Textural Properties of Emulsion-Filled Gel Formulated with Oleogels as Oil Fraction Using a Response Surface Methodology

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ABSTRACT: *Looking for the development of new food ingredients, the Box-Behnken design was employed to determine the effect of two different oleogels, elaborated with a celluloses mixture or with candelilla wax, as oil fraction, on the textural properties of emulsion-filled gels with egg white as emulsify/gelling agent, at different ionic strength conditions. Compression test parameters were determined on both samples (force, work, and modulus) to analyze the effect of the variables on texture. Emulsion-filled gels with candelilla wax oleogel resulted in firmer and more difficult to compress, as compared to cellulose oleogel, with a less hard and softer texture. The increase in protein concentration resulted in a stiffer texture, but when the oil fraction (oleogel proportion) increased, the emulsion-filled gel texture turned more squishable. No major effect was observed by the employed ionic strength conditions. The model predictions for textural parameters in both samples were closely correlated to the experimental results obtained. The use of different ingredients that can be employed as oil fractions with different textures that can be manipulated, distinct oleogel formulations - as the type of organogelator agent, a type of edible oil- allows the designing of textural and thermal properties of emulsion-filled gels, with great potential as fat replacers in processed foods.*

KEYWORDS: *Emulsion-filled gel; Candelilla wax, Celluloses; Oleogel; Box-Behnken design; Texture.*

INTRODUCTION

Emulsions are defined as the mixture of at least two immiscible phases, generally, oil and water, where one of the liquids is dispersed in small droplets into the other phase, called the continuous phase, with an emulsifier agent to prevent phase separation. Most of the food emulsions are much more complex since the aqueous phase may content many water-soluble compounds (sugars, acids, salts, proteins, and/or polysaccharides), and the composition of the oil phase may be complex as well (triacylglycerols, diacylglycerols, monoacylglycerols, free fatty acids, sterols, etcetera), and then the interfacial region may content a mixture of the different surface-active components acting as surfactants (proteins, polysaccharides, phospholipids, among others) [1]. On the other hand, the protein gelation process depends on three-dimensional network development, as a result

of the protein interactions with protein and water, via intermolecular interactions. The cross-linking of proteins, and hence, the elasticity or gel strength, is the result of hydrogen bonding, ionic and hydrophobic interactions, van der Waals forces, and covalent disulfide bonding [2]. Since the solvent is water, this kind of gels are termed "hydrogels"; when an organic liquid, such as edible oil, is employed as the solvent, the term is "organogel", which can be formulated with low molecular weight gelators, as fatty acids, or with high molecular weight gelators, as polymers [3]. Effects of fatty acids on human health, specifically trans and saturated fatty acids, demand dietary guidelines to suggest a reduction in the consumption of these kinds of fats, with the increase in the consumption of mono and polyunsaturated fatty acids, with vegetable oils as the main source. Nonetheless, the direct replacement of saturated or trans fats with unsaturated oils is a challenge in processed foods, since most of the time saturated fats are responsible for textural properties and mouthfeel, and hence to prevent textural differences or oil leakage, oil structuring methods must be employed to develop unsaturated fats alternatives to equal or exceed saturated or trans fats functionality [4]. Organogels, or oleogels, were developed looking for fat-mimetic ingredients to replace saturated and trans fats in foods, that have shown health risks, but that also play a major role in texture, mouthfeel, and possibly aroma and flavor sensation experienced while consuming fat products [5].

The emulsified filled gel is a composite system considered as a network of cross-linked polymers surrounding oil droplets, produced by the gelation of the continuous phase of an emulsion with a gel-able biopolymer (proteins) [6]. A solid-like emulsion gel is generated from a stable liquid-like emulsion by gelling the continuous phase and/or aggregating the emulsion droplets. The composite structure of emulsion-filled gels is then regarded as and hybrid network assembled by the combination of partly aggregated droplets in a crosslinked biopolymer molecules network, resulting in a complex colloidal material that lies both as an emulsion and as a gel, but the overall emulsion texture is determined by the continuous phase [7]. The filler particle within a gel matrix, oil droplets, can be considered active (bound fillers, connected to the gel network with a relatively higher gel strength) or inactive (unbound, with low chemical affinity and interaction with the gel matrix,

resulting in a softer gel structure) [8]. The structural organization of the filled gel is determined by the droplets and the gel matrix, considering aspect as droplet aggregation (as the effective volume fraction acting as filler particles in the gel) and accumulation of the droplets in gel strands, as well as the hardness of the solid fat inside the droplets [9]. In this view, this research is oriented to the optimization of an emulsion-filled gel formulated with egg white employing a candelilla wax oleogel or celluloses mixture oleogel as oil fraction.

EXPERIMENTAL SECTION
Samples preparation

The egg white was obtained from fresh eggs, separating the yolk, and homogenizing at constant magnetic low-speed stirring under refrigeration (4±1 °C) overnight. Protein content was determined by the biuret method [10] to adjust protein concentration according to the points of the experimental design, making the pertinent dilutions.

Oleogels elaboration

Celluloses oleogel was elaborated according to the methodology reported by *Totosaus et al.* [11]. A mixture comprised 7.370% (w/v) of ethyl cellulose (viscosity 100 cP, Sigma-Aldrich, St. Louis, proportion), 1.815% (w/v) of Avicel RC-591 (FMC Biopolymers, Philadelphia), and 1.815% (w/v) of α-cellulose (Sigma-Aldrich, St. Louis) (proportion 0.670, 0.165, 0.165, respectively, for a total of 11%, w/v) plus 3.67% of Span 60 as a surfactant were dissolved in 85.33% of soybean oil (Industrias Ragasa S.A., Monterrey, México) was heated to 120 °C with magnetic stirring at a constant speed for 25 min, until the ingredients were completely solubilized. After completion of the heating process, molten soybean oil oleogel was poured into beakers and cooled to room temperature before being stored (at least 24 h) under refrigeration (4±1 °C).

Candelilla was oleogel and adapted the methodology Toro-Vazquez et al. reported [12]. Candelilla wax (Bliss Nature, Mexico City) was dispersed into soybean oil (Industrias Ragasa S.A., Monterrey, México) at 3% (w/v) to be heated at 90 °C in a convection oven for 25 min, mixed for one minute, and heated again at 90 °C during ten more minutes. After this, molten candelilla wax soybean oil oleogel was poured into beakers and cooled to room temperature before being stored (at least 24 h) under refrigeration (4±1 °C).

Emulsion-filled gel procedure

Emulsion-filled gels were elaborated in two steps. First, candelilla wax oleogel or celluloses oleogel, as oil fraction, were emulsified into egg white solution (40 mL) with a commercial homogenizer (Oster Mexicana, Mexico City) for 3 minutes, employing 50 mL centrifuge tubes. Emulsions were kept under refrigeration overnight looking for phase separation. In the second step, a heat treatment (water bath at 90±2 °C for 15 minutes) was applied to tubes containing the emulsions to form an egg white protein gel. Samples were stored for at least 24 h before analysis.

Emulsion-filled gels texture analysis

Emulsion-filled gels were carefully removed from tubes to cut a cylindrical sample of 15 mm length. Samples were axially compressed at 60% of deformation at 1 mm/s speed head in a LFRA 4500 texture analyzer (Brookfield Engineering Laboratories, Middleboro, N. J., USA), calculating from the force-deformation curves the following parameters: compression force (maximum force detected during compression, compression work (area under the compression curve, defined as the energy required to compress the sample, N/s), and compression modulus (defined as the initial slope of the force-deformation curve before failure point during compression, N s) [13]

Experimental design and data analysis

The Box-Behnken design, a balanced incomplete block factorial design [14], was employed to evaluate the effect of the combined effect of independent variables, egg white protein content (X_1 = 8, 9 and 10%), oil fraction (X_2= 0.2, 0.3, and 0.4) and ionic strength (X_3= 0.0, 0.2 and 0,4 M NaCl) on the textural properties of filled-emulsions gels formulated with the two types of oleogels. Experimental data were adjusted to the second-order polynomial equation (Eq. 1), as follows:

$$Y_j = \beta_0 + \sum_{i=1}^{k} \beta_i X_1 + \sum_{i=1}^{k} \beta_{ii} X^2 + \sum_{i=1}^{k} \beta_{ij} X_i X_j \qquad (1)$$

Where Y_j is the textural parameters of the different emulsion-filled gels (j=1-2), β_0, β_i, β_{ii} and β_{ij} are the respective regression coefficients of the mean, linear, quadratic, and cross-product calculated from the experimental results by the least-squares method, and the levels of independent variables are represented by X_i and X_j. Experimental data from the central composite design

was analyzed with SAS v.9.1.3 statistical software (SAS Institute, Cary).

RESULTS AND DISCUSSION

The compression fore for emulsion-fille gel ranges from 6.5 to 23.9 N and from 8.8 to 26.1 N, for the samples with cellulose oleogel (Table 1) and candelilla wax oleogel (Table 2), respectively. For compression work, the range was 11.5-28.5 N/s for celluloses oleogel samples (Table 1) and 12.4-37.6 N/s for candelilla wax oleogel samples (Table 2). Finally, for the compression modulus the cellulose oleogel samples presented values from 3.0 to 8.8 N s (Table 1), and candelilla wax oleogel samples with values from 1.3 to 8.9 N s (Table 2).

Analysis of variance for the regression parameters of the predicted response surface model of the two different emulsion-filled gels is listed in Table 1. For the compression force, candelilla wax emulsion-filled gels presented a higher β_0 value than the celluloses emulsion-filled gels, this is, candelilla was as oil fraction resulted in a harder structure (almost 6-fold). Linear parameters were significant, demonstrating the effect of the independent variables on this textural parameter, where higher oil fraction resulted in a softer texture (negative sign). For the quadratic parameters, the protein β_{11} and the oil fraction β_{22} coefficients were highly significant (P<0.01) in candelilla wax emulsion-filled gels, but only the protein was significant (P<0.05) for the celluloses emulsion-filled gels, with no significant (P>0.05) effect by the oil fraction β_{22} parameters. Protein content×oil fraction cross products parameters were highly significant (P<0.01) for candelilla wax emulsion-filled gels, and only significant (P<0.05) for the emulsion-filled gels of celluloses. For oil fraction×ionic strength cross product was highly significant (P<0.01) in candelilla wax oleogels. Response surface models indicated that both linear and quadratic parameters were significant (P<0.05) for the cellulose emulsion-filled gels and highly significant (P<0.01) for the candelilla was emulsion-filled gels. Cross products were highly significant (P<0.01) for the candelilla regression model, and no significant (P>0.05) for the regression model of celluloses samples. Applied regression models presented no lack of fit. A lower correlation was obtained for the compression force in cellulose samples than in candelilla wax samples (67.84 and 96.50, respectively). The effect of protein content and oil fraction on

Table 1: Central Composite design matrix and experimental yields for the filled-emulsion gels with celluloses oleogel as oil fraction.

Run	Coded variables			Uncoded variables			Experimental			Predictive		
	X_1	X_2	X_3	X_1	X_2	X_3	Comp. force (N)	Comp. work (N/s)	Comp. modulus (N s)	Comp. force (N)	Comp. work (N/s)	Comp. modulus (N s)
1	-1	-1	0	8	20	0.2	13.7	14.0	1.3	13.3	14.1	2.4
2	1	1	0	10	20	0.2	23.9	28.5	8.9	23.7	29.4	8.9
3	-1	-1	0	8	40	0.2	13.9	19.5	6.2	13.4	18.6	5.9
4	1	1	0	10	40	0.2	12.5	16.7	5.3	12.2	16.6	3.8
5	-1	-1	-1	8	30	0.0	11.9	16.7	5.2	12.5	16.3	4.5
6	1	1	-1	10	30	0.0	16.9	24.3	6.1	17.1	23.2	6.5
7	-1	-1	1	8	30	0.4	10.5	11.5	4.2	10.8	12.6	3.0
8	1	1	1	10	30	0.4	15.0	18.7	5.7	15.4	19.0	5.5
9	0	0	-1	9	20	0.0	22.5	28.3	8.5	22.8	28.5	7.8
10	0	0	1	9	40	0.0	6.5	12.0	2.9	6.9	13.1	3.7
11	0	0	1	9	20	0.4	10.5	14.4	4.8	10.9	13.3	3.2
12	0	0	1	9	40	0.4	14.8	20.6	5.9	15.3	20.4	5.8
13	0	0	0	9	30	0.2	11.5	15.6	4.5	12.2	15.3	4.8
14	0	0	0	9	30	0.2	13.2	16.6	4.8	12.2	15.3	4.8
15	0	0	0	9	30	0.2	13.5	13.8	5.6	12.2	15.3	4.8

Table 2: Central Composite design matrix and experimental yields for the filled-emulsion gels with candelilla wax oleogel as oil fraction.

Run	Coded variables			Uncoded variables			Experimental			Predictive		
	X_1	X_2	X_3	X_1	X_2	X_3	Comp. force (N)	Comp. work (N/s)	Comp. modulus (N s)	Comp. force (N)	Comp. work (N/s)	Comp. modulus (N s)
1	-1	-1	0	8	20	0.2	12.7	14.4	4.5	10.9	15.3	6.5
2	1	1	0	10	20	0.2	18.7	14.7	8.5	19.3	19.9	11.5
3	-1	-1	0	8	40	0.2	8.8	12.4	3.0	9.6	13.3	6.9
4	1	1	0	10	40	0.2	13.2	18.5	4.5	16.5	23.7	9.2
5	-1	-1	-1	8	30	0.0	13.0	21.3	4.6	13.6	20.8	4.3
6	1	1	-1	10	30	0.0	26.1	37.6	8.8	21.2	28.3	7.9
7	-1	-1	1	8	30	0.4	10.4	14.4	3.1	10.8	14.7	9.8
8	1	1	1	10	30	0.4	17.5	21.9	5.9	18.5	22.2	13.5
9	0	0	-1	9	20	0.0	10.8	20.3	3.8	12.8	19.8	4.9
10	0	0	1	9	40	0.0	14.6	22.8	4.2	13.9	22.3	3.9
11	0	0	1	9	20	0.4	14.0	21.1	3.9	13.2	15.4	10.4
12	0	0	1	9	40	0.4	11.5	20.3	3.2	8.0	14.6	9.5
13	0	0	0	9	30	0.2	12.0	21.6	3.1	13.9	21.5	7.5
14	0	0	0	9	30	0.2	14.0	16.7	4.9	13.9	21.5	7.5
15	0	0	0	9	30	0.2	12.8	16.8	4.5	13.9	21.5	7.5

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compression force for the celluloses oleogel as oil fraction (Fig. 1-a, left) and candelilla wax oleogel as oil fraction (Fig. 1-b, left) was more noticeable in samples containing candelilla wax oleogel (higher compression force values)

About the compression work, candelilla wax emulsion-filled gels presented as well a higher β_0 value than the celluloses emulsion-filled gels, meaning that candelilla wax emulsion-filled gels required higher energy to be compressed. In cellulose emulsion-filled gels, only β_1 was significant ($P<0.05$) in the regression model, whereas for the candelilla wax emulsion-filled gels the linear parameters were highly significant ($P<0.01$), where oil fraction and ionic strength presented a negative sign. Both quadratic and cross-product parameters were not significant ($P>0.05$) in the cellulose emulsion-filled gels regression model. In contrast, for candelilla wax emulsion-filled gels both quadratic and cross-product parameters were highly significant ($P<0.01$). Applied regression models presented no lack of fit. A lower correlation was obtained once again for the compression force in cellulose emulsion-filled gels as compared to candelilla wax emulsion-filled gels (63.66 and 96.77, respectively) (Table 1). Although the surface contour was similar, higher compression work values were observed in candelilla samples (Fig. 1-b, center) as compared to cellulose oleogel samples (Fig. 1-a, center).

Finally, for the compression modulus, although the β_0 value for candelilla wax emulsion-filled gels was higher, the β_0 value for cellulose emulsion-filled gels presented a close value (5.05 and 3.88, respectively). In both regression models, only the linear parameters for protein content (β_1) and oil fraction (β_2) were significant. In emulsion-filled gels containing celluloses oleogel, the protein was highly significant ($P<0.01$) and oil fraction was significant ($P<0.05$). In candelilla wax emulsion-filled gels both protein content and oil fraction were only significant ($P<0.05$), with a negative sign for the oil fraction parameter. There was no significant ($P>0.05$) effect of the ionic strength linear term on the emulsion-filled gels compression modulus regression model. For the quadratic parameters, only protein (β_{11}) presented a significant ($P<0.05$) effect on the regression model. Both cross products parameters for protein content×oil fracti and oil fraction×ionic strength were not significant ($P>0.05$). In consequence, only linear parameters were significant ($P<0-05$). Applied regression models presented

no lack of fit. In the same manner, also a lower correlation was obtained for the compression force in cellulose emulsion-filled gels than in candelilla wax emulsion-filled gels (59.86 and 74.16, respectively) (Table 1). For the compression modulus, although higher values can be observed for the celluloses containing samples (Fig. 1-a, right), higher oil fraction decreased the force required to the initial compression until initial failure in candelilla wax samples (Fig. 1-b, right).

Emulsion-filled gels elaborated with celluloses mixture was in general softer than the candelilla wax Emulsion-filled gels. In the cellulose oleogel samples, linear parameters influenced the compression force values, where at higher oil fraction the compression force was lower. More oil phase to emulsify resulted in a softer structure. The same behavior was also observed in candelilla wax samples, i.e., higher oil phase decreased the force required to compress the samples. This was reflected in the negative effect on the compression force of oil phase interaction with protein content. Candelilla wax samples required more energy to be compressed, as compared to the celluloses mixture ones. As for compression force, the higher oil phase resulted in lower compression work, also the oil phase interaction with protein decreased compression force values.

The fundamental differences in oleogelation mechanism between candelilla wax and celluloses resulted in different oleogel structures, that implies, on one hand, different fat dispersion pattern within the continuous phase of the filled emulsion, and on the other hand, when emulsion was submitted to heat treatment, the differences in oleogels melting properties, as thermoreversibility, affected the oleogel interaction with protein gel network during heat-set gelling of the egg white emulsion.

According to Davidovich-Pinhas [15], oil structuring agents are classified into two types: low molecular weight and high molecular weight. Small molecules that can form a stable crystal-oil network by hydrophobic interaction (hydrophobic and Van der Walls interactions, in addition to hydrogen bonds) as waxes, low molecular weight compounds, are highly sensitive to shear forces and temperature. In contrast, celluloses with a higher molecular weight, from hydrogen bond interactions a three-dimensional network in the presence of surfactant. Waxes as a low molecular weight organogelator created a solid fiber organogel, where the formation of aggregates

Table 1. Regression coefficients and significance of the predicted response surface regression parameters (parenthesis indicate the calculated P-value).

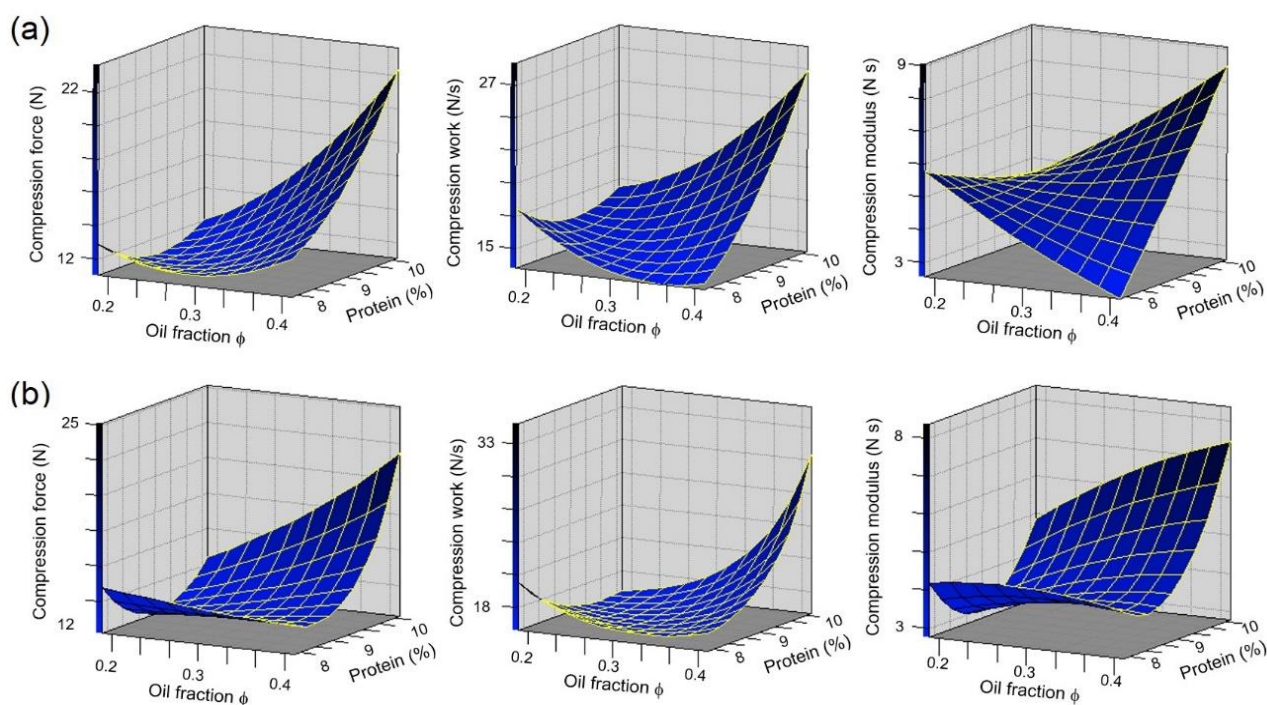| Variable	Compression force (N)		Compression work (N/s)		Compression modulus (N s)	
	Celluloses mixture oleogel	Candelilla wax oleogel	Celluloses mixture oleogel	Candelilla wax oleogel	Celluloses mixture oleogel	Candelilla wax oleogel
β_0	2.45	12.24	0.046	15.60	4.88	5.05
β_1 protein (%)	0.17 (0.0123)	2.29 (0.0002)	0.009 (0.0261)	3.31 (0.0003)	1.36 (0.0074)	1.13 (0.0355)
β_2 oil fractions (ϕ)	-0.13 (0.0365)	-2.28 (0.0001)	-0.0007 (0.0745)	-2.68 (0.0078)	-0.78 (0.0565)	-0.32 (0.0451)
β_3 ionic strength (M)	0.05 (0.0359)	0.88 (0.0165)	0.005 (0.0108)	1.38 (0.0017)	0.21 (0.5283)	0.33 (0.4325)
β_{11}	0.27 (0.0113)	1.69 (0.0064)	0.007 (0.2003)	1.98 (0.0174)	1.86 (0.0112)	0.18 (0.0129)
β_{12}	-0.18 (0.0386)	-2.90 (0.0004)	-0.006 (0.1837)	-4.32 (0.0005)	-0.82 (0.1221)	-2.12 (0.7568)
β_{22}	0.008 (0.9988)	1.69 (0.0064)	0.007 (0.1840)	2.28 (0.0101)	0.29 (0.5234)	0.25 (0.6681)
β_{23}	0.002 (0.9767)	5.05 (0.0001)	0.002 (0.6747)	6.35 (0.0001)	0.025 (0.9572)	1.82 (0.0229)
Linear	0.0242	0.0001	0.0508	0.0005	0.0209	0.0223
Quadratic	0.0352	0.0060	0.0446	0.0194	0.0465	0.9511
Cross products	0.1339	0.0001	0.5136	0.0002	0.1213	0.0591
Lack of fit	0.0437	0.9900	0.4876	0.7948	0.4536	0.1490
R square	83.92	98.25	87.02	98.39	79.93	87.08
R adjusted	67.84	96.50	63.66	96.77	59.86	74.16

Fig. 1. Response surface graph for the compression force (left), compression work (center), and compression modulus (right) as a function of protein content and oil fraction (fixed ionic strength = 0.2 M) for the (a) filled-emulsions gels with celluloses oleogel and (b) filled-emulsions gels with candelilla wax oleogel.

by intermolecular cooperative interaction of the gelator molecules defines the crystal morphology [16]. For cellulose oleogels, high molecular weight polymers form a macromolecular gel structure, forming hydrogen bonds with the solvent and the surfactant as a plasticizer, interacting the latter within gel junctions, and increasing free volume [17]. This decreased drastically the oleogel structural gel integrity, resulting in a softer or weaker structure, comparing cellulose oleogel with wax oleogel. When liquid vegetable oil is replaced by solid fat, the hardness of the emulsion-filled gel increases due to the presence of a fat crystal network, as in candelilla wax oleogel [9].

According to van Vliet [18], when emulsion droplets are entrapped into a gel matrix an emulsion-filled gel is obtained, where the mechanical properties will depend on many factors, as the physicochemical properties of both the gel matrix and emulsion droplets, the oil phase volume fraction, size and distribution of emulsified droplets, and the emulsion droplets and gel matrix interaction. If the emulsion droplets have a mechanical interaction with the gel network, an active network is formed increasing gel strength, but if the emulsion droplets are not connected with the gel network, an inactive network is formed with a weak gel structure since the emulsified droplets are not incorporated into the gel network [19]. There are two structural arrangements, the emulsion-filled protein gel (a type of particle-filled solid, a protein gel matrix with embedded emulsion droplets, with rheological properties as a solid-like, determined by the network properties of the continuous matrix), and the protein-stabilized emulsion gel (a type of particulate gel, where rheological properties are predominantly determined by the network of aggregated emulsion droplets) [7].

In this case, candelilla wax oleogel could present a higher degree of interaction, because, in wax containing oleogels, there is a development of microcrystalline structures during the gelling process that retains the oil-liquid phase due to the annealing of gelators molecules in waxes, like sterols, and phospholipids, among others, in amorphous and/or ordered regions [12]. In contrast, the heat-induced gelation process of celluloses is driven by hydrophobic forces and intra-molecular interactions leading to the formation of clusters or fringed micelles, promoting crosslinking, responsible for junction zone formation [5]. This suggests that the mechanism of

gelation of cellulose organogels does not involve the formation of a highly ordered secondary structure (this is, fatty acids crystallization) involved in the biopolymer glass transition before the partition of the polymeric chains with the edible oil as solvent [20]. So, in emulsions containing pre-crystalized fatty acids, as in the case of the candelilla wax oleogel samples, the inhomogeneous crystal network formed created during crystallization is destroyed during the emulsification process, and fatty acids crystals are free to migrate to the interface [21]. Since both organogels are thermoreversible gel structures, either those formulated with celluloses [22] or waxes [12], and the formation of the gel in egg white starts at 71-74°C, regardless of albumin concentration of about 80% of the protein aggregation was found at 75°C, and almost all of the protein aggregated at 80 °C [2], under the experimental conditions employed, both organogels were dispersed within the gelled egg white, since the egg white protein concentrations maintained the emulsion stability (no phase separation observed) during and after the thermal process to form a gel. In this view, the presence of crystals in the candelilla wax oleogels increased filled-emulsion gel strength.

CONCLUSIONS

The use of two different types of oleogels elaborated with candelilla wax or cellulose mixture resulted in different emulsion-filled gels' textural properties. Compression force for emulsion-filled gels represents the structural matrix of the protein stabilizing the oil phase, in this research comprised of the two different oleogels. Egg proteins in the emulsion aqueous phase are first responsible for the oil phase stabilization, and during and after thermal treatment, proteins are responsible for the development of the three-dimensional protein matrix. Candelilla wax oleogel as oil fraction in emulsion-filled gels resulted in firmer and more difficult to compress, as compared to cellulose oleogel, with a less hard and softer texture. The increase in protein concentration resulted in a stiffer texture, but when the oil fraction (oleogel proportion) increases, the emulsion-filled gel texture turned more squishable. No major effect was observed by the employed ionic strength conditions, this is, no major effect on egg-white protein solubility that enhanced emulsion stability. The augment of the dispersed phase, oleogel, interfered with the protein matrix structure.

Both oleogels presented different thermoreversible capacity, since crystalized fatty acids developed during oleogel elaboration, as in the case of candelilla wax oleogel, are dispersed freely to migrate to the interface, being ten more involucrate in the interface stability, as active filler, resulting in a strong emulsion-filled gel during and after thermal treatment. This means that by manipulating the protein concentration and oleogel oil proportion the texture of emulsion-filled gels can be tailored according to the specific food requirements.

Acknowledgments

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