software. The best fitting of experimental data for flow curves were fitted to the Herschel Bulkley model ($\tau = \tau_0 + K\gamma^{n,}$ where τ is shear stress [Pa], τ_0 is yield stress and γ is shear rate [s^{-1}]). The K (consistency index) and n (flow behavior index) parameters with apparent viscosity were calculated. Regression coefficient (R^2) was over 0.99 and thixotropic loop was modeled using the Herschel-Bulkley model as referred to thixotropy (Pa·s-^{1}). The equation of the model was given in Eq (1).

$$\tau = \tau_0 + K\gamma^n \tag{1}$$

τ is the shear stress (Pa), τ_0 is the yield stress (Pa), γ is the shear rate (s^{-1}), K is the consistency coefficient, n is the flow behavior index.

Statistical Analysis

Statistical procedures were performed on parameters among effect of different mayonnaise formulations on flow behavior and physicochemical characteristics using LSM-PROG GLM of the SAS program (SAS Institute, Cary, NC). Analysis of variance was carried out on all measured parameters among the formulas to determine any significant differences. Statistical significance was defined as P values of 0.05 or less.

RESULTS AND DISCUSSION

Proximate Composition

The production of mayonnaise using β-CD treated cholesterol-reduced egg yolk (CREY) and its effects on physicochemical properties and flow behaviors were analyzed. The proximate composition of the CREY, the reduced-fat and low-cholesterol mayonnaises and the control samples are presented in Table 2. The amount of carbohydrate in the CREY was found to be higher (2.20 ± 0.02) than that of raw EY (1.16 ± 0.01) on a dry weight basis, which may be explained by the conversion of residual β-CD, which is formed from oligosaccharide to glucose units after treatment with α-amylase [10]. The reduction of cholesterol in the EY was 83%. In previous studies, the reported values ranged from 81.7% to 89.2% [12, 24]. The CREY samples contain less lipid and protein and more carbohydrate and ash (data not given) than control. Our present results support an earlier observation with Awad et al. [10] and Lamas et al. [30] in significance importance of carbohydrate content of control (1.12 ± 0.37) and β-CD added (1.87 ± 0.67) samples.

It can be seen from Table 2 that the amount of protein, lipid, and cholesterol in the products

Table 2. Composition of mayonnaise samples, cholesterol-reduced liquid egg yolk (CREY) and control samples.

Liquid EY Samples	Protein (g/100 g)	Carbohydrate (g/100 g)	Lipid (g/100 g)	pH	Cholesterol (mg/100 g)
Control*	15.47 ± 0.04	1.16 ± 0.01	25.63 ± 0.05	5.94 ± 0.00	896.33 ± 3.21
Low-cholesterol EY	13.40 ± 0.03	2.20 ± 0.02	21.70 ± 0.04	4.40 ± 0.01	152.66 ± 2.51
Mayonnaise Samples**					
F1	1.26 ± 0.03^{c}	8.47 ± 0.03^{d}	2.10 ± 0.01^{c}	4.26 ± 0.01^{a}	17.43 ± 0.15^{e}
F2	3.24 ± 0.03^{a}	8.07 ± 0.05^{e}	3.11 ± 0.01^{b}	4.12 ± 0.01^{c}	20.56 ± 0.15^{c}
F3	1.20 ± 0.01^{d}	11.26 ± 0.03^{a}	2.21 ± 0.16^{c}	4.23 ± 0.00^{b}	17.96 ± 0.11^{d}
F4	3.10 ± 0.01^{b}	10.10 ± 0.01^{c}	3.01 ± 0.03^{b}	4.14 ± 0.01^{d}	21.36 ± 0.15^{b}
Control (commercial mayonnaise)	1.14 ± 0.01^{e}	11.55 ± 0.05^{b}	7.65 ± 0.05^{a}	3.75 ± 0.01^{e}	25.76 ± 0.06^{a}

Data are expressed as mean ± standard deviation.
[a-e]Means in the same column with different lowercase letters are significantly different ($p \leq 0.05$).
*raw liquid EY.
**F1 (EY 4%; XG 0.5%), F2 (EY 6%; XG 0.5%), F3 (EY 4%; XG 0.7%) and F4 (EY 6%; XG 0.7%).

Table 3. Color parameters of mayonnaise and liquid EY samples.

Liquid EY Samples	L^*	a^*	b^*
Control*	33.31 ± 0.00^{b}	1.47 ± 0.02^{c}	17.88 ± 0.00^{a}
CREY	29.41 ± 0.01^{c}	5.66 ± 0.01^{a}	14.85 ± 0.00^{c}
Liquid EY (commercial)	31.85 ± 0.05^{a}	5.01 ± 0.02^{b}	15.64 ± 0.01^{b}
Mayonnaise Samples**	L^*	a^*	b^*
F1	45.07 ± 0.22^{a}	− 0.43 ± 0.03^{b}	7.38 ± 0.04^{b}
F2	45.46 ± 0.72^{a}	− 0.36 ± 0.06^{a}	7.63 ± 0.13^{a}
F3	38.51 ± 0.30^{c}	− 0.35 ± 0.06^{a}	6.76 ± 0.03^{c}
F4	42.00 ± 0.43^{b}	− 0.54 ± 0.02^{c}	4.34 ± 0.11^{e}
Control	39.23 ± 0.22^{b}	− 0x.71 ± 0.07^{d}	4.91 ± 0.03^{d}

Data are expressed as mean ± standard deviation.
[a-e]Means in the same column with different lowercase letters are significantly different ($p \leq 0.05$).
*raw liquid EY.
**F1 (EY 4%; XG 0.5%), F2 (EY 6%; XG 0.5%), F3 (EY 4%; XG 0.7%) and F4 (EY 6%; XG 0.7%).

increased as the amount of EY in the formulation increased from 4 to 6 wt%. Furthermore, an increase in the amount of XG in the formulation resulted in an increase in the amount of carbohydrate in the products.

Color Parameters

Color parameters (L^*, a^* and b^*) of CREY, low-cholesterol mayonnaises, and control samples are presented in Table 3. The L^* value of the CREY (29.41 ± 0.01) was significantly lower than that of the control liquid EY (33.31 ± 0.00) ($p < 0.05$) and commercial liquid EY sample (31.85 ± 0.05), which may be explained by β-CD treatment leading to discoloration in agreement with previous studies and our findings were similar to those of Awad, Bennink and Smith [10] and Lamas, Anton, Miranda, Roca-Saavedra, Cardelle-Cobas, Ibarra, Franco and Cepeda [30]. The CREY samples b^* value were also significantly lower (14.85 ± 0.00) than control (17.88 ± 0.00) and commercial sample (15.64 ± 0.01) due to complexation of β-CD with β-carotene, which is responsible for yellow-orange color pigments in EY [10]. Liquid EY colors affected the color parameters of the final product (mayonnaise). The L^*, a^* and b^* values of the low-cholesterol mayonnaise samples (F1, F2 and F3) showed significant differences in accordance with the control sample ($p < 0.05$). The treated samples generally presented significantly higher L^*, a^*, and b^* values compared to the control sample, except F3 for L^* value and F4 for b^* value, which had the lowest.

It is known that the color and color stability of mayonnaise is related to the formulation ingredients, especially EY and oil ratios. It can be seen from Table 3, L^* values of treated samples increased when the amount of the EY in

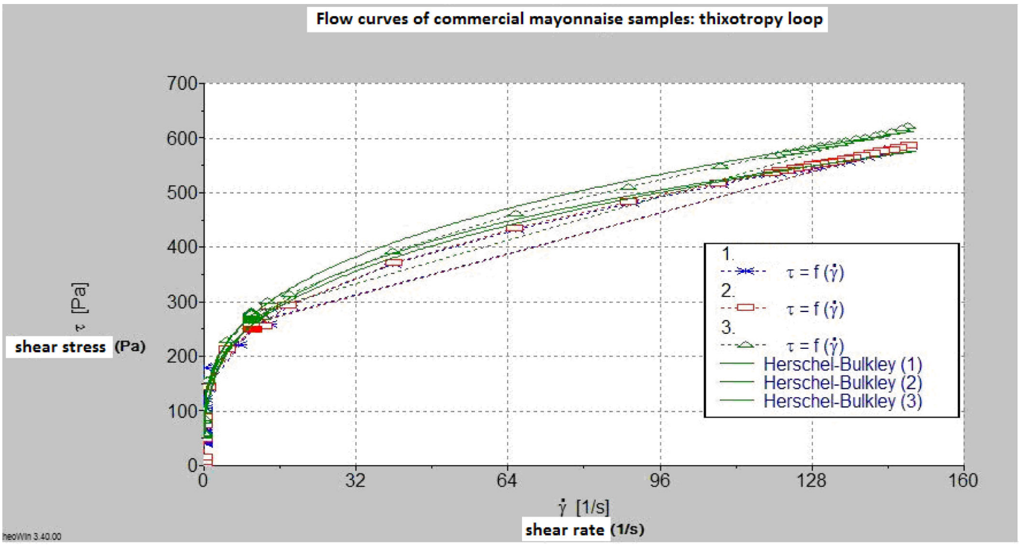

Figure 1. Flow curves of commercial mayonnaise samples: thixotropy loop.

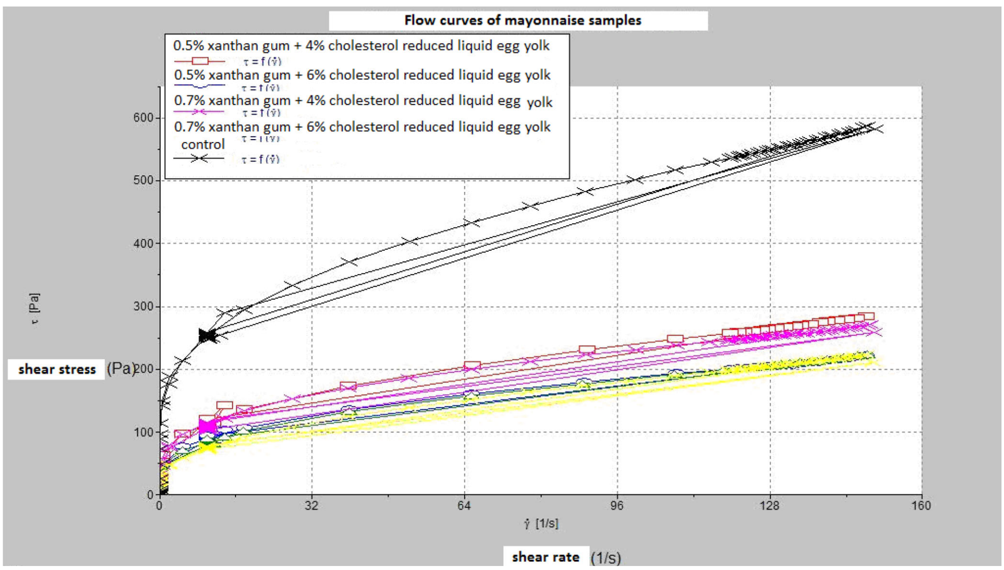

Figure 2. Flow curves of mayonnaise samples.

the formulation increased from 4 to 6% in presence of 0.7% XG. At the lowest content of XG in the formulation, a* and *b** values of the products increased with an increase in the amount of EY, whereas *a** and *b** values of the products were found to decrease at highest content of XG. It can be interpreted that XG may dilute the color of the products because of its light-yellow color and interactions between hydrocolloid and protein.

Rheological Behavior

The rheological properties of liquid egg products and mayonnaise are of primary importance in the engineering design of manufacturing process. Flow properties of commercial mayonnaise presented in Figure 1 and flow curves of mayonnaise samples are given in Figure 2. Yield stress (τ_0) and consistency coefficient (K) for each flow curve are presented in Table 4.

Table 4. Model-fitting flow equation parameters of mayonnaise samples (Herschel Bulkley (HB) model for yield stress, HB consistency coefficient and flow behavior index).

Mayonnaise Samples**		Up curve			Down curve	
	$\tau_{0\ (Pa)}$	K_{HB} ($Pa{\cdot}s^n$)	n_{HB}	$\tau_{0\ (Pa)}$	K_{HB} ($Pa{\cdot}s^n$)	n_{HB}
F1	11.88	58.93	0.317	16.73[a,b]	40.02[a]	0.369[b]
F2	10.09	50.84	0.293	13.02[b]	30.95[b]	0.368[b]
F3	7.49	65.84	0.271	12.28[b]	43.02[a]	0.349[b]
F4	5.29	37.47	0.344	21.43[a]	16.55[c]	0.489[a]
Control	7.54	44.72	0.316	21.91[a]	16.58[c]	0.489[a]

Data are expressed as mean ± standard deviation.

[a-c]Means in the same column with different lowercase letters are significantly different ($p \leq 0.05$).

**F1 (EY 4%; XG 0.5%), F2 (EY 6%; XG 0.5%), F3 (EY 4%; XG 0.7%) and F4 (EY 6%; XG 0.7%)

Shear stress obtained from the decreasing-order of shear rate (down curve) was found to be lower than those from the increasing-order of shear rate (up curve), which showed thixotropic behavior. In the literature, thixotropic behavior was reported for mayonnaise [4, 45, 46] and some food products [47, 48]. Thixotropic behavior is a characteristic of some pseudoplastic fluids, which become less viscous when they are subjected to mechanical stress. Thixotropic behavior can be related to structural changes in the sample owing to the generated hydrodynamic forces and the subsequent arrangement of the molecules in the flow direction [49].

The area between down curve and up curve, called a hysteresis loop, was observed in all samples. Structural breakdown with an increase in shear stress leading changes in the structure can be attributed to hysteresis [48]. The flow curves of F3 and F4 showed very narrow hysteresis loop indicating that the hysteresis loop of the samples disappeared with increasing contents of XG. Similar findings were reported for starch/XG gel [48]. The decrease in the hysteresis area may be related to the rigid, rod-like conformation of XG reducing structural breakdown by shear field [50]. These findings are in agreement with the previous study [51].

Yield stress showing stability of food emulsion under mechanical stress is an important parameter for the design of food-processing systems. It has been used in engineering calculation, product quality and sensorial assessment [52, 53]. The yield stress values of the samples ranged from 5.29 to 21.91 Pa. The yield stress values of up curve and down curve are different, revealing that the consistency of the samples has changed due to mechanical stress. The yield stress values of down curves presented significant difference ($p < 0.05$) with respect to the formulations. F4 showed the highest yield stress value indicating that it was the most stable emulsion, whereas F3 exhibited the lowest yield stress value in down curve. The yield stress values of the samples increased when the amount of EY in the formulation increased from 4 to 6 wt% at the highest content of XG. However, no significant difference was observed at the lowest content of XG ($p > 0.05$). Therefore, it is difficult to evaluate the effect of EY on the yield stress. The yield stress values of desserts thickened with starch-XG were reported to be higher with an increase in the amount of XG [54]. In our study, the yield stress values appeared to increase with an increase in the amount of XG at the highest content of EY, whereas an increase in XG content had no effect on the yield stress value at the lowest content of EY. Therefore, the content of EY-XG has a critical effect on the yield stress value of the mayonnaise samples. These results revealed that the interaction of EY and XG might have influence on the yield stress values.

The consistency coefficients of the samples ranged from 16.55 to 65.84 $Pa{\cdot}s^n$. The significant differences in the consistency coefficients of down curves were observed ($p < 0.05$). The consistency coefficient can be used as a criterion of viscosity. Therefore, it can be interpreted that F3 was the most-viscous sample and F4 was the least-viscous sample. The consistency coefficient values of the samples decreased with an increase in the amount of EY, furthermore, they increased with an increase in the content of XG at the highest content of EY. However, XG content was found to have no significant effect on the consistency value of the mayonnaise samples containing 4 wt% of EY ($p > 0.05$). Our findings were similar to those found in the literature. The consistency of the dessert sauces was found to be influence irregularly by an increase in the amount of XG [54].

The flow behavior index of the samples varied from 0.271 to 0.489, indicating a typical pseudoplastic behavior (n < 1). The flow behavior indices of down curves showed no significant differences according to the mayonnaise formulations ($p < 0.05$). The highest flow behavior indices value was achieved for F4. However, F3 had the lowest flow behavior index value. The flow behavior index increased as the amount of EY in the formulation increased at highest content of XG, whereas EY had no significant effect at the lowest content of XG. Flow behavior index values were found to increase with increasing content of the XG content at the highest content of EY. However, no significant effect on the flow behavior index was observed at the lowest content of EY ($p > 0.05$). It can be interpreted that the flow behavior may be influenced by the interaction between EY and XG. In the rheological measurements carried out, the mayonnaises with EY (6 wt%) and XG (0.7 wt%) in formulation has the most similar flow behavior to that of a commercial one used as reference. The present findings seem to be consistent with previous researcher findings by Liu et al. [4] and Aslanzadeh et al. [55] in terms of flow behavior index of mayonnaise samples as shear thinning fluids and n values were less than 1.

CONCLUSIONS AND APPLICATIONS

The reduced-fat and low-cholesterol mayonnaises were prepared with a cholesterol reduced liquid EY obtained from β-CD treatment. The cholesterol removal efficiency of the experiment was 83% achieved using β-CD, that comparable to that obtained by previous studies. The flow behaviors of the samples showed thixotropic behavior and were well fitted to the Herschel Bulkley model. The rheological properties (τ_0, K, n) of the product containing EY (6 wt%) and XG (0.7 wt%) were similar to the commercial product, indicating that this process may be an alternative way to produce commercial low-fat and low-cholesterol mayonnaise. The study showed β-CD treated EY has a significant effect on mayonnaise rheology. Further studies on the linear oscillation regime of cholesterol-reduced mayonnaise are required. This investigation supports the potential use of cholesterol reduced EY by treatment with β-CD as functional ingredient in the mayonnaise industry.

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